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PETROLEUM PRODUCTS, PROPERTIES, QUALITY, APPLICATION

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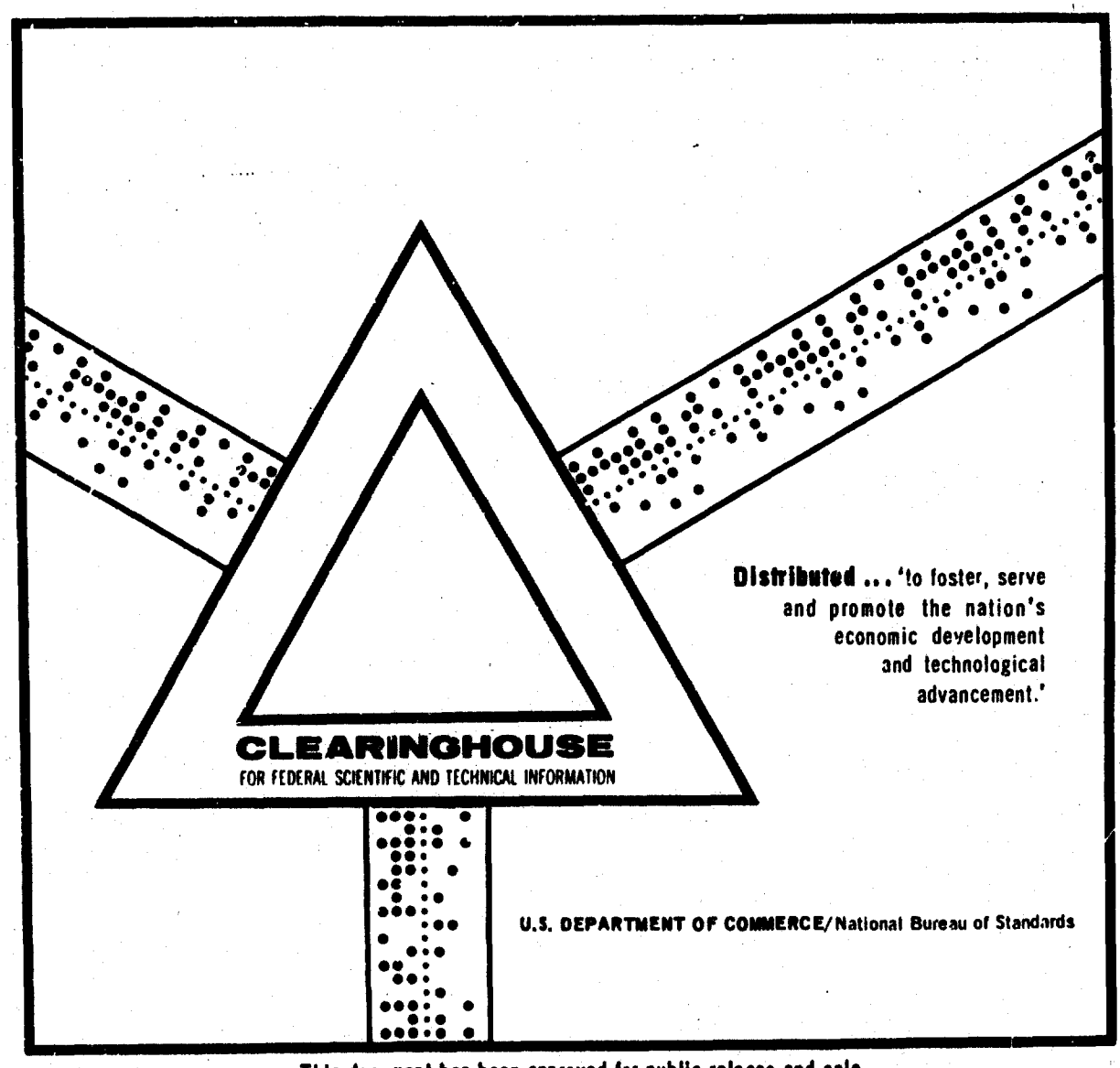

FTD-HT-23-347-68 Part 4 of 4

FOREIGN TECHNOLOGY DIVISION

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By

B. V. Losikov

FTD-HT-23-347-68
Part 4 of 4

EDITED TRANSLATION

PETROLEUM PRODUCTS, PROPERTIES, QUALITY, APPLICATION

By: B. V. Losikov, (Editor)

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Chapter 11

ADDITIVES FOR OILS

The simplest and least expensive way to improve the operational properties of petroleum and synthetic oils in various applications is to add special additives to them. In many cases, this approach is not only the closest at hand, but also the only one possible.

Oil additives are classified on the basis of their ability to improve some given property of the oils. The following types of additives are distinguished: 1) viscosity additives, which increase the viscosities of oils and improve their viscosity-temperature properties; 2) depressor additives, which depress oil pour points; 3) antioxidant additives, which increase the stability of the oils to the oxidizing action of atmospheric air; 4) anticorrosion additives, which lower the corrosive aggressiveness of the oils; 5) antiwear additives, which improve the lubricating properties of oils and protect the rubbing parts of engines and mechanisms from wear; 6) antifoam additives, which lower the surface tension of oils and thereby prevent formation of foam in them; 7) detergent additives, which prevent the formation of various deposits, such as carbon, varnish or sludge, on engine parts; 8) multipurpose additives, which have the ability to modify two or more oil operational properties in the desired direction simultaneously.

When it is necessary to improve the operational properties of oils as regards not one, but several indices, several additives are used in it. It is the combination of these additives that confers the desired properties on the oil.

1. VISCOSITY ADDITIVES

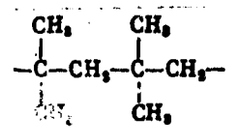
A variety of polymer products are used as viscosity additives. Polyisobutylene, polymethacrylates, and vinyl-ether polymers have come into practical use, as, to a lesser degree, have polyalkylstyrenes and copolymers: hydrocarbon (for example, the copolymer of isobutylene and isoamylenes – octol), derivatives of methacrylic acid and nitrogen-containing monomers and a number of others. Certain polymer additives, together with their ability to improve the viscosity properties of oils, also have depressor or detergent properties, or both together.

Polyisobutylene

Polyisobutylenes with molecular weights of 15,000-20,000 are

used as viscosity additives.

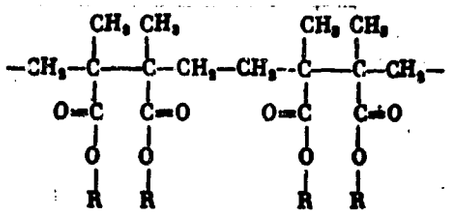
The main chain of polyisobutylene is



In the Soviet Union, polyisobutylenes are produced in accordance with Ministry of the Chemical Industry Technical Specifications (ТУ МХП) 1761-54. Abroad, polyisobutylene-based additives are manufactured under the names Opanol and Exanol. For convenience in use, polyisobutylene is produced in the USA in the form of a 20-30% solution in medium-weight mineral oil. This solution has come to be known as Paratone.

Polymethacrylates

The main chain of the polymethacrylate macromolecule is



where R is an aliphatic radical with 4 to 22 carbons.

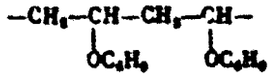
The properties and effectiveness of the polymers as additives depend on the size and structure of the radical R. Polymers with radicals containing from 12 to 18 carbons are most effective; such polymers have depressor properties in addition to their viscosity properties.

Two types of polymethacrylates are produced in the Soviet Union: V (viscosity) and D (depressor).

Vinipols

Polymers of vinyl-*n*-butyl ether, or Vinipols, are used as viscosity additives primarily for hydraulic fluids.

The main chain of the Vinipol macromolecule is



The Vinipols used as viscosity additives have molecular weights of 9000-12,000. Below we present the properties of one specimen of Vinipol with a molecular weight of 9000:

Density ρ_4^{20}	0.932
Refractive index n_D^{20}	1.4588
Conventional viscosity at 100°C, °VC.	312
Flash point (open crucible), °C	210

Commercial specimens of the polymers have broad fractional composition (Fig. 11.1). For example, polyisobutylene with an average molecular weight of 27,000, separated by the adsorption method into narrow molecular-weight fractions, contains only about 30% of hydrocarbons with molecular weights of 25,000-30,000; the remaining 70% of the components have molecular weights from 5000 to 50,000. A similar picture is also observed for other polymers (Table 11.1).

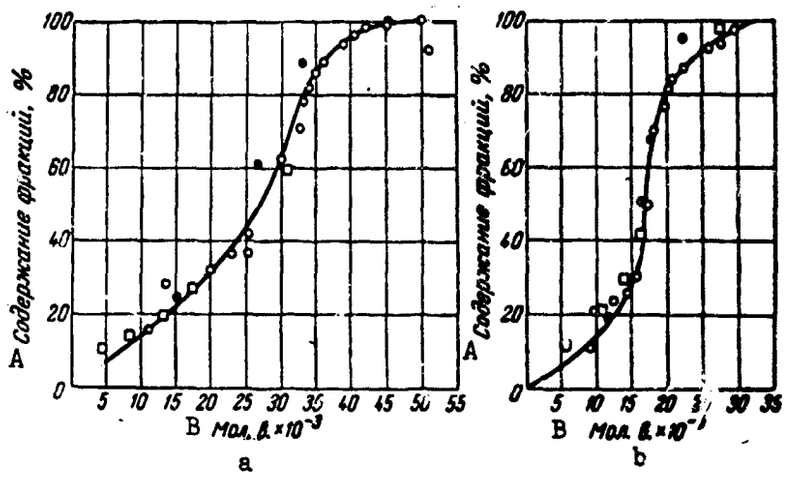


Fig. 11.1. Fractional distribution in adsorption separation: a) polyisobutylene with m.w. of 27,000; b) polyisobutylene with m.w. of 17,000; o) on activated charcoal; ●) on silica gel; c) fractional sedimentation. A) Content of fractions, %; B) M.w. × 10^{-3}.

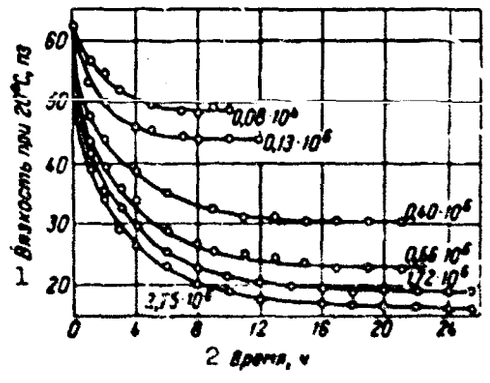


Fig. 11.2. Viscosity change of 20% polyisobutylene solution (m.w. 30,000) in MK-8 oil in the mechanical destruction process at various shear stresses [4]. The figures on the lines indicate shear stress in dynes/cm^2. 1) Viscosity at 20°C, poises; 2) time, h.

TABLE 11.1

Fractional Composition of Commercial Specimens of Polyisobutylene and Vinipol [1]

1 Полиизобутилен среднего молекулярного веса				4 Винипол среднего мол. веса 12000	
27000		17000			
содержание фракции, % 2	молекулярный вес 3 фракции	содержание фракции, % 2	молекулярный вес 3 фракции	содержание фракции, % 2	молекулярный вес фракции 3
0,66	50000	0,53	29000	41,10	20000
1,32	45000	0,77	27500	16,7	14800
1 [illegible]	42000	6,00	26000	5,45	12000
3 23	41000	3,50	22600	6,45	9500
3,74	39000	2,73	22300	11,32	9000
3,71	36000	2,23	20400	10,05	5900
3,81	35000	28,40	20000	6,20	5500
4,05	34000	5,50	18000		
7,37	33500	8,00	16800		
8,30	33000	11,55	16000		
20,95	30000	4,20	15500		
5,19	25300	2,43	14700		
1,58	22700	1,86	12350		
6,02	19500	10,90	10000		
13,00	13800	10,90	8000		
15,42	11000				
5 Средневзвешенный молекулярный вес . . .	27300		16300		14800

1) Polyisobutylene with average molecular weight of
2) Content of fraction, %
3) Molecular weight of fraction
4) Vinipol with average molecular weight of 12,000
5) Weighted average molecular weight.

TABLE 11.2

Thickening Ability of Various Polymer Additives Used in AS-6 Oil (after R.Sh. Kuliyev)

A Присадка	Содержание присадки в масле, B %	C Вязкостные свойства загущенного масла			D Индекс вязкости
		ν_{100}	ν_{50}	ν_{100}/ν_{50}	
E Полиизобутилен	1,3	47,9	9,7	5,0	102
	1,5	51,8	10,4	5,0	104
	2,0	61,8	12,2	5,1	109
F Полиметакрилат	1,5	41,5	8,1	4,5	113
	2,0	46,2	10,1	4,8	118
	2,5	51,5	11,5	4,5	121
G Винипол	3,0	44,6	9,1	4,8	102
	3,5	47,5	9,8	4,9	107
	4,0	50,5	10,4	5,0	113
H Масло без присадки	—	29,6	6,1	4,8	54

A) Additive
B) Content of additive in oil, %
C) Viscosity properties of thickened oil

D) Viscosity index
E) Polyisobutylene
F) Polymethacrylate
G) Vinipol
H) Oil without additive.

Polymer additives differ in their ability to thicken oils (Table 11.2): polyisobutylene takes first place, surpassing polymethacrylates and Vinipols. However, oils prepared by thickening a base with polymethacrylates are considerably superior as regards viscosity-temperature properties to oils thickened with other polymers.

The thickening tendency of polymers depends on their concentration in the oil (Table 11.3) and on their molecular weights (Tables 11.4 and 11.5). All polymer viscosity additives are subject to destruction on heating or severe mechanical disturbances, with the result that their thickening ability declines (Tables 11.6 and 11.8 and Figs. 11.2 and 11.3, a and b). The higher the molecular weight of the polymer, the more liable it is to destruction. Polymethacrylates and Vinipols are more susceptible to destruction than polyisobutylenes. The extent of destruction also depends on the concentration of the polymer in the oil and the duration of the mechanical or thermal disturbance. The only possible way to counter mechanical destruction is to use polymers of relatively low molecular weight (3000-5000) to thicken the oil. Additives are used in the oil to prevent thermal destruction of the polymers. Usually, antioxidant additives serve this purpose (Table 11.7 and Fig. 11.4).

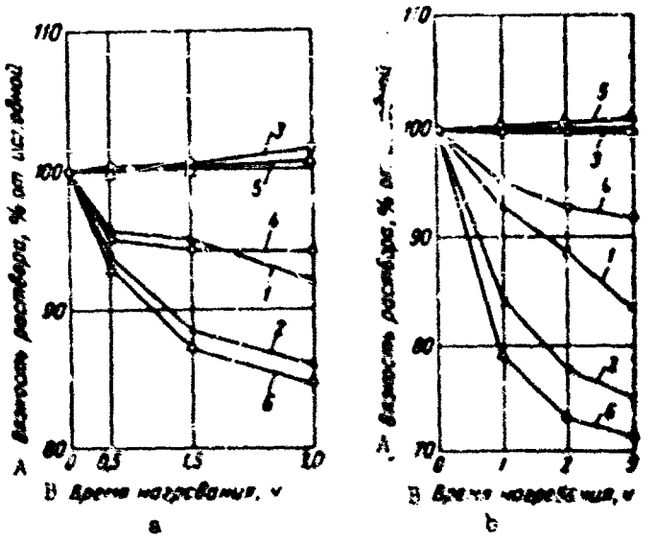


Fig. 11.3. Destruction of 5% polymer solutions in turbine oil 22 (L) in oxygen (a) and air (b) at 150°C [5]: 1) Vinipol (m.w. 12,000); 2) same + 2% iron naphthenate; 3) polymethacrylate (m.w. 12,000); 4) same + 2% iron naphthenate; 5) polyisobutylene (m.w. 20,000); 6) same + 2% iron naphthenate. A) Solution viscosity, % of initial; B) heating time, h.

TABLE 11.3

Influence of Polyisobutylene on Oil Viscosity (after Ye.G. Semenido)

A	B Вязкость (в сст) при					
	100°C	50°C	100°C	50°C	100°C	50°C
	C индустриальное 12 (веретенное 2)		D автол 6		D автол 18	
0	3.6	12.4	7.4	55	10.5	71.4
2	7.4	28.5	16.3	105	21.0	155
4	13.2	55.5	31.1	201	39.1	—
6	23.2	94.3	48.1	350	57.0	462
8	34.2	150	74.7	582	92.8	768

A) Concentration of m.w. 20,000 polyisobutylene in oil, %
B) Viscosity (cSt) at
C) Industrial 12 (spindle 2)
D) Avtol ...

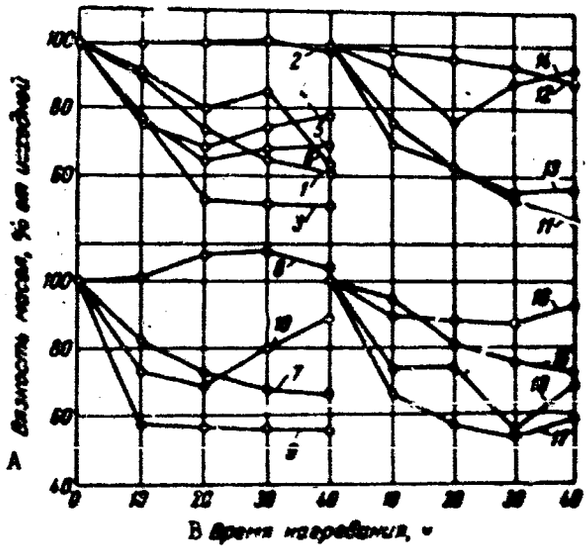


Fig. 11.4. Change in viscosities of thickened oils with various additives during heating [6]: 1) transformer oil + 10% Vinipol (150°C); 2) same + 0.5% p-hydroxydiphenylamine; 3) transformer oil + 10% Vinipol (200°C); 4) same + 0.5% p-hydroxydiphenylamine; 5) transformer oil + 10% polymethacrylate (200°C); 6) same + 1% p-hydroxydiphenylamine; 7) spindle oil + 10% Vinipol (150°C); 8) same + 0.5% p-hydroxydiphenylamine; 9) spindle oil + 10% Vinipol (200°C); 10) same + 1% p-hydroxydiphenylamine; 11) synthetic oil 36/1 + 10% Vinipol (150°C); 12) same + 0.5% p-hydroxydiphenylamine; 13) synthetic oil 36/1 + 10% Vinipol (200°C); 14) same + + 0.5% p-hydroxydiphenylamine; 15) synthetic oil 36/1 + 10% polymethacrylate (150°C); 16) same + 1% p-hydroxydiphenylamine; 17) synthetic oil 36/1 + 10% polymethacrylate (200°C); 18) same + 1% p-hydroxydiphenylamine. A) Oil viscosity, % of initial; B) heating time, h.

TABLE 11.4

Influence of Polyisobutylene Molecular Weight on Oil Viscosity (after N.G. Puchkov)

A Молекулярный вес полиизобутилена	B Вязкость масла (в сст) при 50° С при добавлении полиизобутилена			
	0%	1%	2%	3%
6000	13	15,4	17,7	20,7
15000	13	18,4	25,2	34,0
23000	13	20,9	32,0	—

A) Molecular weight of polyisobutylene
B) Oil viscosity (cSt) at 50°C on addition of ... of polyisobutylene.

TABLE 11.5

Influence of Polymer Molecular Weight on Viscosity-Temperature Properties of Oils with Light Base [2]

1 Полимер			5 Вязкость (в сст) при							6 Отношение ν_{100}/ν_{210}	7 Вязкость (в пз) при				
2 название	3 молекулярный вес	4 количество в масле, %	150° С	140° С	130° С	120° С	110° С	100° С	50° С		0° С	−15° С	−30° С	−40° С	−50° С
8 Полиизобутилен	30000	4.1	7.57	8.45	10.65	12.80	15.1	18.3	73.0	3.99	12.8	31	81	224	675
	30000	5.3	7.88	9.12	10.80	12.80	15.1	18.3	76.3	4.17	14.7	38	105	316	1256
	10000	8.2	7.65	8.90	10.56	12.55	15.2	18.3	81.1	4.43	16.6	48	162	630	2510
	5000	12.0	7.70	8.88	10.64	12.82	15.1	18.3	84.9	4.63	26.2	68	218	880	3980
9 Полиметакрилат	18000	6.6	8.20	9.45	10.70	12.80	15.3	18.3	67.5	3.52	9.5	20	45	120	478
	10000	9.7	8.20	9.38	10.90	12.80	15.2	18.3	67.5	3.69	10.4	22	56	173	630
10 Масляная основа	—	—	1.67	1.88	2.16	2.48	2.9	3.47	12.1	3.49	—	9	20	54	265

1) Polymer
2) Name
3) Molecular weight
4) Quantity in oil, %
5) Viscosity (cSt) at
6) Ratio
7) Viscosity (poises) at
8) Polyisobutylene
9) Polymethacrylate
10) Oil base.

TABLE 11.6

Influence of Polymer Molecular Weight on Thermal Destruction (after Ye.G. Semenido)

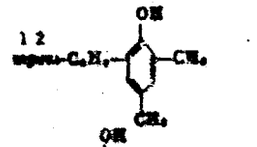
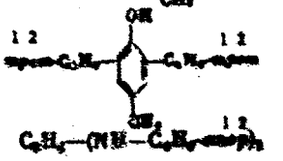
1 Молекулярный вес полимера	2 Начальная вязкость 5%-ных растворов полимеров (в сст) при 100°C	3 Изменение вязкости масла (в сст) и показателя ПСВ* в процессе деполимеризации при											
		100°C			150°C			200°C			250°C		
		4 4 ч	12 ч	ПСВ	4 ч	12 ч	ПСВ	4 ч	12 ч	ПСВ	4 ч	12 ч	ПСВ
5 Полиизобутилен													
15000	17.35	17.3	17.1	98.5	16.8	16.7	96.3	16.1	15.0	86.7	15.8	13.8	79.6
20000	21.40	21.2	20.9	97.7	21.0	20.4	95.2	19.8	16.3	76.2	18.6	15.2	71.0
6 Винипол													
9000	11.80	10.9	10.3	93.0	9.2	10.0	79.6	8.3	4.6	67.3	8.0	6.2	55.0
12000	15.40	14.7	14.4	96.5	11.3	10.0	66.2	10.2	8.4	55.7	9.8	6.0	39.8

*ПСВ is the oil viscosity stability index in % (the viscosities of the oils after 12 hr of heating are compared with the initial viscosities).

1) Polymer molecular weight
2) Initial viscosity of 5% solutions of polymers (cSt) at 100°C
3) Change in oil viscosity (cSt) and ПСВ index* during depolymerization at
4) 4 hours
5) Polyisobutylene
6) Vinipol.

TABLE 11.7

Influence of Antioxidant Additives* on Depolymerization Stability of 5% Polyisobutylene Solution in Turbine Oil [2]

1 Характеристика присадки		4 Формула	Вязкость масла при 5 100°C, сст			9 Показатель стабильности вязкости (ПСВ)
2 марка	3 состав		6 исходного	7 после нагрева при 200°C		
				8 4 ч	12 ч	
10 Тонилен-А	11 3,4-диметил-6-трет-бутилфенол		28.8	28.5	28.4	98.6
13 Тонилен-О	14 4-метил-2,6-ди-трет-бутилфенол		29.1	29.5	28.2	96.9
15 Тонилен-М	16 N,N'-ди-втор-бутил-п-фенилендиамин		28.6	28.5	27.7	96.1
17 ФЧ-16	Продукт переработки черного дегтя углей	—	28.8	28.8	28.8	98.3
18 Термовый крекинг	Продукт сухой перегонки бурового дистиллята	—	28.6	28.5	28.4	98.4
21 Дрожжево-солевой антиокислитель	Продукт сухой перегонки дрожжевого	—	28.6	28.7	28.6	100.0
—	22 Масло без присадки	—	27.6	27.3	25.6	91.7

*2% additive.

1) Characteristics of additives
2) Type
3) Composition
4) Formula
5) Oil viscosity at 100°C, cSt
6) Initial
7) After heating at 200°C for
8) 6 hours
9) Viscosity stability index
10) Topanol-A
11) 2,4-dimethyl-6-*tert*-butylphenol
12) *tert*
13) Topanol-O
14) 4-methyl-2,6-di-*tert*-butylphenol
15) Topanol-M
16) N,N'-di-*sec*-butyl-*p*-phenylenediamine
17) FCh-16
18) Product of refining Cheremkhovo coals
19) Retarder preparation
20) Product from dry distillation of beechwood
21) Wood-tar antioxidant
22) Product of dry distillation of wood
23) Oil without additive.

TABLE 11.8

Change in Viscosity of Thickened Oils as a Result of Mechanical Destruction of Polymer at 20°C in K.I. Klimov's Rotary Tester [3]

1 Состав масла	Вязкость (в сст) при продолжительности опыта 2			
	3 0 минут	30 минут	120 минут	300 минут
4 Турбинное 22 + 5% полиизобутилена мол. веса 20000	1148	928	823	423
5 Керосин + 20% того же полиизобутилена	1153	975	848	415

1) Composition of oil
2) Viscosity (cSt) after test time of
3) Minutes
4) Turbine 22 + 5% polyisobutylene with m.w. of 20,000
5) Kerosene + 20% of the same polyisobutylene.

TABLE 11.9

Properties of Voltols (after Yu.A. Pinkevich)

1 Показатели	2 Образцы вольтолей		
	А	3 В	4 В
5 Средний молекулярный вес	676	887	985
6 Иодное число	9,2	9,8	9,1
7 Плотность d_4^{20}	0,871	0,867	0,863
8 Вязкость, сст:			
9при 50° С	686	4150	1211
» 100° С	145	749	295

1) Index
2) Voltol specimen
3) B
4) C
5) Average molecular weight
6) Iodine number
7) Density
8) Viscosity, cSt
9) At.

Oils with viscosity additives (m.w. 15,000-25,000 polyisobutylene) AKZ_p-6 and AKZ_p-10 are produced in the Soviet Union (All-Union State Standard [AUSS] (ГОСТ) 1862-60). These are automotive oils used chiefly in the middle belt of the country.

Small quantities of voltols (Table 11.9), which are obtained by subjecting paraffin and petroleum, vegetable, and animal oils and mixtures thereof to high-voltage discharges (several thousand volts), are used abroad as viscosity additives.

2. DEPRESSOR ADDITIVES

The depressor additives now in practical use include alkylnaphthalenes, alkylphenol derivatives, esters of alkylphenols and phthalic acid, and certain polymethacrylates. The alkylnaphthalenes include the AzNII (AUSS 8443-57) and Paraflow (USA) depressor additives. The alkyl chains of these additives contain 22-24 carbons.

Below we list the properties of the AzNII depressor:

Depression on addition of 0.1% of additive to AK-15 oil with pour point not above -5°C, in °C, not below	10
Ash, %, not above	0.2
Coking capacity, %, not above	3.5
Mechanical impurities, %, not above	0.15
Water-soluble acids and alkalies	None
Water	"

The Paraflow additive has the following properties:

Pour point, °C	15-20
Coking capacity, %	3.2-5.8

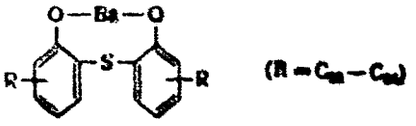
Ash, %.....	0.5-1.0
Elementary composition, %:	
C.....	87.0
H.....	12.0
Density at 20°C, g/cm^3.....	0.905-0.925
Kinematic viscosity at 100°C, cSt.....	85-140
Molecular weight.....	800-900

These additives are usually employed in concentrations of 0.5-1.0%.

The alkylphenol derivatives include the additive AzNII-TsIATIM-1 (АзНИИ-ЦИАТИМ-1), which has the following properties (AUSS 7189-54):

Kinematic viscosity at 100°C, cSt.....	32-60
Acid number, mg of KOH to 1 g of additive, no more than.....	0.5
Mechanical impurities,[1] %, not above.....	0.15
Including those dissolved in water, %, not above.....	0.10
Water, %, not above.....	0.2
Ash, %.....	4.0-5.5
Barium, %, not below.....	2.0
Sulfur, %.....	3.0-4.5
Chlorine, %, not above.....	2.0
Pinkevich corrosion of MT-16 base oil with 3% additive on type S-1 or S-2 steel sheet (AUSS 3778-56), g/m^2, not above.....	6
PZV detergent properties of base oil MT-16 with 3% additive, points, not above.....	3

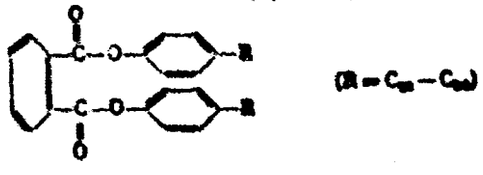
A typical formula of the additive is



АзНИИ-ЦИАТИМ-1 is a multipurpose additive (it exhibits anticorrosion, detergent and depressor properties). Recently, it has been used only as a depressor additive. It is produced in accordance with AUSS 7189-54.

The esters of alkylphenols with phthalic acid (Santopure) are also used as depressor additives.

The type formula of Santopure is



[1] /760

According to N.A. Ragozin, one Santopure specimen had the following properties:

Density at 15°C, g/cm³	0.894
Kinematic viscosity at 100°C, cSt	35.4
Pour point, °C	-12
Coking capacity, %	1.4
Acid number, mg of KOH to 1 g	0.02

Among the polymethacrylates (see viscosity additives), polymethacrylate D exhibits depressor properties.

Depressor additives adjust the pour points of oils when they are affected by formation of a paraffin crystal lattice. Hence the effectiveness of these additives is conspicuous only in paraffin-base oils that contain dissolved solid paraffinic hydrocarbons (Table 11.10). Depressor additives do not influence the cloud points of the oils (see Table 11.10). Santopure is more effective than Paraflow (Table 11.11). Use of the Santopure additive is especially advantageous when the oils have high paraffin contents.

TABLE 11.10

Effectiveness of Paraflow Depressor [7]

A Масло	Температура помутнения, B °C	Температура застывания, C °C
D С высоким содержанием парафина	−1	−4
E То же + 1% парафлоу	−1	−29
F С минимальным содержанием парафина	−17	−18
E То же + 1% парафлоу	−17	−32
G Асфальтового основания с естественной низкой температурой застывания	−32	−32

A) Oil
B) Cloud point, °C
C) Pour point, °C
D) With high paraffin content
E) Same + 1% Paraflow
F) With minimum paraffin content
G) Asphalt base with natural low pour point.

TABLE 11.11

Comparative Effectiveness of Santopure and Paraflow [8]

1 Масло	Содержание твердых углеводородов в масле, 2 %	Содержание депрессора в масле, % 3	Эффект при добавлении 4 в масло парафлоу	
			5 сантопур	6 парафлоу
7 Авиационное	2.0	0.5	3	1
8 Трансформаторное	2.0	0.5	53	7
9 Индустриальное	1.0	1.0	40	6
10 Веретенное	2.0	1.0	30	12

1) Oil
2) Solid hydrocarbon content in oil, %

3) Depressor content in oil, %
4) Effect when oil contains additive
5) Santopure
6) Paraflow
7) Aviation
8) Transformer
9) Industrial
10) Spindle.

TABLE 11.12

Influence of Depressor Additives on Pour Points of Oil Fractions (after A.M. Kuliyev, R.Sh. Kuliyev, M.I. Aliyev)

1 Пределы кипения фракций, °С	2 Плотность d_4^{20}	3 Кинематическая вязкость при 50° С, сст	4 Температура застывания, °С		
			5 исходной фракции	6 с 0,3% АзНИИ-ТСИАТИМ-1	7 с 0,3% депрессора АзНИИ
8 Балаханская масляная нефть					
300—320	0,8716	3,95	—45	—70	—68
320—340	0,8811	5,93	—43	—66	—66
340—360	0,8901	8,32	—42	—63	—64
360—380	0,8921	11,02	—40	—58	—57
380—400	0,8974	16,90	—34	—52	—52
400—420	0,9029	30,21	—32	—44	—42
420—440	0,9103	47,14	—29	—38	—36
440—460	0,9164	97,40	—25	—34	—28
460—480	0,9147	110,26	—24	—34	—26
9 Балаханская тяжелая нефть					
300—320	0,9087	4,78	—64	—68	—68
320—340	0,9192	6,93	—55	—58	—60
340—360	0,9224	10,36	—52	—52	—58
360—380	0,9240	15,86	—48	—47	—47
380—400	0,9280	25,91	—40	—40	—42
400—420	0,9337	60,56	—30	—30	—31
420—440	0,9388	112,04	—24	—25	—26
440—460	0,9451	222,08	—17	—17	—18
460—480	0,9447	309,50	—16	—16	—16

1) Fraction boiling range, °C
2) Density
3) Kinematic viscosity at 50°C, cSt
4) Pour point, °C
5) Initial fraction
6) With 0.3% AzNII-TsIATIM-1
7) With 0.3% AzNII depressor
8) Balakhany oily crude
9) Balakhany heavy crude.

Residual oils containing solid ceresin hydrocarbons (which have a crystal structure differing from that of paraffin) are rather unresponsive to depressor additives. However, Santopure is slightly more effective than Paraflow even in this case.

Distillate oil fractions are more responsive to depressor additives than are the residual products. However, their responsiveness decreases with increasing boiling point (Table 11.12).

TABLE 11.13

Properties of Alkylated Hydrocarbons with Various Side Chains [9]

1 Присадка	2 Формула	3 Количество присадки, %	4 Депрессия температуры застывания масла АК-15 с присадкой, °С
5 Моногептилбензол	$C_7H_{15}—C_6H_5$	0,5	0
6 Дигептилбензол	$(C_7H_{15})_2—C_6H_4$	0,5	1
7 Тригептилбензол	$(C_7H_{15})_3—C_6H_3$	0,5	2
8 Моноцетилбензол	$C_{16}H_{33}—C_6H_5$	0,5	2
9 Дицетилбензол	$(C_{16}H_{33})_2—C_6H_4$	0,5	3
10 Трицетилбензол	$(C_{16}H_{33})_3—C_6H_3$	0,5	4
11 Моноалкилбензол (алкильная цепь — парафин)	$C_{24}H_{49}—C_6H_5$	0,5	4
12 Диалкилбензол (алкильная цепь — парафин)	$(C_{24}H_{49})_2—C_6H_4$	0,5	15
13 Моногептилнафталин	$C_7H_{15}—C_{10}H_7$	0,5	0
14 Дигептилнафталин	$(C_7H_{15})_2—C_{10}H_6$	0,5	1
15 Моноцетилнафталин	$C_{16}H_{33}—C_{10}H_7$	0,5	2
16 Дицетилнафталин	$(C_{16}H_{33})_2—C_{10}H_6$	0,5	3
17 Диалкилнафталин (алкильная цепь — парафин)	$(C_{24}H_{49})_2—C_{10}H_6$	0,1	16
18 Моноцетилантрацен	$C_{16}H_{33}—C_{14}H_9$	0,5	2
19 Дицетилантрацен	$(C_{16}H_{33})_2—C_{14}H_8$	0,5	3
20 Моногептилтетралин	$C_7H_{15}—C_{10}H_{11}$	0,5	4
21 Дигептилтетралин	$(C_7H_{15})_2—C_{10}H_{10}$	0,5	5
22 Тригептилтетралин	$(C_7H_{15})_3—C_{10}H_9$	0,5	6
23 Моноцетилтетралин	$C_{16}H_{33}—C_{10}H_{11}$	0,5	7
24 Дицетилтетралин	$(C_{16}H_{33})_2—C_{10}H_{10}$	0,5	8
25 Диалкилфенантрен (алкильная цепь — парафин)	$(C_{24}H_{49})_2—C_{14}H_8$	0,2	14
26 Депрессор АзНИИ (заводского изготовления)	$(C_{24}H_{49})_2—C_{10}H_6$	0,1	13

1) Additive
2) Formula
3) Amount of additive, %
4) Pour-point depression of AK-15 oil with additive, °C
5) Monoheptylbenzol
6) Diheptylbenzol
7) Triheptylbenzol
8) Monocetylbenzol
9) Dicetylbenzol
10) Tricetylbenzol
11) Monoalkylbenzol (paraffinic alkyl chain)
12) Dialkylbenzol (paraffinic alkyl chain)
13) Monoheptylnaphthalene
14) Diheptylnaphthalene
15) Monocetylnaphthalene
16) Dicetylnaphthalene
17) Dialkylnaphthalene (paraffinic alkyl chain)
18) Monocetylanthracene
19) Dicetylanthracene
20) Monoheptyltetralin
21) Diheptyltetralin
22) Triheptyltetralin
23) Monocetyltetralin
24) Dicetyltetralin
25) Dialkylphenanthrene (paraffinic alkyl chain)
26) AzNII depressor (refinery-prepared).

TABLE 11.14

Influence of Polymethacrylate D Concentration on Pour Point and Viscosity of Selectively Refined Oils [7]

1 Масло	2 Вязкость (в сст) при 50° С	при 100° С	3 Температура застывания, °С
А	12,87	3,88	−25
4 А + депрессор:	13,70	3,93	−44
0,25%	14,55	4,18	−44
0,5%	20,28	5,11	−17
5 Б			
6 Б + депрессор:	20,40	5,13	−25
0,25%	20,65	5,23	−25
0,50%	20,90	5,27	−27
0,75%	21,75	5,56	−29
1,0%	31,02	7,97	−25
2,0%	20,35	5,13	−24
7 В			
8 В + депрессор:	20,95	5,23	−29
0,25%	22,22	5,61	−37
0,5%	23,47	5,93	−41
0,75%	24,93	6,27	−43
1,0%			

1) Oil
2) Viscosity (cSt) at
3) Pour point, °C
4) A + depressor
5) B
6) B + depresscr
7) V
8) V + depressor.

TABLE 11.15

Properties of Polymethacrylate D and AzNII-TsIATIM-1 Additive (according to All-Union Scientific Research Institute for the Petroleum Industry [AUSRI PI] (ЗНИИ НП))

A Масло	B	C	D	E				F
			0,10%	0,25%	0,50%	1,00%	1%
G АС-9,5	17 000	−12	—	−27	−30	−30	—
H Дистиллятное ($\nu_{100}^{6,1}$ сст)	17 000	−10	−17	−31	−33	−35	−18
I АС-5 ($\nu_{100}^{4,6}$ сст)	15 000	−20	−22	−38	−36	−35	—
J НС-20	17 000	−17	—	−40	−41	−41	—

TABLE 11.15 (continued)

	A	B	C	D Температура застывания (в °С) после добавления присадок				
				E				F
				0,10%	0,25%	0,50%	1,00%	1%
K	МС-12	17 000	−28	—	−45	−46	—	—
L	Фракция 300—400° С	24 000	−14	—	−30	—	—	−14
M	То же	24 000	−20	—	−33	—	—	−20
	»	24 000	−30	—	−35	—	—	−30
L	Фракция 350—400° С	24 000	−10	—	−25	—	—	−14
M	То же	24 000	−20	—	−30	—	—	−20
	Фракция 420—500° С	24 000	−15	—	−25	—	—	—
N	МС-20	17 000	−19	—	—	—	−19	—
O	Типа МС-20	17 000	−12	—	−13	−22	−25	—
M	То же	17 000	−1	—	−16	—	−17	—

*Oils from mixture of eastern sulfur-containing crudes.

A) Oil*
B) Conventional molecular weight of polymethacrylate
C) Pour point of initial oil, °C
D) Pour point (°C) after introduction of additives
E) Polymethacrylate
F) AzNII-TsIATIM-1
G) AS-9.5
H) Distillate (ν_{100} = 6.4 cSt)
I) AS-5 (ν_{100} = 9.4 cSt)
J) IS-20
K) IS-12
L) 300-400°C fraction
M) Same
N) MS-20
O) Type MS-20.

TABLE 11.16

Compatibility of Polymethacrylate (Depressor) with Multipurpose Additives when Used in Industrial Oil 20 [2]

1 Многофункциональная присадка*	2 Содержание полиметакрилата, %	3 Температура застывания, °С	1 Многофункциональная присадка*	2 Содержание полиметакрилата, %	3 Температура застывания, °С
4 3% ВНИИ НП-360	0,2	—28	11 3,5% ДФ-11	0,2	—30
5 То же	0,4	—31	12 3,5% ДФ-1	0,2	—41
»	1,0	—36	То же	0,4	—42
6 7,5% СБ-3	0,2	—28	13 0,4% депрессора АзНИИ	—	—31
7 4,5% МНИ НП-22	0,2	—27	14 3% АзНИИ-ЦИАТИМ-1	—	—35
8 То же	0,4	—28	15 3% ВНИИ НП-360 + 1% АзНИИ-ЦИАТИМ-1	—	—31
9 4% АзНИИ-8	0,2	—27	16 Масло без присадки	—	—15
10 То же	0,4	—32	То же	0,2	—28
11 3% ЦИАТИМ-339	0,4	—32	»	0,4	—28
12 3% ЦИАТИМ-339 + 1% ДФ-11	0,2	—27	»	1,0	—30

*The structure and composition of the DF-11 and DF-1 additives are given in Table 11.[illegible]1. For the depressor additives AzNII and AzNII-TsIATIM-1, see page ... and Table 11.13; for additive MNI IP-22, see page 1089; VNII NP-360, page 1087; AzNII-8, page , SB-3, page and TsIATIM-339, page 1086.

1) Multipurpose additive*
2) Polymethacrylate content, %
3) Pour point, °C
4) 3% VNII NP-360
5) Same
6) 7.5% SB-3
7) 4.5% MNI IP-22
8) 4% AzNII-8
9) 3% TsIATIM-339
10) 3% TsIATIM-339 + + 1% DF-11
11) 3.5% DF-11
12) 3.5% DF-1
13) 0.4% AzNII depressor
14) 3% AzNII-TsIATIM-1
15) 3% VNII NP-360 + + 1% AzNII-TsIATIM-1
16) Oil without additive.

Depressors are not effective with paraffin-free tarry crudes (such as heavy Balakhany). The effectiveness of depressor additives depends basically on the length of the alkyl side chains on the aromatic rings. The longer the side chains, the more effective the additive. Compounds in which two alkyl radicals with normal structure, containing 24 carbons each, are attached to the aromatic ring are most effective (Table 11.13).

Usually, rather small quantities of the depressor additives are all that is needed to depress the pour points of the oils. In the case, for example, of polymethacrylate D, the optimum concentration is 0.25% (Table 11.14). A further increase in the additive concentration in the oil has practically no effect on its pour

point. Polymethacrylates D with molecular weights around 17,000 are particularly effective (Table 11.15). Addition of 0.25% of this additive to the oils is more effective than 1% of AzNII-TsIATIM-1 additive.

However, polymethacrylate D has one important shortcoming - it has poor compatibility with many multipurpose additives. Its addition to oils containing multipurpose additives is frequently less effective than addition to the pure base oil (Table 11.16).

3. ANTIOXIDANT ADDITIVES

Antioxidant additives are classified on the basis of their nature and the mechanism of their action as a function of oil working conditions and composition.

TABLE 11.17

Influence of Antioxidants on Oxidation of White Oil at 130°C [10]

1 Соединение	2 Формула	3 Длительность индукционного периода, ч при 0.01% присадки	1 Соединение	2 Формула	3 Длительность индукционного периода, ч при 0.01% присадки
4 Фенилизоцианид	C_6H_5NC	—1.0*	14 Дифенилгуанидин	$NH=C(NHC_6H_5)_2$	1.0
5 п-Толуидин	$CH_3C_6H_4NH_2$	—0.5	15 β-Нафтиламин	$C_{10}H_7NH_2$	3.0
6 2,3-Ксилидин	$(CH_3)_2C_6H_3NH_2$	—0.5	16 Этил-α-нафтиламин	$C_{10}H_7NHC_2H_5$	3.0
7 Хинолин	C_9H_7N	—0.5	17 Метил-α-нафтиламин	$C_{10}H_7NHCH_3$	4.5
8 Дифенил	$C_6H_5—C_6H_5$	—0.5	18 α-Нафтиламин	$C_{10}H_7NH_2$	4.5
9 Анилин	$C_6H_5NH_2$	0	19 п-Аминофенол	$HOC_6H_4NH_2$	5.0
10 Толидин	$(CH_3C_6H_3NH_2)_2$	0	20 Дифениламин	$(C_6H_5)_2NH$	8.5
11 Фенилгидразин	$C_6H_5NH—NH_2$	0	21 Фенил-α-нафтиламин	$C_6H_5NHC_{10}H_7$	11.0
12 Гидрохинон	$C_6H_4(OH)_2$	0	22 Дифенилгидразин	$C_6H_5NH—NHC_6H_5$	13.0
13 Оксанилид	$(CONHC_6H_5)_2$	0			

*The minus sign indicates that addition shortens the induction time, i.e., the compound accelerates oxidation of the oil.

1) Compound
2) Formula
3) Retardation of oxidation by 0.01% of additive, hr
4) Phenylisocyanide
5) p-Toluidine
6) 2,3-Xylidine
7) Quinoline
8) Biphenyl
9) Aniline
10) Tolidine
11) Phenylhydrazine
12) Hydroquinone
13) Oxanilide
14) Diphenylguanidine
15) β-Naphthylamine
16) Ethyl-α-naphthylamine
17) Methyl-α-naphthylamine
18) α-Naphthylamine
19) p-Aminophenol
20) Diphenylamine
21) Phenyl-α-naphthylamine
22) Diphenylhydrazine.

Antioxidant additives (or, as they are frequently called, antioxidants) whose mechanism is based on their ability to form oxidative chains are used for relatively deeply refined oils used at temperatures not above 100-120°C. These antioxidants include compounds of an aminic or phenolic nature, e.g., phenyl-α-naphthylamine (Neozon-*a*), p-dihydroxydiphenylamine, 2,6-di-*tert*-butyl-4-methylphenol (Ionol), certain nitrogen, sulfur, and phosphorus compounds, and others. Parahydroxydiphenylamine, phenyl-α-naphthylamine and others are added to deep-refined oils (turbine and transformer oils, MK-8 jet-engine oil, etc.) in amounts of 0.01-0.02%, and Ionol in amounts of 0.2-0.7%. Such additives are most effective when used in unstable white oils (vaseline, medical), from which the natural antioxidants have been extracted during refining (Tables 11.17-11.21). Some antioxidants are capable of lowering the oxidizability of these oils by tens or even hundreds of times (see Table 11.21). Addition of antioxidants to turbine and transformer oils is also quite effective; the stability of the oils is several times higher (Tables 11.22-11.24).

Screened phenols have acquired particular importance in recent years as antioxidant additives (Table 11.25). They dissolve well in the oils and are not precipitated from them at low temperatures. The additive 2,6-di-*tert*-butyl-4-methylphenol, which is known as Ionol here and in the USA, as Topanol-O in England, and as Kerobit in the FRG, has come into practical use.

High antioxidant activity is also found in the *bis*-phenols and their sulfur derivatives (Table 11.26).

Antioxidant additives may also be highly effective when the oxidation process is catalyzed by oxidation accelerators: the metals Cu, Fe, Mn or their salts (Table 11.27).

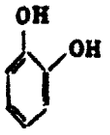
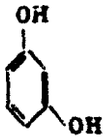
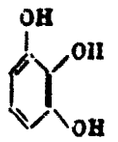
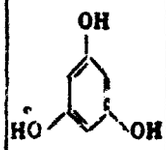
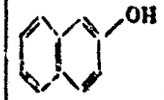
K.I. Ivanov et al. classify oxidation inhibitors into three groups in accordance with the age of the oxidation process at which they are most active (Table 11.28). The additives of the different groups behave differently with respect to hydrocarbon and peroxide radicals (Figs. 11.5 and 11.6). Thus, group I antioxidants are effective only when introduced into the oil before the end of the induction period, those of group II when added either in the initial stage or in the process of active development of the oxidation process. Group III antioxidants are capable of retarding oxidation when introduced into the oil during the induction phase or during the autocatalytic stage if oxidation has not progressed too far.

It has been shown that mixtures of antioxidant additives from different groups have the highest activity. The phenomenon in which a mixture of additives is found to be more effective than each additive taken alone in the same concentration is known as "synergism" (Tables 11.29 and 11.30 and Figs. 11.7-11.9).

Working from the mechanism of the antioxidant effect, R.A. Lipshteyn, A.Ya. Mikhel'son and Ye.R. Shtern classified a number of the best-known additives by a kinetic approach that they developed themselves (Table 11.31).

TABLE 11.18

Influence of Various Phenols on Oxidation of Medical Oil [11]

1 Присадка	2 Формула	3 Кислотное число, мг KOH на 1 г	4 Число омыления, мг KOH на 1 г	5 Кислые продукты, %	6 Продукты уплотнения, %	7 Всего продуктов окисления, %	8 Примечание
9 Пирокатехин:							
0,1%		10 Следы	2,1	0,2	1,6	1,8	Масло мутное, осадка нет 11
1%		1,5	1,9	10 Следы	1,6	1,6	Черный смолистый осадок 12
3%		1,4	1,5	0,8	2,1	2,4	То же 13
14 Гидрохинон:							
0,1%		24,1	43,7	14,7	21,4	36,1	Осадка нет 15
1%		Следы 10	0,1	0,1	1,7	1,8	Взвешенный черный осадок 16
3%		»	0,1	0,1	2,2	2,3	То же 13
17 Резорцин:							
0,1%		4,8	5,4	3,4	8,8	12,2	Незначительный осадок 18
1%		0,9	1,2	0,3	1,7	2,0	Черный смолистый осадок 19 12
3%		1,4	1,8	1,2	2,8	4,0	То же 13
19 Пирогаллол:							
0,01%		18,2	33,4	14,0	16,5	30,5	»
0,1%		2,7	4,9	2,5	4,3	6,8	»
1%		1,2	1,2	0,3	2,9	3,2	Черный взвешенный осадок 20
21 Флороглюцин:							
0,1%		15,0	49,7	17,9	11,9	29,8	То же 13
3%		24,8	50,6	17,0	17,5	34,5	»
22 β-Нафтол:							
0,1%		0,5	0,5	0,3	1,5	98,2	Осадка нет 15
1%		0,9	1,2	1,3	1,4	2,7	Взвешенный осадок 23
3%		1,9	3,0	2,4	3,2	5,6	
24 Масло без присадки		39,5	75,7	24,5	20,5	45,0	Темный смолистый осадок 25 Осадка нет 15

Note Oxidation by oxygen in Butkov "bomb" at 150°C and pressure of 15 atm for 3 h. Weight of oil taken: 5 g.

1) Additive
2) Formula
3) Acid number, mg of KOH to 1 g
4) Saponification number, mg of KOH to 1 g
5) Acid products, %
6) Condensation products, %
7) Total oxidation products, %
8) Remarks
9) Pyrocatechol
10) Traces
11) Oil cloudy, no sediment
12) Black gummy sediment
13) Same
14) Hydroquinone
15) No sediment
16) Suspended black sediment
17) Resorcinol
18) Small amount of sediment
19) Pyrogallol

20) Black sediment in suspension
21) Phloroglucinol
22) β-Naphthol
23) Suspended sediment
24) Oil without additive
25) Dark gummy sediment.

TABLE 11.19

Influence of Amines on Oxidation of Medical Oil* [11]

1 Присадка	2 Формула	3 Кислотное число, мг KOH на 1 г	4 Число омыления, мг KOH на 1 г	5 Кислые продукты %	6 Продукты уплотнения, %
7 Анилин:					
0.1%		38.5	74.3	29.1	27.0
1%		38.8	74.0	28.8	25.3
3%		2.5	2.5	1.6	8.5
5%		1.6	1.6	1.1	5.2
10%		0.6	—	0.9	2.7
8 β-Нафтиламин:					
0.1%		8.3	8.7	8.5	10.6
1%		0.6	3.1	2.5	3.7
3%		9Следы	1.6	1.6	1.6
5%		»	9Следы	1.4	5.1
10%		»	»	0.7	8.1
10 Масло без присадки		45.0	83.0	30.9	15.7

*Oxidation conditions similar to those indicated in Table 11.18.

1) Additive
2) Formula
3) Acid number, mg of KOH to 1 g
4) Saponification number, mg of KOH to 1 g
5) Acid products, %
6) Condensation products, %
7) Aniline
8) β-Naphthylamine
9) Traces
10) Oil without additive.

TABLE 11.20

Influence of Nitrogen-Containing Heterocyclics on Oxidation of Medical Oil* [11]

1 Присадка	2 Формула	3 Кислотное число, мг KOH на 1 г	4 Число омыления, мг KOH на 1 г	5 Кислые продукты, %	6 Продукты уплотнения, %
7 Пиридин:					
0.1%		52.0	—	28.8	28.5
1%		49.7	99.8	31.7	28.1
3%		47.0	97.0	27.5	26.3
5%		46.1	90.1	25.9	28.3
10%		46.6	91.6	26.7	26.4
8 Хинолин:					
1%		48.0	80.0	25.7	26.6
5%		47.0	81.4	25.0	23.3
10%		45.0	—	17.5	18.8
9 Масло без присадки		45.0	83.0	30.9	15.7

*Oxidation conditions similar to those indicated in Table 11.18.

1) Additive
2) Formula
3) Acid number, mg of KOH to 1 g
4) Saponification number, mg of KOH to 1 g
5) Acid products, %
6) Condensation products, %
7) Pyridine
8) Quinoline
9) Oil without additive.

TABLE 11.21

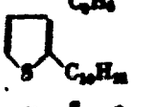
Antioxidation Properties of Phosphites and Aminophenol Compounds [11]

1 Присадка	2 Формула	3 Окисляемость по ГОСТ 981—55: кислотное число, мг KOH на 1 г	4 осадок	5 водорастворимые кислоты
7 0.01% п-оксидифениламина	$C_6H_5NHC_6H_4OH$	0.01	8 Нет	8 Нет
9 0.01% трибутилфосфита	$(C_4H_9O)_3P$	0.03	8	8
10 0.01% трифенилфосфита	$(C_6H_5O)_3P$	0.05	8	12 8
11 Масло без присадки		0.57	8	Есть

1) Additive
2) Formula
3) AUSS 981-55 oxidizability
4) Acid number, mg of KOH to 1 g
5) Sediment
6) Water-soluble acids
7) 0.01% p-hydroxydiphenylamine
8) No
9) 0.01% tributyl phosphite
10) 0.01% triphenyl phosphite
11) Oil without additive
12) Yes.

TABLE 11.22

Influence of Sulfur Compounds on Autooxidation of Commercial Turbine Oil [11]

1 Присадка	2 Формула	3 Содержание серосодержащего соединения, %	4 Стабильность по ГОСТ 981–55: 5 кислотное число, мг KOH на 1 г	4 Стабильность по ГОСТ 981–55: 6 осадок, %
7 Динонилсульфид	$(C_9H_{19})_2S$	0,01	0,08	8 Нет
9		0,10	0,20	0,05
9 Дифенилсульфид	$(C_6H_5)_2S$	0,01	0,07	8 Нет
		0,10	0,15	0,03
10 Дибензилсульфид	$(C_6H_5CH_2)_2S$	0,01	0,09	8 Нет
		0,10	0,21	0,05
11 Динонилдисульфид	$(C_9H_{19})_2S_2$	0,01	0,20	0,05
		0,10	0,26	0,05
12 Дифенилдисульфид	$(C_6H_5)_2S_2$	0,01	0,12	13 Нет
		0,10	0,27	13 Следы
14 Тио-β-нафтол	$C_{10}H_7SH$	0,01	0,13	8 Нет
		0,10	0,21	9
15 α-Фенилэтилмеркаптан	$H_3C-CH-SH$ (C6H5)	0,01	0,54	0,14
		0,10	0,64	0,22
16 α-Децилтиофен	 ($C_{10}H_{21}$)	0,01	0,19	0,03
		0,10	0,19	0,05
17 Тиантрен		0,01	0,10	8 Нет
		0,10	0,11	9
18 Масло без присадки			0,13	0,04

1) Additive
2) Formula
3) Content of sulfur compound, %
4) AUSS 981-55 stability
5) Acid number, mg of KOH to 1 g
6) Sediment, %
7) Dinonyl sulfide
8) None
9) Diphenyl sulfide
10) Dibenzyl sulfide
11) Dinonyl disulfide
12) Diphenyl disulfide
13) Traces
14) Thio-β-naphthol
15) α-Phenylethyl mercaptan
16) α-Decylthiophene
17) Thianthrene
18) Oil without additive.

TABLE 11.23

Influence of Sulfonylamide Compounds on Autoxidation of Oils [12]

1 Окисляемый продукт	2 Формула присадки	3 Окисляемость (ГОСТ 981–55)		
		4 кислотное число мг KOH на 1 г	5 осадок, %	6 водорастворимые кислоты
7 Турбинное масло 30 (УТ) без присадки (к. ч. 0,018 мг KOH на 1 г)		0.21	0.054	8 Есть
9 То же + присадка:				
10 0,02% о-сульфаминбензойнокислого натрия (сульфантрола)	$NH_2-C_6H_4-SO_2$ | $NaOOC-C_6H_4-NH$	0.08	0.009	11 Нет
12 0,02% 2-п-аминобензолсульфамидопиридина (сульфидина)	$NH_2-C_6H_4-SO_2$ | NC_5H_4-NH	0.09	0.012	»
13 0,01% п-оксидифениламина	$C_6H_5NHC_6H_4OH$	0.10	0.063	»
14 Турбинное масло 22 (Л) эксплуатационное (к. ч. 0,15 мг KOH на 1 г)		0.42	0.170	»
15 То же + присадка:				
16 0,02% сульфидина		0.20	0.080	17 Следы
18 0,01% п-оксидифениламина		0.20	0.150	» Есть

1) Product oxidized
2) Additive formula
3) Oxidizability (AUSS 981-55)
4) Acid number, mg of KOH to 1 g
5) Sediment, %
6) Water-soluble acids
7) Turbine oil 30 (UT) without additive (acid number 0.018 mg of KOH to 1 g)
8) Yes
9) Same + additive
10) 0.02% sodium *o*-sulfonylaminobenzoate (sulfanthrol)
11) No
12) 0.02% 2-*p*-aminobenzolsulfamidopyridine (sulfidine)
13) 0.01% *p*-hydroxydiphenylamine
14) Turbine oil 22 (L), in use (acid number 0.15 mg of KOH to 1 g)
15) Same + additive
16) 0.02% sulfidine
17) Traces
18) 0.01% *p*-hydroxydiphenylamine.

TABLE 11.24

Influence of Antioxidants on Stability of Oils by VTI Method [13]

1 Окисленный продукт	2 Количество присадки, %	3 Количество осадка, %	4 Кислотное число, мг KOH на 1 г
5 Температура окисления 120°C			
6 Масло МК-8 без присадки, образец 1	—	0.070	0.24
7 То же + присадка:			
8 АзНИИ-11ф	0.10	0.018	0.08
9 Ионол	0.10	0.038	0.21
10 п-Оксидифениламин	0.05	0.040	0.08
11 Фенил-α-нафтиламин	0.05	0.012	0.22
5 Температура окисления 150°C			
6 Масло МК-8 без присадки, образец 1	—	1.01	3.8
7 То же + присадка:			
8 АзНИИ-11ф	0.1	0.21	0.8
〃	0.3	0.24	0.6
〃	0.5	0.30	0.4
〃	0.7	0.17	0.2
〃	1.0	0.18	0.1
9 Ионол	0.1	1.01	3.8
6 Масло МК-8 без присадки, образец 2	—	2.40	3.20
7 То же + присадка:			
12 АзНИИ-11	0.05	0.35	0.85
〃	0.1	0.25	0.45
9 Ионол	0.05	0.70	1.30
〃	0.1	1.00	1.75
5 Температура окисления 170°C			
6 Масло МК-8 без присадки, образец 2	—	3.20	4.00
7 То же + присадка:			
12 АзНИИ-11	0.05	1.30	2.80
〃	0.1	1.55	2.00
9 Ионол	0.05	2.30	3.70
〃	0.1	2.30	3.60
13 Масло МК-6	—	1.32	2.30
7 То же + присадка			
10 АзНИИ-11	0.5	0.41	0.84
9 Ионол	0.5	0.61	1.21

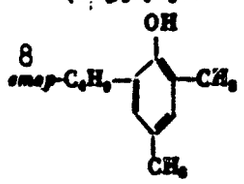
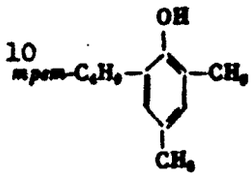
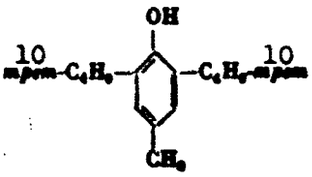
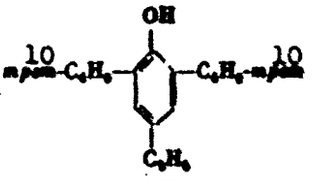
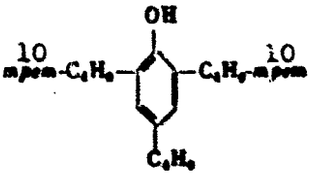
Note. AzNII-11 additive is a product of formaldehyde condensation of the alkylphenol obtained by alkylation of phenol in fractions (100-180°C) of the thermal-cracking distillate of paraffin and urea.

AzNII-11f additive is a product of condensation of industrial alkylphenol with furfuramide [illegible] where R = C_9.

1) Product oxidized
2) Amount of additive, %
3) Amount of sediment, %
4) Acid number, mg of KOH to 1 g
5) Oxidation temperature ...
6) MK-8 oil without additive, specimen ...
7) Same + additive
8) AzNII-11f
9) Ionol
10) p-Hydroxydiphenylamine
11) Phenyl-α-naphthylamine
12) AzNII-11
13) MK-6 oil.

TABLE 11.25

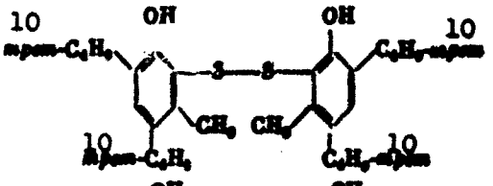
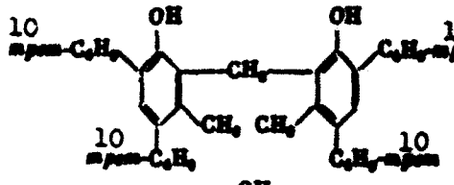
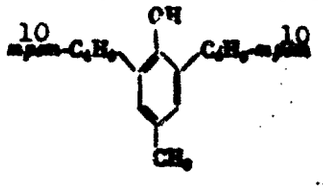
Antioxidant Properties of Various Alkylphenols [14]

1 Присадка	2 Формула	3 Индукционный период окисления, ч
4 Фенол	C_6H_5OH	72
5 Крезол	$CH_3C_6H_4OH$	72
6 2,4-Ксиленол	$(CH_3)_2C_6H_3OH$	72
7 2,4-Диметил-6-*втор*-бутилфенол		150
9 2,4-Диметил-6-*трет*-бутилфенол		250
11 4-Метил-2,6-ди-*трет*-бутилфенол		400
12 4-Этил-2,6-ди-*трет*-бутилфенол		380
13 4-*н*-Бутил-2,6-ди-*трет*-бутилфенол		575
14 Исходное масло		72

1) Additive
2) Formula
3) Oxidation induction period, h
4) Phenol
5) Cresol
6) 2,4-Xylenol
7) 2,4-Dimethyl-6-*sec*-butylphenol
8) *sec*
9) 2,4-Dimethyl-6-*tert*-butylphenol
10) *tert*
11) 4-Methyl-2,6-di-*tert*-butylphenol
12) 4-Ethyl-2,6-di-*tert*-butylphenol
13) 4-*n*-Butyl-2,6-di-*tert*-butylphenol
14) Original oil.

TABLE 11.26

Effectiveness of Antioxidant Additives of the Screened-Phenol Type [15] (AUSS 981-55 Oxidation)

1 Присадка	2 Формула	3	4	5	6	
9 2,2-Дисульфид-бис-(4,6-ди-*трет*-бутил-3-метилфенол)		0.2	0.17	11 Следы	0.013	0.041
12 2,2-Метилен-бис-(4,6-ди-*трет*-бутил-3-метилфенол)		0.2	0.09	0.07	0.004	0.10
13 2,6-Ди-*трет*-бутил-4-метилфенол (ионол)		0.2	0.028	Нет	0.01	0.14
14 Трансформаторное масло из сернистых нефтей		—	0.03	0.01	0.018	0.044

1) Additive
2) Formula
3) Additive concentration, %
4) Acid number, mg of KOH to 1 g
5) Sediment, %
6) Low-molecular acids, %
7) Nonvolatile
8) Volatile
9) 2,2-Disulfide-*bis*-(4,6-di-*tert*-butyl-3-methylphenol)
10) *tert*
11) Traces
12) 2,2-Methylene-*bis*-(4,6-di-*tert*-butyl-3-methylphenol)
13) 2,6-Di-*tert*-butyl-4-methylphenol (Ionol)
14) Transformer oil from sulfur-containing crudes.

TABLE 11.27

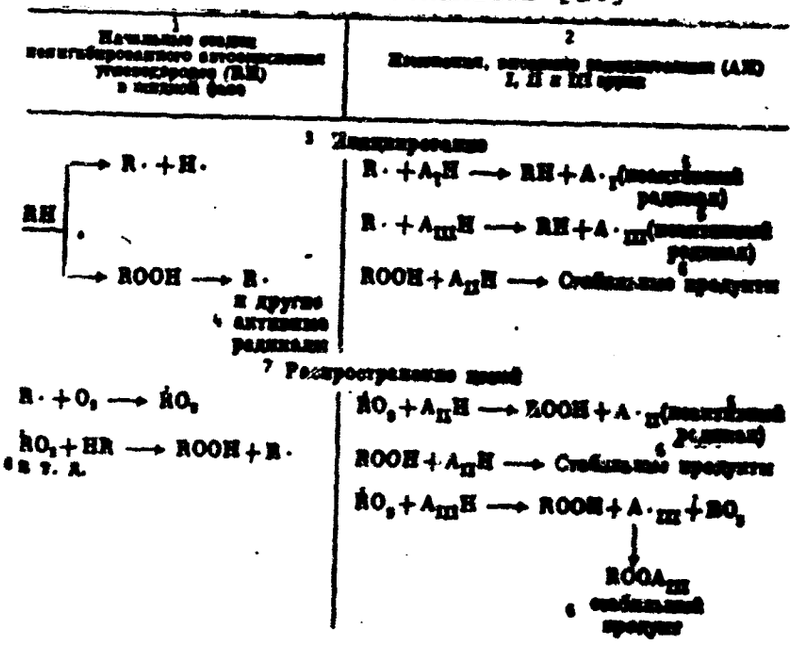
Results of Simultaneous Action of Retarders and Accelerators on Oxidation of Hydrocarbons [16]

1 Углеводород	2 Замедлитель окисления *	3 Ускоритель окисления	4 Скорость поглощения кислорода, в [illegible] O_2 на 1 мл углеводорода	5 Отношение скорости нераспадающейся реакции к скорости [illegible] в [illegible]
6 Этилбензол $C_6H_5C_2H_5$ 6 То же	—	7 Стеарат меди $(C_{17}H_{35}COO)_2Cu$	7.5	—
9	9 Антрацен $(C_{14}H_{10})$	6 То же	0.5	15
9	—	10 Стеарат железа $(C_{17}H_{35}COO)_3Fe$	2.8	—
9	9 Антрацен	6 То же	2.2	2.7
11 1-Метил-4-изопропилциклогексан $CH_3C_6H_{10}CH(CH_3)_2$	—	7 Стеарат меди $(C_{17}H_{35}COO)_2Cu$	5.7	—
6 То же	9 Антрацен	6 То же	1.0	5.7

*2% of the oxidation retarder was added.

1) Hydrocarbon
2) Oxidation retarder*
3) Oxidation accelerator
4) Rate of oxygen absorption in 1 h, ml of O_2 to 1 ml of hydrocarbon
5) Ratio of unretarded to retarded reaction rates
6) Ethyl benzene
7) Copper stearate
8) Same
9) Anthracene
10) Iron stearate
11) 1-Methyl-4-isopropylcyclohexane.

Scheme of Inhibitor Mechanisms [18]



1) Initial stages of uninhibited autooxidation of hydrocarbons (RH) in liquid phase
2) Changes introduced by retarders (AH) of groups I, II and III
3) Initiation
4) And other active radicals
5) (Inactive radical)
6) Stable products
7) Propagation of chains
8) And so forth.

TABLE 1[illegible].

Classification of Antioxidant Additives (according to K.I. Ivanov)

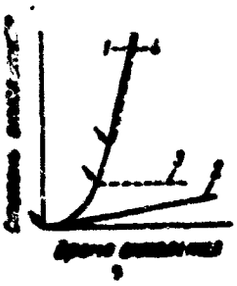
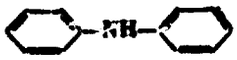
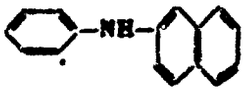
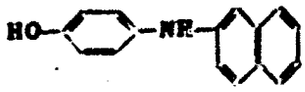
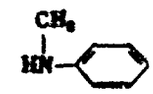
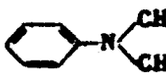
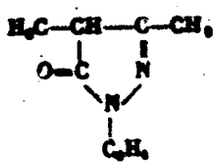
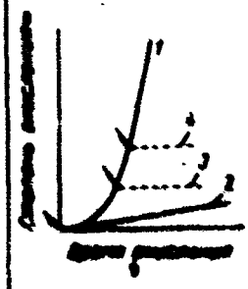
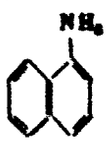
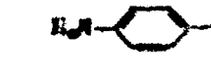
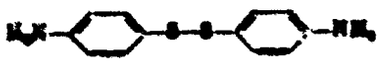
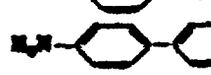
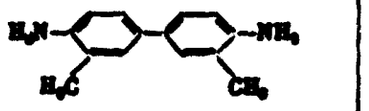
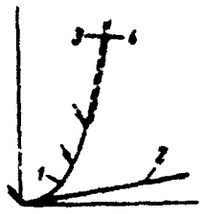
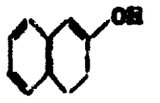
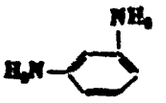
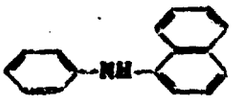
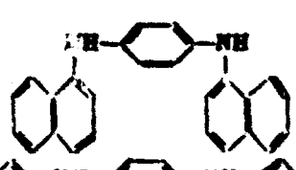
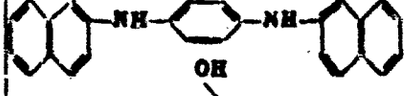
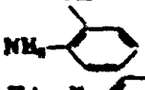
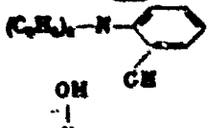
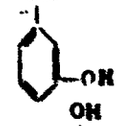
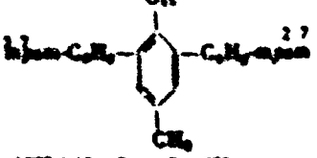
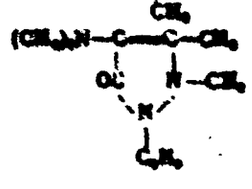
1 Группа	2 Скорость окисления по кривому поглощению кислорода	3 Наименование	4 Формула	5 Концентрация, моль/л	6 Влияние на торможение распада гидроперекиси	7 Взаимодействие с $RO_2^\cdot$
I		10 Дифениламин		0.017	17 Не действует на распад гидроперекисей	18 Взаимодействует с $R^\cdot$ и $RO_2^\cdot$
		11 Фенил-β-нафтиламин		0.033; 0.07		
		12 п-Оксидифениламин		0.018; 0.0068; 0.072		
		13 п-Оксифенил-β-нафтиламин		0.036		
		14 Метиланилин		2		
		15 Диметиланилин		3		
		16 Антипирин		0.05		
II		19 п-Нафтиламин		0.50	23 Активно ингибирует разложение	24 Взаимодействует с $RO_2^\cdot$
		20 п-Нафтол		0.10		
		21 п-Фенилендиамин		0.01		
		22 Дипара-п-фенилендиамин		0.005; 0.017		
		23 п-Аминофенол		0.010		
		24 Гидрохинон		0.100		
		25 Ди-(4-аминофенил-сульфид)		0.005; 0.01; 0.025		
		26 п-трет-Бутилфенол		0.20		
		27 Бензидин		0.005		

TABLE 11.28 (continued)

1 Группа	2 Схемы влияния на кинетику окислительного процесса *	3 Замедлитель	4 Формула	5 Концентрация замедлителя, моль/л	6 Влияние на характер цепной реакции, гидроперекись	7 Взаимодействует с $R^{\cdot}$ и $RO_2^{\cdot}$
		3 1 о-Толидин		0.012		
III	 8 Скорость окисления 9 Время окисления	2 β-Нафтиламин		0.10	Ускоряет, способ стирол разложение	$RO_2^{\cdot}$
		3 β-Нафтол		0.10; 0.30; 0.90		
		4 n-Фенилендиамин		0.010		
		5 Дифенил-п-фенилендиамин		0.020; 0.05		
		6 Фенил-α-нафтиламин		0.07		
		7 Ди-α-нафтил-п-фенилендиамин		0.020		
		8 Ди-β-нафтил-п-фенилендиамин		0.020		
		9 о-Аминофенол		0.010; 0.020		
		10 Диэтил-о-аминофенол		0.07		
		11 Резорцин		0.11		
		12 2,6-Ди-трет-бутил-4-метилфенол		0.002; 0.05; 0.11; 0.22; 0.44; 0.80		
		13 Пиразолон		0.05		

*1) Kinetics of oxidation process; 2) retarder introduced into oil before start of reaction; 3) same, during its autocatalytic phase; 4) same, after reaching constant rate.

1) Group
2) Scheme of influence on kinetics of oxidation process*
3) Retarders
4) Formula
5) Retarder concentration, %
6) Influence on thermal decomposition of hydroperoxides
7) Interaction with free radicals R· and RO_2·
8) Degree of oxidation
9) Oxidation time
10) Diphenylamine
11) Phenyl-β-naphthylamine
12) *p*-Hydroxydiphenylamine
13) *p*-Hydroxyphenyl-β-naphthylamine
14) Methylaniline
15) Dimethylaniline
16) Antipyrine
17) No effect on hydroperoxide composition
18) Reacts with R·
19) α-Naphthylamine
20) α-Naphthol
21) *p*-Phenylenediamine
22) Diethyl-*p*-phenylenediamine
23) *p*-Aminophenol
24) Hydroquinone
25) Di-(4-aminodiphenyl disulfide)
26) *p*-*tert*-Butylphenol
27) *tert*
28) Benzidine
29) Actively promotes decomposition
30) Reacts with RO_2·
31) *o*-Tolidine
32) β-Naphthylamine
33) β-Naphthol
34) *m*-Phenylenediamine
35) Diphenyl-*p*-phenylenediamine
36) Phenyl-α-naphthylamine
37) Di-α-naphthyl-*p*-phenylenediamine
38) Di-β-naphthyl-*p*-phenylenediamine
39) *o*-Aminophenol
40) Diethyl-*o*-aminophenol
41) Resorcinol
42) 2,6-Di-*tert*-butyl-4-methylphenol
43) Pyramidone
44) Moderate promotion of decomposition
45) Reacts with R· and RO_2·.

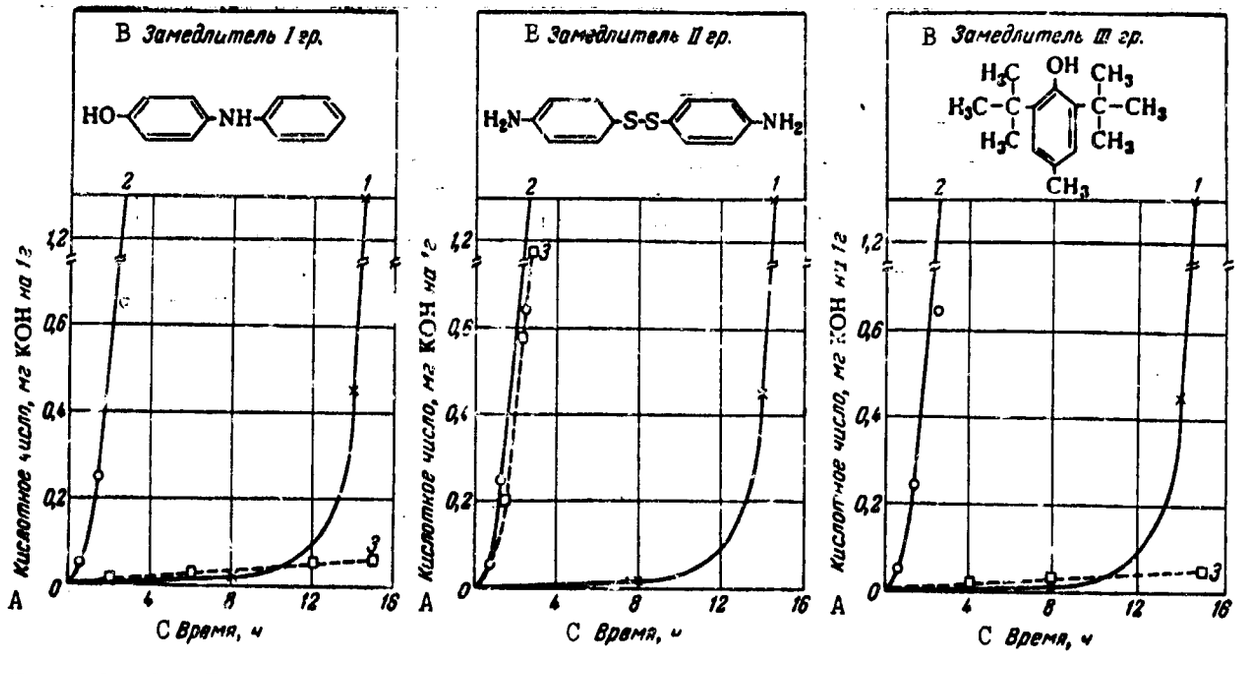


Fig. 11.5. Influence of hydrocarbon radicals on oxidation of oils and effectiveness of antioxidants of the various groups [17]: 1) uninhibited oil; 2) uninhibited oil containing source of ·CH_3 radicals; 3) oil containing antioxidant and source of ·CH_3 radicals. A) Acid number, mg of KOH to 1 g; B) group ... retarder; C) time, h.

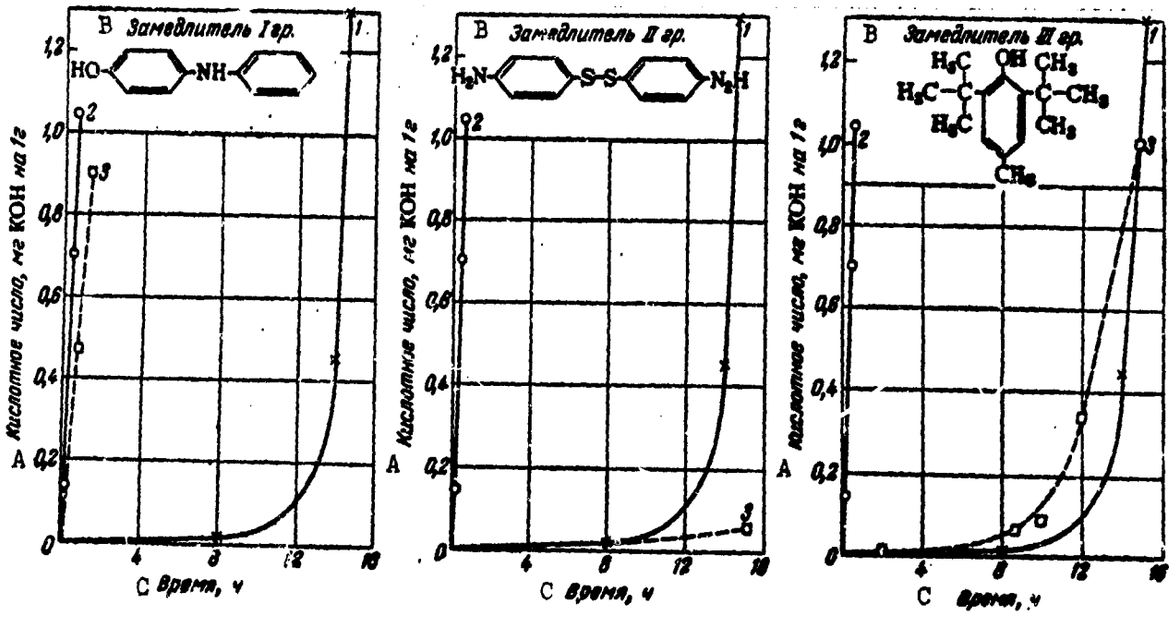


Fig. 11.6. Influence of peroxide radicals on oxidation of oils and effectiveness of antioxidant additives of the various groups [17]: 1) uninhibited oil; 2) uninhibited oil containing source of $RO_2\cdot$ radicals; 3) oil containing antioxidant and source of $RO_2\cdot$ radicals. A) Acid number, mg of KOH to 1 g; B) group ... retarder; C) time, h.

TABLE 11.29

Influence of Group I Antioxidants and Their Mixtures on Stability of Transformer Oil from Balakhany Oily Crude [18]

1 Антиокислитель				2 Стабильность масла по ГОСТ 981—55			
		5	6	7 общая		10 склонность к образованию водорастворимых кислот в начале старения	
3 название	4 формула	группа в классификации	содержание в масле, %	8 кислотное число, мг КОН на 1 г	9 осадок, %	11 кислотное число, мг КОН на 1 г	12 кислотное число, мг КОН на 1 г
13 *n*-Оксидифениламин	$HOC_6H_4NHC_6H_5$	I	0.015	0.14	0.04	0.002	0.003
14 Фенил-β-нафтиламин	$C_{10}H_7NHC_6H_5$	I	0.02	0.17	0.04	0.003	0.003
15 *n*-Оксидифениламин + фенил-β-нафтиламин	—	16 Смесь: I I	0.015 0.020	0.13	0.04	0.003	0.003
17 Масло без присадки	—	—	—	0.38	0.12	0.003	0.002

1) Antioxidant
2) AUSS 981-55 stability of oil
3) Name
4) Formula
5) Group in classification
6) Content in oil, %
7) General
8) Acid number of oil, mg of KOH to 1 g
9) Sediment, %
10) Tendency to form water-soluble acids at start of aging
11) Nonvolatile acids, mg of KOH to 1 g
12) Volatile acids, mg of KOH to 1 g
13) *p*-Hydroxydiphenylamine
14) Phenyl-β-naphthylamine
15) *p*-Hydroxydiphenylamine + phenyl-β-naphthylamine
16) Mixture
17) Oil without additive.

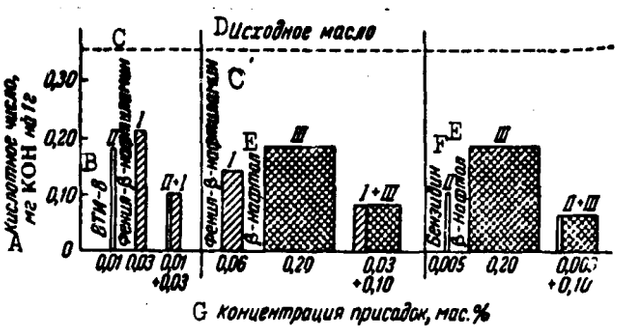


Fig. 11.7. Action of mixtures of antioxidants from various groups on stability of commercial transformer oil made from Buzovna crude [18]. A) Acid number, mg of KOH to 1 g; B) VTI-8; C) phenyl-β-naphthylamine; D) initial oil; E) β-naphthol; F) benzidine; G) additive concentration, % by mass.

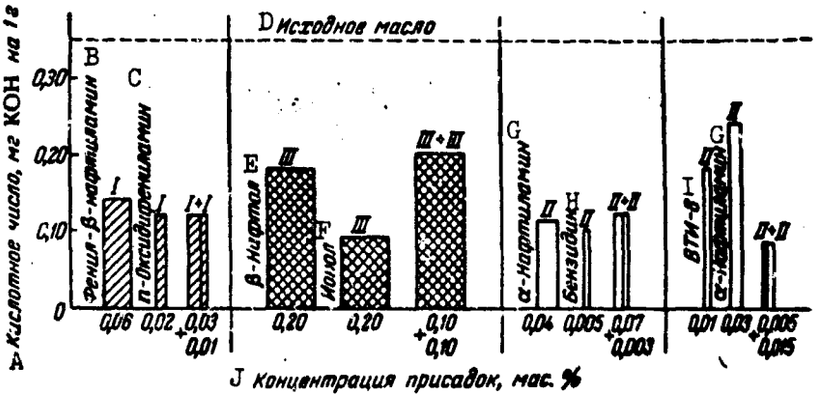


Fig. 11.8. Action of mixtures of antioxidants from the same group on stability of commercial transformer oil obtained from Buzovna crude [18]. A) Acid number, mg of KOH to 1 g; B) phenyl-β-naphthylamine; C) *p*-hydroxydiphenylamine; D) initial oil; E) β-naphthol; F) Ionol; G) α-naphthylamine; H) benzidine; I) VTI-8; J) additive concentration, % by mass.

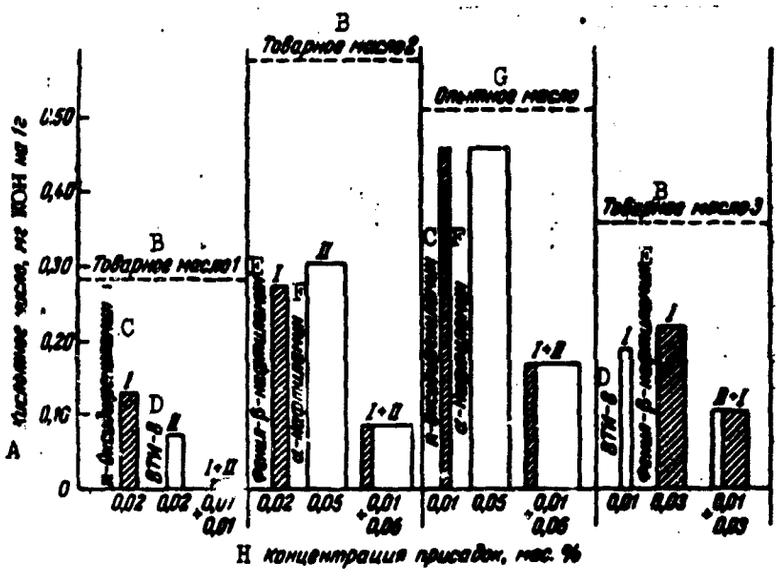


Fig. 11.9. Action of antioxidant mixtures on stability of electrical oils from various origins [18]: oil 1 is a turbine oil from Balakhany oily crude; oil 2 is a transformer oil from Emba oily crudes; oil 3 is transformer oil from Buzovna crude; experimental oil 4 is a transformer oil from Tuymazy crude (S = 0.7%). A) Acid number, mg of KOH to 1 g; B) commercial oil 1; C) p-hydroxydiphenylamine; D) VTI-8; E) phenyl-β-naphthylamine; F) α-naphthylamine; G) experimental oil; H) additive concentration, % by mass.

TABLE 11.30

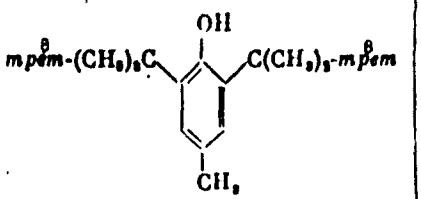
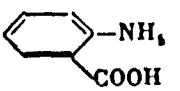
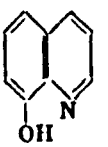
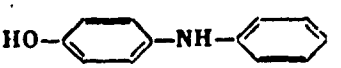
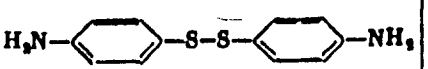
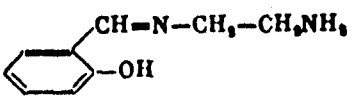
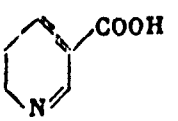
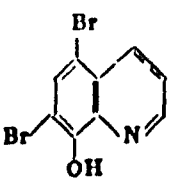
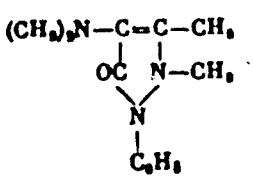
Influence of Group I and II Antioxidants and Their Mixtures on Stability of Electrical Oils [18]

1 Антиокислитель				6 Стабильность масла по ГОСТ 981—55			
				7 общая		10 способность к образованию водорастворимых кислот в начале окисления	
2 название	3 формула	4 группа в классификации	5 содержание в масле, %	кислотное число, мг KOH на 1 г	осадок, %	кислотное число, мг KOH на 1 г	12 эстерное число, мг KOH на 1 г
13 Турбинное масло (товарное из масляной балаханской нефти)							
14 п-Оксидифениламин	$HOC_6H_4NHC_6H_5$	I	0.02	0.13	0.02	0.001	0.007
15 ВТИ-8	—	II	0.02	0.07	0.01	0.002	0.001
17 п-Оксидифениламин + ВТИ-8		Смесь: 16 I II	0.01 0.01	0.01	0.01	18 Нет	0.003
19 Масло без присадки	—	—	—	0.28	0.02	0.003	0.008
20 Трансформаторное масло (товарное из эмбенских масляных нефтей)							
13 п-Оксидифениламин	$HOC_6H_4NHC_6H_5$	I	0.015	0.22	0.03	0.003	—
21 Фенил-β-нафтиламин	$C_{10}H_7NHC_6H_5$	I	0.02	0.27	0.03	—	—
22 α-Нафтиламин	$C_{10}H_7NH_2$	II	0.05	0.30	0.06	—	—
23 п-Оксидифениламин + α-нафтиламин	—	Смесь: 16 I II	0.01 0.05	0.12	0.06	0.005	0.007
23 п-Оксидифениламин + α-нафтиламин		Смесь: 16 I II	0.005 0.03	0.13	0.04	0.006	0.007
24 Фенил-β-нафтиламин + α-нафтиламин		Смесь: 16 I II	0.01 0.05	0.08	0.04	—	—
19 Масло без присадки		—	—	0.57	0.05	0.023	0.030
25 Трансформаторное масло (из туймазинской нефти; содержание серы 0,7%)							
14 п-Оксидифениламин	$HOC_6H_4NHC_6H_5$	I	0.01	0.45	—	0.003	0.011
22 α-Нафтиламин	$C_{10}H_7NH_2$	II	0.05	0.45	0.13	—	—
23 п-Оксидифениламин + α-нафтиламин		Смесь: 16 I II	0.01 0.05	0.16	0.07	0.002	0.010
19 Масло без присадки	—	—	—	0.50	0.08	0.008	0.010
26 Трансформаторное масло (из туймазинской нефти; содержание серы 0,5%)							
14 п-Оксидифениламин	$HOC_6H_4NHC_6H_5$	I	0.01	0.29	0.08	0.002	0.008
27 α-Нафтол	$C_{10}H_7OH$	II	0.05	0.18	0.03	0.002	0.012
28 п-Оксидифениламин + α-нафтол		Смесь: 16 I II	0.01 0.05	0.09	0.03	0.002	0.008
19 Масло без присадки	—	—	—	0.02	0.06	0.021	0.006

1) Antioxidant
2) Name
3) Formula
4) Group in classification
5) Content in oil, %
6) AUSS 981-55 stability of oil
7) General
8) Acid number, mg of KOH to 1 g
9) Sediment, %
10) Tendency to form water-soluble acids at start of aging
11) Nonvolatile acids, mg of KOH to 1 g
12) Volatile acids, mg of KOH to 1 g
13) Turbine oil (commercial, from Balakhany oily crude)
14) *p*-Hydroxydiphenylamine
15) VTI-8
16) Mixture
17) *p*-Hydroxydiphenylamine + + VTI-8
18) None
19) Oil without additive
20) Transformer oil (commercial, from Emba oily crudes)
21) Phenyl-β-naphthylamine
22) α-Naphthylamine
23) *p*-Hydroxydiphenylamine + + α-naphthylamine
24) Phenyl-β-naphthylamine + + α-naphthylamine
25) Transformer oil (from Tuymazy crude; sulfur content 0.7%)
26) Transformer oil (from Tuymazy crude; sulfur content 0.5%)
27) α-Naphthol
28) *p*-Hydroxydiphenylamine + + α-naphthol.

TABLE 11.31

Classification of Antioxidant Additives

1 Присадка	2 Формула	3 Свойства присадок		
		4 ингибирующие	5 дезактивирующие	6 пассивирующие
7 2,6-Ди-*трет*-бутил-4-метилфенол (ионол)		9 Очень сильные	10 Отсутствуют	11 Слабые
12 Антраниловая (*о*-аминобензойная) кислота		11 Слабые	9 Очень сильные	13 Сильные (пленка неустойчивая)
14 8-Оксихинолин		10 Отсутствуют	15 То же	10 Отсутствуют
16 *п*-Оксидифениламин		17 Сильные	10 Отсутствуют	15 То же
18 4,4'-Диаминодифенилдисульфид		9 Очень сильные	15 То же	19 Сильные (пленка устойчивая)
20 Салицилиденэтилендиамин		11 Слабые	9 Очень сильные	10 Отсутствуют
21 Никотиновая (β-пиридинкарбоновая) кислота		10 Отсутствуют	17 Сильные	19 Сильные (пленка устойчивая)
22 5,7-Дибром-8-оксихинолин		15 То же	9 Очень сильные	10 Отсутствуют
23 Пирамидон		24 Очень слабые	10 Отсутствуют	—

1) Additive
2) Formula
3) Properties of additive
4) Inhibiting
5) Deactivating
6) Passivating
7) 2,6-Di-*tert*-butyl-4-methylphenol (Ionol)
8) *tert*
9) Very strong
10) None
11) Weak
12) Anthranilic (*o*-aminobenzoic) acid
13) Strong (unstable film)
14) 8-Hydroxyquinoline

15) Same
16) *p*-Hydroxydiphenylamine
17) Strong
18) 4,4'-Diaminodiphenyldisulfide
19) Strong (stable film)
20) Salicylidene ethylenediamine
21) Nicotinic (β-pyridinecarboxylic) acid
22) 5,7-Dibromo-8-hydroxyquinoline
23) Pyramidone
24) Very weak.

TABLE 11.32

Influence of Tributyl Phosphite $(C_4H_9O)_3P$ on Oxidizability of Oils in Thin Film at 250°C [12]

1 Окисляемый продукт	2 Термическая стабильность по Папок при 250° С, мин	3 Лакообразование (при 250° С, 30 мин), %
4 МК-22 сураханское	32	12
5 То же + 0,5% трибутилфосфита	56	0
6 МК-22 доссорское	21	13
5 То же + 0,5% трибутилфосфита	30	3
7 МК-22 макат-юрское	14	11
5 То же + 0,5% трибутилфосфита	45	0

1) Product oxidized
2) Papok thermal stability at 250°C, min
3) Varnish formation (at 250°C, 30 min), %
4) MK-22, Surakhany
5) Same + 0.5% tributyl phosphite
6) MK-22 Dossor
7) MK-22 Makat-Yur.

TABLE 11.33

Influence of Tributyl Phosphite $(C_4H_9O)_3P$ on Oxidizability of Residual Oils in Thin Film at Various Temperatures [11]

1 Окисляемый продукт	2 Лакообразование по Папок (в %) за 30 мин при				
	240° С	250° С	260° С	270° С	280° С
3 МК-22 сураханское	2	6	22	23	25
4 То же + 0,5% трибутилфосфита	1	1	2	17	23
5 МК-20 сураханo-карачухурское	2	20	21	24	23
4 То же + 0,5% трибутилфосфита	0	3	18	19	21

1) Product oxidized
2) Papok varnish formation (%) in 30 min at
3) MK-22 Surakhany
4) Same + 0.5% tributyl phosphite
5) MS-20 Surakhany-Kara-Chukhur.

TABLE 11.34

Influence of Various Antioxidant Additives on Oxidizability of MT-16 Oil in Thin Film (after K.K. Papok and B.S. Zuseva)

1 Присадка	2 Содержание присадки, %	Термоокислительная стабильность при 260° С, 3 мин	Лакообразование (при 250° С, 30 мин), 4 %	Коэффициент лакообразования 5
6 ВНИИ НП-353 (эфир диалкилфенолдитиофосфорной кислоты)	1	23	0	1.5
	3	65	0	0.4
	5	87	0	0.3
7 АН-22к (нейтральная кальциевая соль диэфирдитиофосфорной кислоты на основе осерненного алкилфенола)	1	40	0	0.8
	3	82	0	0.3
	5	88	0	0.3
8 НГ-183а (фосфоросерненные терпены, нейтрализованные окисью кальция)	1	52	0	0.5
	3	86	0	0.3
	5	92	2	0.3
9 ДФ-11 (диалкилдитиофосфат цинка)	1	28	2	1.0
	3	5'	0	0.6
	5	64	0	0.4
10 ДФ-1 (диалкилдитиофосфат бария)	1	29	2	1.0
	3	60	0	0.4
	5	60	0	0.4
11 АзНИИ-10 (продукт конденсации сульфидалкилфенола и хлорангидрида алкилфенилфосфорной кислоты)	1	40	0	0.8
	3	68	0	0.3
	5	80	0	0.3
12 Масло без присадки	—	18	16	1.9

1) Additive
2) Additive content, %
3) Thermal-oxidation stability at 260°C, min
4) Varnish formation (at 250°C, 30 min), %
5) Varnish-formation coefficient
6) VNII NP-353 (ester of dialkylphenoldinitrophosphoric acid)
7) AN-22k (neutral calcium salt of diesterdithiophosphoric acid based on sulfuretted alkylphenol)
8) NG-183a (phosphorous-sulfuretted terpenes neutralized by calcium oxide)
9) DF-11 (zinc dialkyldithiophosphate)
10) DF-1 (barium dialkyldithiophosphate)
11) AzNII-10 (condensation product of alkylphenol sulfide and acid chloride of alkylphenylphosphoric acid)
12) Oil without additive.

TABLE 11.35

Influence of Antioxidant Additives on Oxidizability of MT-16 Oil Containing SB-3 Sulfonate Detergent Additive [7]

1 Окисляемый продукт	2 Содержание присадки, %	Термоокислительная стабильность при 260° С, 3 мин	Лакообразование (при 250° С, 30 мин), 4 %	Коэффициент лакообразования 5
6 Масло МТ-16+6,5% СБ-3 (сульфонат бария)	0.00	18	5	2.0
7 То же+присадка:				
8 ВНИИ НП-353	3.5	92	0	0.3
9 АН-22к	3.5	72	0	0.4
10 НГ-183а	3.5	95	0	0.3
11 АзНИИ-10	3.5	56	0	0.5

1) Product oxidized
2) Additive content, %
3) Thermal-oxidation stability at 260°C, min
4) Varnish formation (at 250°C, 30 min), %
5) Coefficient of varnish formation
6) Oil MT-16 + 6.5% SB-3 (barium sulfonate)
7) Same + additive
8) VNII NP-353
9) AN-22k
10) NG-183a
11) AzNII-10.

Effective antioxidant additives for insulating oils are 2,6-di-*tert*-butyl-4-methylphenol, disalicylidene ethylenediamine and disalicylidene propylenediamine, *p*-hydroxydiphenylamine, anthranilic acid, pyramidone and other products.

In the case of motor oils, which work at higher temperatures, the additives are compounds of another type, whose mechanism is based for the most part on "passivation" of the catalytic activity of metals. Such antioxidants form adsorption films (passivators) on metal surfaces or deactivate metals dissolved in the oil (deactivators).

Esters of phosphoric [sic] acid, the phosphites, lower the oxidizability of motor oils (Table 11.32). However, their activity is limited to temperatures below 250°C (Table 11.33).

Dialkyldithiophosphates, phosphorus-sulfuretted terpenes and other compounds have high stabilizing activity in motor oils (Table 11.34). Zinc dialkyldithiophosphate (DF-11) and barium dialkyldithiophosphate (DF-1) have come into widespread use.

When additives with different functions are added to oils, it is often necessary to deal with an effect in which an additive that improves some operational properties is detrimental to others, notably the oxidation stability of the oil. For example, sulfonate detergent additives usually lower the stability of oils. Addition of antioxidant additives of the type indicated (dialkyldithiophosphates) are found to be quite effective even in this case (Table 11.35).

4. ANTICORROSION ADDITIVES

For the most part, the anticorrosion additives are organic compounds that contain sulfur or phosphorus or both of these elements. The action of these compounds is based on their ability to form a film on the surface of a metal, which protects the metal from destruction (corrosion) by aggressive products that are formed in the oil during oxidation or enter it from the outside, for example, together with fuel-combustion products.

TABLE 11.36

Physicochemical Properties of Phosphites [19]

1 Препарат	2 Формула	3 Температура плавления, °С	4 Температура кипения, °С (остаточное давление, мм рт. ст.)	5 Плотность d_4^{20}	6 Коэффициент преломления n_D^{20}
7 Трисоктадецилфосфит	$(C_{18}H_{37}O)_3P$	55—56	—	—	—
8 Трибутилфосфит	$(C_4H_9O)_3P$	—	90—91 (1)	0.9225	1.4320
9 Трибутилтиофосфит	$(C_4H_9S)_3P$	—	150—152 (1)	1.0121	1.5430

1) Additive
2) Formula
3) Melting point, °C
4) Boiling point, °C (residual pressure, mm Hg)
5) Density
6) Refractive index
7) Trioctadecyl phosphite
8) Tributyl phosphite
9) Tributyl thiophosphite.

TABLE 11.37

Anticorrosion Properties of Organic Dithiophosphates [12]

1 Присадка	2 Формула	Коррозия по Пинкевичу (на медно-свинцовой пластинке), г/м² 3	
		4 сосягорское масляное масло	5 автол 10 бакинский
6 Диметилциклогексанолдитиофосфат цинка	$\{[(CH_3)_2C_6H_9O]_2PS_2\}_2Zn$	5.2	4.6
7 Диизобутилфенилдитиофосфат цинка	$\{[(C_4H_9)_2C_6H_2O]_2PS_2\}_2Zn$	4.6	3.8
8 Диизобутилфенилдитиофосфат алюминия	$\{[(C_4H_9)_2C_6H_2O]_2PS_2\}_3Al$	2.2	3.0
9 Диизобутилфенилдитиофосфат кальция	$\{[(C_4H_9)_2C_6H_2O]_2PS_2\}_2Ca$	5.2	6.3
10 Дитерпиноолдитиофосфат алюминия	$[(C_{10}H_{17}O)_2PS_2]_3Al$	1.0	1.1
11 Алюминиевая соль дитиофосфорной кислоты, полученная на базе алифатических спиртов (C_{14}—C_{20})	—	13.4	21.8
12 Дипиненидитиофосфат алюминия	$[(C_{10}H_{16})_2HS_2]_3Al$	—	3.0
13 Масло без присадки	—	71.0	52.8

Note. 1% of additives used in the oil.

1) Additive
2) Formula
3) Pinkevich corrosion (on copper-lead plate), g/m²
4) Emba residual oil
5) Baku Avtol 10
6) Zinc dimethylcyclohexanoldithiophosphate
7) Zinc diisobutylphenyldithiophosphate
8) Aluminum diisobutylphenyldithiophosphate
9) Calcium diisobutylphenyldithiophosphate
10) Aluminum diterpineoldithiophosphate
11) Aluminum salt of dithiophosphoric acid obtained from aliphatic alcohols (C_{14}-C_{20})
12) Aluminum dipinenedithiophosphate
13) Oil without additive.

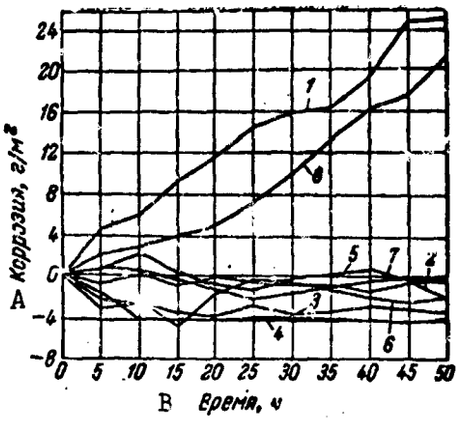


Fig. 11.10. Influence of phosphites on corrosiveness of oil [12]: 1) residual oil from Emba crudes; same + additive: 2) 0.5% tributylphosphite; 3) 0.5% triisoamylphosphite; 4) 0.5% tricyclohexylphosphite; 5) 0.5% triphenylphosphite; 6) 0.9% tricresylphosphite; 7) 0.5% tri-α-naphthylphosphite; 8) 0.5% tri-β-naphthylphosphite. A) Corrosion, g/m²; B) time, h.

Phosphites, sulfides, thiophosphates of various metals, and certain selenium derivatives are used (in amounts of 1-2%) as anticorrosion additives.

As is the case with certain other additives, their addition to oils becomes particularly important when engines are operated on sulfur-containing fuel. The SO_2 and SO_3 produced by combustion of the sulfur compounds present in the fuel get into the oil system and accumulate in the oil in the form of H_2SO_3 and H_2SO_4, which increase the corrosive aggressiveness of oils particularly sharply.

Esters of phosphorous acid (phosphites) are effective anticorrosion additives. Table 11.36 lists properties of certain phosphites and thiophosphites, while Fig. 11.10 shows their effectiveness as anticorrosion additives. The zinc, barium, calcium and other dialkyldithiophosphates that are used as anticorrosion additives to oils are capable of reducing the corrosive aggressiveness of petroleum oils by many times (Tables 11.37 and 11.38 and Figs. 11.11 and 11.12).

Organic compounds containing sulfur and certain sulfuretted products are also used as anticorrosion additives (Tables 11.39 and 11.40).

There are literature reports to the effect that organic selenium derivatives have anticorrosion properties superior to those of the analogous sulfur derivatives (Table 11.41). The organic derivatives of selenium are also highly effective antioxidant additives.

The formation of protective films on metal surfaces protects the metals from being eaten away, or, in the case of an alloy,

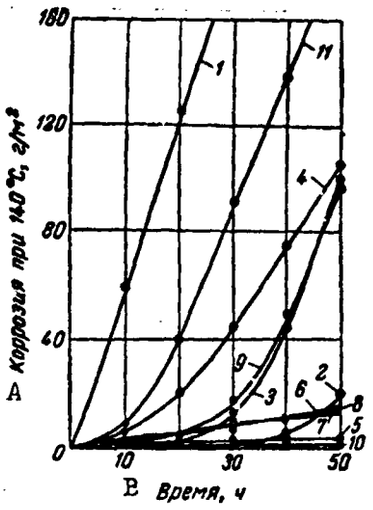


Fig. 11.11. Influence of dialkyldithiophosphates of metals on corrosiveness of oil [23]: 1) oil MT-16; same + additive: 2) 3% DF-1; 3) 3% DF-2; 4) 3% DF-5; 5) 3% DF-8; 6) 3% DF-9; 7) 3% DF-10; 8) 3% DF-11; 9) 3% DF-12; 10) 3% Lubrisol-1060; 11) 3% TsIATIM-339. A) Corrosion at 140°C, g/m²; B) time, h.

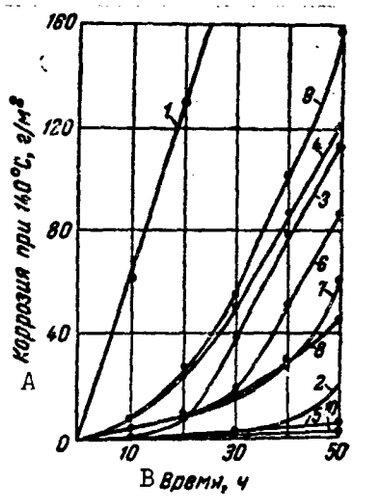


Fig. 11.12. Anticorrosion properties of equimolecular solutions of metal dialkyldithiophosphates in MT-16 oil as functions of oxidation time [21]: 1) oil MT-16; same + additive: 2) 3% DF-1; 3) 2.6% DF-2; 4) 2.8% DF-5; 5) 1.4% DF-8; 6) 1.4% DF-9; 7) 1.2% DF-10; 8) 1.2% DF-11; 9) 1.5% DF-12; 10) 0.7% Lubrisol-1060. A) Corrosion at 140°C, g/m²; B) time, h.

TABLE 11.38

Anticorrosion Properties of Certain Thiophosphate Compounds [20]

1 Присадка	2 Формула	Коррозия по Пинкевичу (на свинцовой пластинке), 3 г/м²
4 Ди-*н*-децилдитиофосфат бария	$[(C_{10}H_{21}O)_2PS_2]_2Ba$	0.9
5 Ди-*н*-октадецилдитиофосфат бария	$[(C_{18}H_{37}O)_2PS_2]_2Ba$	1.7
6 Ди-(2-гептилундецил)дитиофосфат бария	$\left[\left(\begin{matrix}C_7H_{15}\\C_9H_{19}\end{matrix}\right)CHCH_2O\right)_2PS_2\right]_2Ba$	5.1
7 Ди-*н*-децилдитиофосфат никеля	$[(C_{10}H_{21}O)_2PS_2]_2Ni$	11.0
8 Ди-*н*-октадецилдитиофосфат никеля	$[(C_{18}H_{37}O)_2PS_2]_2Ni$	3.6
9 Диоктадецилдитиофосфат (дисульфид)	$[(C_{18}H_{37}O)_2PS_2]_2$	4.3
10 Ди-*н*-октадецилфосфат бария	$[(C_{18}H_{37}O)_2PO_2]_2Ba$	130.7
11 Масло МС-20 эмбенское без присадки	—	46.0

Note. 1.5% by weight of the additives was used in the oil.

1) Additive
2) Formula
3) Pinkevich corrosion (on lead plate), g/m^2
4) Barium di-*n*-decylthiophosphate
5) Barium di-*n*-octadecyldithiophosphate
6) Barium di-(2-heptylundecyl)dithiophosphate
7) Nickel di-*n*-decyldithiophosphate
8) Nickel di-*n*-octadecyldithiophosphate
9) Dioctadecyldithiophosphate (disulfide)
10) Barium di-*n*-octadecylphosphate
11) Emba MS-20 oil without additive.

TABLE 11.39

Influence of Certain Sulfuretted Products on Corrosiveness of Mineral Oils [22]

1 Окисляемый продукт	Коррозия по Пинкевичу (на медно-свинцовой пластинке), 2 г/м²	3 Свойства масла после окисления		
		кислотное число, мг КОН на 1 г 4	осадок, % 5	нейтрализуемость, % 6
7 Дистиллятное без присадки . . .	54.00	0.99	0.62	3.85
8 То же + присадка:				
9 осерненное масло	2.42	0.75	0.23	3.52
10 метиловый эфир оленновой кислоты	34.08	1.03	0.11	5.00
11 осерненный метиловый эфир оленновой кислоты	2.10	0.95	0.35	3.34
12 Остаточное без присадки	16.80	0.59	0.003	1.05
13 То же + присадка:				
14 осерненное масло	1.70	—	0.02	1.12
15 метиловый эфир рицинолевой кислоты	32.06	2.50	0.08	1.72
16 осерненный метиловый эфир рицинолевой кислоты . . .	0.97	1.20	0.14	0.82

Note. Additive used in the oil in concentration of 0.5%.

1) Product oxidized
2) Pinkevich corrosion (on copper-lead plate), g/m^2
3) Properties of oil after oxidation
4) Acid number, mg of KOH to 1 g
5) Sediment, %
6) Coking capacity, %
7) Distillate without additive
8) Same + additive
9) Sulfuretted oil
10) Methyl oleate
11) Sulfuretted methyl oleate
12) Residual without additive
13) Same + additive
14) Sulfuretted oil
15) Methyl recinoleate
16) Sulfuretted methyl recinoleate.

from leaching out of specific components of the alloy (Table 11.42). Here, compounds that form strong, thin films on metals have the most effective anticorrosion properties.

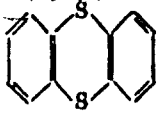
Sulfur or phosphorus in the additive molecule may not penetrate into the interior of the metal (Fig. 11.13a). If the active component of the additive penetrates deep into the metal, the additive becomes ineffective (Fig. 11.13b).

Together with anticorrosion additives whose function is to reduce the corrosiveness of oils during use (basically in motor oils) and antioxidant additives, which also lower the corrosive aggressiveness of oils, since they reduce the accumulation of corrosively aggressive oxidation products, there are also anticorrosion additives that protect metals from rust under exposure to water (rust inhibitors) and additives that are capable of conferring preservative properties on running oils. Recommended rust inhibitors are unsaturated fatty acids and hydroxy acids and their esters (Table 11.43), as well as salts of petroleum sulfo acids, oxidized petrolatum, and others. Nitrogen-containing organic compounds such as dicyclohexylamine nitrite, are vigorous rust inhibitors. Nitrated oils (neutralized with slaked lime) and certain other products (Table 11.44) have recently been recommended as rust inhibitors.

A classification of additives used in oils to improve their anticorrosion properties is given in Table 11.45.

TABLE 11.40

Influence of Sulfur Compounds on Oxidizability and Corrosive Properties of Oil [23]

1 Присадка	2 Формула	Окисление по Пинкевичу (3)	
		4 кислотное число, мг КОН на 1 г	5 коррозия, г/м²
6 Сульфиды:			
7 динонилсульфид	$(C_9H_{19})_2S$	0.43	11.1
8 диоктадецилсульфид	$(C_{18}H_{37})_2S$	0.35	10.2
9 дифенилсульфид	$(C_6H_5)_2S$	0.42	15.9
10 дитолилсульфид	$(CH_3C_6H_4)_2S$	0.36	20.6
11 дибензилсульфид	$(C_6H_5CH_2)_2S$	0.46	29.1
12 дициклогексилсульфид	$(C_6H_{11})_2S$	0.31	9.1
13 дициклопентилсульфид	$(C_5H_9)_2S$	0.46	18.2
14 циклогексилдецилсульфид	$C_6H_{11}—S—C_{10}H_{21}$	0.44	6.6
15 циклопентилдецилсульфид	$C_5H_9—S—C_{10}H_{21}$	0.29	15.0
16 фенилдецилсульфид	$C_6H_5—S—C_{10}H_{21}$	0.53	48.2
17 фенилциклопентилсульфид	$C_6H_5—S—C_5H_9$	0.35	34.8
18 фенилциклогексилсульфид	$C_6H_5—S—C_6H_{11}$	0.50	28.7
19 метил-α-нафтилсульфид	$CH_3—S—C_{10}H_7$	0.38	24.6
20 тритиоформальдегид	$(CH_2S)_3$	0.49	5.6
21 Ди- и полисульфиды:			
22 динонилдисульфид	$(C_9H_{19})_2S_2$	0.66	16.5
23 дифенилдисульфид	$(C_6H_5)_2S_2$	0.43	16.0
24 дитолилдисульфид	$(CH_3C_6H_4)_2S_2$	0.46	21.6
25 дициклогексилдисульфид	$(C_6H_{11})_2S_2$	0.45	15.5
26 дициклопентилдисульфид	$(C_5H_9)_2S_2$	0.33	10.1
27 диэтилтрисульфид	$(C_2H_5)_2S_3$	0.49	10.0
28 фенилэтилдисульфид	$C_6H_5S_2C_2H_5$	0.40	14.5
29 Гетероциклы:			
30 децилтиофен	$C_{10}H_{21}C_4H_3S$	0.50	50.8
31 тетрафенилтиофен	$(C_6H_5)_4C_4S$	0.44	44.0
32 тиантрен		0.52	14.5
33 Меркаптаны:			
34 н-децилмеркаптан	$C_{10}H_{21}SH$	0.52	43.2
35 фенилэтилмеркаптан	$C_6H_5C_2H_4SH$	0.61	12.5
36 циклогексантиол	$C_6H_{11}SH$	0.47	28.4
37 Тиофенолы:			
38 п-тиокрезол	$CH_3C_6H_4SH$	0.60	32.0
39 тио-α-нафтол	$C_{10}H_7SH$	0.35	4.8
40 тио-β-нафтол	$C_{10}H_7SH$	0.41	1.9
41 дитиорезорцин	$C_6H_4(SH)_2$	0.42	8.2
42 Масло без присадки		0.60	48.0

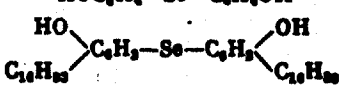
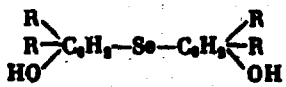
Note. 0.5% of the sulfur compounds was added to the oil.

1) Additive
2) Formula
3) Pinkevich oxidation
4) Acid number, mg of KOH to 1 g
5) Corrosion, g/m²
6) Sulfides
7) Dinonyl sulfide
8) Dioctadecyl sulfide
9) Diphenyl sulfide
10) Ditolyl sulfide
11) Dibenzyl sulfide
12) Dicyclohexyl sulfide
13) Dicyclopentyl sulfide
14) Dicyclohexyldecyl sulfide
15) Cyclopentyldecyl sulfide
16) Phenyldecyl sulfide
17) Phenylcyclopentyl sulfide
18) Phenylcyclohexyl sulfide
19) Methyl-α-naphthyl sulfide
20) Trithioformaldehyde
21) Di- and polysulfides
22) Dinonyl disulfide
23) Diphenyl disulfide

24) Dicolyl disulfide
25) Dicyclohexyl disulfide
26) Dicyclopentyl disulfide
27) Diethyl trisulfide
28) Phenylethyl disulfide
29) Heterocyclics
30) Decylthiophene
31) Tetraphenylthiophene
32) Thianthrene
33) Mercaptans
34) *n*-Decyl mercaptan
35) Phenylethyl mercaptan
36) Cyclohexanethiol
37) Thiophenols
38) *p*-Thiocresol
39) Thio-α-naphthol
40) Thio-β-naphthol
41) Dithioresorcinol
42) Oil without additive.

TABLE 11.41

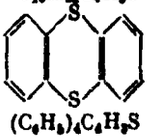
Anticorrosion and Antioxidant Properties of Sulfur- and Selenium-Containing Compounds [9]

	A Присадка	B Формула	Коррозия по Пинкевичу (на свинцовых пластинках), C г/м²		Стабильность по АзНИИ, F мин				J Термическая стабильность (по Папок) в смеси с маслом МК-22, мин
					АК-10		Дизельное масло G		
			D на дизельном масле	E на индустриальном 50	H индукционный период	I время поглощения 20 мл кислорода	H индукционный период	I время поглощения 20 мл кислорода	
K	Дифенилсульфид	$C_6H_5—S—C_6H_5$	61	57	11	104	19	196	41
L	Дифенилселен	$C_6H_5—Se—C_6H_5$	9	10.4	17	110	27	219	50
M	Диоксидифенилсульфид	$HOC_6H_4—S—C_6H_4OH$	1	3	10	96	18	185	47
N	Диоксидифенилселен	$HOC_6H_4—Se—C_6H_4OH$	0	6	13	111	11	220	60
O	Дицетилдиоксидифенилселен		0	0	—	—	18	188	—
P	Диалкилдиоксидифенилселен		0	0	11	77	20	170	30
Q	Трикрезилселенофосфит	$(CH_3C_6H_4O)_3PSe$	+26	—	—	—	23	220	65
R	Трикрезилтиофосфит	$(CH_3C_6H_4O)_3PS$	+1	—	—	—	—	—	—
S	Исходное масло	—	54	47	6	86	13	186	37

A) Additive
B) Formula
C) Pinkevich corrosion (on lead plates), g/m²
D) On diesel oil
E) On industrial 50
F) AzNII stability, minutes
G) Diesel oil
H) Induction period
I) Time for absorption of 20 ml of oxygen
J) Thermal stability (Papok) in mixture with MK-22 oil, minutes
K) Diphenyl sulfide
L) Diphenylselenium
M) Dihydroxydiphenyl sulfide
N) Dihydroxydiphenylselenium
O) Dicetyldihydroxyphenylselenium
P) Dialkyldioxydiphenylselenium
Q) Tricresyl selenophosphite
R) Tricresyl thiophosphite
S) Original oil.

TABLE 11.42

Layer Analysis of Copper-Lead Alloy; Results of Microscopic Examination and Pinkevich Corrosion Test [23]

1 Присадка	2 Формула	Вымывание свинца в слое 0,02 мм (послойный анализ), 3 %	Глубина вымывания свинца (под микроскопом), мм 4	Коррозия по Пинкевичу (на медно-свинцовой пластинке), г/м² 5
6 Первая группа присадок — вымывание свинца до 10%				
7 Тио-β-нафтол	$C_{10}H_7SH$	0,0	—	1,92
8 Дитиорезорцин	$C_6H_4(SH)_2$	3,2	—	8,10
9 Динонилсульфид	$(C_9H_{19})_2S$	10,0	0,013	11,11
10 Тригноформальдегид	$(CH_2S)_3$	10,0	0,012	5,65
11 Фенилэтилмеркаптан	$C_6H_5C_2H_5SH$	10,0	0,012	12,51
12 Вторая группа присадок — вымывание свинца до 20%				
13 Диэтилтрисульфид	$(C_2H_5)_2S_3$	17,4	0,003	9,97
14 Дифенилдисульфид	$(C_6H_5)_2S_2$	18,0	0,009	16,04
15 Динонилдисульфид	$(C_9H_{19})_2S_2$	19,1	0,009	16,50
16 Осерненное масло	—	20,0	0,011	3,33
17 Третья группа присадок — вымывание свинца до 30%				
18 Дифенилсульфид	$(C_6H_5)_2S$	29,1	0,040	15,90
19 Четвертая группа присадок — вымывание свинца до 50%				
20 *п*-Тиокрезол	$CH_3C_6H_4SH$	34,2	—	31,90
21 *N*-Децилтиофен	$C_{10}H_{21}C_4H_3S$	37,2	—	56,80
22 Тиантрен		45,9	0,040	14,72
23 Тетрафенилтиофен	$(C_6H_5)_4C_4H_2S$	48,9	0,057	44,00
24 Пятая группа присадок — вымывание свинца свыше 50%				
25 Дибензилсульфид	$(C_6H_5CH_2)_2S$	56,4	0,093	29,10
26 Масло без присадки	—	72,0	—	35,20

1) Additive
2) Formula
3) Leaching of lead in 0.02-mm layer (layer analysis), %
4) Depth of leaching out of lead (under microscope), mm
5) Pinkevich corrosion (on copper-lead plate), g/m²
6) First group of additives — up to 10% of lead leached out
7) Thio-β-naphthol
8) Dithioresorcinol
9) Dinonyl sulfide
10) Trithioformaldehyde
11) Phenylethyl mercaptan
12) Second group of additives — up to 20% of lead leached out
13) Diethyl trisulfide
14) Diphenyl disulfide
15) Dinonyl disulfide
16) Sulfuretted oil
17) Third group of additives — up to 30% of lead leached out

18) Diphenyl sulfide
19) Fourth group of additives – up to 50% of lead leached out
20) *p*-Thiocresol
21) *n*-Decylthiophene
22) Thianthrene
23) Tetraphenylthiophene
24) Fifth group of additives – over 50% of lead leached out
25) Dibenzyl sulfide
26) Oil without additive.

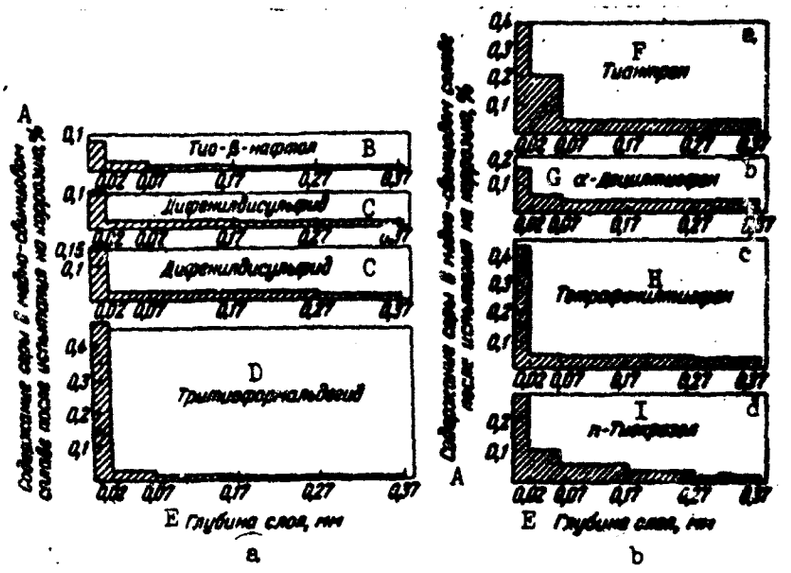


Fig. 11.13. Influence of sulfur-containing additives on penetration of sulfur into metal [23]: a) effective additives; b) ineffective additives. A) Sulfur content in copper-lead alloy after corrosion test, %; B) thio-β-naphthol; C) diphenyl disulfide; D) trithioformaldehyde; E) depth of layer, mm; F) thianthrene; G) α-decylthiophene; H) tetraphenylthiophene; I) *p*-thiocresol.

TABLE 11.43

Influence of Corrosion Inhibitors on Rusting (in Humidity Chamber) of Steel Specimens Preserved with Turbine Oil 30 [24]

1 Присадка	2 Содержание присадки, %	3 Время до появления коррозии на поверхности, ч	
		4 вертикальной	5 горизонтальной
6 Непредельные жирные кислоты	0,5	72	10
	1,0	72	25
7 Эфиры непредельных жирных кислот	0,5	72	28
	1,0	9 72	35
8 Стеариновая кислота	0,5	1 ч 15 мин	72
	1,0	2 ч 05 мин	72
10 Метиловый эфир стеариновой кислоты	0,5	4	72
	1,0	4 ч 30 мин	72
11 Смесь эфиров стеариновой кислоты и непредельных жирных кислот	0,5	72	72
	1,0	72	72

1) Additive
2) Additive content, %
3) Time to appearance of surface corrosion, hours
4) Vertical
5) Horizontal
6) Unsaturated fatty acids
7) Esters of unsaturated fatty acids
8) Stearic acid
9) 1 h 15 min
10) Methyl stearate
11) Mixture of stearates and esters of unsaturated fatty acids.

TABLE 11.44

Properties of Certain Rust Inhibitors [25]

1 Присадка	2 Содержание присадки, %	3 Моющие свойства (по ПЗВ), баллы	4 Термоокислительная стабильность при 250° С, мин	5 Диспергирующая эффективность $Д_э$ (96 ч), %	6 Время до появления коррозии (испытание на коррозию Ст. 40), сутки	
					7 в камере влажности при 40/20° С	8 на границе масло — вода
9 НГ-104*	5	0—0.5	20	96	2	1
10 МНИ-5**	5	6	18	0	20	18
11 КСК***	5	3	9	54	14	14
13 Нитрованное масло	5	4	10	22	16	12 Темная полоса на границе раздела 14
14 АКОР-1****	5	0.5—1	10	85	13	14
	2	1.5—2	10	60	5	2
	10	0	8	81	26	—
	15	0	8	88	30	>30
	20	0—0.5	8	95	>90	—
	25	0—0.5	9	95	>90	—
15 Масло ДС-11 без присадки	—	4.5	21	12	1	1

*NG-104 is a calcium sulfonate obtained by sulfonating MS-20 oil.

**MNI-5 is an additive based on oxidized petrolatum.

***KSK is a calcium sulfonate concentrate obtained by sulfonation of AS-6 oil.

****AKOR-1 is an additive based on nitrated oil.

1) Additive
2) Additive content, %
3) Detergent properties (PZV), points
4) Thermal-oxidation stability at 250°C, min
5) Dispersing effectiveness De (96 h), %
6) Time to appearance of corrosion (tested on St. 40 steel), days
7) In humidity chamber at 40/20°C
8) At oil-water interface
9) NG-104*
10) MNI-5**
11) KSK***
12) Dark band at interface
13) Nitrated oil
14) AKOR-1****
15) DS-11 oil without additive.

TABLE 11.45

Classification of Additives Used in Oils to Improve Their Anticorrosion Properties [26]

Additive	Range of additive application	Additive types	Purpose and mechanism of action
Antioxidant	Oils: transformer, turbine, industrial, working at temperatures below 150°C	Organic amines (diphenylamine, *p*-hydroxydiphenylamine), screened phenols (Ionol, 2,2-methylene-*bis*-6-*tert*-(butyl-4-methylphenol), disulfides (4,6-di-*tert*-butyl-3-methylphenol disulfide), etc.	To prevent formation of corrosive substances on oxidation of oil by retarding formation of hydroperoxides, terminating autooxidati chain, destroying hydroperoxides, etc.
Antioxidant-anticorrosion	Motor oils (Avtols and diesel oils), drive-line and hypoid oils	Sulfuretted terpenes; olefinic hydrocarbons, sulfides and disulfides. Organic phosphites; dithiophosphates. Products of reaction of pentavalent phosphorus with terpenes or with olefinic hydrocarbons. Alkylphenol additives. Sulfonate additives	Protection of internal engine parts (nonferrous-alloy bearings, etc.) from corrosion and wear by suppressing oxidation of oil and creating protective adsorption film on metal surfaces
Anticorrosion additives – low-solubility corrosion inhibitors (rust inhibitors)	Liquid preservative lubricants and greases	Oxidized petrolatum, oxidized petrolatum extract (MNI-5), oxidized ceresin, dibutylphthalate, salts of dicyclohexylamine, lanolin, calcium sulfonate from AS-6 oil, nitrated oil	Corrosion protection of external and internal parts of mechanisms and engines by formation of protective adsorption films
		Calcium sulfonate from AS-6 oil and nitrated oil	Running and preservative oils that protect internal engine parts for several years

TABLE 11.45 (continued)

Additive	Range of additive application	Additive types	Purpose and mechanism of action
Water-soluble corrosion inhibitors (rust inhibitors)	Same	Sodium nitrite, dicyclohexylammonium nitrite, hexamethylenediamine chromate, mercaptobenzothiazole, sodium benzoate, monoethanolamine, and others	Preservative oils and lubricants for external corrosion protection

5. ANTIWEAR ADDITIVES

Oil additives that improve lubricating properties (friction conditions) can be classified on the basis of type of action into three basic groups: 1) antifriction; 2) antiwear and 3) antiscoring.

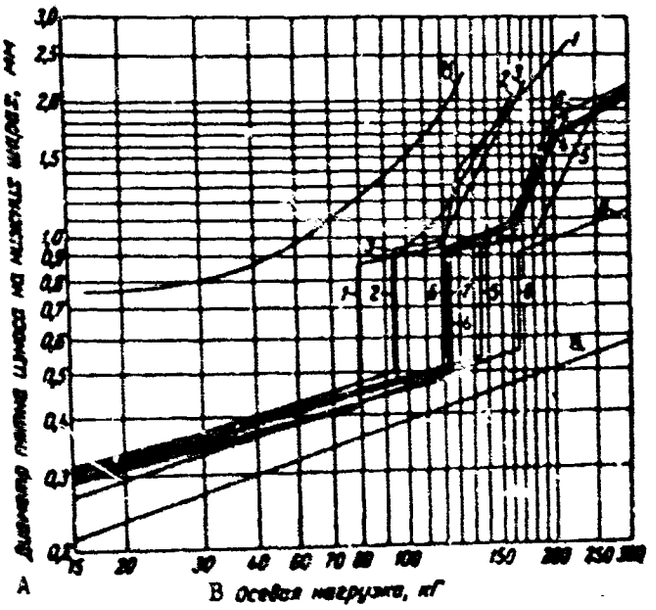


Fig. 11.14. Influence of chloroalkanes on antiwear properties of oil [27]. Additive concentration in oil 6 mmole to 100 g of oil (0.8-1.9%). 1) oil without additive; same + additive: 2) $CH_3(CH_2)_3CH_2Cl$; 3) $CH_3(CH_2)_3CH_2Cl$ (24 mmole, or 3.2%); 4) CCl_4; 5) $CCl_3CH_2CH_2Cl$; 6) $CCl_3(CH_2)_3CH_2Cl$; 7) $CCl_3(CH_2)_9CH_2Cl$; 8) $CCl_3PO(OC_4H_9)_2$; a) elastic-deformation line; b) wear in dry friction. A) Diameter of worn spot on lower balls, mm; B) axial load, kg.

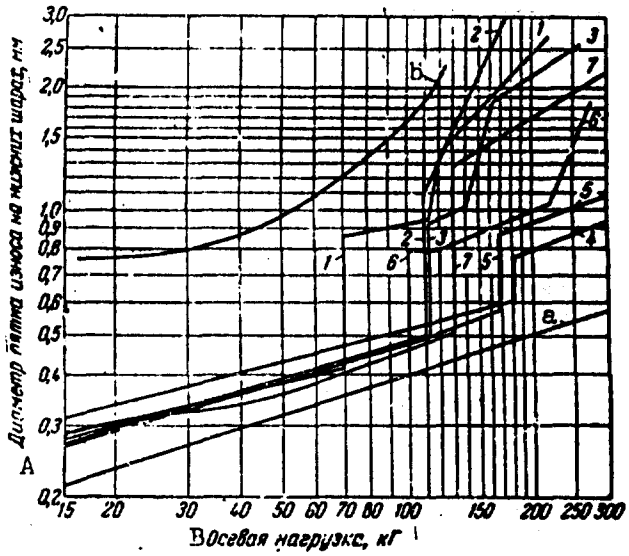


Fig. 11.15. Influence of methylphosphonic acid derivatives containing the CCl_3 group on antiwear properties of oil [27]. Additive concentration in oil 6 mmole to 100 g of oil (1.3-4%): 1) oil without additive; same + additive: 2) $CH_3PO(OC_4H_9)_2$; 3) $ClCH_2PO(OC_4H_9)_2$; 4) $CCl_3PO(OC_2H_5)_2$; 5) $CCl_3PO(OC_4H_9)_2$; 6) $CCl_3PO(OC_6H_5)_2$; 7) $CCl_3PO[N(CH_3)C_{18}H_{37}]_2$; a) elastic deformation line; b) wear in dry friction. A) Diameter of worn spot on lower balls, mm; Б) axial load, kg.

Antifriction additives must also lower and stabilize coefficients of friction, antiwear additives must not permit progressive wear of surfaces under moderate and heavy loads, and antiscoring additives must raise the seizure load and buffer the seizing process by reducing surface destruction and friction.

The following types of compounds, in pure form or in mixtures, are used as additives to reduce friction and wear and prevent seizure:

1) animal and vegetable fats or fatty acids;

2) organic sulfur compounds (sulfuretted products, xanthogenates, etc.);

3) organic chlorine compounds (Sovol – pentachlorobiphenyl);

4) organic compounds of phosphorus (tricresyl phosphate) and other Group V elements;

5) various compounds of metals (lead soaps, oxide and sulfide compounds of molybdenum, sulfur compounds of tungsten, organic compounds of zinc, colloidal iron, etc.);

6) compounds containing several active elements in a single molecule (sulfur, chlorine, phosphorus, etc.).

The additives are injected into the oil in quantities of 3-5% and more.

Organic compounds containing chlorine, phosphorus, or sulfur have come into extensive use in recent years (Tables 11.46-11.49, Fig. 11.14).

The most effective approach is to combine several active elements into a single additive: chlorine and phosphorus (see Tables 11.47 and 11.48 and Figs. 11.15 and 11.16), phosphorus and sulfur (Fig. 11.17), chlorine and sulfur (Fig. 11.18). The same effect can be obtained not only by introducing several active elements into the molecule of one compound, but also by combining various compounds, each of which contains one or another active element (Tables 11.50 and 11.51). A characterization of antiwear additives developed in the Soviet Union and abroad is given in Table 11.52.

Additives whose action is directed toward neutralization of the detrimental influence of products that promote corrosive wear of metallic surfaces are also utilized. These include acids that may form in the oil during operation, perhaps from sulfur gases (SO_2 and SO_3) that enter the oil from the combustion chambers when engines are operated on sulfur-containing fuels.

Alkylphenolates, sulfide alkylphenolates and other compounds are used as additives to neutralize the effect of these harmful agents and thus reduce corrosive wear (Fig. 11.19). Figure 11.20 shows wear of engine parts as a function of sulfur content in the fuel and additive concentration in the oil.

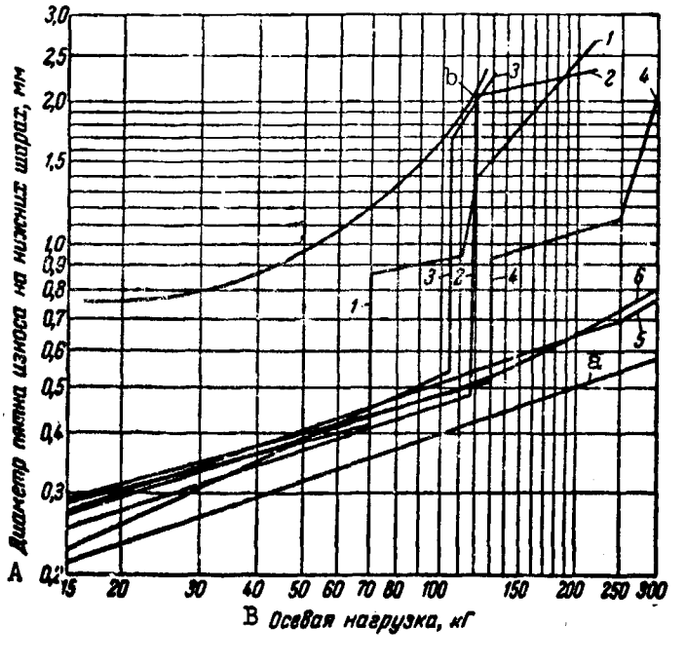


Fig. 11.16. Influence of chloroalkyl phosphites on antiwear properties of oil [27]. Additive concentration in oil 6 mmole to 100 g of oil (1.0-3.4%): 1) oil without additive; same + additive: 2) $(CH_3CH_2O)_3P$; 3) $(ClCH_2CH_2O)_3P$; 4) $CCl_3CH_2OP(OCH_2CH_3)_2$; 5) $(CCl_3CH_2O)_3P$; 6) $[CCl_3C(CH_3)_2O]_3P$. a) Elastic deformation line;

b) wear in dry friction. A) Diameter of worn spot on lower balls, mm; B) axial load, kg.

TABLE 11.46

Properties of Certain Chloroalkanes Used as Antiwear Additives [27]

1 Присадка	2 Формула	Температура кипения, °С (остаточное давление мм рт. ст.) 3	Плотность d_4^{20} 4	Коэффициент преломления n_D^{20} 5	Содержание хлора, % 6
7 1,1,1,3-Тетрахлорпропан	$CCl_3CH_2CH_2Cl$	45—46 (10)	1.4576	1.4823	78.02
8 1,1,1,5-Тетрахлорпентан	$CCl_3(CH_2)_3CH_2Cl$	67—68 (2)	1.3470	1.4873	67.61
9 7-Хлоргептан	$CH_3(CH_2)_5CH_2Cl$	37—39 (15)	0.8825	1.4240	26.39
10 1,1,1,7-Тетрахлоргептан	$CCl_3(CH_2)_5CH_2Cl$	80—89 (2)	1.2603	1.4836	59.66

1) Additive
2) Formula
3) Boiling point, °C (residual pressure in mm Hg)
4) Density
5) Refractive index
6) Chlorine content
7) 1,1,1,3-Tetrachloropropane
8) 1,1,1,5-Tetrachloropentane
9) 7-Chloroheptane
10) 1,1,1,7-Tetrachloroheptane.

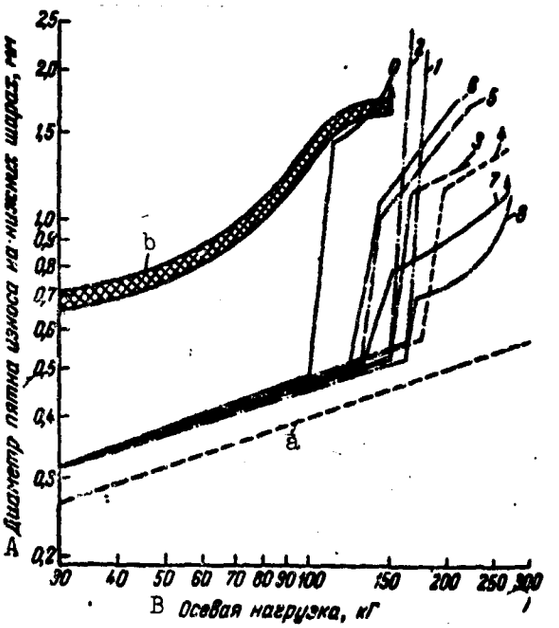


Fig. 11.17. Influence of organophosphorus additives on antiwear properties of naphthenoparaffinic fraction of oil MS-20 [29]. 3% of additive used: 0) naphthenoparaffinic fraction; same + additive: 1) tri-*n*-butyl phosphite; 2) tri-*n*-butyl phosphate; 3) tri-

n-butyl dithiophosphite; 4) tri-*n*-butyl trithiophosphite; 5) tri-*n*-butyl thiophosphite; 6) tri-*n*-butyl dithiophosphate; 7) tri-*n*-butyl trithiophosphate; 8) tri-*n*-butyl tetrathiophosphate; a) elastic deformation line; b) region of wear in dry friction. A) Diameter of worn spot on lower balls, mm; B) axial load, kg.

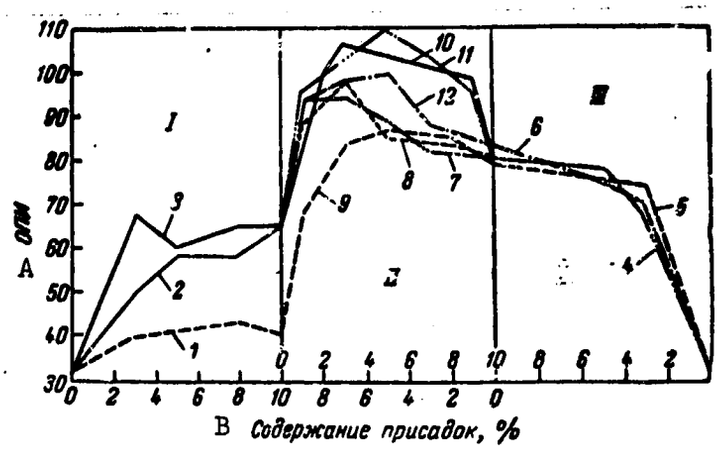


Fig. 11.18. Generalized wear index [GWI] (ОПИ) as a function of sulfur and chlorine additive contents in DS-14 oil [30]: I) chlorine additives; II) sulfur-chlorine additives; III) sulfur additives; 1) Sovol; 2) chlorinated paraffin; 3) hexachloroethane; 4) dibenzyl disulfide; 5) LZ-6/9; 6) sulfuretted terpenes; 7) dibenzyl sulfide + chlorinated paraffin; 8) LZ-6/9 + chlorinated paraffin; 9) LZ-6/9 + Sovol; 10) LZ-6/9 + hexachloroethane; 11) hexachloroethane + sulfuretted terpenes; 12) chlorinated paraffin + sulfuretted terpenes. A) GWI; B) additive content, %.

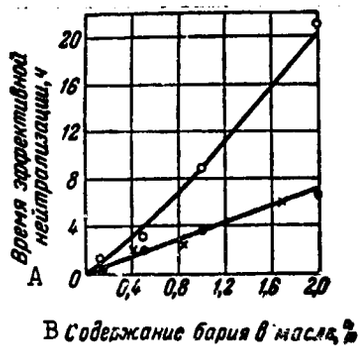


Fig. 11.19. Influence of additive concentration in AS-9.5 oil on decrease in corrosive wear [32]: o) VNII NP-350 additive; ×) VNII NP-360 additive; •) TsIATIM-339 additive. A) Time of effective neutralization, hours; B) barium content in oil, %.

TABLE 11.47

Properties of Certain Derivatives of Methylphosphonic Acid Used as Antiwear Additives [27]

1 Присадка	2 Формула	3 Температура плавления, °C	4 Температура кипения, °C (при 2 мм рт. ст.)	5 Плотность d_4^{20}	6 Коэффициент преломления n_D^{20}
7 Диэтиловый эфир трихлорметилфосфиновой кислоты	$CCl_3PO(OC_2H_5)_2$	—	88—89	1.3699	1.4615
8 Дибутиловый эфир метилфосфиновой кислоты	$CH_3PO(OC_4H_9)_2$	—	84—85	0.9769	1.4251
9 Дибутиловый эфир хлорметилфосфиновой кислоты	$ClCH_2PO(OC_4H_9)_2$	—	112—113	1.0832	1.4420
10 Дибутиловый эфир трихлорметилфосфиновой кислоты	$CCl_3PO(OC_4H_9)_2$	—	124—125	1.2289	1.4560
11 Дифениловый эфир трихлорметилфосфиновой кислоты	$CCl_3PO(OC_6H_5)_2$	66.5—67.0	—	—	—
12 Ди(метилоктадециламид)трихлорметилфосфиновой кислоты	$CCl_3PO[N(CH_3)C_{18}H_{37}]_2$	53.0—53.5	—	—	—

1) Additive
2) Formula
3) Melting point, °C
4) Boiling point, °C (at 2 mm Hg)
5) Density
6) Refractive index
7) Diethyl ester of trichloromethylphosphonic acid
8) Dibutyl ester of methylphosphonic acid
9) Dibutyl ester of chloromethylphosphonic acid
10) Dibutyl ester of trichloromethylphosphonic acid
11) Diphenyl ester of trichloromethylphosphonic acid
12) Di(methyloctadecylamide)trichloromethylphosphonic acid.

TABLE 11.48

Properties of Certain Chloroalkyl Phosphites Used as Antiwear Additives [27]

	1 Присадка	2 Формула	3 Температура плавления, °С	4 Температура кипения, °С (при остаточном давлении, мм рт. ст.)	5 Плотность d_4^{20}	6 Коэффициент преломления n_D^{20}	7 Содержание хлора, %
8	Триэтилфосфит	$(CH_3CH_2O)_3P$	—	49.0—50.0 (12)	0.9685	1.4125	—
9	Три(хлорэтил)фосфит	$(ClCH_2CH_2O)_3P$	—	112.0—115.0 (2.5)	1.3443	1.4818	39.47
10	Диэтилтрихлорэтилфосфит	$(CCl_3CH_2O)P(OC_2H_5)_2$	—	84.0—84.5 (3)	1.2724	1.4588	39.47
11	Три(трихлорэтил)фосфит	$(CCl_3CH_2O)_3P$	—	163.0—165.0 (5)	1.6485	1.5182	68.08
12	Три(трихлорбутил)фосфит	$[CCl_3C(CH_3)_2O]_3P$	43.5—44.5	—	—	—	56.10

1) Additive
2) Formula
3) Melting point, °C
4) Boiling point, °C (at residual pressure of ..., mm Hg)
5) Density
6) Refractive index
7) Chlorine content
8) Triethyl phosphite
9) Tri(chloroethyl) phosphite
10) Diethyltrichloroethyl phosphite
11) Tri(trichloroethyl) phosphite
12) Tri(trichlorobutyl) phosphite.

TABLE 11.49

Properties of Additives Synthesized from Xanthogenates [28]

1 Присадка	2 Формула	3 Состав присадки	4 Температура застывания, °С	5 Плотность, г/см³	6 Вязкость (в сст) при		7 Содержание, мас. %		10 Критическая нагрузка $P_к$, кГ (четырехшариковая машина)	11 Диаметр следа износа, мм
					−10° С	+50° С	8 серы	9 хлора		
12 ЛЗ-24	$(C_2H_5OC(=S)-S-CH_2)_2$	13 Этилен-бис-этилксантогенат	−35 (кристалл.) 14	—	12.28	2.38	52.3	0.09	130	0.97
ЛЗ-23	$(C_3H_7OC(=S)-S-CH_2)_2$	15 Этилен-бис-изопропилксантогенат	16 Ниже −45.1	1.1900	21.49	3.30	44.2	0.24	130	0.91
ЛЗ-6/9	$(C_4H_9OC(=S)-S-CH_2)_2$	17 Этилен-бис-бутилксантогенат	» −60	1.1528	50.22	5.05	40.1	0.20	160	0.91
ЛЗ-25	$(изо\text{-}C_4H_9OC(=S)-CH_2)_2$	19 Этилен-бис-изобутилксантогенат	» −60	1.2207	151.06	7.45	38.8	0.92	140	0.91
ЛЗ-19	$(изо\text{-}C_5H_{11}OC(=S)-CH_2)_2$	20 Этилен-бис-изоамилксантогенат	» −60	—	28.50	3.35	33.1	2.15	140	0.91
ЛЗ-22	—	21 Этилен-бис-ксантогенат спиртов C_7—C_9	−37 (кристалл.) 14	0.9872	56.45	5.11	21.1	0.85	126	0.90
ЛЗ-23к	$(изо\text{-}C_3H_7O-C(=S)-S-CH_2)_2$	22 Этилен-бис-изопропилксантогенат (кристаллический)	+49	—	—	—	40.25	—	100	1.08
ЛЗ-25к	$(изо\text{-}C_4H_9O-C(=S)-S-CH_2)_2$	23 Этилен-бис-изобутилксантогенат (кристаллический)	+37.5	—	—	—	37.1	—	100	0.86
ЛЗ-21	$(C_4H_9OC(=S)-S-CH_2-CH_2)_2O$	24 Дибутилксантоль	16 Ниже −60	1.1544	52.13	4.92	28.9	5.08	130	0.97
ЛЗ-20	$(изо\text{-}C_5H_{11}OC(=S)-S-CH_2-CH_2)_2O$	25 Диизоамилксантоль	» −60	1.1347	58.44	4.90	27.6	5.50	130	0.91

Note. Except for LZ-24, the antiwear properties of the additives were determined in spindle oil AU. The antiwear properties of LZ-24 additive were determined in synthetic oil 36/1. In all cases, the additive concentration in the oil corresponded to a sulfur content of 1.5%.

1) Additive
2) Formula
3) Composition of additive
4) Pour point, °C
5) Density, g/cm^3
6) Viscosity (cSt) at
7) Content of ..., % by mass
8) Sulfur
9) Chlorine
10) Critical load P_k, kg (four-ball machine)
11) Worn-spot diameter, mm
12) LZ-...
13) Ethylene-*bis*-ethyl xanthogenate
14) (Crystallizes)
15) Ethylene-*bis*-ethylpropyl xanthogenate
16) Below
17) Ethylene-*bis*-butyl xanthogenate
18) *iso*-
19) Ethylene-*bis*-isobutyl xanthogenate
20) Ethylene-*bis*-isoamyl xanthogenate
21) Ethylene-*bis*-xanthogenate of C_7-C_9 alcohols
22) Ethylene-*bis*-isopropyl xanthogenate (crystalline)
23) Ethylene-*bis*-isobutyl xanthogenate (crystalline)
24) Dibutyl xanthol
25) Diisoamyl xanthol.

TABLE 11.50

Comparative Antiscoring Properties of Commercial and Experimental Additives in DS-14 Oil [30] (ChShM-3 Four-Ball Machine, AUSS 9490-60 Test)

1 Присадка	2 Формула	3 Название	4 Рекомендуемая концентрация присадки, %	5 Содержание активных элементов в присадке	6 Результаты испытаний масла с присадкой: 7 ОЦИ	$P_{кр}$	$P_{св}$
8 ЛЗ-6/9	$(C_2H_5OC(=S)-S-CH_2)_2$	9 Этилен-бис-бутилксантогенат	5	39% S 0,5% Cl	76,8	112	501
10 БЭК	$(C_2H_5OC(=S)-S)_2$	11 Бис-этилксантогенат	5	43% S	68	112	794
ЛЗ-19	$(изо\text{-}C_5H_{11}OC(=S)-S-CH_2)_2$	13 Этилен-бис-изоамилксантогенат	5	33% S 2% Cl	76	126	447
ЛЗ-23	$(изо\text{-}C_3H_7OC(=S)-S-CH_2)_2$	14 Этилен-бис-изопропилксантогенат	5	42,7% S 0,5% Cl	73	100	447
ЛЗ-20	$(изо\text{-}C_5H_{11}OC(=S)-S-CH_2-CH_2)_2O$	15 Дикоамилксантоль	10	29% S 2,8% Cl	63	126	355
ЛЗ-21	$(C_4H_9OC(=S)-S-CH_2-CH_2)_2O$	16 Дибутилксантоль	10	30,3% S 4,2% Cl	62	126	316
17 Осерненные терпены МДС	$(RCOOCH_2-CH_2-S)_2$	18 β,β'-Меркаптоэтиловый эфир	5 10	25% S 19% S	51 48	100 89	224 282
19 НАМИ-Т-122	От $C_{20}H_{41}Cl$ 20 до $C_{22}H_{40}Cl_{12}$ 21	22 Хлорированный парафин	10	40% Cl 29% Cl	59	89	316
23 АзНИИ-9	—	24 Хлорированная нефть	8	30% Cl	66	79	355
25 Гексахлорэтан	C_2Cl_6	—	5	40% Cl	66	100	355
26 Совол	$C_6H_5-C_6HCl_4$ 27 и $C_6H_5-C_6Cl_5$	28 Смесь тетра- и пентахлордифенила	5	34% Cl	41	89	224
29 Хлореф-40	$CCl_3PO(OC_4H_9)_2$	30 Бутиловый эфир трихлорметилфосфиновой кислоты	2	34% Cl 10% P	88	158	562
31 Хлорфосфорная присадка	32 $(изо\text{-}C_5H_{11}O)_2PCHCCl_3$ (OCOCH₃)	33 Диизоамиловый эфир трихлорацетоксиметилфосфиновой кислоты	2	23,8% Cl 6,8% P	86,5	158	447
29 Хлореф-15	$ClCH_2PO(OC_4H_9)_2$	33 Бутиловый эфир монохлорметилфосфиновой кислоты	2	24,5% Cl 12,4% P	53	126	200
34 Л-6/9 + + молибденовая сила	—	—	5	11,7% S 0,15% Mo	78,5	158	447
35 ЭФО	—	36 Остаточный экстракт, обработанный пятисернистым фосфором	10	7,0% S 2,5% P	48	100	251
37 СФ-2	—	38 Кубовые остатки ректификации алкилата для присадки масел, обработанные пятисернистым фосфором	5	3,0% S	56	112	282
8 ЛЗ-30	—	39 Дитиофосфат, полученный обработкой алкилфенола пятисернистым фосфором	8	6,0% S 2,0% P	49	112	200
	40 Исходное масло		—	—	37,5	79	158

1) Additive
2) Formula
3) Name
4) Recommended concentration in oil, %
5) Content of active elements in additive
6) Results of tests of oil with additive
7) GWI
8) LZ-...
9) Ethylene-*bis*-butyl xanthogenate
10) BEK
11) *Bis*-ethyl xanthogenate
12) *iso*-
13) Ethylene-*bis*-isoamyl xanthogenate
14) Ethylene-*bis*-isopropyl xanthogenate
15) Diisoamyl xanthol
16) Dibutyl xanthol
17) MDS sulfuretted terpenes
18) β,β'-Mercaptoethyl ester
19) NAMI-T-122
20) From
21) To
22) Chlorinated paraffin
23) AzNII-9
24) Chlorinated naphtha
25) Hexachloroethane
26) Sovol
27) And
28) Mixture of tetra- and pentachlorodiphenyl
29) Chloref-...
30) Butyl ester of trichloromethylphosphonic acid
31) Chlorine-phosphorus additive
32) Diisoamyl ester of trichloroacetoxyethylphosphonic acid
33) Butyl ester of monochloromethylphosphonic acid
34) L-5/9 + molybdenum blue
35) EFO
36) Residual extract treated with phosphorus pentasulfide
37) SF-2
38) Bottoms from distillation of alkylate for Ionol additive, treated with phosphorus pentasulfide
39) Dithiophosphate obtained by treating alkylphenol with phosphorus pentasulfide
40) Original oil.

TABLE 11.51

Characterization of Antiscoring Additives Containing Several Active Elements, and Test Results for DS-14 Oil with the Additives [30]

1 Присадки	2 Формула	3 Название	4 Содержание активных элементов в присадке	5 Результаты испытаний масла с присадками				
				6 концентрация присадки, вес.%	7 коррозия стали, г/м²	8 Испытания на четырехшариковой машине ЧШМ-3*		
						9 ОСИ	$P_{кр}$	$P_{св}$
10 Присадки, содержащие хлор и фосфор								
11 Хлороф-60	$CCl_3PO(OC_4H_9)_2$	12 Бутиловый эфир трихлорметилфосфоновой кислоты	24% Cl 10% P	2	0,9	84	188	562
11 Хлороф-16	$CH_2ClPO(OC_4H_9)_2$	13 Бутиловый эфир монохлорметилфосфоновой кислоты	16,5% Cl 12,6% P	2	1,46	81	156	390
14 Присадки, содержащие серу и фосфор								
15 ЭФО		16 Остаточный экстракт, обработанный пятисернистым фосфором	7% S 2,5% P1 9	10	—	41	100	251
17 СФ-2	—	18 Кубовые остатки ректификации алкилата для присадки ионол, обработанные пятисернистым фосфором	3% S. Фосфор не определялся	5	—	75	113	282
20 ЛЗ-30	—	21 Дитиофосфат, полученный путем обработки алкилфенола пятисернистым фосфором	6% S 3% P	6	—	49	112	300
22 Присадки, содержащие серу, хлор и серу, хлор и фосфор								
23 Гексахлорсульфид	$(CCl_3C_6H_{11})_2S$	24 Ди-(трихлорметилциклогексил)сульфид	55,8% Cl 6,6% S	4	0,77	87,8	190	631
25 Гексахлорсульфид и ДФ-11	—	26 То же в смеси с диалкилдитиофосфатом цинка (см. табл. 12.63)	31,8% Cl 0,1% S; 1,0% P 2,1% Zn	7	0,32	84,8	141	631
27 Присадки, содержащие молибден и серу								
28 ЛЗ-6/9 и молибденовая соль	—	—	11,7% S 0,19% Mo	5	1,75	80,8	156	447

*Tests run by method of AUSS 9490-60.

1) Additive
2) Formula
3) Main
4) Active-element contents in additive
5) Test results for oil with additives
6) Amount of additive, % by mass
7) Corrosion of steel, g/m²
8) Tests on ChShM-3 four-ball machine*
9) GWI
10) Additives containing chlorine and phosphorus
11) Chloref-...
12) Butyl ester of trichloromethylphosphonic acid
13) Butyl ester of monochloromethylphosphonic acid
14) Additives containing sulfur and phosphorus
15) EPO
16) Residual extract treated with phosphorus pentasulfide
17) SF-2
18) Bottoms from distillation of alkylate for Ionol additive, treated with phosphorus pentasulfide
19) 3% S. Phosphorus not determined
20) LZ-30
21) Dithiophosphate obtained by treating alkylphenol with phosphorus pentasulfide
22) Additives containing sulfur, chlorine and sulfur, chlorine and phosphorus
23) Hexachloro sulfide

24) Di-(trichloroheptyl) sulfide
25) Hexachloro sulfide and DF-11
26) Same, in mixture with zinc dialkyl dithiophosphate (see Table 12.63)
27) Additives containing molybdenum and sulfur
28) LZ-6/9 and molybdenum blue.

TABLE 11.52

Characteristics of Domestic and Foreign Antiwear Additives [31]

1 Присадки	2 Область применения	3 Содержание активных элементов в присадке, %				4 Рекомендуемая концентрация присадки в масле, %
		S	Cl	P	Zn	
5 Отечественные присадки						
6 ЭЗ-2	7 Червячные передачи	2.6	—	1.2	—	5—10
6 ЭЗ-5	8 Зубчатые передачи (за исключением гипоидных)	17.5	27	—	—	5
ОТ-1	9 То же	18	3.8	—	—	5
10 ЛЗ-6/9	»	39—40	11 Следы	—	—	5
12 Сульфол	»	8	55.8	—	—	4
10 ЛЗ-309	»	19.6	9.36	10.5	—	5
13 Хлореф-40	14 Гипоидные передачи	—	34	10	—	2
15 Сульфол и ДФ-11	9 То же	8.66	31.8	1.9	2.27	7
16 ДФ-11	17 Различное назначение, в том числе гидравлические системы и гидродинамические передачи	5.55	—	4.8	5.28	0.5—3.0
16 ДФ-1*	9 То же	3.4	—	1.63	—	3.5

40 Заказ 578.

TABLE 11.52 (continued)

1 Присадка	2 Область применения	3 Содержание активных элементов в присадке, %				4 Рекомендуемая концентрация присадки в масле, %
		S	Cl	P	Ba	
18 Зарубежные присадки						
19 *Фирма «Лубризол»*						
20 Англамол-48	7 Червячные передачи	1.7	15.0	1.2	—	2
Англамол-70	21 Гипоидные передачи по CS-2758	4.9	21.7	0.33	—	9
22 Англамол-71 или Англамол-91	9 То же	16—17.5	16.8—18	2.9—3.3	3.1—3.6	10
Англамол-82	23 Зубчатые передачи MIL-L-2105	10.5	2.8	0.3	—	10
Англамол-83	9 То же	5.25	21.8	0.33	—	8—9
Англамол-85	»	6.7	19.0	0.2	—	8.75
Англамол-88	»	4.8	20.0	0.3	—	9
Англамол-93	24 Масло серии GL-4 для гипоидных передач по MIL-L 2105A	16.0	16.5	3.0	3.0	9.5
Англамол-50	25 Зубчатые передачи и смазочно-охлаждающие жидкости для обработки металла	—	49	—	—	2—7
Англамол-40	9 То же	—	≈40	—	—	10
Англамол-31	»	42.5	0.2	—	—	0.3—3
Англамол-35	»	19	23	—	—	1—12
Англамол-36	»	18	22.5	—	—	1—10
Англамол-32	»	46	—	—	—	0.5—5
26 Лубризол-1060	27 Моторные и трансмиссионные масла	16.5	—	8.0	8.3	0.6—2.5 объемн. %[28]
Лубризол-1360	9 То же	1.53	—	0.74	0.77	0.6—4.25 объемн. %[28]
Лубризол-880	29 Турбинные и гидравлические масла	0.58	13.3	—	—	2.5
30 Лубризол-284**	31 Гидропередачи, жидкости типа А, Суффикс А	3.5	—	1.65	1.90	5
Лубризол-243	33 Гидравлические масла	9.25	—	—	—	2.9—7.0
Лубризол-245	33 Индустриальные масла	10.0	—	—	—	1—3
33 *Фирма «Монсанто»*						
34 Сантопонд-22, RI	35 Зубчатые передачи, в том числе гипоидные	12	13.5	3.3	3.5	6.5—15
Сантопонд-23, RI	9 То же	13.3	14.0	4.1	3.7	10—15
Сантопонд-32	»	8.2	26.0	0.56	—	6.5
Сантопонд-33	»	8.2	26.0	0.55	—	6.75
Сантопонд-44	»	12.3	27.5	1.5	1.6	10
36 Монтогир-Б	»	4.0	30.2	1.8	2.0	5.5—12
37 *Фирма «Инджей К°»*						
38 Парапонд-109	39 Индустриальные масла	7.0	0.3	0.2	—	—
39 *Фирма «Эльф лабрифиан»*						
40 CL-концентрат***	14 Гипоидные передачи	4.7	4.3	—	—	—
41 *Фирма «Керлинг»*						
42 Альфа-хлор-33	43 Зубчатые передачи	—	33	—	—	10
43 *Фирма «Бадише анилин унд содафабрик»*						
44 Байер И-ГЛ****	9 То же	—	18	8.5	—	0.1—1
45 Байер-ЛБ	»	—	18	9.1	—	0.1—1.5

*Barium content 4.2%.
**Barium content 14%.
***PbO content 7.5%
****Nitrogen content 0.5%.

1) Additive
2) Range of application
3) Content of active elements in additive, %
4) Recommended additive concentration in oil, %
5) Domestic additives
6) EZ-...
7) Worm drives
8) Gear drives (except for hypoid types)
9) Same
10) LZ-...
11) Traces
12) Sul'fol
13) Chloref-40
14) Hypoid drives
15) Sul'fol and DF-11
16) DF-...
17) Multipurpose, e.g., hydraulic systems and fluid drives
18) Foreign additives
19) Lubrisol
20) Anglamol-...
21) Hypoid drives according to CS-2758
22) Anglamol-71 or Anglamol-91
23) Gear drives, MIL-L-2105
24) Series GL-4 oil for hypoid drives according to MIL-L-2105A
25) Gear drives and cutting fluids for metals
26) Lubrisol-...
27) Motor and drive train oils
28) % by volume
29) Turbine and hydraulic oils
30) Hydraulic drives, fluids of type A, suffix A
31) Hydraulic oils
32) Industrial oils
33) Monsanto
34) Santopoid-...
35) Gear drives, including hypoid
36) Montogear-B
37) *Indzhey K°*
38) Parapoid-109
39) Elco Lubricant
40) CL concentrate***
41) Carlisle
42) Alpha-Chlor-33
43) Badische Anilin- und Soda-fabrik
44) Bayer I-GL****
45) Bayer-LE.

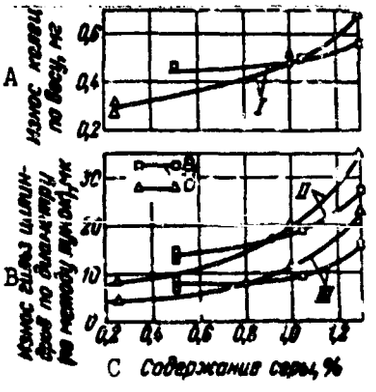


Fig. 11.20. Wear of YaAZ-204 engine parts as a function of sulfur content in fuel and additive concentration in oil [33]: I) top compression rings; II) upper belt of cylinder sleeves; III) second belt of cylinder sleeves; □) oil + 5% TsIATIM-339 additive; Δ) oil + 3% TsIATIM-339 additive. A) Weight worn off rings, mg; B) cylinder-sleeve diametral wear (by crescent method), μm; C) sulfur content, %.

6. DETERGENT AND MULTIPURPOSE ADDITIVES

Detergent additives are those whose use in the oil keeps engine parts clean, i.e., ensures that metal surfaces in contact with the oil will remain free of carbon deposits in the form of varnish and sludge.

Soaps of naphthenic or sulfo acids or phenolates are used as detergent additives. The metals in the soaps or phenolates are usually Ba and Ca, and less often Zn, Al, and Mg. In some cases, the metal is introduced into the additive in a quantity substantially exceeding the stoichiometrically possible amount by formation of higher complexes, such as $(RArSO_3)_2 - Ca \cdot CaO \cdot Ca(OH)_2$. Such complexes have excess alkalinity and can neutralize fuel combustion products and acid products that form in the oil.

Detergent additives are used in oils in amounts of 1-3 to 5-10%, and sometimes more. Most of them are introduced simultaneously with other additives, chiefly antioxidant, anticorrosion and antifoam additives.

The mechanism by which detergent additives act is based on their ability:

to hold insoluble oxidation products (formed in the oil) and soots (which get into the oil from outside) in a finely dispersed state, preventing aggregation and sedimentation of these particles from the oil and their settling on engine parts;

to disperse large particles that have already formed and convert them to fine suspensions;

to neutralize aggressive acid products (basically those formed during combustion of sulfur-containing fuel) and delay the accumulation of insoluble soaps in the oil;

to render oxidation products soluble and absorb them, both at the time of their formation and in later stages of the oxidative polymerization process by the action of additive micelles present in the oil in the form of a colloidal suspension.

Not infrequently, detergent additives are also carriers of other major operational properties of the oils: anticorrosion, rust-preventive, etc. In such cases, they may be classed as multipurpose additives.

Multipurpose additives are those which are capable of improving several operational properties of the oils. This is usually brought about by introducing various functional groups, which are responsible for the versatility of the additive, into a single compound.

As an example, we might cite the sulfuretted barium alkylphenate examined above, which exhibits anticorrosion and antioxidant properties simultaneously by virtue of its content of sulfide sulfur, detergent properties by virtue of the barium phenolate group, and, if R is a macromolecular alkyl radical ($\sim C_{28}$-C_{34}),

TABLE 11.53

Properties of Sulfonate Additives [26]

1 Показатели	2 Присадки			
	3 СБ-3	4 ПМС'Я	5НГ-102	НГ-104
6 Внешний вид	7 Черная густая жидкость	8 Черная малоподвижная масса		9 Желтая прозрачная жидкость
10 Вязкость кинематическая при 100° С, *сст*	16.77	71.3	91.3	26.6
11 Зольность, % (сульфатная)	7.4	25,0	6.7	16
12 Зольность, %	6,°	7,5	—	9
13 Щелочность, *мг* КОН на 1 *г*:				
14 по фенолфталеину	1,81	8,6	9.9	66.4
15 по бромфенол синему	11,8	127	15.4	100
16 Цвет NPA, марки:				
17 без разбавления	8	8	8	3.5—4
18 разбавление 1:30 в бензине	8	8	8	0
19 разбавление 1:60 в бензине	3	5	4	0

1) Index
2) Additive
3) SB-3
4) PMS'Ya
5) NG-102
6) External appearance
7) Thick black liquid
8) Immobile black mass
9) Transparent yellow liquid
10) Kinematic viscosity at 100°C, cSt
11) Ash, % (sulfates)
12) Ash, %
13) Alkalinity [sic], mg of KOH to 1 g
14) Phenolphthalein indicator
15) Bromphenol blue indicator
16) NPA color, grade
17) Undiluted
18) 1:30 dilution in gasoline
19) 1:60 dilution in gasoline.

then depressor properties as well.

Metal dialkyl dithiophosphates are also to be included among the multipurpose additives. For example, barium dialkyl dithiophosphate $[(RO)_2PSS]_2Ba$ has anticorrosion, antioxidant, antiwear and detergent properties.

In many cases, however, it is more convenient to introduce several additives with different functions into the oil, rather than a single compound containing all of the necessary functional groups; in some cases, the latter is simply impossible.

Combination of additives to form mixes is more convenient.

Mixes of several multipurpose additives or of multipurpose with single-purpose additives are frequently compounded. It must be remembered, however, that single-purpose additives are practically nonexistent, since all additives influence several properties of oils (to a greater or lesser degree).

Tables 11.53-11.60 present data characterizing metal-sulfonate-type additives, their influence on the physicochemical and

operational properties of motor oils, and the influence of metal-sulfonate composition on effectiveness.

Metal sulfonates are effective detergents; they lower the stability of oils to oxidation and have little influence on the corrosive properties of the oils; in the presence of a large number of carbons in the alkyl side chains, sulfonates may exhibit depressor properties. To obtain oils with high detergent, antioxidant and anticorrosion properties, it is expedient to combine metal sulfonates with antioxidant and anticorrosion additives.

TABLE 11.54

Comparative Laboratory Tests of Oils with Sulfonate Additives [26]

1 Показатели	2 Присадки			
	3 ПМС'Я	4 СВ-3	5 НГ-102	НГ-104
6 Вязкость кинематическая при 100° С, *сст*:				
7 до окисления	21,0	19,8	21,6	19,0
8 после окисления	40	37	66	37
9 Моющие свойства по ПЗВ, 2% сульфоната в ДС-11, баллы	0,5—1	0—0,5	0—0,5	0—0,5
10 Термоокислительная стабильность по Папок, 10% сульфоната в ДС-11, *мин*	28	20	26	32
11 Коррозия по Пинкевичу (испытания на свинцовой пластинке), 10% сульфоната в ДС-11, *г/м²*	9,1	4,2	6,8	3,3
12 Испытания в приборе ДК-2, 10% сульфоната в МС-20: кислотное число, *мг* КОН на 1 *г*:				
13 до окисления	—0,12*	—0,23*	—0,14*	—0,41*
14 после окисления	5,1	3,4	6,0	1,8
15 Осадок после окисления (нерастворимые в бензине), %	0,58	0,55	0,63	0,005
16 Потеря массы медной пластинки, *г*	0,0046	0,0035	0,0045	0,0022

*The minus sign indicates that the oil had an alkaline reaction before oxidation.

1) Index
2) Additive
3) PMS'Ya
4) SB-3
5) NG-102
6) Kinematic viscosity at 100°C, cSt
7) Before oxidation
8) After oxidation
9) PZV detergent properties, 2% sulfonate in DS-11, points
10) Papok stability to thermal oxidation, 10% sulfonate in DS-11, min
11) Pinkevich corrosion (lead-plate test), 10% sulfonate in DS-11, g/m^2
12) Tests in DK-2 instrument, 10% sulfonate in MS-20: acid number, mg of KOH to 1 g
13) Before oxidation
14) After oxidation
15) Sediment after oxidation (gasoline-insoluble), %
16) Loss of mass by copper plate, g.

TABLE 11.55

Petroleum Products as Raw Materials for Production of Sulfonates [26]

Raw material	Molecular weight	Type of sulfonates obtained	Basic application
Kerosenes, gas oils, cracked paraffins, MVP oil, light industrial oils	170-300	Sodium salts, water-soluble sulfonates	Wetting, degreasing and detergent properties. Demulsifiers. Foaming agents
AS-6 oil, selective-refining extracts	350-370	Sodium salts, water-oil-soluble sulfonates	Oil-in-water emulsifiers, base for production of Emulsols
		Calcium salts, oil-soluble sulfonates	Rust inhibitors, anticorrosion additives for fuels and oils
Oils AS-9.5; DS-8, DS-11, MS-20, etc.	400-600	Salts of all metals – oil-soluble sulfonates	Detergent-dispersing additives to motor oils

TABLE 11.56

Influence of Number of Carbons in Alkyl Side Chains of Sulfo Acid Salts on Their Effectiveness [34]

1 Продукт	2 Предполагаемая эмпирическая формула	3 Моющие свойства по ПЗВ, баллы	4 Стабильность по АзНИИ, мин		7 Коррозия по Пинкевичу (50 ч)	
			5 индукционный период	6 время осветления 20 мл эмульсии	8 кислотное число, мг КОН на 1 г	9 коррозия стальной пластинки, г/м²
10 Масло индустриальное 50	–	5–5.5	5	175	0.21	59.34
11 То же + присадка: бариевая соль:						
12 моно-октилнафталинсульфокислоты	$(C_8H_{17}-C_{10}H_6-SO_3)_2Ba$	4.5	6	72	–	35.78
13 моно-додецилнафталинсульфокислоты	$(C_{12}H_{25}-C_{10}H_6-SO_3)_2Ba$	3.5	5	66	0.36	38.74
14 моно-цетилнафталинсульфокислоты	$(C_{16}H_{33}-C_{10}H_6-SO_3)_2Ba$	2.0–2.5	7	61	0.43	55.37
15 моно-тетрапропилнафталинсульфокислоты	$(C_{12}H_{25}-C_{10}H_6-SO_3)_2Ba$	1.5–2.0	6	58	0.51	67.77

Note. Additive content in oil 1% by mass.

1) Product
2) Hypothetical empirical formula
3) PZV detergent properties, points
4) AzNII stability, minutes
5) Induction period
6) Time to absorb 20 ml of oxygen
7) Pinkevich corrosion (50 hours)
8) Acid number, mg of KOH to 1 g
9) Corrosion of lead plate, g/m^2
10) Industrial oil 50
11) Same + additives: barium salts
12) *iso*-octylnaphthalenesulfoacid
13) *iso*-dodecylnaphthalenesulfoacid
14) *iso*-cetylnaphthalenesulfoacid
15) *iso*-tetracosylnaphthalenesulfoacid.

TABLE 11.57

Influence of Nature of Metal on Effectiveness of Sulfoacids [34]

1 Продукт	2 Предполагаемая эмпирическая формула	3 Моющие свойства по ПЭВ, баллы	4 Стабильность по АзНИИ, мин		7 Коррозия по Пинкевичу (50 ч)	
			5 индукционный период	6 время поглощения 20 мл кислорода	8 кислотное число, мг KOH на 1 г	9 коррозия свинцовой пластинки, г/м^2
10 Масло индустриальное 50	—	5—5.5	5	175	0.21	59.34
11 То же + присадка:						
12 кальциевая соль *изо*-цетилбензолсульфокислоты	$(C_{16}H_{33}—C_6H_4—SO_3)_2Ca$	3.5—4.0	5	64	0.26	43.31
13 бариевая соль *изо*-цетилбензолсульфокислоты	$(C_{16}H_{33}—C_6H_4—SO_3)_2Ba$	3.0	6	49	0.33	62.00
14 стронциевая соль *изо*-цетилбензолсульфокислоты	$(C_{16}H_{33}—C_6H_4—SO_3)_2Sr$	3.5—4.0	7	61	0.70	42.15
15 свинцовая соль *изо*-цетилбензолсульфокислоты	$(C_{16}H_{33}—C_6H_4—SO_3)_2Pb$	3.0	8	103	0.92	64.71
16 кобальтовая соль *изо*-цетилбензолсульфокислоты	$(C_{16}H_{33}—C_6H_4—SO_3)_2Co$	2.5	16	145	0.91	44.47
17 медная соль *изо*-цетилбензолсульфокислоты	$(C_{16}H_{33}—C_6H_4—SO_3)_2Cu$	4.5	9	110	0.89	44.47

Note. Additive content in oil 1% by mass.

1) Product
2) Hypothetical empirical formula
3) PZV detergent properties, points
4) AzNII stability, minutes
5) Induction period
6) Time to absorb 20 ml of oxygen
7) Pinkevich corrosion (50 hours)
8) Acid number, mg of KOH to 1 g
9) Lead-plate corrosion, g/m^2
10) Industrial oil 50
11) Same + additives
12) Calcium salt of *iso*-cetylbenzolsulfoacid
13) Barium salt of *iso*-cetylbenzolsulfoacid
14) Strontium salt of *iso*-cetylbenzolsulfoacid

15) Lead salt of *iso*-cetylbenzolsulfoacid
16) Cobalt salt of *iso*-cetylbenzolsulfoacid
17) Copper salt of *iso*-cetylbenzolsulfoacid.

TABLE 11.58

Influence of Type of Aromatic Ring and Functional Groups on Effectiveness of Sulfoacid Salts [34]

1 Продукт	2 Предполагаемая эмпирическая формула соли	3 Моющие свойства ПЗВ, баллы	Стабильность по АзНИИ, 4 мин: 5 индукционный период	6 время поглощения 20 мл кислорода	7 Коррозия по Пинкевичу (50 ч): 8 кислотное число, мг КОН на 1 г	9 коррозия свинцовой пластинки, г/м²
10 Масло индустриальное 50	—	5—5.5	5	175	0.21	59.34
11 То же + присадка:						
12 кальциевая соль *изо*-цетилбензолсульфокислоты	$(C_{16}H_{33}—C_6H_4—SO_3)_2Ca$	3.5—4.0	5	64	0.26	43.31
13 бариевая соль *изо*-цетилбензолсульфокислоты	$(C_{16}H_{33}—C_6H_4—SO_3)_2Ba$	3.0	6	49	0.33	62.00
14 кальциевая соль *изо*-цетилнафталинсульфокислоты	$(C_{16}H_{33}—C_{10}H_6—SO_3)_2Ca$	3.5	7	86	0.2[illegible]	22.46
15 бариевая соль *изо*-цетилнафталинсульфокислоты	$(C_{16}H_{33}—C_{10}H_6—SO_3)_2Ba$	2.0—2.5	7	62	0.43	55.07
16 кальциевая соль *изо*-цетилтетралинсульфокислоты	$(C_{16}H_{33}—C_{10}H_{10}—SO_3)_2Ca$	4.0	7	81	0.37	42.64
17 бариевая соль *изо*-цетилтетралинсульфокислоты	$(C_{16}H_{33}—C_{10}H_{10}—SO_3)_2Ba$	3.5	5	54	0.41	56.53
18 кальциевая соль *изо*-цетилфенолсульфокислоты	$[C_{16}H_{33}—C_6H_3(OH)—SO_3]_2Ca$	4.0	31	219	0.29	63.08
19 бариевая соль *изо*-цетилфенолсульфокислоты	$[C_{16}H_{33}—C_6H_3(OH)—SO_3]_2Ba$	3.5	30	205	0.36	71.72
20 кальциевая соль *изо*-цетилмонохлорбензолсульфокислоты	$(C_{16}H_{33}—C_6H_3Cl—SO_3)_2Ca$	3.0—3.5	7	97	0.31	41.83
21 бариевая соль *изо*-цетилмонохлорбензолсульфокислоты	$(C_{16}H_{33}—C_6H_3Cl—SO_3)_2Ba$	3.0	5	86	0.34	67.44

Note. Additive content in oil 1% by mass.

1) Product
2) Hypothetical empirical formula
3) PZV detergent properties, points
4) AzNII stability, minutes
5) Induction period
6) Time to absorb 20 ml of oxygen
7) Pinkevich corrosion (50 hours)
8) Acid number, mg of KOH to 1 g
9) Lead-plate corrosion, g/m²
10) Industrial oil 50
11) Same + additives
12) Calcium salt of *iso*-cetylbenzolsulfoacid
13) Barium salt of *iso*-cetylbenzolsulfoacid
14) Calcium salt of *iso*-cetylnaphthalenesulfoacid
15) Barium salt of *iso*-cetylnaphthalenesulfoacid
16) Calcium salt of *iso*-cetyltetralinsulfoacid
17) Barium salt of *iso*-cetyltetralinsulfoacid
18) Calcium salt of *iso*-cetylphenolsulfoacid
19) Barium salt of *iso*-cetylphenolsulfoacid
20) Calcium salt of *iso*-cetylmonochlorobenzolsulfoacid
21) Barium salt of *iso*-cetylmonochlorobenzolsulfoacid.

TABLE 11.59

Influence of Sulfoacid Salts on Pour Point of AK-15 Oil [34]

A Продукт	B Предполагаемая эмпирическая формула	C Температура застывания, °C	D Депрессия температуры застывания, °C
E Масло АК-15		F От −3 G до −5	—
H То же + присадка:			
I бариевая соль *изо*-цетилбензосульфокислоты	$(C_{16}H_{33}-C_6H_4-SO_3)_2Ba$	От −4 до −6	1
J кальциевая соль алкилбензолсульфокислоты (алкилирование бензола хлорированным парафином)	$(C_{24}H_{49}-C_6H_4-SO_3)_2Ca$	От −20 до −22	17
K бариевая соль алкилбензолсульфокислоты (алкилирование бензола хлорированным парафином)	$(C_{24}H_{49}-C_6H_4-SO_3)_2Ba$	От −20 до −22	17
L бариевая соль *изо*-цетилнафталинсульфокислоты	$(C_{16}H_{33}-C_{10}H_6-SO_3)_2Ba$	От −3 до −6	0
M кальциевая соль *изо*-тетракозилнафталинсульфокислоты	$(C_{24}H_{49}-C_{10}H_6-SO_3)_2Ca$	От −20 до −22	17
N бариевая соль *изо*-тетракозилнафталинсульфокислоты	$(C_{24}H_{49}-C_{10}H_6-SO_3)_2Ba$	От −20 до −22	17
O бариевая соль *изо*-цетилфенолсульфокислоты	$(C_{16}H_{33}-C_6H_4OH-SO_3)_2Ba$	От −4 до 6	1
P бариевая соль *изо*-цетилмонохлорбензолсульфокислоты	$(C_{16}H_{33}-C_6H_3Cl-SO_3)_2Ba$	От −4 до −6	1

Note. Additive content in oil 1% by mass.

A) Product
B) Hypothetical empirical formula
C) Pour point, °C
D) Pour-point depression, °C
E) AK-15 oil
F) From
G) To
H) Same + additives
I) Barium salt of *iso*-cetylbenzosulfoacid
J) Calcium salt of alkylbenzolsulfoacid (alkylation of benzol by chlorinated paraffin)
K) Barium salt of alkylbenzolsulfoacid (alkylation of benzol by chlorinated paraffin)
L) Barium salt of *iso*-cetylnaphthalenesulfoacid
M) Calcium salt of *iso*-tetracosylnaphthalenesulfoacid
N) Barium salt of *iso*-tetracosylnaphthalenesulfoacid
O) Barium salt of *iso*-cetylphenolsulfoacid
P) Barium salt of *iso*-cetylmonochlorobenzolsulfoacid.

TABLE 11.60

Results of Laboratory Tests on Oils with Various Sulfonate Additives [34]

1 Продукт	2 Зольность, %	3 Моющие свойства по ПЗВ, баллы	4 Коррозия по Пинкевичу (на свинце), г/м²	5 Окисление по ВТИ (14 ч., при 160° С): 6 выпадение осадка, %	5 Окисление по ВТИ (14 ч., при 160° С): 7 кислотное число, мг KOH на 1 г
8 Дизельное масло ДС-11 (бакинское сырье) . .	—	5—5.5	30.0	0.41	1.88
9 То же + присадки:					
10 5% СБ-3	0.48	1.0—1.5	5.5	0.53	2.99
8% СБ-3	0.87	0.5—1.0	2.3	0.01	3.97
10% СБ-3	0,76	0.5	2.9	0.006	5.85
11 10% присадки СБ-3 (кальциевая соль)	0.27	0.5	12 Отсутствие	0.027	1.32
13 10% ПМС'Я	1.15	0.5—1.0	14 То же	0.018	0.97
15 15% НГ-104	0.81	0.5—1.0	6.3	2.91	0
16 Дизельное масло ДС-11 (восточное сырье) . .	—	4.5—5.0	12.3	0.056	1.5
17 То же + присадки:					
10% СБ-3	0.76	0.5	1.6	0.012	3.08
18 10% ПМС-19 . . .	1.21	0.5	1.3	0.005	2.91
19 15% НГ-102	0.84	0.5	9.9	0.000	3.67

1) Product
2) Ash, %
3) PZV detergent properties, points
4) Pinkevich corrosion (on lead plates), g/m^2
5) VTI oxidation (14 hours at 160°C)
6) Amount of sediment, %
7) Acid number, mg of KOH to 1 g
8) DS-11 diesel oil (Baku crude)
9) Same + additives
10) SB-3
11) 10% of SB-3 additive (calcium salt)
12) None
13) 10% PMS'Ya
14) Same
15) 15% NG-104
16) DS-11 diesel oil (eastern crude)
17) Same + additives
18) 10% PMS-19
19) 15% NG-102.

Tables 11.61-11.67 set forth the properties of dialkyl dithiophosphate derivatives used as multipurpose additives. These additives are effective antioxidation, anticorrosion and antiwear agents. A number of additives of this type also have effective detergent and deemulsifying properties. In combination with sulfonate additives, metal dialkyl dithiophosphates are used to prepare oils with high operational properties.

The properties of a number of commercial multipurpose additives of the sulfuretted-alkylphenolate type, formaldehyde-con-

densation alkylphenol additives, and others are given in Tables 11.68-11.73. Tables 11.74 and 11.75 indicate the effectiveness of these additives.

TABLE 11.61

Structure of Technical Additives of the Dialkyl Dithiophosphate Type [35]

A Присадка	B Формула	C Молекулярный вес (вычислено)	D Состав (найдено), мас. % E металл	F фосфор	G сера
H ДФ-1	$[(RO)_2PSS]_2Ba$; $R = C_{20}-C_{24}$	1516–1740	4.20	1.63	3.40
ДФ-2	$[(RO)_2PSS]_2Ba$; $R = C_{16}-C_{20}$	1293–1516	4.84	1.93	4.23
ДФ-12	$\left\{\left[CH_3-(CH_2)_3-\underset{C_2H_5}{\underset{\vert}{CH}}-CH_2O\right]_2PSS\right\}_2Ba$	844.5	7.90	3.29	–
ДФ-5	$[(RO)_2PSS]_2Zn$; $R = C_{21}-C_{24}$	1444–1668	1.80	1.93	3.87
ДФ-8	$\left\{\left[CH_3-(CH_2)_3-\underset{CH_3}{\underset{\vert}{CH}}-CHO\right]_2PSS\right\}_2Zn$	772.5	4.18	3.34	8.22
ДФ-9	$\left\{\left[CH_3-(CH_2)_3-\underset{C_2H_5}{\underset{\vert}{CH}}-CHO\right]_2PSS\right\}_2Zn$	772.5	3.90	3.84	8.18
ДФ-10	$\left[CH_3-(CH_2)_3-\underset{CH_3}{\underset{\vert}{CHO}}\right]PSSZnSSP[X]_2$*	660.3	5.00	4.86	9.60
ДФ-11	$\left[CH_3-(CH_2)_3-\underset{C_2H_5}{\underset{\vert}{CH}}-CH_2O\right]PSSZnSSP[X]_2$*	660.3	5.28	4.50	9.58

* $X = -OCH_2CH(CH_3)_2$.

A) Additive
B) Formula
C) Molecular weight (calculated)
D) Composition (found), % by mass
E) Metal
F) Phosphorus
G) Sulfur
H) DF-...

Table 11.76 presents the properties of additives of a highly promising type (ash-free multipurpose), representing copolymers of methacrylates with certain nitrogen-containing compounds.

Copolymers of lauryl methacrylate and 2-diethylaminoethyl methacrylate typify these compounds:

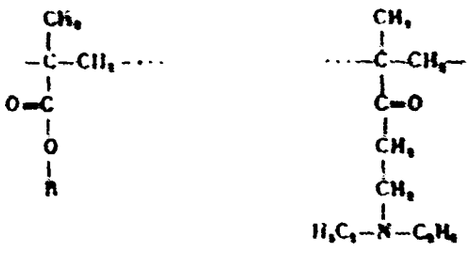


TABLE 11.62

Influence of Metal Dialkyl Dithiophosphate Additives on Properties of DS-8 Oil [35]

1 Продукт	2 Моющие свойства по ПЗВ (ужесточенный метод)		5 Деэмульгирование (количество несгруппированной эмульсии), %	Коррозионная агрессивность по НАМИ (в г/м²) при испытании с маслом		9 Стабильность против окисления		12 Критическая нагрузка $P_к$, кг (четырехшариковая машина, шары по отеч. ШХ-9, диаметр 12,7 мм. Относительная скорость скольжения 0,25 м/сек)
	баллы 3	количество нагарных отложений, г 4		7 ДС-8	8 МТ-16 (эмбовское)	10 термоокислительная стабильность по Папок, мин	11 содержание смол в масле после ПЗВ, %	
13 Масло без присадки	4—4,5	0.35	22	2.2	33.7	19	15.2	64
14 То же + присадка:								
15 ДФ-1	2.5	0.15	0	0.9	2.1	65	7.0	80
ДФ-2	4.0	0.30	0	1.8	5.2	50	—	145
ДФ-12	3.0	0.25	4	—	4.2	66	—	104
ДФ-5	3.0	0.20	12	4.9	10.9	60	8.0	92
ДФ-8	4.0	0.20	16	4.7	13.5	66	7.4	142
ДФ-9	2.5	0.05	18	3.8	11.5	62	6.0	145
ДФ-10	3.0	0.15	16	4.4	11.2	63	7.3	125
ДФ-11	3.0	0.10	18	5.3	8.3	56	6.8	135

Note. Dialkyl dithiophosphate content in oil 3.5%.

1) Product
2) PZV detergent properties (upgraded method)
3) Points
4) Amount of varnish deposits, g
5) Deemulsification (amount of nonseparating emulsion), %
6) NAMI corrosive aggressiveness (g/m^2) in test with oil
7) DS-8
8) MT-16 (Emba)
9) Oxidation stability
10) Papok thermal-oxidation stability, minutes
11) Content of tars in oil after PZV, %
12) Critical load P_k, kg (four-ball machine, steel ShKh-9 balls, diameter 12.7 mm. Relative slip speed 0.25 m/s)
13) Oil without additive
14) Same + additives
15) DF-1.

TABLE 11.63

Influence of Technical Dialkyl Dithiophosphates on Detergent Properties and Corrosiveness of Aviation Oils [36]

1 Присадка	2 Моющие свойства по ПЗВ, баллы		3 Коррозионность масла МС-20 (по ГОСТ 5162—48), г/м²
	МК-22	4 МС-20	
5 Базовое масло	4.0	4.5	46.0
6 То же + присадка:			
7 диалкилдитиофосфат бария	2.5—3.0	0.5—1.0	4.3
8 диалкилдитиофосфат кальция	3.5	2.0—2.5	8.3
9 диалкилдитиофосфат никеля	4.5	2.0	0.7
10 диалкилдитиофосфат меди	5.5	4.5	45.5

Note. Content of dialkyl dithiophosphates in oil 1.5%.

1) Additive
2) PZV detergent properties, points
3) MS-20
4) Corrosiveness of MS-20 oil (according to AUSS 5162-49), g/m²
5) Base oil
6) Same + additives
7) Barium dialkyl dithiophosphate
8) Calcium dialkyl dithiophosphate
9) Nickel dialkyl dithiophosphate
10) Copper dialkyl dithiophosphate.

TABLE 11.64

Detergent and Corrosion Properties of Oils as Functions of DF-1 Additive Concentration [36]

1 Масло	2 Моющие свойства по ПЗВ, баллы					3 Коррозия (по ГОСТ 5162—48), г/м²				
	3 без присадки	4 с присадкой				3 без присадки	4 с присадкой			
		0.5%	1%	2%	5%		0.5%	1%	2%	5%
6 МС-20 (грозненское)	5	—	2—2.5	0.5—1	3.5	4.8	—	1.2	4.0	8.6
МК-22	4.5—5	—	3.5	2	4.5—5	0.6	—	2.5	4.0	6.7
7 Дизельное (из эмбенских нефтей)	5	2.5—3	1.5—2	2	2.5	48.5	52.7	13.7	6.5	8.8

1) Oil
2) PZV detergent properties, points
3) Without additive
4) With additive
5) Corrosion (AUSS 5162-49), g/m²
6) MS-20 (Groznyy)
7) Diesel (from Emba crudes).

TABLE 11.65

Influence of Length of Hydrocarbon Radical on Deemulsifying Properties of Nickel and Barium Dialkyl Dithiophosphates [37]

1 Присадка	2 Формула	3 Количество эмульсии, %
4 Ди-*н*-бутилдитиофосфат никеля	$[(C_4H_9O)_2PSS]_2Ni$	22
5 Ди-*н*-децилдитиофосфат никеля	$[(C_{10}H_{21}O)_2PSS]_2Ni$	28
6 Ди-*н*-октадецилдитиофосфат никеля	$[(C_{18}H_{37}O)_2PSS]_2Ni$	40
7 Ди-*н*-децилдитиофосфат бария	$[(C_{10}H_{21}O)_2PSS]_2Ba$	12
8 Ди-*н*-октадецилдитиофосфат бария	$[(C_{18}H_{37}O)_2PSS]_2Ba$	0

Note. Additive content in oil (AK-10) 1.5%; deemulsifying ability of additives determined by centrifuging mixture of oil with 1% sludge (from oil filter of automotive engine) and distilled water for 30 min.

1) Additive
2) Formula
3) Amount of emulsion, %
4) Nickel di-*n*-butyl dithiophosphate
5) Nickel di-*n*-decyl dithiophosphate
6) Nickel di-*n*-octadecyl dithiophosphate
7) Barium di-*n*-decyl dithiophosphate
8) Barium di-*n*-octadecyl dithiophosphate.

TABLE 11.66

Influence of Metals in Organophosphorus Compounds on Their Deemulsifying Properties [37]

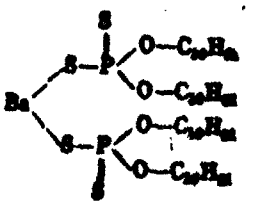
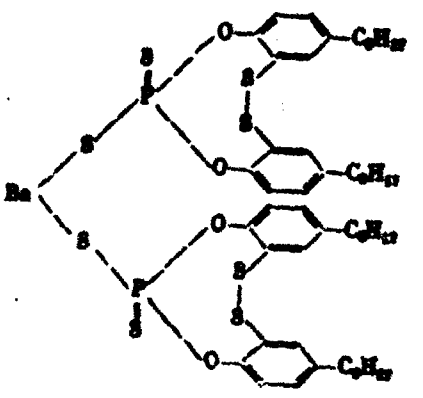
1 Присадка	2 Формула	3 Количество эмульсии (в %) после центрифугирования в течение, мин			
		5	10	15	30
4 Диалкилдитиофосфат бария	$[(RO)_2PSS]_2Ba$	40	0	0	0
5 Диалкилдитиофосфат кальция	$[(RO)_2PSS]_2Ca$	> 30	> 30	30	22
6 Диалкилдитиофосфат цинка	$[(RO)_2PSS]_2Zn$	22	14	12	10
7 Дисульфидтиофосфат	$(C_{10}H_{21}O)_2PSS-SSP(OC_{10}H_{21})_2$	34	28	28	24

Note. Dialkyl dithiophosphates obtained from technical macromolecular alcohols; additive content in oil (D-11) 1.5%; deemulsifying ability determined after 30-min test of oil on PZV machine in accordance with AUSS 5726-53.

1) Additive
2) Formula
3) Amount of emulsion (in %) after centrifuging for ... minutes
4) Barium dialkyl dithiophosphate
5) Calcium dialkyl dithiophosphate
6) Zinc dialkyl dithiophosphate
7) Disulfidethiophosphate.

TABLE 11.67

Influence of Structure of Barium Dialkyl Dithiophosphates on Their Deemulsifying Properties [37]

1 Присадка	2 Формула	3 Количество эмульсии, %
4 Ди-н-децилдитиофосфат бария		12
5 Дисульфидиоктилфенилдитиофосфат бария		26

Note. Test conditions for additives similar to those indicated for Table 11.65.

1) Additive
2) Formula
3) Amount of emulsion, %
4) Barium di-n-decyl dithiophosphate
5) Barium disulfidedioctylphenyl dithiophosphate.

TABLE 11.68

Physicochemical Properties of AzNII-5 and AzNII-7 Additives

1 Показатель	2 АзНИИ-5	3 АзНИИ-7
3 Плотность d_4^{20} . . .	0.9550—0.9560	1.0340
4 Вязкость кинематическая при 100° С, сст	18—25	8.76
5 Температура застывания, °С	28—30	—
6 Зольность, % . . .	8—9	11.0
7 Сера, %	2—3	3—4
8 Коксуемость, % . .	10—11	—
9 Коррозия по Пинкевичу масла индустриального 50 с 3% присадки, г/м²	—	0—5
10 Моющие свойства масла индустриального 50 с 3% присадки по методу ПЗВ, баллы	—	2—2.5

1) Index
2) AzNII-...
3) Density
4) Kinematic viscosity at 100°C, cSt
5) Pour point, °C
6) Ash, %
7) Sulfur, %
8) Coking capacity, %
9) Pinkevich corrosion of industrial oil 50 with 3% additive, $g/10^2$
10) Detergent properties of industrial oil 50 with 3% additive by PZV method, points.

TABLE 11.69

Physicochemical Properties of BFK-1 Additive

1 Показатель	2 Норма
3 Плотность d_4^{20} . . .	1.0190
4 Вязкость кинематическая при 100° С, сст	126.34
5 Молекулярный вес. .	880
6 Температура вспышки (в открытом тигле), °С	180
7 Зольность, % . . .	9—10
8 Коррозия по Пинкевичу масла Д-11 с 5% присадки, г/м²	2—3
9 Моющие свойства масла Д-11 с 5% присадки по методу ПЗВ, баллы	0.5—1.0

1) Index
2) Norm
3) Density
4) Kinematic viscosity at 100°C, cSt
5) Molecular weight
6) Flash point (open crucible), °C
7) Ash, %
8) Pinkevich corrosion of D-11 oil with 5% additive, g/m^2
9) Detergent properties of D-11 oil with 5% additive, by PZV method, points.

The amount of nitrogen-containing monomer in the copolymer is usually 5-10%. It is also possible to use other polymeric monomers based on derivatives of pyridine and certain amines.

TABLE 11.70

Physicochemical Properties of TsIATIM-339 Additive

1 Показатели	2 Норма	1 Показатели	2 Норма
3 Вязкость кинематическая при 100° С, сст, не менее	15	12 Вода, %, не более	0.1
4 Содержание, %:		13 Базовое масло МТ-16 с 3% присадки:	
5 бария, не менее	4.7	14 коррозия, г/м², не более	15
6 хлора, не более	0.3	15 моющие свойства по ПЗВ, баллы, не более	1.5
7 серы	4—5.5	Испытание на растворимость присадки в масле	17 Выдерживает
8 Реакция присадки	9 Щелочная		
10 Зольность, %, не менее	8.5		
11 Механические примеси, %, не более	16 0.15		

1) Index
2) Norm
3) Kinematic viscosity at 100°C, cSt, not less than
4) Contents, %
5) Barium, no less than
6) Chlorine, no more than
7) Sulfur
8) Reaction
9) Alkaline
10) Ash, %, nc less than
11) Mechanical impurities, %, no more than
12) Water, %, no more than
13) MT-16 base oil with 3% additive
14) Corrosion, g/m², not above
15) PZV detergent properties, points, not above
16) Test for solubility of additive in oil
17) Passes.

TABLE 11.71

Physicochemical Properties of VNII NP-360 Additive and its Components

1 Показатели	2 Компоненты		4 [illegible]*
	3 ВНИИ НП-354	3 ВНИИ НП-350	
5 Вязкость кинематическая при 100° С, сст	30—80	19—25	13—20
6 Содержание, %:			
7 фосфора	—	2.4—2.5	0.75—1.0
8 [illegible]	—	2.3—2.6	0.6—1.0
9 бария	10.5—12.0	—	3.0—4.5
10 Зольность, %	11—16	7—8	12.5—16.5
11 Сера, %	—	5.0—5.5	1.4—2.0
12 Механические примеси, %, не более	0.15	0.15	0.15
13 Вода	14 Отсутствие		

*Composition of VNII NP-360 additive: 2 parts by weight of VNII NP-354 and 5 parts by weight of VNII NP-350.

1) Index
2) Components
3) VNII NP-...
4) VNII NP-360 additive*
5) Kinematic viscosity at 100°C, cSt

6) Contents, %
7) Phosphorus
8) Zinc
9) Barium
10) Ash, %
11) Sulfur, %
12) Mechanical impurities, %, no more than
13) Water
14) None.

TABLE 11.72

Physicochemical Properties of VNII NP-370 and VNII NP-371 Additives

1 Показатели	2 ВНИИ НП-370	3 ВНИИ НП-371
3 Вязкость кинематическая при 100° С, сст	20—30	20—35
4 Щелочность, мг КОН на 1 г	35—40	60—65
5 Содержание, %		
6 металла	2—2.1	7—7.7
7 механических примесей	0.05—0.25	0.05—0.2
8 воды	9 Отсутствие	
10 золы (сульфатной)	7—7.5	12—13

1) Index
2) VNII NP-...
3) Kinematic viscosity at 100°C, cSt
4) Alkalinity [sic; neutralization number?], mg of KOH to 1 g
5) Contents, %
6) Metal
7) Mechanical impurities
8) Water
9) None
10) Ash (sulfate).

TABLE 11.73

Physicochemical Properties of MNI IP-22k Additive

1 Показатели	2 Норма
3 Вязкость кинематическая при 100° С, сст	18—25
4 Содержание, %, не менее:	
5 палладия	4.0
6 фосфора	1.7
7 Зольность, %	10—14
8 Сера, %, не менее	8
9 Механические примеси, %, не более	0.15
10 Базовое масло МТ-16 с 4.5% присадки:	
11 коррозия, г/м², не более	1.0
12 моющие свойства по ПЗВ, баллы, не более	1
13 термоокислительная стабильность по Пенн., мин, не менее	60
14 моторная испаряемость за 30 мин, %, не более	65
15 рабочая фракция за 30 мин, %, не менее	35
16 нагарообразование за 30 мин, %, не более	1
17 критическая температура нагарообразования за 30 мин, °С, не менее	280

1) Index
2) Norm
3) Kinematic viscosity at 100°C, cSt
4) Contents, %, not below
5) Calcium
6) Phosphorus
7) Ash, %

8) Sulfur, %, not below
9) Mechanical impurities, %, not above
10) MT-16 base oil with 4.5% additive
11) Corrosion, g/m², not above
12) PZV detergent properties, points, not above
13) Papok thermal-oxidation stability, min, not below
14) Motor vaporizability in 30 min, %, not above
15) 30-min working fraction, %, not below
16) Varnish formation in 30 min, %, not above
17) Critical 30-min varnishing temperature, °C, not below.

TABLE 11.74

Operational Properties of MT-16 NKZ Oil with Additives [38]

1 Показатели	2 Масло без присадки	3 Масло с присадками		
		4 3% ТсИАТИМ-339	5 6% ВНИИ НП-360	6 4,5% ВНИИ НП-22к
7 Моторные свойства:				
8 испаряемость, %	51	46	46	46
9 рабочая фракция, %	47	52	50	50
10 лак, %	2	0	0	0
11 критическая температура лакообразования, °С	225	265	270	270
12 термоокислительная стабильность при 260 °С, мин	34	38	62	71
13 лаковый остаток при 260 °С, %	41	35	25	28
14 коэффициент лакообразования	1,2	0,9	0,4	0,4
15 моющие свойства по ПЗВ, баллы	3,0—3,5	—	0,5—1,0	0,5—1,0
16 способность к нагарообразованию, %	6,0	6,8	7,9	8,8
17 Перечное моторное испытание по методу ГСМ-20:				
18 образование на поршне черного лака, %				
19 за 5 ч	55	35	30	30
за 20 ч	100	90	50	40
20 коррозия за 10 ч, г/м²	18	6	0	0

1) Index
2) Oil without additive
3) Oil with additives
4) 3% TsIATIM-339
5) 6% VNII NP-360
6) 4.5% VNI IP-22k
7) Motor properties
8) Vaporizability, %
9) Working fraction, %
10) Varnish, %
11) Critical varnish-formation temperature, °C
12) Stability to thermal oxidation at 260°C, min
13) Varnish residue at 260°C, %
14) Varnish-formation coefficient
15) PZV detergent properties, points

16) Tendency to form carbon deposits, %
17) Primary motor test by GSM-20 method
18) Formation of black varnish on piston, %
19) After ... hours
20) Corrosion in 10 hours, g/m².

TABLE 11.75

Laboratory Evaluation of Import and Domestic Oils with Additives [39]

1	2	3	4	5	6	7
8 Премиальное ESSO-20W/30	0,27	2,0	8	Загусте-вает		22
10 Масло АС-8,5 + присадки:						
11 ЦИАТИМ-339	0,27	1,5	8	22		45
12 ЦИАТИМ-339 + АФВ	0,52	1,0	8	22		45
13 ВНИИ НП-370	0,48	2,0	8	22		20
ВНИИ НП-371	0,86	1,5	8	22		34
14 Серия I						
15 Кастрол-30	1,0	1,0	10	Загусте-вает		30
16 Шелл-Х-100	0,6	1,0	10	17 мм		57
17 Масло ДС-11 + присадки:						
18 ВНИИ НП-360	0,82	0,5	8	15		28
19 НП-22	0,48	0,5	8	—		10
20 ПМС'Я	1,7	0	0	12		20
21 СБ-3	0,8	0	12	25		27
22 НГ-102	1,4	0	10	Загусте-вает		28
23 Серия II						
24 Римула-30	2,2	0	0	7		43
25 Масло ДС-11 + присадки:						
18 ВНИИ НП-360	2,0	0	0	12		22
26 ПМС'Я + ВНИИ НП-353	1,8	0	Следы 27	12		25
28 Серия III						
29 Мобилгард-503	3,0	0	0	—		25
30 ДС-11 + Сантогард-911	2,8	0	0	5		25

1) Oil and additives
2) Ash, %
3) PZV detergent properties, points
4) Oxidizability in DK-2
5) Sediment, %
6) Kinematic viscosity at 100°C, cSt
7) Thermal stability, min
8) Esso-20W/30 premium
9) Thickens
10) AS-9.5 + additives
11) TsIATIM-339
12) TsIATIM-339 + AFB
13) VNII NP-...
14) Series I
15) Castrol-30
16) Shell X-100
17) Same
18) DS-11 + additives
19) IP-22
20) PMS'Ya
21) SB-3
22) NG-102
23) Series II
24) Rimula-30
25) DS-11 oil + additives
26) PMS'Ya + VNII NP-353
27) Traces
28) Series III

29) Mobilgard 593 30) DS-11 + Santolube-311.

TABLE 11.76

Physicochemical Properties of Certain LOA (DuPont Catalogue)

1 Показатели	LOA-564	LOA-565
2 Плотность d_4^{20}	0.89	0.89
3 Вязкость кинематическая, сст:		
4 при 99,8° С	280	680
5 37,8° С	1980	3500
5 Температура, °С:		
6 вспышки	198	198
7 воспламенения	215	215
8 застывания	—28	—28
9 Число омыления, мг KOH на 1 г	8.0	8.0
10 Зольность, %	0	0

1) Index
2) Density
3) Kinematic viscosity, cSt
4) At
5) Temperatures, °C
6) Flash point
7) Flame point
8) Pour point
9) Saponification number, mg of KOH to 1 g
10) Ash, %.

Such compounds, which have thickening and detergent (dispersing) properties simultaneously, are produced abroad under the designations LOA-564, LOA-565 (DuPont), OLOA-1200 (Orobis), and others.

7. ANTIFOAM ADDITIVES

Silicon-organic compounds: polymethyl siloxane (PMS-200A), polydimethyl siloxane, polyethyl siloxane and others are used as antifoam additives (Table 11.77). The amounts of the additives used in the oils range from 0.002-0.005%. The mechanism of the action of antifoam additives is based on their depression of the oil's surface tension. The result is that air dissolved in the oil can be eliminated more easily without the formation of a heavy foam. Recently, antifoam additives have been coming into use together with detergent additives, since the latter usually promote foaming of the oils.

Some of the silicon-organic compounds with antifoaming properties are also capable of influencing other physicochemical and operational properties of oils.

Polysiloxanes lower saturation vapor pressure and hence the vaporizability of oils (the flash points of oils with polysiloxane are considerably higher than those of the pure oils). During oxidation, smaller amounts of tarry and acidic products are formed in a body of oil containing polysiloxane, and the oxidation induction

TABLE 11.77

Action of Silicones as Antifoam Additives for Oils [40]

1 Масло	2 Температура масла, °С	3 Количество присадки в масле, %	Объем образовавшейся пены (в см³) при добавлении в масло присадки		
			5 этилсилоксана	6 изопропилсилоксана	7 бутилсилоксана
8 Индустриальное 50	20	0.0	74	74	74
		0.5	25	50	30
		1.0	13	20	19
	100	0.0	12	12	12
		0.5	9 Нет	9 Нет	9 Нет
10 Автол 10	20	0.0	60	60	60
		1.0	4	12	5
	100	0.0	15	15	15
		0.5	2	10	10
		1.0	9 Нет	3	2
11 Турбинное	20	0.0	15	15	15
		0.5	5	6	5
		1.0	9 Нет	9 Нет	9 Нет
	100	0.5	5	5	5
		1.0	9 Нет	9 Нет	9 Нет

Note. Oil delivered into cylinder with test oil at 33 liters/h.

1) Oil
2) Oil temperature, °C
3) Amount of additive in oil, %
4) Volume of foam formed (cm^3) on introduction of additive into oil
5) Ethyl siloxane
6) Isopropyl siloxane
7) Butyl siloxane
8) Industrial 50
9) None
10) Avtol 10
11) Turbine.

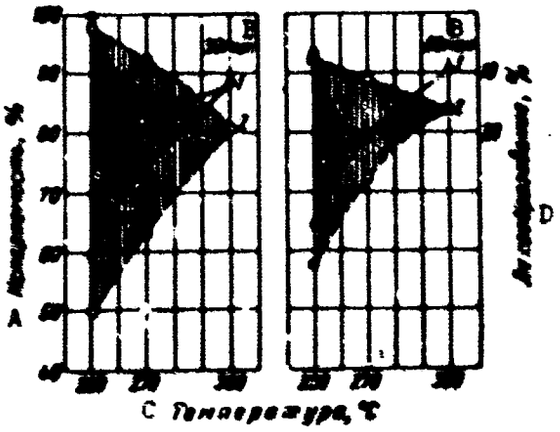


Fig. 11.21. Influence of polysiloxane additive on vaporizability, working fraction, and varnish-forming tendency of MS-20 oil during its oxidation on chromium-plated evaporators [41]: 1) MS-20; 2) MS-20 + 0.002% polysiloxane (molecular weight 4435). A) Vaporizability, %; B) min; C) temperature, °C; D) varnish formation, %.

time increases. In thin-film oxidation, the vaporizability of the oil is also reduced, varnish formation is slower, and hence the working fraction of the oil increases (Fig. 11.21). In the presence of polysiloxanes, oils run off hot metal surfaces more slowly and the varnish films formed are less adhesive. Polysiloxanes are also highly effective when used in additive mixes: they improve the thermal-oxidation stability of the oil and its detergent properties (Tables 11.78 and 11.79). The mechanism of the many-sided action of polysiloxanes is obviously related to their adsorption on the oil-air and oil-metal interfaces and their ability to form a thermochemically stable surface layer that prevents diffusion of oxygen into the oil and weakens the catalytic action of the metal surface. This conception is quite consistent with the high surface activity of siloxanes, which has made it possible to use them as antifoam additives.

The slower oxidation of oils with siloxane additives not only reduces the amount of oxidation products formed, but also changes the nature of these products. For example, the varnish contained considerably larger amounts of products of the initial oxidation stage (tars) and less of the deep-condensation products (asphaltenes); this helps reduce piston-ring burning, since asphaltenes and hydroxy acids are the most harmful components of the varnish films.

TABLE 11.78

Influence of Methyl Polysiloxane on Detergent Potential and Thermal-Oxidation Stability of DS-11 Oil [42]

1 Продукт	2 Термоокислительная стабильность при 250° С, мин	3 Моющий потенциал при 250° С, %
4 ДС-11	33	0
5 ДС-11 + присадка:		
6 0,002% метилполисилоксана	55	1
0,005% »	70	3
0,1% »	70	7
7 6,5% БФК	47	20
8 6,5% БФК + 0,005% метилполисилоксана	84	40
9 10% БФК + 1% ВНИИ НП-353	100	48
10 10% БФК + 1% ВНИИ НП-353 + 0,005% метилполисилоксана	123	70
11 10% БФК + 1% АН-22к	78	26
12 10% БФК + 1% АН-22к + 0,005% метилполисилоксана	108	30
13 10% БФК + 1% АзНИИ-10	96	48
14 10% БФК + 1% АзНИИ-10 + 0,005% метилполисилоксана	130	60

1) Product
2) Thermal oxidation stability at 250°C, min
3) Detergent potential at 250°C, %
4) DS-11
5) DS-11 + additives
6) 0.002% methyl polysiloxane
7) 6.5% BFK
8) 6.5% BFK + 0.005% methyl polysiloxane
9) 10% BFK + 1% VNII NP-353
10) 10% BFK + 1% VNII NP-353 + 0.005% methyl polysiloxane
11) 10% BFK + 1% AN-22k
12) 10% BFK + 1% AN-22k + 0.005% methyl polysiloxane
13) 10% BFK + 1% AzNII-10
14) 10% BFK + 1% AzNII-10 + 0.005% methyl polysiloxane.

TABLE 11.79

Influence of Temperature on Effectiveness of Methyl Polysiloxane [42]

1 Продукт	2 Термоокислительная стабильность (в мин) при				3 Моющий потенциал (в %)			
	240°C	250°C	260°C	270°C	240°C	250°C	260°C	270°C
4 ДС-11 + 6,5% БФК . .	72	47	29	23	30	30	30	25
5 ДС-11 + 6,5% БФК + +0,005% полиметилсилоксана	104	84	55	44	60	40	30	25

1) Product
2) Thermal oxidation stability (min) at
3) Detergent potential (%)
4) DS-11 + 6.5% BFK
5) DS-11 + 6.5% BFK + 0.005% methyl polysiloxane.

8. RECEPTIVENESS OF OILS TO ADDITIVE

The receptiveness of oils to additives depends to a major degree on the chemical composition of the oils, i.e., on the nature of the crude from which the oil was prepared and on the depth

TABLE 11.80

Influence of Additives on Thermal Oxidation Stability of MT-16 Oils from Various Origins [43]

1 Продукт	2 Масло			6 Смеси сернистых нефтей	
	3 эмбинское	4 жирновское	5 заречухурсурахан-ское	7 НУНПЗ	8 НКЗ
МТ-16	18	25	24	25	34
9 То же + присадка:					
10 3% ЦИАТИМ-339 . . .	34	39	38	38	52
11 4,5% МНИ ИП-22к . .	44	57	61	53	70
12 6% ВНИИ НП-360 . .	82	71	77	79	97

Note. Thermal oxidation stability determined at 260°C.

1) Product
2) Oil
3) Emba
4) Zhirnovsk
5) Kara-Chukhur-Surakhany
6) Mixture of sulfur-containing crudes
7) NUNPZ [НПЗ = refinery]
8) NKZ
9) Same + additives
10) 3% TsIATIM-339
11) 4.5% MNI IP-22k
12) 6% VNII NP-360.

and method of refining. Hence the effectiveness of additives must be established separately for each type of oil. An additive that is effective for oils from nonsulfurous Baku crudes may be ineffective for oils made from sulfur-containing crudes, and vice versa. The chemical composition of the base oil is particularly important in selecting antioxidant additives. Such additives as *p*-hydroxy diphenylamine, phenyl-α-naphthylamine, and others are most effective in deep-refined oils that contain a small percentage of aromatic and tarry components. This is because the tarry products passivate the action of antioxidants of this type. For depressor additives, the nature and concentration of solid hydrocarbons and the content of tarry substances is essential, while fractional composition is important for viscosity additives. The same applies to multifunctional and mixed additives. Oils that have been quite thoroughly refined are usually more responsive to additives. However, a sufficiently effective additive mix gives good (equivalent) results when it is added to oils with various refining depths. The necessary degree of refining of the oil or the optimum chemical composition of the base oils must be established empirically in each specific case as a function of the nature of the raw material (Table 11.80) and the effectiveness of the additives (Tables 11.81 and 11.82).

Table 11.83 presents data characterizing the responsiveness of oils with various chemical and fractional compositions to detergent and multipurpose additives; the distillate oils are more receptive to detergent additives than are the residual oils. When the additive has pronounced antioxidant properties (additive DF-1), addition of residual oil to the distillate component increases the effectiveness of such additives sharply (Table 11.81) because of the responsiveness of aromatic hydrocarbons present in the residual oil (primarily medium and heavy ones) to additives that have an antioxidant effect (Table 11.82).

TABLE 11.81

Influence of Additives on Detergent and Antioxidant Properties of Distillate and Compounded DS-8 Oil [44]

1 Продукт	2 Лакообразование на поршне установки ПЗВ *		5 Анализ масла после испытания		
	3 балл	4 г	6 кислотное число, мг КОН на 1 г масла	7 содержание смол, % **	отложение нерастворимого осадка, в % ***
9 ДС-8 дистиллятное	4.5—5	0.55	0.88	9.1	0.67
10 То же + присадка:					
11 3% БФК	2.5	0.10	0.86	8.7	0.44
12 3,5% ДФ-1	4	0.50	1.11	4.4	0.87
13 4% СБ-3	3	0.20	1.76	14.3	0.40
14 ДС-8 компаундированное	4—4.5	0.35	0.85	6.4	0.31
101 То же + присадка:					
11 3% БФК	2.5	0.10	0.89	9.5	0.49
12 3,5% ДФ-1	2—2.5	0.15	0.82	3.3	0.15
13 4% СБ-5	3	0.20	2.0	16.6	0.48

*Test conducted by upgraded method.

**Desorption of tars from silica gel by alcohol-benzol mixture after washing columns with benzol.

***Oil dissolved in "Galosha" gasoline.
****Mixture of 86% distillate and 14% residual oils.

1) Product
2) Varnish formation on piston of PZV machine*
3) Points
4) g
5) Analysis of oil after test
6) Acid number, mg of KOH to 1 g of oil
7) Tar content, %**
8) Content of insoluble residue, %***
9) DS-8 distillate
10) Same + additives
11) 3% BFK
12) 3.5% DF-1
13) 4% SB-3
14) DS-8 compounded****.

TABLE 11.82

Influence of Additives on Thermal Oxidation Stability of Fractions of DS-8 and MS-20 Hydrocarbon Oils [44]

1 Продукт	2 Термоокислительная стабильность при 250° С, мин			
	3 без присадки	4 с присадками		
		5 3% БФК	6 3,5% ДФ-1	7 4% СБ-3
8 ДС-8 дистиллятное	18	21	45	18
9 Нафтено-парафиновая фракция	8	10	15	8
10 Фракция ароматических углеводородов:				
11 легкая	18	18	40	16
12 средняя	18	20	54	23
13 тяжелая	21	35	63	34
14 Смолы	15	18	28	25
15 МС-20	45	48	104	44
9 Нафтено-парафиновая фракция	24	19	32	21
10 Фракция ароматических углеводородов:				
11 легкая	34	29	63	40
12 средняя	54	93	122	65
14 Смолы	57	67	93	58

1) Product
2) Thermal oxidation stability at 250°C, min
3) Without additive
4) With additives
5) 3% BFK
6) 3.5% DF-1
7) 4% SB-3
8) DS-8 distillate
9) Naphthenoparaffinic fraction
10) Aromatic hydrocarbons fraction
11) Light
12) Medium
13) Heavy
14) Tars
15) MS-20.

TABLE 11.83

Receptiveness of Various Oils to TsIATIM-339 and VNII NP-360 Additives [45]

1 Масло	2 Лакообразование на поршне трения ПЗВ, баллы*
3 Дистиллятный компонент НУ НПЗ, очищенный 220% фенола	5
4 То же + присадка:	
5 3% ЦИАТИМ-339 + 1% АзНИИ-ЦИАТИМ-1	2.5
6 6% ВНИИ НП-360	0.5—1
7 Остаточный компонент НУ НПЗ, очищенный 200% фенола	3.5
4 То же + присадка:	
5 3% ЦИАТИМ-339 + 1% АзНИИ-ЦИАТИМ-1	2—2.5
6 6% ВНИИ НП-360	2
8 Масло ДС-11**	4
4 То же + присадка:	
5 3% ЦИАТИМ-339 + АзНИИ-ЦИАТИМ-1	2
6 6% ВНИИ НП-360	1.5
9 Масло МТ-16***	4
4 То же + присадка:	
5 3% ЦИАТИМ-339 + 1% АзНИИ-ЦИАТИМ-1	2—2.5
6 6% ВНИИ НП-360	2

*Test run by upgraded method.
**70% distillate component + 30% residual component.
***25% distillate component + 75% residual component.

1) Oil
2) Varnish formed on PZV-machine piston, points*
3) NU NPZ distillate component refined with 220% phenol
4) Same + additives
5) 3% TsIATIM-339 + 1% AzNII-TsIATIM-1
6) 6% VNII NP-360
7) NU NPZ residual component refined with 200% phenol
8) DS-11 oil**
9) MT-16 oil***.

9. DEPLETION OF ADDITIVES

When an engine runs on an oil containing a detergent (or multipurpose) additive, a decrease in the concentration of additive in the oil is observed, and its effectiveness diminishes (the additive is depleted). Lowering of detergent-additive contents in the oil may be caused by:

a) direct adsorption of the additive onto the filtering elements of oil filters;

b) removal, by oil-filter elements or centrifuges, of oil-insoluble contaminating products together with additive adsorbed on them;

c) interaction between the additive and the surfaces of engine parts lubricated by the oil.

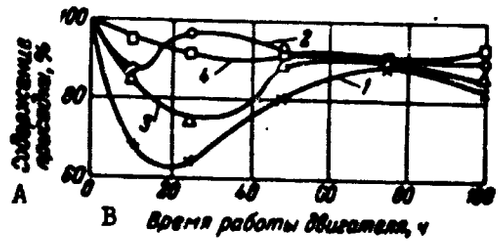


Fig. 11.22. Change in metal content of additives in DS-8 oil during operation of ZIL-164 engine [46]. Additives used: 1) 3% TsIATIM-339 + 1% AzNII-TsIATIM-1; 2) 3.5% DF-1; 3) 4.5% VNII NP-361; 4) 5.5% MNI IP-22K. A) Additive content, %; B) Engine running time, h.

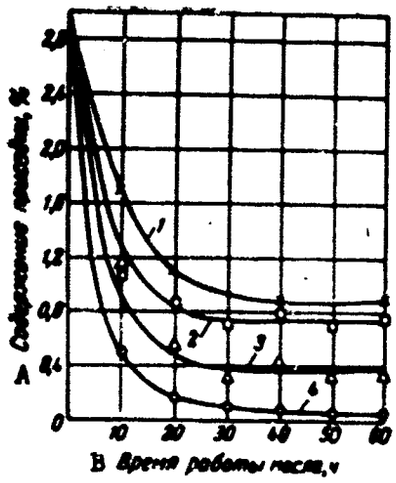


Fig. 11.23. Influence of sulfur content in fuel on depletion of TsIATIM-339 additive from oil (YaAZ-204 engine) [33]. Sulfur in fuel: 1) 0.2%; 2) 0.5%; 3) 1.0%; 4) 1.3%. A) Additive content, %; B) oil operating time, h.

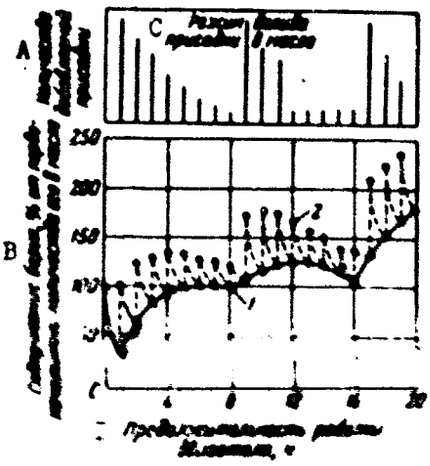


Fig. 11.24. Change in barium content in oil as a function of frequency of replenishment of additive in oil [47] (additive replenished at one-hour intervals): 1) before replenishment; 2) after replenishment of additive. A) Amount of additive added; B) barium content, % of original quantity in oil; C) additive replenishment program; D) engine running time, hours.

The rate of loss of additive from the oil is determined to a substantial degree by engine-testing conditions. During the first hours of engine operation, additives are removed from the oil with particular rapidity (Fig. 11.22).

When oil is cleaned by centrifuging, smaller amounts of additives are extracted from it, as a rule, than when the oil is passed through fine filters.

An increased sulfur content in the fuel results in a sharp decrease in oil additive concentration (Fig. 11.23). The quality of the additive also has substantial influence on the rate at which it is lost from the oil.

When the additive concentration in the oil is increased (or replenished) (Fig. 11.24), more of it is lost from the oil. At the same time, the rate of additive loss (expressed as a percentage of the initial amount) is independent of the initial additive concentration in the oil. Since the effectiveness of a detergent additive in the oil is determined by its content in the oil and by the accumulation of contaminating products in it, the decisive element in determining the effectiveness of the additive at a given time during the test will be the ratio characterizing the contents of additive and contaminating products in the oil at that time.

As the depletion tendency of detergent additives becomes stronger, the ratio of the amount of additive metal in the oil to the amount of contaminating products will decrease.

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Manuscript Page No.	Footnote
673	[1]Sand and other abrasive substances are not permitted among the mechanical impurities.

Manuscript Page No.	Transliterated Symbols
723	к = k = kriticheskiy = critical
725	кр = kr = kriticheskiy = critical
725	св = sv = svaryvaniye = seizure

Chapter 12

LUBRICANTS

The assortment of lubricants prepared by the petroleum industry and enterprises of the Ministry of Railroads contains more than 100 names; a list of these lubricants and their principal characteristics is presented in Table 12.29 (see p. 818). Included among them are certain lubricating oils (for example, clock and instrument) but not special instrument lubricants and special purpose lubricants prepared in small amounts in experimental plants or in certain instrument building enterprises for their own needs.

1. CLASSIFICATION OF LUBRICANTS

Lubricants can be classified according to various characteristics:

1) aggregate state – liquid, semiliquid, plastic, solid (powders, films, coating);

2) colloid structure – sols, true gels, pseudogels, emulsions, suspensions (pastes);

3) chemical characteristics – basic, weakly basic, neutral, weakly acid, acid;

4) melting point – low-melting, average-melting, high-melting (for plastic and solid lubricants);

5) the lubricants' behavior toward water (the chief external reagent) – water-resistant (hydrophobic) and nonwater-resistant (hydrophilic);

6) type of oil base – prepared in mineral oils, in silicones or other synthetic oils, in mixtures of silicones and mineral oils;

7) type of thickening agent (principal) – hydrocarbon, saponaceous, pigmented, silica gel, bentonitic, prepared in urea derivatives, polymeric (thicknened with high polymers, esters and their derivatives);

8) by type of filler – graphite, molybdenite; mica, metalloprotector, mixed;

9) by metallic base of the soap (saponaceous lubricants) – sodium, calcium, lithium, zinc, barium, aluminum, lead, etc., lubricants in mixed soaps containing soaps of several metals – sodium-calcium, lithium-lead, etc. also belong here;

10) by purpose – protective (conservation, preservative), antifriction, antifriction-preservative, friction, sealing, technological, cleaning, etc.;

11) by temperature conditions of use – low-temperature (arctic), high-temperature, tropical, universal (providing for operation of friction joints in a wide range of temperatures);

12) by areas of use – aviation, automotive, railraod, marine, artillery, instrument, industrial, textile, cable, pump, gas container, metallurgic, rotary, etc.

In this handbook lubricants are divided into groups according to the last criterion, – by areas of use, and groups of protective plastic and liquid preservative (protective) lubricants are distinguished.

2. PRINCIPAL PROPERTIES OF LUBRICANTS

Texture and Structure of Lubricants

Lubricating greases are a special class of lubricating materials whose properties differ considerably from the properties of lubricating oils. Lubricating greases are prepared by the introduction into lubricating oils of finely dispersed thickening agents which fulfill two functions: 1) they confine the liquid component (lubricating oil), forming a stable structural skeleton in it; 2) they impart to the dispersion its inherent properties which determine the lubricant's sphere of application, grade and quality.

The external appearance of lubricants is determined by their color and texture – rough structure; lubricants are conventionally divided into granular, fibrous and smooth according to texture. Granular lubricants are agglomerates of "granules" of irregular or more or less regular shape with dimensions from several tenths of a millimeter to 1-2 mm. These lubricants do not form a smooth uniform layer (especially large-grain lubricants) when they are smeared on metallic surfaces or on glass.

Fibrous lubricants when applied to glass or to a metal with a glass rod extend beyond it, sometimes forming long thin fibers; when tested on the fingers they form a "whisker," stretching into fine threads which break upon a comparatively great separation of the fingers. The longer the whisker, the more stickiness the fibrous lubricant possesses. Lubricants containing rubber are capable of stretching into threads several decimeters long. The texture of fibrous lubricants is caused by the formation of strings and fibers of microscopic and sometimes larger cross section.

Smooth lubricants upon examination with the naked eye and low magnification in an optical microscope seem uniform; they usually form a small whisker. The smooth texture imparts a pleasant external appearance to the lubricants; they are deposited better (smoother layer) on the surfaces being lubricated, they lubricate bearings and other friction joints better, promoting their normal operation under more difficult conditions. A smooth texture is often one of the principal requirements for a lubricant and is included in the

specifications. Lubricants with a granular texture frequently are additionally rubbed through rollers or in various homogenizers to impart a smooth texture to them. Usually in this case their mechanical stability increases, syneresis is decreased, etc. Smooth lubrications pass through narrow tubes more freely and fill lubricators better; they contain fewer air bubbles and protect metals against corrosion better than granular and fibrous lubricants with the same properties.

The internal structure of lubricants and most of their physicochemical properties are determined by their fine structure. The structures of various lubricants photographed at a magnification of 10 thousand times under an electron microscope are presented in Fig. 12.1. The structural skeleton of lubricating greases consists of fibers, strings, flakes and other particles of different sizes and shapes.

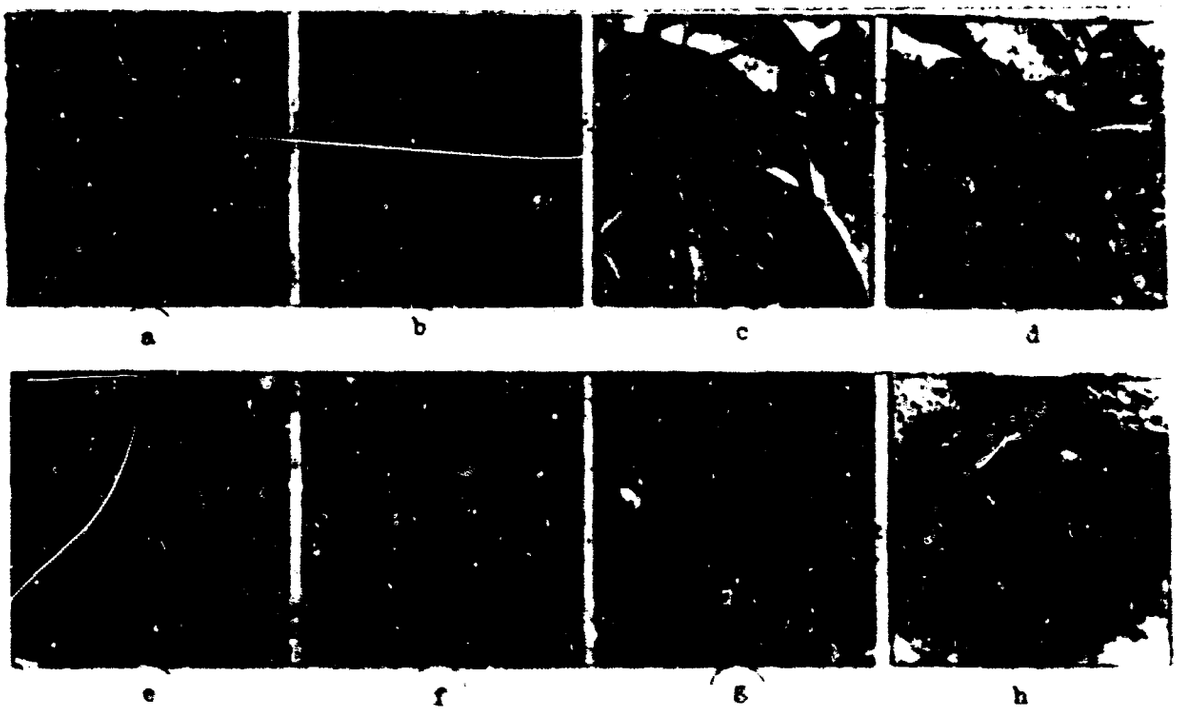

Fig. 12.1. The structure of commercial lubricants. a) Fatty grease US-2; b) synthetic grease USs-2; c) fatty konstalin; d) fatty lubricant I-13; e) lubricant TsIATIM-201; f) aluminum stearate in aluminum lubricant; g) ceresin brand 80; h) lubricant 2TsKP.

The structural skeleton of a fatty grease (see Fig. 12.1, a) consists of twisted string and thread-like particles of a calcium soap of fatty acids (oleic, stearic, palmitic and others) which make up cottonseed oil. The capacity to twist into braids is possessed by calcium soap in a lubricant containing stabilization water whose removal leads to "untwisting" of the particles and loss of the mechanical strength and colloidal stability of the lubricant.

The structural skeleton of a synthetic grease (Fig. 12.1, b) consists of lamellar crystalline aggregates of average size, irregularly arranged in layers with large spaces between them filled with oil. However, the structure of synthetic greases can be distinguished depending on the fractions of synthetic fatty acids which were used in producing the lubricant, and on the technology of the lubricant's preparation.

The structure of konstalin (sodium lubricant) is shown in Fig. 12.1, c and the structure of sodium-calcium lubricant 1-13 in Fig. 12.1, d. The structural skeleton of these lubricants consists of long strings; some of them are twisted into bundles which are larger in lubricant 1-13 which also has a more expressed granular texture.

The structural skeleton of a lubricant thickened with lithium stearate (Fig. 12.1, e) consists of needles and strings, irregularly interwoven and forming a dense network.

The particles of soap in aluminum lubricants when examined in an electron microscope seem very fine and do not have a definite shape (Fig. 12.1, f). They evidently form unstable polymeric chains which disintegrate during preparation of specimens for examination in the electron microscope.

The structure of lubricants thickened with solid hydrocarbons (ceresins, paraffins) differs from the structure of saponaceous lubricants. The solid hydrocarbons are crystallized under laboratory conditions from light solvents and certain fractions of mineral oils in the form of orthorhombic or hexagonal multistage pyramidal crystals (Fig. 12.1, g). The longitudinal and cross-sectional dimensions of these crystals considerably exceed their thickness. Each layer which forms a plate of such a crystal consists of densely packed hydrocarbon molecules; the thickness of a layer is one molecule.

During the preparation of a hydrocarbon lubricant, growth of the crystals is hampered because of the high concentration of thickneing agent in the oil, therefore, the structural skeleton of the lubricant undergoes breakage; as a result it consists of shapeless amorphous flakes and aggregates of them (Fig. 12.1, h). However, the basic structure of hydrocarbon crystals is retained in commercial lubricants.

The chemical composition of the oils has very little effect on the shape and size of the particles forming the structure (skeleton) of lubricating greases. Soap particles of the same chemical composition in lubricants can differ considerably in shape and size depending on the crystallization conditions, additional heat treatment, viscosity of the oil and certain other factors. The greater the viscosity of an oil, the longer the crystals; this is connected with the fact that the already formed string-like particles grow smaller the higher the rate of formation of "seeds" of new soap crystals. However, in the case of very high oil viscosities, the formation of strings does not occur, but a finely granular mass is obtained.

A list of the principal methods of determining lubrication constants and of verifying the quality of lubricating materials is presented in Table 12.1.

The Stability of Lubricants

Lubricants are designed for specific conditions of work and for different periods of storage during which they should not change their operating properties. The more stable a lubricant, the less it changes its chemical and physical properties, the longer these periods, the more reliably it provides for the operation of mechanisms and machines and protects metals against corrosion. At the present time fixed guarantee periods of working in mechanisms, sometimes very long (8-10 years and more) are required of many lubricants. In this case the lubricants must retain their initial properties and qualitative indices not only in the container (jar, can, barrel) but also after being applied to working surfaces, in a thin layer, during the action of oxygen of the air, the elevated temperatures of the tropics and severe frosts of an arctic climate on them.

TABLE 12.1

Principal Methods of Determining the Constants and Testing the Qualities of Lubricating Materials

GOST or TS method	Brief description of method or testing procedure
Method of determining the drop point of lubricants (GOST 6793-53)	The temperature (in °C is recorded at which the first drop of the test lubricant falls during its gradual heating in a Ubbelode apparatus consisting of a thermomenter in a unit with a case and small cup
Method of determining the solidification point of oils and dark petroleum products (GOST 1533-42)	The temperature (in °C) is determined at which the test liquid product loses its mobility; the test is conducted in a test tube
Method of determining the ignition and flash point of oils and dark petroleum products in an open crucible (GOST 4333-48)	The temperature (in °C) at which the petroleum product heated in an open crucible according to GOST 1369-42 ignites when a flame is applied to it is recorded
Method of determining the flash point of petroleum products in a closed crucible (GOST 6356-52)	The temperature (in °C) at which the vapors of a petroleum product heated in a closed crucible in a GOST 1421-53 apparatus form a mixture with the surrounding air which ignites upon application of a flame is determined

GOST or TS method	Brief description of method or testing procedure
Method of determining lubricants' tendency toward slipping (GOST 6037-51)	The capacity of a 2 mm thick layer of lubricant not to slip and not to flow off at a given temperature from a smooth vertical metal surface is established. The temperature at which slipping does not occur (or slipping begins) is also determined
Method of determining the capacity of a lubricant to retain a continuous layer on the surface of a metal (GOST 6953-54)	The amount of lubricant which remains on the surface of a metal in the form of a continuous layer at a specific temperature (usually 60°C) in the course of a given time is determined; it is expressed in mg/cm^2
Method of determining the penetration of lubricating greases (GOST 5346-50)	The depth of submersion of a standard cone of a GOST 2440-42 penetrometer in the test lubricant in 5 s is determined and is expressed in degrees (units of penetration) registered by the arrow on the scale of the penetrometer's dial which corresponds to tenths of a millimeter; the method characterizes the consistency of lubricants
Method of testing petroleum bitumens (GOST 2400-51)	The depth of penetration of the needle of an instrument – a penetrometer (GOST 1440-42) in 5 s is determined; it is used for determining the solidity of ceresins and paraffins; it is expressed in degrees which correspond to the depth of the needle's penetration in tenths of a millimeter
Klimov's method of determining the maximum strength of lubricating greases (GOST 7143-54)	The maximum strength of lubricating greases is determined from the pressure which at a given temperature produces a shift in the lubricant in the capillary of a K-2 plastometer; the maximum strength is expressed in gf/cm^2
The MINKhi GP method of determining the maximum strength of lubricating greases* in a MNI-2 apparatus	The pressure necessary for producing a shift of a ribbed plate in the lubricant is determined; the maximum strength is expressed in gf/cm^2

GOST or TS method	Brief description of method or testing procedure
Method of determining the kinematic viscosity of petroleum products (GOST 33-53)	The time for the passage of a petroleum product through the capillaries of Pinkevich (or Volarovich) viscosimeters at a given temperature is determined; it is expressed in stokes (St) or centistokes (cSt)
Method of determining the conventional viscosity of petroleum products (GOST 6258-52)	The conventional viscosity of petroleum products is determined in a viscosimeter (GOST 1532-54); it is used for liquid petroleum products which produce a continuous stream during the entire test, but whose viscosity is impossible to determine by GOST 33-53; the viscosity is expressed in arbitrary degrees (°VC)
Method of determining the viscosity of lubricating greases (GOST 7163-63)	The viscosity of lubricants is determined with the help of the AKV-2 automatic capillary viscosimeter at a given temperature; it is expressed in poises
Method of determining the viscosity and ultimate strength with a plastoviscosimeter (GOST 9127-59)	The resistance shown by a lubricant which is in the gap between the core and body of the apparatus upon rotation of the cores is determined. The viscosity and the maximum strength are determined in a PVR-1 plastoviscosimeter; the viscosity is expressed in poises and is related to a specific rate of deformation expressed in s^{-1}
Method of determining the colloidal stability of lubricating greases (GOST 7142-54)	The amount of oil (in %) which is pressed from the lubricant in a KSA apparatus at room temperature is determined; the method is intended for determining the tendency of a lubricant to give off oil during storage
Method of determining the syneresis of lubricating greases (GOST 2633-48)	The amount of the liquid phase (in %) which is given off from a lubricant in a specific time as a result of structural changes in its colloidal system is determined; the method is based on the use of the accelerating effect of the mechanical treatment of a lubricant, increased temperature and capillary forces

GOST or TS method	Brief description of method or testing procedure
Tekhratsnet method of determining the content of mechanical impurities in lubricating greases (GOST 1036-50)	The amount of substances insoluble in an alcohol-benzene mixture and hot distilled water is determined in lubricants by extraction of the lubricant with an alcohol-benzene mixture and treatment of the residue on the filter with hot distilled water; it is expressed in %
Method of determining the content of mechanical impurities in lubricating greases using acid decomposition (GOST 6479-53)	The content in the lubricants of substances which are insoluble in petroleum ether, hydrochloric acid, alcohol-benzene mixture and distilled water is determined; it is expressed in %
Method of determining the content of mechanical impurities in petroleum products (GOST 6370-52)	The content in a petroleum product of mechanical impurities retained on the filter during filtration of the petroleum product or its benzene or gasoline solution is determined by the gravimetric method; it is expressed in %
The method of determining the content of mechanical contaminants in lubricants with the help of a counting chamber (GOST 9270-59)	The determination is carried out by counting the number of particles of mechanical contaminants on a special slide
Method of determining the content of free bases and free organic acids in lubricating greases (GOST 6707-57)	The content of free bases and free organic acids is determined in lubricants thickened with soaps; the free base content is expressed in converting to NaOH in %; the free acid content by the acid number in mg of KOH per g, or in % in converting to oleic acid
Method of determining water soluble acids and bases in petroleum products (GOST 6307-60)	The presence of water soluble acids and bases in liquid petroleum products is determined qualitatively by their extraction with distilled water and by establishing the reaction of the aqueous extract with the indicators methyl orange and phenophthalein

GOST or TS method	Brief description of method or testing procedure
Method of determining the acid number in oils (GOST 5985-59)	The determination is based on the extraction of organic acids from the oil with boiling ethyl alcohol and their titration with an alcoholic solution of potassium hydroxide. The acid number is expressed in mg of KOH per g of oil
Method of determining the resistance of lubricants against oxidation (GOST 5734-62)	The resistance of lubricating greases against oxidation is evaluated from the amount of organic acids formed upon heating a lubricant which has been applied in a thin layer to a copper plate which serves as a catalyst. The evaluation is carried out from the change in the acid number of the lubricant and is expressed as the difference in acid numbers of the lubricant before and after oxidation in mg of KOH per g of lubricant
MINKhiGP method of determining the chemical stability of lubricants	The degree of oxidation of the lubricant after irradiation with a quartz lamp at a given temperature (usually about 50°C) and in the course of a given time (16 or 32 h) is determined. The evaluation is carried from the change in the lubricant's acid number and is expressed as the difference in the lubricant's acid numbers before and after oxidation in mg of KOH per g of lubricant
Method of determining the water content of lubricating greases (GOST 1044-41)	Water is removed from a lubricating grease mixture with "Galosh's" gasoline in a GOST 1594-59 apparatus and its content is expressed in %
Qualitative method of determining water (GOST 1548-42)	The presence of small amouts of water in lubricants is determined qualitatively (from crepitation upon heating in a test tube)
Method of determining ash content (GOST 1461-59)	A weighed sample of the test petroleum product is evaporated with the help of a wick from a benzene filter and the solid

GOST or TS method	Brief description of method or testing procedure
	(cont'd) residue is calcined until the mass is constant; the ash content is expressed in %
Method of determining the sulfur content in heavy petroleum products by combustion in a bomb (GOST 3877-49)	A weighed sample of the petroleum product is combusted in a calorimetric bomb and then the amount of SO_4^{2-} ions found in the distilled water with which the bomb was washed is determined; precipitation is carried out by barium chloride; the sulfur content is expressed in %
VTI method of determining sulfur content (GOST 1431-64)	A weighed sample of the product is combusted in a crucible with a mixture of manganese peroxide and soda and sulfur is determined in the form of barium sulfate
Fast method of determining the corrosive effect of lubricating greases on metals (GOST 5757-51)	The change in the surface of metallic (polished steel, copper, brass or bronze) plates submerged for 3 h in the test lubricant heated to 100°C is recorded visually
Method of testing lubricating greases for corrosion of metallic plates (GOST 1037-41)	The change in the color of metallic (copper, steel or brass) plates as a result of corrosion from the action of the lubricant at 15-20°C for a fixed time is recorded visually
Method of determining the protective properties of lubricating greases (GOST 4699-53)	The corrosion defects of metal plates (steel, copper, brass or bronze) covered with the lubricating greases and kept in a humid environment are visually determined
Fast method of determining the protective properties of lubricating greases (GOST 2926-45)	The capacity of the lubricants to protect metals from corrosion when moisture condenses on them is determined; it is expressed by the number of cycles which a sample of the lubricant endures

*Trudy MINKhi GP[Trans. of the Moscow Institute of the Petrochemical and Gas Industry], No. 32, Gostoptekhizdat [State Scientific and Technical Oil and Mineral-Fuel Press], 1960, p. 141.

Physical Stability

Lubricants should not change their colloidal and structural-mechanical properties (colloidal stability, evaporability and thermal stability) from the effect of temperature, stresses and other physical factors. Physical stability depends to a large degree on the combination of chemical and physical transformations in lubricants.

Colloidal Stability

A lubricant should not give off oil during storage in a container or on lubricated surfaces. This property is due to the structure of the lubricant and its chemical nature and depends on the properties of the thickening agent and oil, their proportion, the presence of water, additives and impurities in the lubricant, the dispersion and crystallization conditions and on all the factors on which structure formation depends. It depends primarily on the completeness of the structural skeleton, the shape, size and degree of uniformity of the lubricant's structural particles.

The colloidal stability of lubricants is only partly connected with syneresis and therefore these properties cannot be identified. The higher the thickening capacity of a thickening agent and the more there is of it in a lubricant, the better the liquid phase is bound in it. Hydrocarbon lubricants – homogeneous fusions of mineral oils with solid hydrocarbons (ceresin and paraffin) distributed in lubricants in the form of thin monomolecular layers, crystals (see Fig. 12.1, g) – are distinguished by high colloidal stability during storage. Lubricants thickened with soaps are less stable since the structural skeleton is not as dense and the crystalline lattic of the soaps has a considerably smaller oil capacity than the crystalline lattice of hydrocarbons; there is relatively more mechanically retained oil in the skeleton of soaps and it is more poorly retained. Moreover, soapy lubricants are more subject to aging processes as a result of which there are structural changes and the liberation of oil associated with them.

Weakly basic lubricants are more stable than weakly acid ones. Proper heat treatment (exposure at a specific temperature) of a lubricant during its crystallization can considerably increase its colloidal stability. The treatment of a lubricant on rollers, in homogenizers and other grinding machines leads as a rule to destruction of the structural skeleton of the lubricants and to the liberation of part of the oil. Lubricants with a low colloidal stability (for example, TsIATIM-201) are packed in a small container in order to avoid large separation of the liquid phase.

The separation of oil is accelerated from the effect of stresses (its own weight, applied pressure, centrifugal forces, etc.) and a change in temperature.

Evaporability

When a lubricant is used under high temperature conditions and it is changed infrequently or the friction joint is generally lubricated once during its assembly, the evaporability of lubricants

is of great importance. High evaporability can have a negative effect on the protective properties of the lubricant layer during long storage of products covered with it, especially in a hot climate. In optical instruments lubricants are not replaced for ten years, and from evaporation of the liquid phase of the lubricants vapors of petroleum products can condense on the optical glass and form condensation deposits which put the instruments out of commision. Some lubricants work in a vacuum where evaporation takes place especially intensively. In the absence of air movement evaporability is retarded and in a closed air-tight space (for example, in metal cans and containers) evaporation practically does not occur.

During the evaporation of oil lubricants decrepitate, crusts appear on the surface of the layer; from heavy evaporation, only soaps remain which form dry, sometimes crumbling layers which do not possess protective and anti-friction properties. The evaporation of oil from low-temperature lubricants impairs their frost-resistance; dried lubricants do not provide operation of mechanisms at low temperatures.

The evaporability of lubricants depends on the fractional composition of the oil which enters into their composition. Lubricants prepared in MVP oil dry up considerably more rapidly, those prepared in industrial oils 12 and 20 more slowly and those prepared in heavy aviation oils MS-14, MS-20, MK-22 and others even more slowly.

The quantitative evaluation of the evaporability of lubricants is based on measurement of the loss of mass of a lubricant sample kept under strictly determined conditions for a specific time. The temperature conditions should be as close as possible to those in which the lubricant is used. The temperature is increased to 50-100°C to accelerate the testing. A method which is a variation of the determination of the evaporability of oils by GOST 9566-60 is sufficiently accurate. Other methods are also used: the keeping of lubricant press cakes on pieces of glass under a solux lamp, determination of evaporability in an air current and others.

Water Resistance

This property has great importance both for protective and for anti-friction lubricants, especially for those which are used in products stored or operated in the open air in countries with a tropical humid climate. Lubricants should not be washed off with water, should not form an emulsion with it, dissolve in water and change its anti-friction and protective properties in interacting with water.

Easily washed off lubricants should not be used for covering the outer surfaces of products which during transportation, storage and use are not protected from rain, snow and other atmospheric precipitations falling directly on them; they should not be used in marine and river vessels.

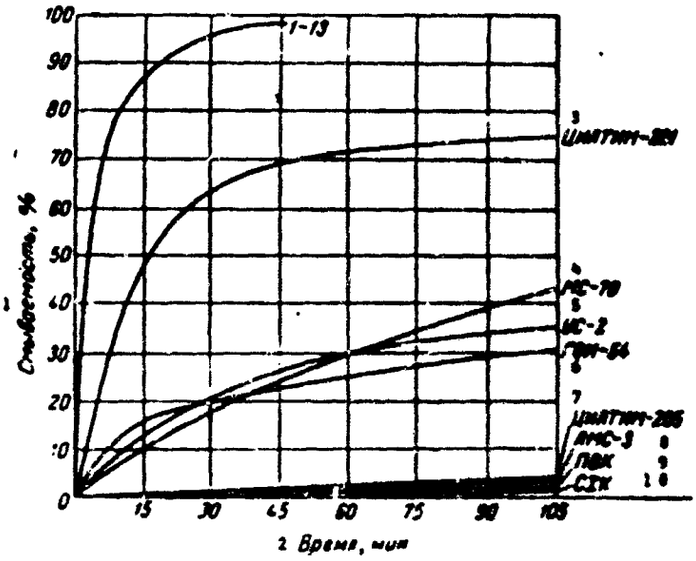

Fig. 12.2. Water erosion capacity of lubricants at a temperature of 31°C. 1) Erosion capacity, %; 2) time, min; 3) TsIATIM-201; 4) MS-70; 5) US-2; 6) GOI-54; 7) TsIATIM-205; 8) AMS-3; 9) PVK; 10) SKhK.

Water resistance depends on the chemical and physical properties of the lubricant, on their viscous and other mechanical characteristics, the temperature of the lubricant and of the wash water. The temperature of rainwater rarely exceeds 25-30°C. Therefore lubricants are frequently tested for water resistance at these temperatures. The curves of the water erosion capacity of some commercial lubricants at 31°C are presented in Fig. 12.2. Lubricant 1-13 which contains a sodium (water soluble) soap is washed off most quickly of all. Lubricant TsIATIM-201 is also washed off rapidly because of its low mechanical properties. The group of lubricants containing hydrophobic soaps and having greater stability of the layer (MS-70, fatty grease, GOI-54) occupy a middle position in erosion capacity. The hydrocarbon lubricants SKhK, PVK, TsIATIM-205 are the most resistant; the aluminum marine lubricant AMS-3 is part of this group.

Data on water resistance obtained in the laboratory have proved to be correct under conditions of practical use of the lubricants.

Slipping

The slipping of lubricating (plastic) greases, in contrast to liquid or molten plastic lubricants takes place at temperatures which are considerably lower than their melting point (drop point). For example, gun lubricant has a drop point of 52-56°C, while the slipping temperature is 32-36°C; the drop point of lubricant GOI-54 (GOST 3276-54) is above 60°C, while it slipped at 40°C. Slipping is of great practical importance especially for those lubri-

cants which are used for protection against corrosion of large metal products which are heated in the sunshine sometimes to comparatively high temperatures.

On vertical surfaces covered with lubricant, slipping is usually manifested immediately. Fissures and cracks in the layer appear which rapidly enlarge and the whole layer or a large part of it is shifted and slides down, exposing the surface of the metal on which a thin layer of the liquid oily base of the lubricant remains.

The slipping temperature depends on many factors: the composition and method of cooling the lubricant, the presence of air bubbles in it, the thickness of the layer, treatment of the lubricated surface and even on the metal on which it is applied. Slipping is a result of boundary syneresis – an increase in the concentration of the liquid phase near the surface of the metal. Slipping of the lubricant layer along a smooth surface takes place even in the presence of a very thin layer of liquid which has separated out on the surface of the metal. The thicker the layer, the lower the temperature at which it slips. Additives – oxidized petroleum products (MNI-3, MNI-7) increase the temperature of slipping of hydrocarbon lubricants (gun, GOI-54). The preparation of the new protective lubricants PVK, GOI-54). The preparation of the new protective lubricants PVK, GOI-54p, SKhK and others whose slipping point is close to the drop point is based on this. The slipping point is determined by GOST 6037-51 with certain refinements.

Hygroscopicity

This property is evaluated from the amount of water absorbed under specific conditions. The increases in weight of lubricant samples (in %) in a humid atmosphere in 16 h are presented below:

TsIATIM-221	7.1
Fatty Grease	3.29
TsIATIM-201	0.16
Gun	0.07
TsIATIM-205	0.01

Among water resistant lubricants calcium lubricants are most hygroscopic, lithium are less hygroscopic and hydrocarbon lubricants absorb even less moisture.

Chemical Stability

The chemical stability of lubricants depends mainly on the ability of their components to interact with oxygen of the air. If a lubricant during operation comes into contact with some other chemically active substances (acids, bases, solvents, etc.), its chemical stability depends on whether it does or does not react with them.

Products which have an acid reaction are accumulated in a lubricant as a result of combining with oxygen, and its acid number increases.

Hydrocarbon lubricants as a rule oxidize slowly: in 7 years when stored in cans their acid number increases by 0.1-0.3 mg of KOH per g, and in equipment - by 0.6-0.8 mg of KOH per g.

Soapy lubricants are oxidized considerably faster; fatty grease, for example, is weakly alkaline at first, in 7 years in a container it acquires an acid number of 0.8-1.6 mg of KOH per g, and in wheel hubs - 1.9-7.9. The acid number of fatty konstalin can reach 10-45 mg of KOH per g in this time. Certain lubricants are oxidized especially rapidly. Products which cause the corrosion of metals and which change the structure of a lubricant are accumulated in a lubricant after considerable oxidation leads to the destruction of the structural skeleton of soapy lubricants, a change in the resistance of the diffusion of vapors of corrosive-aggressive substances (water), etc. Those lubricants in which chemical changes do not have a noticeable effect on operating properties during the entire time of storage (usually counted in years) or in friction joints are considered as chemically stable. The most rigid requirements for chemical stability are made of lubricants which are used in important mechanisms where a change in the lubricant (or its replenishment) is impossible or is greatly hampered and the operating conditions are rather rigid.

The oxidation of lubricants takes place especially actively at elevated temperatures and pressure, in the presence of catalysts, from the effect of ultraviolet and solar radiation as well as atomic radiation. The majority of soaps are catalysts of oxidation. Metals, especially, nonferrous, and their oxides also promote the oxidation of lubricants which are in contact with them. Glycerin, alcohols, free fatty acids and oxidized petroleum products accelerate oxidation in a majority of cases. The presence of moisture reduces the induction period of the oxidation.

Aromatic hydrocarbons which form during the oxidation of phenol type compounds, some sulfur compounds and aromatic amines, on the other hand, inhibit oxidation processes. Diphenylamine, p-oxydiphenylamine, α-naphthol and other inhibitors of oxidation are introduced into lubricants as antioxidizing additives.

Several methods are used to determine the chemical stability of lubricants. For example, chemical stability is determined in an incubator at 120°C according to GOST 5734-62. Methods have been developed in which oxidation is carried out under the ultraviolet radiation of a quartz lamp. The evaluation is made from the change in the lubricant's acid number and from other criteria (change in oxygen pressure in a KhS-4 apparatus).

Radiation Resistance

For products which are used in special equipment where they may be subjected to α-, β- and γ-radiation (from the decay of radioactive elements) as well as to the effect of electrons, protons and neutrons formed during the splitting of atoms, radiation resistance is of great importance. The wide use of atomic energy for peaceful purposes has furthered the study of the radiation resistance of lubricants.

From the effect of the great energies of ionizing radiation which activate molecules of a lubricating material, rupture of their chemical bonds takes place. New compounds whose structure and properties differ from those of the original compounds are obtained from the interaction of the free radicals which have formed among themselves or with other activated molecules. Polymerization and oxidation reactions usually take place from which volatile products of low molecular weight are formed. Mineral and synthetic oils darken after irradiation, become more viscous and from the absorption of large doses of radiation even gelatinize or solidify. The same thing occurs in lubricating greases with an oily base. In the initial stage of irradiation the structural skeleton of soapy lubricants is destroyed and the lubricants become soft. Later, during the gelatinization of the liquid phase, the lubricants harden and become brittle. The profoundness of the changes depends on the dose of absorbed radiation and the chemical composition of the lubricant. Significant changes in the properties of a majority of lubricants begin to appear at an absorbed radiation dose of $1 \cdot 10^8$ rad. However, lubricants have been developed which are 5-7 times more resistant [12].

After irradiation lubricants acquire induced radioactivity, whose magnitude depends on the presence of sulfur, phosphorus, a metallic soap radical and other factors. Antioxidants deteriorate rapidly in lubricants upon irradiation and become ineffective. The radiation resistance of lubricants in a working state from intensive agitation in bearings, reducing gears and other mechanisms is considerably lower than in a state of rest [12].

Yield Point

This property which is also called the yield stress or strength defines the actual boundary line between a state of rest and the plastic flow of a lubricant. In practice it serves different purposes and is expressed in gf/cm^2.

TABLE 12.2

Strength Determined in K-2 Plastometer

1 Смазка	2 Предел прочности (Г/см²) при		
	80° C	50° C	20° C
3 Солидол синтетический:			
4 УСс-1	0	0,9—1,3	1,3—1,8
5 УСс-2	0	0,5—3	2—4
6 УСс — автомобильная	0	1,5—4,5	3—6
7 Солидол жировой УС-2	0	2—3,5	3—6
8 Констатин жировой	1—2,5	3—6	5—10
9 1-13 жировая	0,5—2,5	1,5—4,5	3—6
10 1-13с (синтетическая)	1—2	2,0—2,5	4—8
11 ЯНЗ-2	0,7—1,5	1,7—1,5	2,5—4,5
12 ЦИАТИМ-201	1—2	2—4	4—6
13 НК-50	1,0—1,5	3—4	4—5
14 ЦИАТИМ-221	0,7—1,0	2—2,5	2—2,5
15 ЦИАТИМ-221с	1,0	1,8	3,0

1) Lubricant; 2) strength (gf/cm^2) at; 3) synthetic grease; 4) USs-1; 5) USs-2; 6) USs — automotive; 7) US-2 fatty grease; 8) fatty konstalin; 9) fatty 1-13; 10) 1-13s (synthetic); 11) YaNS-2; 12) TsIATIM-201; 13) NK-50; 14) TsIATIM-221; 15) TsIATIM-221s.

Being a true physical characteristic of the degree of consistency of lubricants, it makes it possible to distinguish lubricants by grades more objectively and validly than by the penetration index. It is possible to judge the content of thickening agent in a lubricant and its thickening capacity by it. The temperature at which the yield point becomes equal to zero is the true transition point of a lubricating grease from a plastic to a liquid state. It characterizes more validly the limits of a lubricant's use than an empirical index – the drop point.

The yield points of some commercial lubricants determined in a K-2 plastometer according to GOST 7143-54 are presented in Table 12.2.

The PVR-1 rotating plastoviscosimeter (GOST 9127-59) is another standardized instrument for determining the yield point (strength) of lubricants. The absolute values of strength obtained on this instrument differ from the corresponding values obtained in the K-2 apparatus.

Residual Shear Stress

The residual shear stress is a property which expresses the thickness and consistency of lubricants and is determined according to GOST 6407-52 with the help of a penetrometer. The greatest submersion depth of a cone in a lubricant is measured with a micrometer. The residual shear stress is expressed in gf/cm^2.

Viscosity Properties of Lubricants

The ability of lubricants to show resistance to movement in flowing is called viscosity, or internal friction. The viscosity of lubricants depends on the rate of deformation and therefore even at a constant temperature it cannot be expressed by a constant value similarly to the viscosity of oils. The viscosity of a lubricant at a constant temperature and a variable rate of deformation is called the effective viscosity and is denoted by

$$\eta_t^{\bar{D}} = \frac{\tau}{\bar{D}}$$

where t is the temperature in °C, $\bar{D}$ is the mean rate of deformation in s^{-1} and τ is the shear strength in dyn/cm^2.

The intensity of the change in viscosity with a change in the rate of deformation of shearing determines the viscosity-rate characteristic (VSKh) of lubricants, and with a change in temperature – the viscosity-temperature characteristic (VTKh).

The effective viscosity is determined with the help of the AKV-2 automatic viscosimeter, as well as with the simplified AKV-4 viscosimeter. The effective viscosities of some commercial lubricants determined at different temperature in the AKV-2 instrument [8] are presented in Table 12.3 and the values of the effective viscosities of three lubricants determined in the PVR-1 rotating viscosimeter according to GOST 9127-59 are given in Table 12.4.

The indices which characterize the viscosity properties of lubricating greases are of great practical importance. The capacity of lubricants to be pumped through pipes, grease ducts and other communications into friction joints with the help of various filling devices (presses, lubricating values, etc.) depends on the viscosity properties. The expenditure of energy on the operation of mechanisms and on the movement of the lubricant itself is also determined by the viscosity of a lubricating material. Here, the dependence of the viscosity on the temperature and the rate of deformation plays a large role. With an increase in the rate of deformation, the power expended on moving the lubricant or on the operation of mechanisms increases much more slowly than in the use of oil.

TABLE 12.3

Effective Viscosity of Commercial Lubricants Determined in AKV-2 Apparatus

1 Смазка	2 Вязкость (в пз) при градиенте скорости деформации 10 сек$^{-1}$ и температуре				
	80° C	20° C	0° C	−15° C	−50° C
3 Солидол синтетический:					
4 УСс-1	--	400—600	1000—1800	3000—5000	—
5 УСс-2	—	400—1000	1000—5000	2000—15 000	—
6 Солидол жировой УС-2	—	800—1200	1500—2500	3000—4500	—
7 Констелин жировой	—	1000—2000	3000—5000	8000—12 000	—
8 1-13 жировая	—	1000—2000	3000—5000	8000—10 000	—
9 1-13с	—	800—1500	1500—3200	10 000—20 000	—
10 ЯНЗ-2	—	800—1500	1400—2000	8000—12 000	—
11 ЦИАТИМ-201	—	700—1000	1000—1500	1500—2500	9000—11 000
12 НК-50	400—500	4000—5000	12 000—15 000	25 000—30 000	—
13 ЦИАТИМ-221	100—200	200—400	600—700	1300—1700	6000—8000
14 ЦИАТИМ-221с	—	400	—	—	10 000

1) Lubricant; 2) viscosity (in poises) at a gradient of the deformation rate of 10 s^{-1} and a temperature of; 3) synthetic grease; 4) USs-1; 5) USs-2; 6) fatty grease US-2; 7) fatty konstalin; 8) fatty 1-13; 9) 1-13s; 10) YaNZ-2; 11) TsIATIM-201; 12) NK-50; 13) TsIATIM-221; 14) TsIATIM-221s.

The viscous resistance of lubricants increases with a decrease in temperature. The temperature at which its internal friction increases so much that the power of the drive mechanism becomes insufficient to bring the mechanism into motion or for output into the necessary circuit is usually taken as the lower limit of the use of a lubricating grease.

TABLE 12.4

Effective Viscosity of Commercial Lubricants Determined in PVR-1 Apparatus

1 Температура, °С	2 Градиент скорости деформации, сек⁻¹	3 Вязкость, пз			1 Температура, °С	2 Градиент скорости деформации, сек⁻¹	3 Вязкость, пз		
		4 ЦИАТИМ-201	5 солидол жировой УС-2	6 1-13 жировая			4 ЦИАТИМ-201	5 солидол жировой УС-2	6 1-13 жировая
50	10	21.0	149.0	5.3	0	10	76.2		69.2
	50	10.0	43.4	3.1		50	37.7	—	—
	252	0.8	11.5	1.8		252	21.0	—	47.1
	1250	0.6	10.0	—		1250	11.5	—	30.0
20	10	73.6	—	42.1	—50	10	113		
	50	19.7	51.0	15.6		50	59.8		
	252	7.2	33.4	9.7		252	40.8		
	1250	5.5	18.0	—		1250	28.3		

1) Temperature, °C; 2) gradient of deformation rate, s^{-1}; 3) viscosity, poises; 4) TsIATIM-201; 5) fatty grease US-2; 6) fatty 1-13.

Lubricating greases in the working temperature range change their viscosity to a considerably smaller degree than the oils in which they are prepared. Thanks to good viscosity-temperature and viscosity-rate properties, lubricating greases are used where great changes in temperature and rate conditions of the operation of mechanisms occur.

Thixotropy

Thixotropy is the ability of dispersed systems to liquefy under the influence of a mechanical effect and to congeal again after its cessation. The thixotropic properties of lubricating greases are manifested in a decrease in strength or viscous resistance during a mechanical effect and in their recovery after cessation of this effect.

Soap-oil systems obtained from a melt (that is, the overwhelming majority of saponaceous lubricants) have two structures which differ fundamentally in properties:

1) a friable condensation (crystallization) structure which is formed after cooling of the melt which is not restored after mechanical treatment;

2) a reversible thixotropic (dispersed) structure whose formation is possible under isothermic conditions.

During cooling of the melt when the thickening agent (soap) dispersed in the oil begins to form a crystalline structure, two processes take place simultaneously: the growth of the crystals and the coupling of the crystalline particles among themselves; from a mechanical effect rupture of the bonds between individual dispersed particles (for example, fibers, strings) and breaking

down of the particles themselves into small particles (shorter fibers and strings) takes place in the condensation structure.

Thixotropic structure formation is a spontaneous process which takes place under isothermic conditions; the thixotropic bonds are reversible, they are restored as a result of the dispersed particles (fibers, strings) approaching the distance of the effect of intramolecular forces from thermal movement in a liquid medium without thermal treatment.

Commercial lubricating greases have condensation and thixotropic structures. After decantation from the digesters, the overwhelming majority of saponaceous lubricants have a condensation structure. During homogenization of lubricants by mechanical treatment on rollers, in special homogenizers and other grinding machines, some of the condensation structures of the elements is destroyed, the lubricant becomes softer, more plastic and smoother. Later, in the absence of a mechanical effect, only thixotropic bonds are formed between individual particles. But after homogenization, some of the condensation structure is retained in the lubricants, which with each subsequent mechanical treatment (for example, during work of the lubricant in a bearing) becomes more and more decomposed. This must be taken into consideration when using lubricants in friction joints. In order that the lubricant work for a long time without considerable change, be well retained in bearings, not thrown off and not run out at high speeds, it must have when packed a sufficiently completely decomposed condensation structure which changes little during further mechanical treatment and high thixotropic properties.

The bulk of solid lubricating greases do not change into a liquid state no matter how intensive and prolonged the mechanical effect. Their thixotropic conversions are manifested outwardly in a change in the strength of the structure: a decrease during mechanical action and recovery after its cessation.

The following patterns are observed during the destruction of lubricants from a mechanical effect:

a) during each specific mechanical effect, first an intensive decrease in the strength of the structural skeleton takes place, then its relatively slow decrease and, finally, an equilibrium state is reached;

b) the final strength of a lubricant with a destroyed structure depends on the intensity of the mechanical effect and for lubricants which do not contain surface active substances, it decreases with an increase in the mechanical effect. The majority of commercial lubricants thickened with the soaps of natural fats behaves in this way;

c) if a lubricant contains surface active substances, a higher equilibrium strength can correspond to a greater intensity of mechanical action.

Lubricants can be divided into three groups depending on thixotropic recovery:

1. Completely thixotropic lubricants whose structure is restored in the shortest time. For example, fatty grease whose strength is practically completely restored after 2 h of rest belongs among them.

2. Lubricants developing thixotropic "fatigue" which are restored slowly at first and then, after a comparatively long time, intensively. Synthetic greases which contain surface active substances, for example, belong among them.

3. Thixolabile lubricants which are restored very weakly or are not restored at all after cessation of the mechanical effect.

3. RAW MATERIAL FOR THE PRODUCTION OF LUBRICANTS AND ADDITIVES FOR LUBRICANTS

The following serve as the principal raw material for the production of lubricating greases for different purposes:

1) mineral (petroleum) oils of different viscosities and degrees of purity;

2) hydrocarbon thickening agents (petrolatums, ceresins, paraffine);

3) soaps of fatty acids isolated from natural fats and natural fats themselves of animal and plant origin;

4) soaps of synthetic fatty acids;

5) various products of chemical synthesis (silico-organic liquids, complex esters, dyes, etc.).

In addition, additives which improve individual properties or several different properties (multifunctional) as well as oxidation inhibitors, corrosion inhibitors and other components are introduced into lubricants.

Mineral Oils

Mineral oils with various viscosity characteristics usually not containing additives are used to prepare lubricating greases (Table 12.5). In addition mixtures of various oils and oils from light petroleum products (kerosene, T-1 fuel oil, etc.), different substitutes manufactured according to MRTU and VTU and others are used.

The still residues of instrument oils, some heavy paraffin and ozocerite distillates, etc., are used for preparing non-crucial lubricants. Silico-organic liquids (silicone oils), complex esters and other products of chemical synthesis are used in the preparation of instrument and special lubricants.

TABLE 12.5

Oils Used in the Production of Lubricating Greases

1 Масло	2 ГОСТ	3 Температура, °С			8 Вязкость кинематическая	
		4 вспышки, не ниже		7 застывания, не выше	9 температура,	10 сСт
		5 в открытом тигле	6 в закрытом тигле			
11 Авиационное МС-14	1013—49	—	200	—30	100	27 Не менее 14
12 Авиационное МС-20	1013—49	—	225	—18	100	27 Не менее 20
13 Авиационное МК-22	1013—49	—	230	—14	100	27 Не менее 22
14 АКп-10	1862—60	200	—	—25	100	27 Не менее 10
15 АК-15	1862—60	220	—	—5	100	27 Не менее 15
16 Вазелиновое медицинское	3164—52	—	185	—	50	28—36
17 Веретенное АУ	1642—50	163	—	—45	50	12—14
18 Индустриальное для высокоскоростных механизмов Л (велосит)	1840—51	—	112	—25	50	4.0—5.1
19 Индустриальное 12	1707—51	165	—	—30	50	10—14
19 Индустриальное 20	1707—51	170	—	—20	50	17—23
19 Индустриальное 20В	2854—51	170	—	—15	50	17—23
19 Индустриальное 30	1707—51	180	—	—15	50	27—23
19 Индустриальное 45	1707—51	190	—	—10	50	38—52
19 Индустриальное 50	1707—51	200	—	—20	50	42—58
20 Осевое Л	610—48	135	—	—15	50	36—52
21 Парфюмерное	4225—54	160	—	—	50	16—24
22 Приборное МВП	1805—51	—	120	—60	50	6.3—8.5
23 Трансмиссионное автотракторное летнее (нигрол)	542—50	180	—	—5	100	29—32
24 Трансформаторное	982—56	135	—	—45	50	28 Не более 9.6
25 Цилиндровое 11 (легкое)	1841—51	215	—	+5	100	9—13
26 Цилиндровое тяжелое 52 (вапор)	6411—52	310	—	—5	100	44—64

1) Oil; 2) GOST; 3) temperature, °C; 4) flash points, not below; 5) in open crucible; 6) in closed crucible; 7) pour points, not above; 8) kinematic viscosity; 9) temperature, °C; 10) cSt; 11) MS-14 aviation; 12) MS-20 aviation; 13) MK-22 aviation; 14) AKp-10; 15) Ak-15; 16) medical vaseline; 17) AU axle; 18) industrial for high-speed mechanisms L (velosite), 19) industrial; 20) axle L; 21) perfumery; 22) MVP instrument; 23) transmission summer automotive (nigrol); 24) transformer; 25) cylinder 11 (light); 26) heavy cylinder 52 (lubricating oil for steam engine cylinders); 27) not less than; 28) not more than.

Hydrocarbon Thickening Agents of Lubricants

Protective lubricants – gun, PVK, SKhK, technical vaseline and others are prepared by thickening petroleum oils with solid hydrocarbon products – ceresins, paraffins and petrolatums.

Petrolatums

Petrolatums are mixtures (fusions) of petroleum ceresins and paraffins with residual petroleum oils. They are marked according to method of purification of the oils from which they are isolated during deparaffinization (Table 12.6): PK – sulfate purification, PS – selective and PSs – selective purification from sulfur petroleums.

Petrolatums of different compositions are obtained in different plants. Close in physical constants, they are differentiated by chemical composition and thickening capacity. Petrolatums contain different amounts of oil and solid components. The residual oils contained in them have different viscosity characteristics (Table 12.7).

TABLE 12.6

Requirements for Petrolatum Quality (GOST 4096-62)

1 Показатели	2 Нормы по маркам		
	3 ПК	4 ПС	5 ПСс*
6 Цвет	7 Светло-коричневый		
8 Температура каплепадения, °С, не ниже	55	55	55
9 Температура вспышки, °С, не ниже	250	240	230
10 Кислотное число, *мг* КОН на 1 *г*, не более	0,1	0,1	0,1
11 Водорастворимые кислоты и щелочи	12 Отсутствие		
13 Сера, %, не более	14 Не нормируется		0,6
15 Содержание фенола	Не нормируется	12 Отсутствие	
16 Механические примеси**, %, не более	0,04	0,03	0,04
17 Вода, %, не более	1,0	18 Следы	
19 Испытание корродирующего действия на стальных и медных пластинках по ГОСТ 5757—51	20 Выдерживают. Допускается изменение цвета медных пластинок и побежалость		

*Petrolatum PSs which is supplied for production of petroleum lubricants and fusions must have a viscosity of not less than 16 cSt at 70°C; that supplied for wood drying must have a flash point of not lower than 200°C and can contain no more than 0.66% mechanical impurities.

**Sand and other abrasive mechanical impurities are not permitted.

1) Properties; 2) standard specifications by brand; 3) PK; 4) PS; 5) PSs*; 6) color; 7) light brown; 8) drop point, °C, not below;

9) flash point, °C, not below; 10) acid number, mg of KOH per g, not above; 11) water soluble acids and bases; 12) absent; 13) sulfur, %, no more than; 14) not standardized; 15) phenol content; 16) mechanical impurities**, %, not above; 17) water, %, not above; 18) traces; 19) testing of corrosive effect on steel and copper plates according to GOST 5757-51; 20) pass. A change in the color of copper plates and iridescence is permitted.

TABLE 12.7

The Composition and Principal Properties of Some Brands of Petrolatum

1 Марка по ГОСТ 4096—62	2 Завод-изготовитель	3 Температура каплепадения, °С	4 Содержание в петролатуме, %		7 Температура каплепадения твердых продуктов, °С	8 Вязкость масла (в сст) при	
			5 масла	6 твердых продуктов		50° С	100° С
9 ПС	10 Грозненский	61	35	64	64.5	—	20.3
11 ПК	12 Волгоградский	71	38	60.5	73.5	—	16.5
13 ПСс	14 Ново-Уфимский	64	7.6	90.1	65.5	30.8	11.77
13 ПСс	15 Новокуйбышевский образец 1	61.5	23.1	68.9	65.5	—	16.7
13 ПСс	16 То же, сбразец 2	62.5	37	58.5	66.5	—	12.5

1) Quality according to GOST 4096-62); 2) manufacturing plant; 3) drop point, °C; 4) content in petrolatum, %; 5) of oil; 6) of solid products; 7) drop point of solid products, °C; 8) viscosity of oil (in cSt) at; 9) PS; 10) Groznyy; 11) PK; 12) Volgograd; 13) PSs; 14) Novo-Ufa; 15) Novokuybyshevsk sample 1; 16) same, sample 2.

TABLE 12.8

Group Chemical Composition of Petrolatums

1 Марка по ГОСТ 4096—62	2 Завод-изготовитель	3 Температура каплепадения обезмасленной части, °С	4 Групповой химический состав, %					10 Реакция с карбамидом, %	
			5 нафтено-парафиновые	6 ароматические		9 смолы		11 образующие комплекс	12 не образующие комплекс
				7 легкие	8 тяжелые				
13 ПС	14 Грозненский	69.5	83.3	9.7	3.3	2.2		22.5	72.5
15 ПК	16 Волгоградский	73.5	88	—	8	4		26	74
17 ПСс	18 Ново-Уфимский	65.5	91.7	—	5.5	2.8		24	76
17 ПСс	19 Новокуйбышевский	65.5	90.3	4.16	2.57	1.73		30	66

1) Quality according to GOST 4096-62; 2) manufacturing plant; 3) drop point of oilless part, °C; 4) group chemical composition, %; 5) napthene-paraffin; 6) aromatic; 7) light; 8) heavy; 9) resins; 10) reaction with carbamide, %; 11) forming complex; 12) not forming complex; 13) PS; 14) Groznyy; 15) PK; 16) Volgograd; 17) PSs; 18) Novo-Ufa; 19) Novokuybyshevsk

Petrolatums differ considerably in oil content (from 7 to 38%) and in drop point which depends chiefly on the drop point of the solid hydrocarbons contained in them (see Table 22.7).

The group chemical composition of petrolatums is presented in Table 12.8.

Ceresins

Ceresins are obtained from the digestion and purification of ozocerite or a "paraffin plug" as well as from the deoiling of petrolatum. They are widely used in technology mainly as a component of hydrocarbon and certain saponaceous lubricants as well as of various cements and packing materials. Since ceresins are contained in petrolatums they naturally are a part of all petrolatum lubricants (CKhK, technical vaseline), although they are not specially introduced into them.

Commercial ceresin is a wax-like uniform white or light yellow material without noticeable mechanical inclusions with a characteristic fine-grained cross-section. Upon examination in a polarization microscope, ceresins are composed of needle-like crystals, in an electron microscope (X 10,000-13,000) it is seen that they are an aggregation of regular rhomboid pyramids and each layer of these pyramids is made up of one row of molecules (see Fig. 12.1, g).

Ceresins isolated from petroleums and ozocerites of different origins are a complex mixture primarily of naphthene hydrocarbons which belong among mono-, di- and tricyclic compounds with straight and branched side chains. The amount of aromatic hydrocarbons in ceresins isolated from ozocerites is small (3-5%) since commercial ceresin is obtained by sulfate purification during which aromatic hydrocarbons are removed.

Commercial ceresins of different origin (Table 12.9) manufactured by industry differ considerably among themselves in physical properties, hydrocarbon content of different group composition and in structure. In addition to the ceresins presented in Table 12.9, a high-melting ceresin of grades 85 and 87 (with a drop point of no lower than 85 and 87°C, respectively) is prepared for special high quality lubricants. It is produced by extraction (extraction ceresin) or vacuum distillation (vacuum ceresin of part of the low-boiling hydrocarbons contained in ceresin of grades 75 or 80.

Extraction ceresin of grade 87 has a considerably greater thickening capacity than vacuum ceresin of the same grade.

Ceresins also differ in dependence on sites of the raw material. For example, ceresin prepared from ozocerite from the Shor-Su deposit is called shorsinsk and that from ozocerites of the Borislavskiy deposit - borislavsk.

Ceresin is also prepared from a paraffin plug deposited on the walls of pipes through which petroleum passes and in vessels in which petroleum rich in paraffin and ceresin is stored. Grosnyy ceresin of three grades, 67, 75 and 80 has been produced according to TS 293-49.

TABLE 12.9

The Quality of Ceresins Used for Preparing Lubricating Greases (Standards)

1 Марка церезина	2 ГОСТ или ТУ	3 Температура каплепадения, °С не ниже	4 Глубина проникания иглы при 25° С и нагрузке 100 г по ГОСТ 2400—51, не более	5 Кислотное число, мг KOH на 1 г, не более
6 Церезин	7 ГОСТ			
57 белый 8	2488—47	57	30	0,28
57 желтый 9		57	30	0,28
67 желтый 9		67	30	0,28
75 желтый 9		75	18	0,28
80 желтый 9	11	80	16	0,28
10 Грозненский	ТУ 293—49			
67		67	35	0,28
75		75	25	0,28
80		80	20	0,28
12 Синтетический	7 ГОСТ 7658—55			
90		90	16	0,20
93		93	16	0,20
100		100	16	0,20
13 Конденсаторный		100	16	0,05
14 Для косметических целей	15 ВТУ 499—53	67	—	0,28

1) Brand of ceresin; 2) GOST or TS; 3) drop point, °C not below; 4) penetration depth of needle at 25°C and a stress of 100 gf according to GOST 2400-51, not more than; 5) acid number, mg of KOH per g, not more than; 6) ceresin; 7) GOST; 8) white; 9) yellow; 10) Groznyy; 11) TS 293-49; 12) synthetic; 13) condenser; 14) for cosmetic purposes; 15) VTU.

Synthetic ceresins obtained as a side product in the production of gasolines from carbon monoxide and hydrogen are sometimes added to natural ceresins to increase their melting point. Low-melting ceresin 67 is used in the cosmetic industry.

Paraffins

Paraffins obtained from petroleum as a special product are hardly used in lubricating greases but are oxidized for the purpose of preparing synthetic fatty acids (see p. 796) or are used for other purposes. They are part of petrolatums and are contained in all petrolatum lubricants. The principal properties of commercial paraffins (GOST 784-53) and of synthetic paraffin (VTU NP 471-54) are presented in Table 12.10, and the properties of petroleum paraffin used for synthesis (oxidation) are given in Table 12.11.

Fats and Fatty Acids

Both free fatty acids and those bound in the form of glycerin esters, mainly natural fats, are used in the production of saponaceous lubricating greases. However, in the USSR the use of natural

fats and the fatty acids obtained from them has almost completely ceased in the last ten years as a result of the development of the petrochemical industry which produces lubricants from synthetic fatty acids. Natural fats and the fatty acids obtained from them are used in comparatively small amounts for preparing low-tonnage lubricants which have not yet been replaced by lubricants from synthetic products or which there is no special need to replace. For example, technical stearin, castor and cottonseed oil, oleic acid, hydrogenated fat obtained from plant oils as well as various waste products from the digestion of fats in the food industry are still used for preparing certain lubricants.

Of the plant oils, cottonseed and castor oils are the most important, but sunflower oil and others can also be used.

TABLE 12.10

The Properties of Commercial Petroleum Paraffins

1 Показатели	2 Парафины					
	технические высокоочищенные марки 3		технические очищенные марки 4		7 неочищенные (спичечный)	8 синтетические
	А	Б	5 Г	6 Д		
9 Внешний вид	10 Белая кристаллическая масса				11 Желтая кристаллическая масса	12 Светло-желтая кристаллическая масса
	13 По стеклу № 1		13 По стеклу № 2			
14 Цвет, мм, не менее	250	250	45	45	15 Не нормируется	—
16 Устойчивость цвета: не желтеет на рассеянном дневном свету в течение, дней	7	7	4	4	15 Не нормируется	7
17 Температура плавления °С, не ниже	54	52	51	50	42	—
18 Содержание масла, %, не более	0.6	0.9	1.8	2.3	5.0	34

Note. Paraffins should not contain water soluble acids and bases as well as mechanical impurities and water.

1) Properties; 2) paraffins; 3) technical highly purified brands; 4) technical purified brands; 5) C; 6) D; 7) unpurified (match); 8) synthetic; 9) external appearance; 10) white crystalline mass; 11) yellow crystalline mass; 12) light-yellow crystalline mass; 13) from glass; 14) color, mm, not less than; 15) not standardized; 16) color stability: does not yellow in scattered daylight for, days; 17) melting point °C, not below; 18) oil content, %, not more than.

TABLE 12.11

Properties of Paraffin Used in Petrochemical Synthesis

[1] Показатели	[2] Нормы
[3] Внешний вид	[4] Кристаллическая масса белого или белого со слегка желтоватым оттенком цвета
[5] Запах	[6] Отсутствие отчетливо выраженного запаха продуктов разложения парафина
[7] Цвет, определяемый со стеклом № 2, мм, не более	70
[8] Температура плавления, °С	52—54
[9] Содержание масла, %, не более	2,3
[10] Температура вспышки (в закрытом тигле), °С, не ниже	160
[11] Механические примеси, водорастворимые кислоты и щелочи, а также фенол	[12] Отсутствие
[13] Сера, %, не более	0,05
[14] Вода	[15] Следы

1) Properties; 2) standard specifications; 3) external appearance; 4) white crystalline mass or white with slight yellowish tinge; 5) smell; 6) absence of clearly expressed smell of paraffin decomposition products; 7) color determined with glass No. 2, mm, no more than; 8) melting point, °C; 9) oil content, %, no more than; 10) flash point (in closed crucible), °C, not below; 11) mechanical impurities, water soluble acids and bases as well as phenol; 12) absent; 13) sulfur, %, no more than; 14) water; 15) traces.

Cottonseed oil is obtained from cotton seeds. It consists mainly of unsaturated fatty acids, but can contain up to 25% saturated fatty acids. Its density is 0.918-0.932 and its pour point is about 3°C. Industry manufactures a refined oil used mainly for food purposes as well as an unrefined oil. Both these types of oil can be of the highest, first and second grades which differ in acid numbers (GOST 1128-55). The acid number of unrefined oil of the highest grade is no more than 4, of the first grade – no more than 7 and of the second – no more than 14 mg of KOH per g. The saponification number is 190-200, the flash point is not below 225°C; the iodine number is 101-116. The content of unsaponifiable substances should not be more than 0.1-0.2%.

Cottonseed oil, like sunflower oil is easily hydrogenated to obtain a hydrogenated fat.

Sunflower oil is obtained from sunflower seeds by pressing or extraction. Depending on the method of treatment, it is divided into three types: refined, hydrated and unrefined; refined oil can be neutralized and deodorized and neutralized and undeodorized; hydrated oil is divided into first and second grades depending on the quality indices; unrefined oil is divided into three grades – highest, first and second. All types and grade of oil, except second grade, obtained by pressing as well as by extraction, but neutralized and deodorized are used for food purposes. The other grades of oil are used for technical purposes. Sunflower oil consists of

unsaturated fatty acids: linoleic (up to 65%) and oleic (up to 30-40%), and it contains up to 10% saturated fatty acids.

It has the following basic properties:

Density, g/cm^3	0.927-0.920
Pour point, °C	about -17°C
Flash point, °C, not below	225
Saporification number, mg KOH per g	185-194
Acid number, mg KOH per g, not more than	
highest grade	1.5
first "	2.25
second "	6.0
Iodine number	119-144

Castor oil is mainly used for preparing lubricants 1-13 (fatty) and 1-LZ, as well as various gasoline-resistant and oil-resistant lubricants. It can serve as a base for the production of sodium and potassium soaps or is added to lubricants in the form of an additive to increase the lubricating and other performance properties. It is obtained from castor plant seeds. It consists mainly of glycerides of ricinoleic acid; it dissolves well in aromatic hydrocarbons (benzene, toluene) and ethyl alcohol, but is poorly soluble in gasoline at low temperatures. Its solubility in gasoline increases with an increase in temperature. For example, at 0°C 3-4% of the oil dissolves in gasoline, while at 20°C, 10-12%. Gasoline dissolves well in castor oil: at 0°C up to 35%, and at 20°C up to 47-50% (according to Panyutin and Rappoport). Up to 25% castor oil dissolves in mineral (petroleum) oils rich in aromatic hydrocarbons, while not more than 0.5-1.0% dissolves in oils with a paraffin base. No more than 1% castor oil dissolves in well purified aviation oils. The solubility of castor oil increases with an increase in the temperature and viscosity of mineral oil. Depending on the method of treatment unrefined and refined technical castor oil is produced (Table 12.12).

The splitting off of ricinoleic acids occurs during the oxidation of castor oil and saturated aldehyde enantone and unsaturated undecylenic acid $C_{11}H_{20}O_2$ as well as normal valeric acid, dicarboxylic acids, etc. are formed. The oxidation product has a specific viscosity of 9.0-9.5 at 100°C, an acid number of not more than 20 mg of KOH per g, and a pour point of no higher than 20°C. It is used in gasoline-resistant lubricating greases: pump, No. 54, BU and others since it is comparatively a difficult soluble in gasoline, ligroin, petroleum oils as well as in water.

Rapeseed, soybean, palm (coconut) and olive oils whose technical indices are presented in Table 12.13 can also be used in the production of lubricants.

Animal fats – beef, horse, pig, sperm whale and others are used as raw material for the production of saponaceous lubricating greases. Sperm whale fat is used as a softening agent in munition lubricants. The composition and technical indices of animal fats are presented in Table 12.14. Sperm whale fat is separated into

cavity (sperm) fat obtained from the head of the whale and body fat. To improve the quality of marine animal fat, it is subjected to hydrogenation or sulfuring. Sulfured sperm whale fat is used in lubricant TsIATIM-203 intended for work at high loads.

TABLE 12.12

Quality of Technical Castor Oils According to GOST 6757-53

1 Показатели	2 Рафинированное		5 Нерафинированное
	3 1-й сорт	4 2-й сорт	
6 Плотность, *г/см*³	0.947—0.970		—
7 Условная вязкость, не менее:			
8 при 50° С	17.2	—	—
» 90° С	3.2	—	—
9 Температура вспышки, °С:			
10 в закрытом тигле	240		
11 в открытом тигле, не менее	275		
12 Температура застывания, °С	—16.0	—	—
13 Кислотное число, *мг* КОН на 1 *г*, не более	1.6	3.0	5.0
14 Иодное число (по иодно-ртутному методу)	82—88		
15 Число омыления, *мг* КОН на 1 *г*	176—186		
16 Неомыляемые вещества, %, не более	1.0		
17 Растворимость в равном объеме 96%-ного этилового спирта	18 Полная		
19 Минеральные кислоты и щелочи	20 Отсутствие	21 Следы	
22 Механические примеси	20 Отсутствие		—
23 Отстой по весу, %, не более	20 Отсутствие		0.2
24 Зольность, %, не более	0.008	—	—
25 Вода и летучие вещества, %, не более	0.25	0.25	0.3

1) Properties; 2) refined; 3) 1st grade; 4) 2nd grade; 5) unrefined; 6) density, g/cm^3; 7) specific viscosity, not less than; 8) at; 9) flast point, °C; 10) in closed crucible; 11) in open crucible, not less than; 12) pour point, °C; 13) acid number, mg KOH per g, not more than; 14) iodine number (by iodine-mercury method); 15) saponification number, mg KOH per g; 16) unsaponifiable substances, %, not more than; 17) solubility in equal volume of 96% ethyl alcohol; 18) complete; 19) mineral acids and bases; 20) absent; 21) traces; 22) mechanical impurities; 23) residue by weight, %, not more than; 24) ash content, %, not more than; 25) water and volatile substances, %, not more than.

Stearic acid $CH_3(CH_2)_{16}COOH$ is a saturated organic acid of the fatty series with a normal structure; mol. wt. is 284.47; density about 0.92 g/cm^3 (0.85 at 70°C), m.p. 69.3°C; b.p. 360°C (with decomposition) or 291°C at 100 mm Hg column. Solubility: in 100 parts by weight of water — 0.03 part by weight at 25°C; in 100 parts by weight of ethyl alcohol — 2.2 parts by weight at 0°C; in 100 parts of weight of ethyl ether — 6 parts by weight at 0°C; in chloroform — complete. Together with other fatty acids (palmitic oleic), it is part of natural fats in the form of glycerin esters.

TABLE 12.13

Quality of Plant Oils

1 Показатели	2 Масло			
	3 пальмовое	4 рапсовое	5 соевое	6 оливковое
7 Плотность при 15° С, г/см³	0.921—0.925	0.911—0.931	0.922—0.934	0.914—0.920
8 Вязкость при 50° С, сст	—	—	59—71.7 **	28.4
9 Показатель преломления при 20° С	1.453—1.455 *	1.471—1.472	1.474—1.478	1.466—1.471
10 Температура застывания, °С	23—28	—	26 От —15 27 до —18	26 От 0 до 27 —6
11 Кислотное число, мг КОН на 1 г	2—10	25 Не выше 8	4.8—6.0	0.2—6.0
12 Число омыления, мг КОН на 1 г	250—264	168—18:	189—195	185—200
13 Иодное число	8—10	94—115	120—141	72—89
14 Титр, °С	36—47	—	14—25	17—27
15 Состав, мас. %:				
16 Неомыляемые кислоты	0.2—1.0	27 До 1,5	0.5—2.0	0.5—3.0
17 стеариновая	2.0—6.5	27 До 2	4.5—7.3	3.3—7.0
18 пальмитиновая	32—47	4.0—4.5	2.5—6.0	7.0—15.6
19 миристиновая	1—4.5	—	0.1—0.4	—
20 олеиновая	27 (до 17) 39—51	15—32	23—29	64—86
21 линолевая	5—11	15—21	51—57	4—14
22 линоленовая	—	27 До 10	3—6	—
23 эруковая	—	38—5	—	—
24 лауриновая	45—51	—	—	—

*At 40°C.
**At 20°C.

1) Indices; 2) oil; 3) palm; 4) rapeseed; 5) soybean; 6) olive; 7) density at 15°C, g/cm^2; 8) viscosity at 50°C, cSt; 9) index of refraction at 20°C; 10) pour point, °C; 11) acid number, mg KOH per g; 12) saponification number, mg KOH per g; 13) iodine number; 14) titer, °C; 15) composition, % by mass; 16) unsaponifiable acids; 17) stearic; 18) palmitic; 19) myristic; 20) oleic; 21) linoleic; 22) linolenic; 23) erucic; 24) lauric; 25) not above; 26) from; 27) to.

TABLE 12.14

Quality of Animal Fats

1 Показатели	2 Говяжий	3 Свиной	4 Конский	5 Кашалотовый	
				6 полостной	7 туловищный
8 Плотность при 15° С, г/см³	0,925—0,953	0,915—0,938	0,916—0,922	0,875—0,890	11 Около 0,89
9 Вязкость при 45° С, сст	39,3	25**	—	—	—
10 Показатель преломления при 40° С	1,454—1,459	1,458—1,461	—	1,454—1,458	1,464*
12 Температура застывания, °С	30—38	22—32	22—37	7—15	15—20
13 Титр, °С	38—48	—	—	28—9 (до 16)	Около 11 10
14 Кислотное число, мг КОН на 1 г	—	29 Не более 2,2	—	29 Не более 2—3	3,4—4,0
15 Число омыления, мг КОН на 1 г	190—200	193—203	193—200	120—150	132—163
16 Йодное число	32—47	42—66	71—86	62—93	85—123
17 Ацетильное число	2,7—8,6	До 2,6	—	—	Около 11
18 Состав, мас. %:	28	28 11			11
19 Неомыляемые	До 1,0	Около 0,5	—	32—45	25—30
20 Кислоты					30
21 стеариновая	24—29	8—16	7	2,0	Следы
22 пальмитиновая	27—20	24—32	29	8,0	6,0
23 миристиновая	2—2,5 (до 8)	До 1,0	—	14,0	5,0
24 лауриновая	28—	28 11 Около 0,1	—	16,0	1,0
25 олеиновая	43—49	37—44	55	До 17	28 До 37
26 линолевая	2—5	28 До 8	7	29—	—
27 линоленовая	0,2—0,6	28 До 0,8	2	—	—

*At 20°C.
**At 50°C.

1) Indices; 2) beef; 3) pig; 4) horse; 5) sperm whale; 6) cavity; 7) body; 8) density at 15°C, g/cm^3; 9) viscosity at 45°C, cSt; 10) refractive index at 40°C; 11) about; 12) pour point, °C; 13) titer, °C; 14) acid number, mg KOH per g; 15) saponification number, mg KOH per g; 16) iodine number; 17) acetyl number; 18) composition, % by mass; 19) unsaponifiable; 20) acids; 21) stearic; 22) palmitic; 23) myristic; 24) lauric; 25) oleic; 26) linoleic; 27) lenolenic; 28) up to; 29) not more than; 30) traces.

Stearin – technical stearic acid – contains an admixture of palmitic, oxystearic and isoleic acids. A semi-transparent solid mass of white or yellowish color, it is fatty to the touch. It is obtained from a mixture of fatty acids which form in the splitting of animal fats and plant oils by distillation and pressing. Stearin is manufactured as 1) two grades of distilled; each grade is produced as pressed and unpressed (the latter is manufactured from plant oils) and 2) undistilled. First grade distilled stearin should be white, 2nd grade can be white or slightly yellowish, distilled stearin in a melted state should be completely transparent. Undistilled stearin is brown, in melted form it is turbid. Stearin is produced in the form of slabs, blocks and plates.

TABLE 12.15

Requirements for the Quality of Stearic Acid by GOST 6484-53

1 Показатели	2 Стеарин дистиллированный				7 Стеарин недистиллированный
	3 1-й сорт		4 2-й сорт		
	5 прессованный	6 непрессованный	5 прессованный	6 непрессованный	
8 Температура застывания, °С, не ниже	52	50	49	52	52
9 Число омыления, мг КОН на 1 г	200—212	198—212	200—212	196—212	194—208
10 Кислотное число, мг КОН на 1 г	198—210	198—210	198—210	196—210	182—196
11 Минеральные кислоты и механические примеси	13 Отсутствие				
12 Иодное число, не более	18	28	32	32	32
14 Нейтральный жир, % не более	13 Отсутствие				8,0
15 Неомыляемые вещества, %, не более	0,2	0,2	0,4	0,4	0,5
16 Зольность, %, не более	0,02	0,02	0,02	0,02	0,02
17 Вода, %, не более	0,2	0,2	0,2	0,2	0,2

1) Indices; 2) distilled stearin; 3) 1st grade; 4) 2nd grade; 5) pressed; 6) unpressed; 7) undistilled stearin; 8) pour point, °C, not below; 9) saponification number, mg KOH per g; 10) acid number, mg KOH per g; 11) mineral acids and mechanical impurities; 12) iodine number, not more than; 13) absent; 14) neutral fat, % not more than; 15) unsaponifiable substances, %, not more than; 16) ash content, %, not more than; 17) water, %, not more than.

Distilled stearin is used in the production of lubricating greases of high quality including lithium, aluminum, lead and others, as well as in the soap making, textile, paper, and rubber industries; undistilled stearin is used in the metal working industry. The technical requirements for technical stearic acid are presented in Table 12.15.

12-Oxystearic acid $CH_3(CH_2)_5CHOH(CH_2)_{10}COOH$ is formed as the result of the hydrogenation of castor oil (ricinoleic acid) with subsequent saponification of the hydrogenated product and decomposition of the soap obtained with acid. Oxystearic acid is isolated from the obtained mixture of fatty acids by distillation. This product is also known under the name of "Oleowax A." Its pour point is not below 85°C, acid number is not more than 1.2 mg of KOH per g, iodine number is not more than 17.

Technical hydrogenated fat (VTU RSFSR 739-63) is the product of the hydrogenation of platn oils during which the glycerides of unsaturated acids (for example, oleic) change into glycerides of saturated acids and the liquid products are converted into solids. Its pour point is 40-54°C, acid number 5-9 mg KOH per g, iodine number 31-65. Hydrogenated fat is widely used in the production of various saponaceous lubricants to obtain sodium, calcium and other saponaceous thickening agents.

TABLE 12.16

Requirements for the Quality of Oleic Acid by GOST 7580-55

1 Показатели	2 Марка		
	А	Б	3 В
4 Температура застывания, °С, не выше	10	16	24
5 Температура застывания для олеина, содержащего до 10% нафтеновых кислот, %, не выше	12	—	—
6 Температура саморазогревания*, °С, не более:			
7 по истечении 1 ч [8]	100	100	18 Не нормируется
» 1,5 ч [8]	102	102	18 —
9 Иодное число	80—90	80—105	Не нормируется
10 Число омыления, мг КОН на 1 г	185—200	185—200	175—210
11 Кислотное число, мг КОН на 1 г	185—200	185—200	19 Не менее 175
12 Жирные кислоты в безводном продукте, %, не менее	—	95	92
13 Сумма жирных и 15% нафтеновых кислот в безводном продукте, %, не менее	95	—	—
14 Неомыленные и неомыляемые вещества, %, не более	3.5	3.5	6.5
15 Зольность, %, не более	0.1	0.1	0.2
16 Минеральные кислоты	20 Отсутствие		
17 Вода, %, не более	0.5	0.5	0.5

*Self-heating temperature is standardized only for olein used in the textile industry.

1) Indices; 2) brand; 3) C; 4) pour point, °C, not above; 5) pour point for olein containing up to 10% naphthenic acid, %, not above; 6) self-heating temperature,* °C, not more than; 7) in the course of 1 h; 8) h; 9) iodine number; 10) saponification number, mg KOH per g; 11) acid number, mg KOH per g; 12) fatty acids in anhydrous product, %, not less than; 13) sum of fatty and 15% naphthenic acids in anhydrous product, %, not less than; 14) unsaponified and unsaponifiable substances, %, not more than; 15) ash content, %, not more than; 16) mineral acids; 17) water, %, not more than; 18) not standardized; 19) not less than; 20) absent.

Oleic acid $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$ is an unsaturated monobasic fatty acid; in the form of glycerides it is part of many liquid and solid fats: linseed, olive, cottonseed, almond, sunflower, coconut (palm) oils, lard, etc. Oleic acid is isolated from the mixture of acids obtained from saponification of fats in the form of its lead salt, soluble in ether. The melting point of the acid is about 14°C, the boiling point is 223°C at 10 mm Hg column, the density is 0.898 g/cm^3 at 14°C. The specifications for the quality of technical oleic acid (olein) are presented in Table 12.16.

Technical olein is subdivided according to method of production into pressed, obtained after crystallization of a mixture of fatty acids and the removal of solid fatty acids from them by press-

ing in hydraulic presses and unpressed, produced mainly from fatty acids of plant oils without their separation by crystallization and subsequent pressing. In addition, technical olein can be distilled and undistilled (saponificate). According to qualitative characteristics, independently of the method of preparation, three brands of technical olein are produced: A, B and C. Brand C olein in the form of undistilled fatty acids of cottonseed and sunflower oils, as well as distilled fatty acids of coriander oil is supplied only to enterprises of the tire industry. Brand A olein intended for the textile industry contains up to 15%, and for the mining industry up to 10% distilled naphthenic acids which must be taken into account in using olein in the production of lubricants.

The color of distilled olein of all brands is from yellow to light brown, the color of undistilled brand C olein is from yellow to dark brown. Melted anhydrous olein of brands A and B is transparent. Olein should not have an unpleasant smell.

Waxy products – are mixtures of various waxes which in turn are mixtures of esters of high molecular weight fatty acids and monoatomic higher alcohols of various origin. Among them are beeswax, wool wax (fatty) and montan wax. Montan wax has received the greatest distribution as saponifiable raw material for the preparation of heat- and moisture-resistant lubricants, chiefly lithium and aluminum. It goes into some lubricants as a thickening component without saponification.

Montan wax is the product of the distillation or extraction of bituminous brown coals with organic solvents. It contains free and bound (in the form of esters) montanic and carboceric acids with considerable admixtures of resins and other compounds. Montan wax is widely used abroad and is beginning to be used here as unsaponifiable and saponifiable raw material for the preparation of lubricating greases.

Beeswax is secreted in the form of very fine flakes by the wax glands of the bee. Technical beeswax is obtained from old and worthless honeycombs, scraps of unrefined beeswax, waxy growths on beehives, etc. There are mixed beehive waxes (the highest quality), pressed, obtained by machine pressing of waxy raw material and extractive, extracted with gasoline from the waste products of wax refineries. Beeswax contains 70-74% complex esters of monoatomic alcohols and fatty acids, 14-15% free fatty acids and 12-15% saturated hydrocarbons. It is distinguished by high resistance to oxidation. It is used in certain lubricants and waxy compounds.

Wool wax is obtained by washing sheep's wool with soapy water or organic solvents. In crude form it has a dark brown color and an unpleasant smell. Purified and dehydrated wool wax is known under the name of lanolin; it has a yellowish color and a slight odor; it is capable of binding up to 300% water; it is stable during prolonged storage (does not turn rancid) and contains cholesterol and its isomers.

The principal indices of the quality of wax products are presented in Table 12.17.

TABLE 12.17

Principal Indices of Wax Products

1 Показатели	2 Монтан-воск	3 Воск пчелиный	4 Воск шерстяной	
			5 сырой	6 очищенный ланолин
7 Плотность, г/см³	8 Около 0.890 *	0.96—0.97 **	0.93—0.94 **	—
9 Температура плавления, °С	78.90	62—67	33—39	35—37
10 Кислотное число, мг КОН на 1 г	—	18—22	10—11	1—2
11 Число омыления, мг КОН на 1 г	80—105	87—107	13 До 146	85—100
12 Иодное число	10—19	7—11	22—24	15—18

*At 100°C.
**At 20°C.

1) Indices; 2) montan wax; 3) beeswax; 4) wool wax; 5) crude; 6) purified lanolin; 7) density, g/cm³; 8) about; 9) melting point, °C; 10) acid number, mg KOH per g; 11) saponification number, mg KOH per g; 12) iodine number; 13) up to.

Synthetic fatty acids [SFA](СЖК) are obtained by oxidation of paraffin and are widely used for the preparation of bulk lubricants which are full-valued substitutes for lubricants prepared from natural fats. Synthetic USs greases and UTs konstalins, YaNA-2 lubricant and many others have almost completely displaced fatty greases and konstalins which are still widely used abroad from the USSR assortment of lubricants.

Industrial processes of the production of SFA include two steps: oxidation of paraffin with air for up to 20 h in column type reactors at 120-140°C in the presence of a catalyst (usually $KMnO_4$, MnO_2, etc.) and the isolation of the specific product from the reaction mixture, which are crude technical fatty acids, and after distillation — heat-refined fatty acids of specific group composition.

Oxidized paraffin contains a mixture of acids of approximately the following composition (in %):

Formic . .	up to 1	C_3-C_6	0.7-0.8
Acetic . .	up to 0.7	C_7-C_9	2.7-2.8
Propionic	up to 0.4	C_{10}-C_{20}.	18-20
Butyric. .	up to 0.4	Acids above C_{20}	up to 5

Low molecular weight acids are removed from the product by washing out with hot water. The fatty acids are saponified with calcined and caustic soda and the soap is separated from the unoxidized paraffin which is again oxidized. The soaps which have been freed from unoxidized paraffin and the bulk of the secondary oxygen-containing products are treated with sulfuric acid and washed with water; crude SFA and a solution of sodium sulfate are obtained by this treatment.

TABLE 12.18

Technical Indices of Synthetic Fatty Acids of Certain Plants

1 Показатели	2 Оренбургский НМЗ, образцы				Ленинградский НМЗ, образцы		Ярославский НМЗ
	1	2	3	4	1	2	
5 Средний молекулярный вес	317	346	380	420	505	467	440
6 Температура плавления, °С	45	36	40	43	44	46	40
7 Вязкость при 70° С, *сст*	16,1	20,1	22,0	28,4	19,7	19,0	15,4
8 Число омыления, *мг* КОН на 1 *г*	151	186	168	143	171	181	176
9 Кислотное число, *мг* КОН на 1 *г*	90,5	118	102	87	89	103	111
10 Эфирное число, *мг* КОН на 1 *г*	70,5	68	66	56	88	79	65
11 Отношение кислотного числа к эфирному	1,14	1,73	1,54	1,55	0,94	1,29	1,65
12 Ацетильное число	22,9	40,0	25,0	30,0	46,0	19,8	41,7
13 Карбонильное число	25,7	27,1	23,5	35,5	19,2	24,9	45,6
14 Иодное число	—	1,5	1,9	4,0	2,0	2,2	—
15 Неомыляемые, мас. %	38,5	28,0	28,5	30,0	30,0	29,0	30,0
16 Кислоты нормального строения, мас. %	12,0	17 Следы	—	13,9	17 Следы	12,0	—
18 Продукты, нерастворимые в петролейном эфире, мас. %	3,4	8,9	6,6	11,7	7,7	4,9	4,6
19 Общая сера, мас. %	0,13	0,12	—	0,12	0,19	—	0,15

1) Indices; 2) Orenburg NMZ, samples; 3) Leningrad NMZ, samples; 4) Yaroslavskiy NMZ; 5) average molecular weight; 6) melting point, °C; 7) viscosity at 70°C, cSt; 8) saponification number, mg KOH per g; 9) acid number, mg KOH per g; 10) ester number, mg KOH per g; 11) ratio of acid number to ester number; 12) acetyl number; 13) carbonyl number; 14) iodine number; 15) unsaponifiable, % by mass; 16) acids of normal structure, % by mass; 17) traces; 18) products insoluble in petroleum ether, % by mass; 19) total sulfur, % by mass.

The technical indices of crude SFA prepared in the Orenburg, Leningrad and Yaroslavsk Petroleum-Oil Plants are presented in Table 12.18. Their content of unsaponifiable substances, mainly unoxidized paraffin, reaches 30-40%. Crude SFA are fractionated under vacuum. Fractions of acids with carbon atoms numbering C_8-C_{11}, C_{12}-C_{13}, C_{14}-C_{16}, C_{17}-C_{22}, C_{14}-C_{20}, etc. are usually separated. So-called still residues are the residual product of the fractional distillation. The qualitative characteristics of SFA from the Shebekinskiy Combine are presented in Table 12.19.

GOST 9975-62 is confirmed on SFA fraction C_{17}-C_{21}, intended specially for the production of lubricants (SFAS) (Table 12.20).

Two grades of these fatty acids have been established: SFAS-H for the production of high-melting lubricants and SFAS-A for the production of average-melting lubricants. However, GOST 9622-57 SFA are still being widely used for the production of

synthetic detergents. They are not full-valued raw material for the production of lubricating greases.

TABLE 12.19

Technical Indices of Synthetic Fatty Acids from the Shebekinskiy Combine

1 Показатели	2 Сырые СЖК	3 Фракция C_{10}—C_{16}	4 Фракция C_{17}—C_{20}	5 Кубовый остаток C_{20} и выше
6 Средний молекулярный вес	280	242	345	842
7 Температура плавления, °С	43	27	57	46
8 Вязкость при 70° С, *сст*	12,8	7,8	17,5	41,7*
9 Число омыления, *мг* КОН на 1 *г*	240,0	254,9	191,4	147,3
10 Кислотное число, *мг* КОН на 1 *г*	235,7	249,7	186,2	110,0
11 Эфирное число, *мг* КОН на 1 *г*	4,8	5,2	5,2	37,3
12 Отношение кислотного числа к эфирному	49	48	35,8	3
13 Ацетильное число	24,0	10,7	12,3	18,8
14 Карбонильное число	7,8	8,7	10,0	11,0
15 Иодное число	8,2	6,5	9,8	19,1
16 Неомыляемые, мас. %	6,0	3,6	4,2	30,0
17 Кислоты нормального строения, мас. %	10,0	55,0	20,0	0
18 Продукты, нерастворимые в петролейном эфире, мас. %	0,26	0,0	0,0	11,0
19 Общая сера, мас. %	0,23	0,44	0,26	2,5

*At 100°C.

1) Indices; 2) crude SFA; 3) C_{10}-C_{16} fraction; 4) C_{17}-C_{20} fraction, 5) still residues, C_{20} and above; 6) average molecular weight; 7) melting point, °C; 8) viscosity at 70°C, cSt; 9) saponification number, mg KOH per g; 10) acid number, mg KOH per g; 11) ester number, mg KOH per g; 12) ratio of acid number to ester number; 13) acetyl number; 14) carbonyl number; 15) iodine number; 16) unsaponifiable, % by mass; 17) acids of normal structure, % by mass; 18) products insoluble in petroleum ether, % by mass; 19) total sulfur, % by mass.

TABLE 12.20

Technical Indices of GOST 9975-62 Synthetic Fatty Acids

1 Показатели	2 СЖКС-Т	3 СЖКС-С
4 Внешний вид	5 Продукт твердой консистенции от кремового до светло-желтого цвета	
6 Кислотное число, *мг* КОН на 1 *г*	195—230	180—240
7 Эфирное число, *мг* КОН на 1 *г*, не более	5	10
8 Иодное число, не более	12	15
9 Неомыляемые, %, не более	5	7
10 Вода, %, не более	0,5	0,5

1) Indices; 2) SFAS-H; 3) SFAS-A; 4) external appearance; 5) product of solid consistency from a cream to a light yellow color; 6) acid number, mg KOH per g; 7) ester number, mg KOH per g; 8) iodine number, not more than; 9) unsaponifiables, %, not more than; 10) water, %, not more than.

TABLE 12.21

Technical Indices of GOST 8622-57 Synthetic Fatty Acids

1 Показатели	C_5—C_6	C_7—C_9	C_{20} и выше
3 Внешний вид	4 Прозрачная маслянистая жидкость, бесцветная или слегка желтоватая		5 Продукт от твердой до мазеобразной консистенции, от светло-коричневого до темно-коричневого цвета
6 Кислотное число, мг KOH на 1 г	420—500	370—410	7 Не менее 100
8 Эфирное число, мг KOH на 1 г, не более	1	3	40
9 Жирные кислоты, %, не более	—	—	85
10 Неомыляемые, %, не более	—	1	—
11 Вода, %, не более	5	1.5	0.5
12 Водорастворимые кислоты . .	—	—	13 Отсутствие

1) Indices; 2) C_{20} and above; 3) external appearance; 4) transparent oily liquid, colorless or slightly yellowish; 5) product of solid to pasty consistency, from light brown to dark brown in color; 6) acid number, mg KOH per g; 7) not less than; 8) ester number, mg KOH per g; 9) fatty acids, %, not more than; 10) unsaponifiables, %, not more than; 11) water, %, not more than; 12) water soluble acids; 13) absent.

Soaps of Fatty Acids

Soaps of fatty acids are the principal thickening component of the majority of saponaceous lubricants used in the most diverse friction joints, as well as of protective and packing lubricants. They are salts of higher fatty acids and various metals, as well as of naphthenic and resin acids. Sodium, lithium, potassium, calcium, barium, aluminum, zinc, lead, magnesium and certain other soaps of stearic, oleic, oxystearic, ricinoleic, naphthenic and other acids, as well as mixtures of them and mixtures with glycerides which are formed during the saponification of plant oils and animal fats are used in the production of lubricants or are obtained in the preparation process itself.

Sodium soaps of stearic and other acids are widely used for the preparation of many lubricating greases (for example, konstalins, ZhD-1 railroad lubricants, ZhB, lubricants 1-13 and others). They have a high melting point and therefore can be used at higher temperatures than many other lubricants. But all sodium soaps are water soluble and therefore lubricants prepared from them must not come into contact with water during use.

Sodium stearate $C_{17}H_{35}COONa$ is a product with m.w. 306.55, softening point of 180-185°C; it has an ash content of 9.5-10.5%; it is 10% soluble in water at 100°C. Ready-made sodium stearate for the preparation of lubricants is not manufactured, but is prepared by saponification of fats and fatty acids during the production of a lubricant.

Potassium stearate $C_{17}H_{35}COOK$ is a product with m.w. 322.55, with m.p. of 132°C; it is 10% soluble in water 100°C, 0.43% in alcohol in the cold and 10% at 66°C. It is part of LZ-188 lubricant.

Lithium stearate $C_{17}H_{35}COOLi$ is a white powder with m.w. 290.47, with m.p. of ~200°C. The technical product contains admixtures of lithium oleate and palmitate, as well as carbonates, free fatty acids and water (not more than 1%). It has low solubility in water. During the production of bulk lithium lubricants (TsIATIM-201, TsIATIM-202 and others), lithium soap is obtained during preparation of the lubricant by saponification of fatty acids with lithium hydroxide (industry produces lithium monohydrate $LiOH \cdot H_2O$). Ready-made lithium soap will find wider use with the transition to a continuous process of the preparation of lithium lubricants.

Calcium stearate $(C_{17}H_{35}COO)_2Ca$ is a product with m.w. 607.0, softening point of 145-150°C; it has an ash content of 9-10% and is practically insoluble in water. It is still not produced in ready-made form in the USSR. It is obtained by the saponification of fatty acids and fats with calcium hydroxide $Ca(OH)_2$. It disperses well in oils in the presence of water of crystallization, forming a characteristic structure (see Fig. 12.1, a).

Magnesium stearate $(C_{17}H_{35}COO)_2Mg$ is a product with m.w. 590, softening point of 145°C; its ash content is 8.9%. It is beginning to be used as a structure modifier of certain domestic and foreign lubricants.

Lead Stearate $(C_{17}H_{35}COO)_2Pb$ is a product with m.w. 774. It is obtained by a double exchange reaction between sodium soap and lead acetate ("sugar of lead") in water solution with subsequent separation of the lead soap from the sodium acetate solution by washing the soap until the bichromate reaction is negative. Repeated centrifugation or washing the lead soap on linen stretched on a frame is used. The washed soap is first dehydrated by heating to 90°C, then the water is completely removed by evaporation at 100-120°C, after which the soap is heated to 130-140°C and fused together. It is poured into molds for cooling. The solid pieces of congealed soap are used for thickening PRGS and other lubricants. Lead soap is a good structure modifier of lithium soaps and increases the anti-friction and anti-abrasion properties of lubricants. It has a m.p. of about 116°C.

Three aluminum soaps (aluminum stearates) are formed from the saponification of stearic acid with aluminum alum: aluminum monostearate $(C_{17}H_{35}COO)Al(OH)_2$ m.w. 344.5, containing about 6% Al_2O_3; aluminum distearate $(C_{17}H_{35}COO)_2Al(OH)$ m.w. 611, containing 8.5-9% Al_2O_3; aluminum tristearate $(C_{17}H_{35}COO)_3Al$ m.w. 850, containing up to 15% Al_2O_3. Aluminum monostearate is most chemically stable, aluminum tristearate which dissociates readily is the least stable. In this case, stearic acid which causes the corrosion of non-ferrous alloys precipitates out. Therefore, a soap which corresponds to aluminum distearate is used in lubricants.

Zinc stearate $(C_{17}H_{35}COO)_2Zn$ is a white powder with m.w. 631, softening point of 112-117°C; it has an ash content of 15%. It

is the zinc salt of stearic acid with an admixture of the zinc salts of palmitic and oleic acids. It is obtained by double decomposition of sodium salts of stearic acid with zinc chloride. It is used in some lubricating greases, but has a low thickening capacity. It is produced according to the technical specifications MPPT-16-53. It is also used in the cosmetic industry and in the production of phonograph records.

Barium stearate $(C_{17}H_{35}COO)_2Ba$ is a product with m.w. 703 and a softening point of 160°C. It is not produced in ready-made form, but it is obtained in the preparation of barium lubricants during the production of No. 9, MS-70 and other lubricants.

Copper naphthenate is the copper salt of naphthenic acids. It is a green viscous sticky mass. The product contains not less than 9% copper, not more than 5% water and no more than 0.2% mechanical impurities; traces of sulfates soluble in water are permitted. Water soluble copper salts must be absent and the reaction of an aqueous extract neutral. It is produced by the chemical industry and is used as an antiseptic for the treatment of power cables and as an additive in certain lubricants (PRGS).

Graphites

Graphites are widely used in lubricants as fillers and antifriction additives. Natural graphite is a mineral consisting of natural carbon; it is encountered in the form of plates and solid masses. The graphite content of industrial ores varies within broad limits. Pyrite, mica and chromite can be contained among the impurities. Pencil, crystalline (silver), graphite P, elementary and cryptocrystalline (amorphous) graphites are produced. Only graphite P is used in the preparation of lubricants — a steel-gray powder (GOST 8295-57), a concentrate obtained by the concentration of graphite ore. Two grades are produced: A and B. Depending on the deposits, the following designations of the grades produced have been established: PB-A — Botogol'skiy grade A; PB-B Botogol'skiy grade B; PZ-A — Zaval'yevskiy grade A and PZ-B Zaval'yevskiy grade B; PT-A and PT-B — Tayginskiy grades A and B. The product must contain (in % by mass):

	Grade A	Grade B
Carbon, not less than	92	90
Ash, not more than	7	9
Volatile substances, not more than	1	1
Sulfur, not more than	0.2	0.2
Moisture, not more than	1	1

Graphite should not contain granules of quartz or the graphite of another deposit; the reaction of a water extract should be neutral; it passes completely through a 0.200 mm sieve; the residue on a 0.160 mm sieve does not exceed 1.5% for graphite of both grades.

Dry colloidal graphite preparation (GOST 5261-50) is a highly dispersed low ash artificial graphite (thermographite). It is pro-

duced in three grades: S-1 from graphite with particles up to 4 μm in size; S-2 from graphite with particles up to 15 μm in size and S-33 – up to 30 μm.

Some standards for colloidal graphite preparations are presented in Table 12.22.

TABLE 12.22

Technical Standards For Colloidal Graphite Preparations

1 Показатели	2 Марки		
	3 С-1	4 С-2	5 С-3
6 Зольность, %, не более	1.5	2	2.5
7 Вещества в золе, нерастворимые в соляной кислоте, в пересчете на препарат, %, не более	0.8	1.0	1.3
8 Остаток, %, не более:			11
9 на сите 0,063 мм	10.5	0.5	Не нормируется
» 0,075 мм	Не нормируется		5
10 Вода, %, не более	0.5	0.5	0.5

1) Indices; 2) grades; 3) S-1; 4) S-2; 5) S-3; 6) ash content, %, not more than; 7) substances in the ash insoluble in hydrochloric acid, on conversion to the preparation, %, not more than; 8) residues, %, not more than; 9) on 0.063 mm sieve; 10) water, %, not more than; 11) not standardized.

TABLE 12.23

Technical Requirements for the Quality of Oily Colloidal Graphite Preparations

1 Показатели	2 Марки		
	3 МП	4 МС	М
5 Содержание графита, %, не менее	24	24	23–33
6 Зола в сухом графите, %, не более	1.5	1.5	2
7 Вещества в золе, нерастворимые в соляной кислоте, в пересчете на сухой графит, %, не более	0.8	0.8	1
8 Остаток на сите 0,063 мм, %, не более	0.1	0.1	9 Не нормируется
10 Вода, %, не более	0.1	0.1	0.1

1) Indices; 2) grade; 3) MP; 4) MS; 5) graphite content, %, not less than; 6) ash in dry graphite, %, not more than; 7) substances in the ash insoluble in hydrochloric acid, on conversion to dry graphite, %, not more than; 8) residues on 0.063 mm sieve, %, not more than; 9) not standardized; 10) water, %, not more than.

The preparation should pass the test for abrasive properties; when ground between two plates of window glass for 10-15 s, there should not be scratches on the glass.

Oily colloidal graphite preparation (GOST 5262-50) is a concentrated suspension of highly dispersed artificial graphite (thermographite) in mineral oil stabilized with petroleum resins. The product's properties depend on the type of mineral oil (aviation, turbine, industrial, etc.) and the quality of the thermographite used for preparing the preparations.

An oily colloidal graphite preparation of three grades is produced: MP from a calcined S-1 preparation, MS from a dried S-1 preparation and M from preparation S-2. The drop in the concentration of graphite in the suspension after standing for 1 h (content of 6 μm particles) is no more than 30% for grade MP and 14% for grade MS. The decrease in the graphite concentration of grade M after standig for 10 min is not more than 14%.

The technical requirements for the quality of oily colloidal graphite preparations are presented in Table 12.23.

Aqueous colloidal graphite preparations are also manufactured: grades K-1, K-2, K-3 and K-4 from natural graphite according to GOST 5613-50; type V – a stable suspension of highly dispersed thermographite in water (stabilized with complex stabilizer V) according to GOST 5245-50, used as a lubricant in the extraction of threads of high-melting metals (molybdenum, tungsten and others) and for other purposes; KGVS colloidal graphite preparation – a water suspension of highly dispersed graphite stabilized with a solution of sterilized agar-agar; preparation RP – for elementary particle counters; SBG colloidal graphite preparation – in an SBS-1 lac base for absorbent coating; ELPV colloidal graphite preparation for conductive coatings.

Molybdenum disulfide MoS_2 (natural) is widely used in lubricants as a component which improves anti-friction and anti-abrasion properties. It can be used for lubricants which operate in increased humidity and a high vacuum. It is not oxidized in air at temperatures up to 400°C and from the effect of nuclear radiation. It is used in the form of a highly purified powder with a high degree of milling, it should not contain more than 2% impurities with abrasive particles. Natural molybdenite is subjected to pulverization in vibrational mills or jet mills, as well as in homogenizers and apparatus using ultrasound. In the latter case particles 1-7 μm in size are obtained. After pulverization in the other apparatus, larger particles are obtained (40-100 μm). The coefficient of friction of MoS_2 slippage is 0.05-0.10, that is, two times less than that of graphite.

MoS_2 is used in many new lubricants.

Additives

To improve the protective, anti-abrasion and many other properties of preservative lubricants, various additives and oxidation inhibitors are used, including oxidized petroleum products (oxidized petrolatum, MNI additives), nitrated oils, nitrated petrolatum and nitrated oxidized petrolatum, calcium and sodium sulfonates, amines and certain waxes.

Oxidized petrolatum is obtained by oxidation of petrolatum in an air column in the presence of a catalyst – potassium permanganate at 140-160°C. Oxidized petrolatum must satisfy the requirements presented in Table 12.24.

TABLE 12.24

Requirements for the Quality of Oxidized Petrolatum According to MRTU 12N No. 64-63

1 Показатели	2 Норма
3 Внешний вид	4 Однородный продукт вязкой консистенции, темно-коричневого цвета
5 Кислотное число, мг КОН на 1 г, не менее	55
6 Число омыления, мг КОН на 1 г, не ниже	140
7 Отношение числа омыления к кислотному числу, не более	3,0
8 Растворимость в уайт-спирите (1:1)	9 Полная
10 Посторонние включения	11 Не допускаются
12 Вода, %, не более	2,0

1) Indices; 2) standards; 3) external appearance; 4) uniform product of viscous consistency, of dark brown color; 5) acid number, mg KOH per g, not less than; 6) saponification number, mg KOH per g, not above; 7) ratio of saponification number to acid number, not more than; 8) solubility in white spirit (1:1); 9) complete; 10) secondary inclusions; 11) not permitted; 12) water, %, not more than.

TABLE 12.25

Requirements for the Quality of MNI-3 and MNI-7 Additives According to GOST 10584-63

1 Показатели	2 Присадка	
	3 МНИ-3	4 МНИ-7
5 Внешний вид	6 Однородный вязкий продукт коричневого цвета	7 Однородный вязкий продукт светло-желтого цвета
8 Температура каплепадения, °С, не ниже	44	60
9 Кислотное число, мг КОН на 1 г	20—30	55—75
10 Число омыления, мг КОН на 1 г	60—80	120—140
11 Содержание продуктов, нерастворимых в петролейном эфире, %, не более	0,4	—
12 Механические примеси, %, не более	0,1	
13 Вода	14 Следы	

1) Indices; 2) additives; 3) MNI-3; 4) MNI-7; 5) external appearance; 6) uniform viscous product of brown color; 7) uniform viscous product of light yellow color; 8) drpp point, °C, not below; 9) acid number, mg KOH per g; 10) saponification number, mg KOH per g; 11) content of products insoluble in petroleum ether, %, not more than; 12) mechanical impurities, %, not more than; 13) water; 14) traces.

Oxidized petrolatum is used as an additive which improves protective (against corrosion) properties in NG-203, NG-204, K-15, K-17 and other lubricants.

MNI additives are produced in three grades: MNI-3, MNI-5 and MNI-7. MNI-3 additives are oxidized petrolatum of grade PK which satisfies the requirements presented in Table 12.25.

Additive MNI-3, in contrast to oxidized petrolatum, which is prepared according to TU NF 585-56, has a smaller acid number and saponification number. It is used both directly in the form of an additive in SKhK, Rzh and other lubricants and for preparing additive MNI-5.

MNI-7 additive is oxidized grade 75 ceresin from the Borislavskiy or Shorsinskiy deposit. It is used in PVK (gun), GOI-54p and other lubricants.

Additive MNI-5 (Table 12.26) is obtained by extraction from additive MNI-3 of high molecular weight esters and acids which are the active component of this product. The extraction is carried out with light oil (velosite type) which satisfies specific requirements.

TABLE 12.26

Requiresments for Quality of Additive MNI-5 According to GOST 10584-63

1 Показатели	2 Норма	3 Примечание
4 Внешний вид	5 Маслянистая прозрачная жидкость коричневого цвета	
6 Кислотное число, мг КОН на 1 г	5—15	7 По ГОСТ 5985—59 с индикатором фенолфталеином
8 Содержание продуктов, нерастворимых в петролейном эфире, %, не более	0.025	
9 Вода	10 Отсутствие	
11 Механические примеси, %, не более	0.07	12
13 Испытание стабильности присадки	14 Выдерживает	На центрифуге после охлаждения до температуры —40°С
15 Испытание на коррозию	16 Выдерживает	На медных пластинках

1) Indices; 2) standard; 3) comment; 4) external appearance; 5) oily transparent liquid of brown color; 6) acid number mg KOH per g; 7) according to GOST 5985-59 with phenolphthalein indicator; 8) content of products insoluble in petroleum ether, %, not more than; 9) water; 10) absent; 11) mechanical impurities, %, not more than; 12) test of additive stability; 13) passes; 14) in centrifuge after cooling to a temperature of —40°C; 15) testing for corrosion; 16) on copper plates.

The content of active components x_1, which are determined from the ratio of the acid number of additive MNI-5 (K_1) to the acid number of the original MNI-3 additive (K_2), is indicated on the record attached to the additive.

$$x_1 = \frac{K_1}{K_2} \cdot 100$$

The amount of additive to be added to the oil (lubricant) is calculated from the content of active components.

Additive T-5 is used in AGM and Gm-50I hydraulic oils, liquid gun lubricant and other petroleum products; it imparts high anti-corrosion (even when water enters the product) and anti-abrasion properties to them.

Calcium sulfonate (average molecular weight) in the form of a concentrate (additive KSK) is used in NG-203 protective lubricants. It is obtained by sulfonation of high molecular weight mineral oils (for example, AS-6) with oleum, gaseous sulfur anhydride and sulfur annydride in liquid sulfur anhydride with subsequent treatment with a solution of unslaked lime.

Sodium sulfonate is a water and oil soluble product obtained by neutralization of acid sulfonated AS-6 oil with sodium hydroxide. Solutions containing 10-25% of the active substance in oil are used. It is used as an additive to YaNZ-2 lubricant.

Nitrated oil is a product obtained by the treatment of mineral oils with nitric acid with subsequent neutralization with unslaked lime. It is used in the production of liquid preservative lubricants NG-204 and NG-204u. It consists of various nitrogen compounds, chiefly of the aromatic series dissolved in dearomatized oil. It serves as an inhibitor of the corrosion of ferrous and some nonferrous metals [7].

Triethanolamine $N(CH_2CH_2OH)_3$ is a colorless, transparent (opalescence is permitted), viscous, hygroscopic liquid with a density of 1.100-1.124 at 20°C; it is obtained by reaction of an ammonia solution with ethylene oxide. It is used as an anticorrosion additive to oils and lubricants (for example to SP-3 lubricant). The b.p. of triethanoplamine is 277-279°C (at 150 mm Hg column), m.p. -21°C. It mixes with water and alcohol; it is soluble in chloroform; it is slightly soluble in ether, benzene and ligroin. It is a strong base.

Diphenylamine $(C_6H_5)_2NH$ is produced in three grades: 1st grade - fine crystals of light gray or light yellow color; 2nd grade - lamellae or crystals of light gray or yellow color; 3rd grade - lamellae of yellowish to dark brown color. It is used as an antioxidizing additive to oils and lubricants (only 1st grade). Its solidification point is 52.6°C.

Paraoxydiphenylamine $C_6H_5NHC_6H_4OH$ is a solid fused mass of from light gray to gray color; it is obtained by the condensation of aniline with hydroquinone. It is used as antioxidizing additive in gasolines, oils and lubricants (for example, PROS, in the AGM

oil). The m.p. is 69-74°C.

Phthalocyanin (copper complex) is a light blue organic pigment. It is used as a thickening agent in lubricant No. 158 and in some other instrument lubricants which work at high temperatures (up to 150°C) and high speeds (up to 10,000 r/min). The copper phthalocyanin molecule has a highly symmetrical structure and is very stable; this product can be sublimated in a vacuum at a temperature of up to 500°C without decomposition and is hardly oxidized in air at temperatures up to 350°C.

Phthalocyanin lubricants retain their structure for a long time under severe operating conditions, they are water resistant and have good colloidal stability; however, at elevated temperatures they are inclined to solidify [6].

4. PROPERTIES AND USE OF VARIOUS LUBRICANTS

Protective Plastic Lubricants (No. 1-9, Table 12.29)

The principal purpose of protective lubricants is to protect metallic products against corrosion (mainly atmospheric). However, most of these lubricants also posses anti-friction properties and are used in friction joints, providing operation of mechanisms within a specific temperature range.

Lubricants such as gun, technical vaseline, PP-95/5 (protective compound), GOI-54, anticorrosion ZhE have been used for many decades. These lubricants are fusions of various hydrocarbons and consist of mineral oils, petrolatums, ceresins and paraffins. Almost all these lubricants contain small amounts of alkali and therefore they have a weakly alkaline reaction. Their acid number is strictly confined to the upper limit (usually, not above 0.3 mg KOH per g).

The protective properties of this group of lubricants have been thoroughly tested during storage of various metal products under the most diverse conditions. If they are properly applied to the clean surfaces of metal products in a layer 0.5-2 mm thick, they can protect these surfaces from corrosion up to 5-7 years.

The old protective lubricants – gun, PP-95/5, GOI-54 and technical vaseline – protect all the principal metals and alloys against atmospheric corrosion and do not react with them or with metallic, phosphate and oxide coatings and most paint and varnish coatings. However, these lubricants have a low slipping temperature (30-40°C) and therefore cannot be used for protecting products against corrosion which are stored and transported in a hot climate and especially in the tropics.

Recently the production of several new protective lubricants has begun: PVK, SKK, GOI-54p. These lubricants consist of petroleum oils, petrolatum, ceresin and the multifunctional additive MNI-3 or MNI-7 (GOST 10,394-63). One of the principal properties which characterize the quality and protective properties of these lubricants is a large acid number (0.5-1.0 mg of KOH per g), since it indicates the presence of an additive in them.

TABLE 12.27

Certain Conditions Under Which Protective Lubricating Greases Protect Products Made of Steel and Non-Ferrous Alloys Against Corrosion

1	2					8		
	3 ПП-95/5	4	5	6	7 ГОИ-54	9 СКК	10 ПВК	11 ГОИ-54п
12 Оптимальные условия нанесения смазок:								
13 нагревать смазки перед нанесением до температуры, °С . .	110	110	110	110	105	110	110	105
14 наносить смазку при температуре, °С	80—90	80—90	70—90	70—80	80—90	80—90	80—90	80—90
15 Минимальная температура, при которой можно наносить смазку, °С	70	10—15	10—15	10	—30	30	10—15	—30
16 Температурные пределы, в которых могут храниться смазанные изделия, °С	—50 +40	—50 +30	—30 +30	—50 +30	—50 +30	—50 +50	—50 +50	—50 +40
17 Допустимые сроки хранения смазок до их применения (в банках, в деревянных бочках):								
18 в южных районах	5/5	5/3	5/3	—	1/0	5/3	5/3	1/0
19 в средней и северной полосе	10/5	10/5	10/5	—	2/0	10/5	10/5	2/0

1) Conditions of lubricant application, storage temperature and time of lubricant storage; 2) old lubricants; 3) PP-95/5; 4) gun; 5) technical vaseline; 6) 1:1 mixture of gun and munition lubricants; 7) GOI-54; 8) new lubricants; 9) SKhK; 10) TsVK; 11) GOI-54p; 12) optimal conditions of lubricant application; 13) lubricants heated before application to temperature of, °C; 14) lubricant applied at a temperature of, °C; 15) minimum temperature at which lubricant can be applied, °C; 16) temperature range in which lubricated products can be stored, °C; 17) permissible storage period of lubricants before their use (in cans, in wooden kegs); 18) in southern regions; 19) in the middle and northern belt.

The new lubricants possess better protective properties than the old. Their principal advantage is a high temperature of slipping. These lubricants either do not slip at all up to their melting points or slip at a temperature 12-15°C higher than the corresponding lubricant without an MNI additive.

The new protective lubricants can be used for protecting metal products against corrosion during storage and transportation in a hot climate. Lubricant GOI-54p (like lubricant GOI-54) cannot be recommended for these conditions since in the warm time of year it gets dry and decrepitates. It is used at temperatures from -40 to +35°C, but only in friction joints with small specific loads and low speeds.

The conditions under which protective lubricants can protect against corrosion are presented in Table 12.27 and the periods during which the lubricants protect against corrosion are given in Table 12.28. They require some refinement since the new lubricants have found wide use only in the past 3-4 years and experience in their use is still being accumudated.

Improvement in packing, the use of improved packaging and new water resistant packing materials, air conditioning and drying lengthen the storage period of lubricants while deterioration of the storage conditions shorten them.

During prolonged storage of products the new lubricants can be replaced 1.5-2 times more infrequently than the old. In a warm climate the old lubricants have to be replaced 4-6 times more frequently than the new ones.

It is recommended that the following lubricants be used to protect products against corrosion:

1) lubricant PVK in place of gun lubricant;

2) lubricant PVK in place of technical vaseline or lubricant SKhK for products stored in the open air for 1-2 years;

3) lubricant SKhK or PVK in place of lubricant PP-95/5, except for cases specially stipulated in the technical documents;

4) lubricant GOI-54p instead of lubricant GOI-54.

Liquid Anti-Corrosion Lubricants (No. 10-20, Table 12.29)

Liquid protective lubricants are simpler to apply and are more easily removed than plastic lubricants. Many protective lubricants do not have to be removed at all which is especially important during temporary shutting down of motors, compressors, various capacitances, etc. If they have good protective properties they can be applied in very thin layers. But they can only be used for the protection of inner surfaces of motors, machines, mechanism and capacitances as well as of those products which are additionally wrapped with parchment or other thick paper, packed in tight containers and stored under conditions which will prevent the direct entry of water, snow, etc., since many of these lubri-

cants are comparatively easily washed off by precipitation and quickly dry up after which they lose their protective properties.

The old liquid protective lubricants such as marine MP (GOST 4700-49), protective SP-1 (GOST 4807-49) and SP-2 (GOST 56-51) have been removed from production and replaced by improved lubricants. Munition lubricant (GOST 3045-51) – then old liquid lubricant for weapons has been almost completely replaced by RZh liquid munition lubricant (GOST 9811-61). Lubricant RZh protects metals well against corrosion and therefore is used for protecting a weapon against rusting during brief storage in military subunits and during marches; it is also used for cleaning gun bores and other weapon mechanisms after firing. It is necessary to replace this lubricant in a weapon in military subunits not less than once a week. It provides normal operation of all types of weapons at any temperatures (from –50 to +40°C).

Lubricant RZh can also be used in other mechanisms where a lubricant of very low viscosity which penetrates well into narrow spaces is required. Mechanisms do not have to be dismantled to replace it; it is sufficient to introduce a few drops of the lubricant which quickly spread along the metal and penetrate into all the narrowest slits of friction joints.

TABLE 12.28

Periods of Protection of Products Against Corrosion Which Have Been Protected with Certain Lubricants and Stored Under Different Conditions

1 Внешние условия хранения	2 Марка защитной смазки									
	3 СКК	4 ПВК	5	6 ЗП-95/5	7 ГОИ-54К	8 Нефтегаз-283 А*	Нефтегаз-283 Б*	9 В*	10 ПВК-ЗП/ЗП-ГОИ-54К	11 К-17*
12 В условиях континента СССР — средняя полоса, северные страны и страны с умеренным климатом										
13 в отапливаемых хранилищах										
14 без тары	5	5	2	5	5	—	—	—	3	—
15 в ящиках	8	7	3	5	5	3	3	3	3	5
16 в неотапливаемых хранилищах										
14 без тары	4	5	2	4	5	—	—	—	3	—
15 в ящиках	5	5	3	4	5	3	3	2	3	3
17 под навесом										
14 без тары	4	5	1.5	3	2	—	—	—	1	—
15 в ящиках	5	6	2	4	3	2	2	1	3	2
18 на открытых площадях										
14 без тары	2	2	0.5	1	—	—	—	—	1	—
15 в ящиках	3	3	1	1.5	2	1	1	1	3	1
19 В приморских условиях										
20 в помещениях с искусственной осушкой воздуха без тары	5	5	1	5	3	3	3	3	3	3
21 в отапливаемых хранилищах										
14 без тары	5	5	1	3	3	—	—	—	3	—
15 в ящиках	5	5	2	4	3	3	3	3	3	3

22 в неотапливаемых хранилищах										
14 без тары	3	3.5	1	2	2	—	—	—	2	—
15 в ящиках	3	4	1	3	3	3	3	2	3	3
23 под навесами и чехлами										
14 без тары	2	3	1	1	1.5	—	—	—	1.5	—
15 в ящиках	3	4	1	2	3	2	2	2	2	2
24 на открытых палубах под чехлами										
14 без тары	1.5	1.5	—	0.5	—	—	—	—	—	—
15 в ящиках	1	1	—	1	—	—	—	—	1	1
25 на открытых палубах без укрытия										
14 без тары	1	1	—	0.5	—	—	—	—	0.5	—
15 в ящиках	1	1	—	0.5	0.5	—	—	—	0.5	—
26 сухом жарком климате (включая тропики) в помещениях										
14 без тары	4	6	—	1	—	—	—	—	3	—
15 в ящиках	5	8	—	3	3	3	3	3	3	3
27 под навесом, брезентовым чехлом										
14 без тары	2	2	—	0.5	—	—	—	—	1	—
15 в ящиках	2	2	—	1	—	1	1	1	2	1
29 на открытой площадке										
14 без тары	1	1	—	—	—	—	—	—	0.5	—
15 в ящиках	2	2	—	0.5	—	1	1	1	2	0.5
30 во влажном тропическом климате в помещениях										
14 без тары	3	4	—	1	—	—	—	—	1	—
15 в ящиках	4	5	—	2	—	2	2	2	3	2
30 под навесами, брезентами										
14 без тары	2	3	—	0.5	—	—	—	—	1	—
15 в ящиках	3	4	—	1	—	1	1	1	3	1
31 на открытых площадках										
14 без тары	1	1	—	—	—	—	—	—	1	—
15 в ящиках	2	2	—	0.5	—	—	—	—	2	—

Notes: 1. Approximate periods; will be refined as data is accumudated.
2. All lubricants are not resistant to molds.
3. The symbol — (dash) denotes that the use of the lubricant under the given conditions is not recommended.
4. Lubricants marked with an asterisk are used only for protecting internal components and surfaces.

1) External storage conditions; 2) brand of protective lubricant; 3) SKhK; 4) PVK; 5) technical vaseline; 6) PP-95/5; 7) GOI-54p; 8) petroleum gas-203; 9) C*; 10) NG-204* and NG-204u; 11) K-17*; 12) in continental USSR - middle belt, northern countries and countries with temperate climate; 13) in heated storehouses; 14) without packing; 15) in containers; 16) in unheated storehouses; 17) under a shed; 18) on open platforms; 19) under maritime conditions; 20) in places with dynamic air drying without packing; 21) in heated storehouses; 22) in unheated storehouses; 23) under

sheds and covers; 24) on open decks under covers; 25) on open decks without covering; 26) in dry warm climate (including the tropics); 27) under a shed or tarpaulin; 28) on open platform; 29) in humid tropical climate; 30) under sheds, tarpaulins; 31) on open platforms.

Several liquid protective lubricants from the Neftegaz plant have received rather wide use for protecting the most diverse metallic products against corrosion: motors, spare parts, instruments, etc. Neftegaz-203 lubricants (No. 12-14, Table 12.29) are gradually being replaced by Neftegaz-204 lubricants (No. 15 and 16, Table 12.29) which are cheaper and possess better protective properties, espeically water resistance.

The liquid protective lubricants K-15 and K17 (No. 17 and 18, Table 12.29) are used in limited amounts for protecting the inner housings of diesel engines stored in seaside regions against corrosion. The motors protected with them can be stored for several years without replacing the lubricant and started up after storage without delay.

Cable Lubricants [No. 21-24, Table 12.29]

Lubricants which have been specially designed for lubricating steel lines (cables) belong to the protective lubricant group and at the same time are antifriction lubricants since they must provide for prolonged work of curved lines with friction between the individual steel wires and between the cable itself and the cylinders of the winches. Their work takes place under very complex conditions, frequently under the influence of corrosive-aggressive agents – atmospheric precipitates, subsurface and shaft waters, dust, sand, etc.

Four special cable lubricants which differ in composition and properties are manufactured. Gun lubricant, technical vaseline and other lubricants are also used for lubricating cables. To protect the hemp strands of certain cables against rotting, they are lubricated with NMZ-3 lubricant which contains an antiseptic – copper naphthenate. The graphite in lubricant IK imparts good lubricating properties to it and prevents premature deterioration of the steel wire of cables.

General Purpose and Automotive Anti-Friction Lubricants [No. 25-42, Table 12.29]

The greatest quantity of lubricants is used in automobiles, tractors and agricultural machines. Greases, konstalins, lubricants 1-13, 1-13s YaNZ-2 and others which are sometimes intended for only one certain mechanism and for machines of only certain types are used in the friction joints of these and many other machines.

Greases comprise approximately 75% of the total output of plastic lubricating materials. They are water resistant and therefore can be used in highly humid conditions and even in direct contact with water. Greases protect lubricated surfaces well against corrosion from moisture and impurities which are usual for machines which operate on dusty and dirty roads, in working the ground and

under other severe conditions. But the protective properties of greases are retained no more than 1-2 years since during this time they are oxidized and dry up. For the protection of mechanisms for long periods, bearings which operate in greases have to be lubricated with hydrocarbon protective lubricants (for example, PVK lubricant). It is impossible to heat greases to temperatures close to their melting points (70-75°C) since they lose water and decompose, and are irreversibly destroyed.

Synthetic greases (GOST 4366-64) of two grades (No. 25 and 26, Table 12.29) are produced: press-grease S and grease S (USs-automobile lubricant). They differ in content of calcium soaps of synthetic fatty acids, but have similar properties, although grease S is more heat resistant. Most lubricating grease is produced under the label of press-grease S which corresponds to the grade of USs-2 grease manufactured according to the above noted GOST 4366-56.

Broad fractions of technical fatty acids and still residues from the production of refined synthetic fatty acids, as well as mineral oils from petroleums of different origin with rather broad viscosity characteristics are used for the preparation of press-grease S, therefore the greases produced in different plants differ considerably in their properties although they satisfy the GOST requirements.

Fatty greases (GOST 1033-51) are produced in very small amounts (No. 27, 28 and 29, Table 12.29). Cottonseed oil, as well as sunflower and certain other plant oils have chiefly been used for their preparation. At the present time, they have been practically entirely replaced by synthetic greases which are not inferior to them in lubricating and protective properties.

Konstalins are high-melting lubricants. They are used for lubricating ball and roller bearings which work at elevated temperatures. Like greases, they were previously prepared from natural fats (fatty konstalins UT-1 and UT-2), while at the present time they are prepared from synthetic fatty acids (synthetic konstalins UTs-1 and UTs-2). All konstalins are sodium lubricants and therefore are not water resistant; they cannot be used under conditions of high humidity and in contact with water; their protective properties are low.

Type 1-13 calcium-sodium lubricants are widely used in the roller bearings of automobiles, electric motors, railroad cars and other equipment. Among them are fatty lubricant 1-13 and its improved modification - lubricant 1-13s (lubricant 1-LZ) which is also prepared from natural fats, and lubricant 1-13s prepared from soaps of synthetic fatty acids and its improved version - lubricant YaNZ-2. All these lubricants have poor water resistance, but can operate at considerably higher temperatures than greases.

Narrowly specialized lubricants find use in automobile roller bearings as well as in the friction joints of other machines: lithium lubricant LZ-31 (for the squeeze bearing of a clutch), a special lubricant for vacuum and pneumatic windshield wipers made from a zinc-aluminum alloy, a sodium lubricant for the ball bearings of automotive electrical equipment and the more up-to-day

phthalocyanin lubricant No. 158 used in the generators of the Moskvich and Volga automobiles and also of combines.

Graphite lubricant USs-A prepared from the calcium soap of synthetic fatty acids is widely used for lubricating rough friction surfaces (springs, cables of clumsy heavily loaded gears, etc.).

Industrial Lubricants [No. 43-51, Table 12.29]

Special industrial lubricants are used for lubricating the bearings and other friction joints of metallurgical equipment (rolling mills, the belts of agglomeration machines, cranes, the cranes of open-hearth, convertor and other metallurgical plants, the mechanisms of hot mills, etc.): calcium-sodium lubricants IP1-L (summer) and IP1-3 (winter), sodium lubricant for rolling mills (lubricant IP-2) prepared from soaps of oxidized petrolatum and automotive transmission oil which is very thick, metallurgical lubricant No. 10 containing a large amount of calcium soaps and therefore less heat resistant than lubricants IP-1 and IP-2 and high-temperature sodium lubricant No. 137.

The new LZ-142 lubricant for lubricating the sheets during cold rolling of steel and other alloys can be placed in the same group; it is atriethyleneglycolic ester of synthetic fatty acids and is a complete substitute for imported oils – palm, castor and others which are still used for the same purposes.

The following narrowly specialized lubricants produced in a limited amount belong among industrial lubricants: sodium textile IT (used for lubricating tortional raceways), aluminum rotation IR (for lubricating the bearings of rotation machines) and Red's lubricant.

Special Lubricants [No. 52-57, Table 12.29]

In aviation, in addition to general purpose lubricants, specialized NK-50 lubricants (airplane motor high-melting ST) prepared from sodium soaps and containing graphite which increases its lubricating properties, especially at high temperatures and lubricant No. 9 for lubricating mechanisms which are subjected to sharp changes in temperature and humidity during flight under various meteorological conditions and at different altitudes which is also used for protecting steel products with metallic and chemical coatings for brief periods are used.

The marine lubricants AMS-1 and AMS-3 possess high stickiness, are little eroded by water and protect well against corrosion from the effect of atmospheric precipitates and sea water; they are used in friction joints of certain ship mechanisms, but only at temperatures above 0°C. Lubricant AMS-1 is soft and sticky, while AMS-3 is thicker and has a higher drop point.

Lubricant MS-70 resists erosion by water well and therefore is used for lubricating mechanisms which operate on the decks of ships and are subjected to the constant action of waves; it cannot be used at temperatures above 60°C. During prolonged storage of lubricated products under atmospheric conditions, it protects

them poorly against corrosion since it dries up and decrepitates and also causes copper alloys to turn green and darken.

Lubricant PRGS has limited use in heavily loaded high-speed reducing gears, providing for their start-up at temperatures up to −50°C and preventing abrasion; lubricant spattered on the walls of the reductor's housing runs off from them.

Railroad Lubricants [No. 58-76, Table 12.29]

Railraod lubricants are used in the friction joints of locomotives, steam engines, electric locomotives, diesel locomotives and railroad cars. It is produced according to MPS technical specifications. These lubricants can be divided into several groups.

1. Solid briquet lubricants containing up to 40% thickening agent, usually sodium soap (ZhD-1, ZhD-1p, ZhD-2 and ZhD-2p). They are similar in external appearance to household soap and are applied in the form of bars of specific shape to slotted and bush bearings where they are pressed by springs to the axle journals.

2. Plastic greases, similar in composition and properties to ordinary general purpose saponaceous lubricants: ZhK, ZhE, Metro of grades M-1 and M-2 and others, including lubricant 1-LZ (gun lubricant 1-13) containing an oxidation inhibitor (0.3% diphenylamine) which prolongs the periods of the lubricant's service several times in comparison with lubricant 1-13.

3. Narrowly specialized lubricants: sulfured summer and winter lubricant for traction electric motors of locomotives, graphite anti-accident coach lubricant, graphite ZhR for lubricating rails, ZhT (4a) for the automatic brakes of rolling stock, dry graphite-coumarone SGS-0 (basic) and its "solution" in a solvent for the contact plates of locomotive pantographs, two formulas of greasing lubricants PS-12 and two formulas of PS-40 and graphite lubricant GMS for the supplying of steady electrical conductance in rail joints. ZhE anticorrosion lubricant (No. 7, Table 12.29) has also been used for protecting the carrier cables of electrified railraods against corrosion.

Instrument Lubricants [No. 77-90, Table 12.29]

Only the major instrument lubricants which have obtained wide distribution and which are produced by the petroleum industry are presented here. Many instrument lubricants are prepared by various enterprises, organizations and institutes for narrowly specialized purposes on special order; they are used in small amounts.

Instrument lubricants can be divided into several subgroups, each of which consists of a series of lubricants which are similar in composition and properties. The lubricants of the individual subgroups are used chiefly in some specific branch of instrument making, but can also be used in allied fields.

Lubricants of the TsKP series (2TsKP, 3TsKP and 4TsKP) as well as of the SK series (2SK and 4SK) are widely used in enterprises of the optical-mechanical industry and in organizations which repair

optical instruments. The lubricants within a series differ in content of the principal thickening agent (ceresin) and oil. Lubricant 2TsKP is the softest, while 4TsKP is the thickest of the TsKP series. Lubricant 2SK is also a soft grease, while 4SK is a very thick mastic used as a cement in sealing the caps of optical instruments. All these lubricants provide for the operation and storage of optical instruments within a rather narrow temperature range (±40°C) which does not satisfy the requirements of present-day instrument making. Optical instruments must operate normally in frosts down to −50°C and not get out of order when working in a warm climate where they are often heated to 70-80°C in the sunlight. Therefore, a search is being conducted for more improved lubricants for optical instruments.

Graphite lubricants of series G which are mixtures of series TsKP lubricants with colloidal graphite in various proportions are used for lubricating heavily loaded joints of optical instruments.

Lubricants of series OKB-122, four plastic and five liquid, which are usually called instrument oils are very common. All these lubricants contain as the oil base mixtures of silicone liquids and highly purified petroleum oils. Thanks to the high content of silico-organic liquids which possess low pour points and a sloping viscosity curve, the lubricants of series OKB-122 provide for the operation of the mechanisms of diverse instruments at very low temperatures (to −70°C) and also can be used at comparatively high temperatures (up to 60-120°C). However, these lubricants cannot be used in the joints of optical instruments which have optical (glass) components since silicon liquids are inclined toward creeping on metallic and glass surfaces and lubricants prepared from them form deposits on the optical components.

Of the large number of instrument lubricants developed by VNII NP, only the lubricants TsIATIM-201, TsIATIM-202, TsIATIM-203 and TsIATIM-221 which are more common and are prepared by the petroleum industry in considerable amounts are presented in Table 12.29.

Lubricant TsIATIM-201 was the first lithium lubricant produced. It has found use in the most diverse fields of technology thanks to its water resistance, high chemical stability and wide range of temperatures in which it provides for the operation of mechanisms. Its shortcomings must be taken into account in using this lubricant: low collodial stability (it gives off oil), comparatively low anti-frictions properties (it cannot be used in heavily loaded joints), rapid drying and poor resistance to water erosion. Oil is given off from it during storage in a large container (cans); therefore it is packaged in beakers with a capacity of about 1 kg.

The lithium lubricants TsIATIM-202 and TsIATIM-203 are used in friction joints with high-reversible roller bearings and with large specific loads, at higher temperatures and in increased humidity since they have better anti-friction and anti-abrasion properties than lubricant TsIATIM-201.

The calcium lubricant TsIATIM-221, in spite of the fact that

it does not possess high water resistance, protects lubricated surfaces rather well against corrosion and is stable during prolonged storage of lubricated mechanisms; it is often used in connecting metallic and rubber components. Insufficiently good antiabrasion properties do not permit its use in heavily loaded friction joints.

Hermetic Sealing Lubricants [No. 91-107, Table 12.29]

Special hermetic sealing and packing lubricants and greases are used to fill narrow slits and chinks in the hermetic sealing of instrument to provide for operation and prolonged sealing of various cranes, bolts, vacuum apparatus and instruments. They are divided according to purpose, type and chemical composition of the base and binder and according to the filler which plays a large role in their capacity to hermetically seal apparatus, especially under large pressures.

The base and binder determine the resistance of the lubricant to the medium with which it comes into contact and the reliability of operation of movable joints at different temperatures.

A hydrocarbon vacuum lubricant (No. 91, Table 12.29) is used to hermetically seal laboratory instruments; it is also used under production conditions. It contains 15% natural rubber, therefore its structure is distinguished by a thread-like character and great stickiness.

The new lubricant LZ-188 is used for hermetically sealing the stopcocks of various pipe lines through which natural or industrial gas is transported under great pressure at temperatures from 20 to 130°C; lubricant BU is used for sealing gasoline pipes and gasoline pumps. Instrument and liner lubricants as well as pump lubricant which is very resistant to the action of petroleum products and alcohol-glycerine liquids have been used for a long time.

Packing lubricants have been developed: No. 15, 1, 2, 3, 4, 5 and 54 for gas cocks, threaded joints and others (No. 98-106, Table 12.29). They have limited use and are prepared on special order of the consumers.

Vaselines and Leather Lubricants [No. 108-111, Table 12.29]

Vaselines are produced according to GOST 3582-52 and MRTU 12N No. 116-64.

The former are used for medical purposes and in preparing creams, pastes and ointments. They are also used in the textile industry.

Vaselines manufactured according to MRTU 12N No. 116-64 are used for medical purposes in agriculture.

Lubricants for leather are used in preparing a fatty mixture for the impregnation of leather products as well as for protecting metal parts against corrosion.

TABLE 12.29

Composition, Principal Characteristics, Purpose and Application Conditions of Lubricants

Composition		Principal methods of use		Principal purpose	Method of packing, packaging, principle methods of use
components	contents, % by mass	index, unit measurement	standard		
Plastic protective lubricants					
1. PVK (gun) lubricant, GOST 10588-63					
Cylinder oil 11 (light)	35-25	Light brown to dark brown grease		For preservation of external and internal surfaces of parts and mechanism joints during prolonged storage, if the temperature of the articles does not exceed 50°C. It can be replaced by gun lubricant at temperatures not above 30-35°C	It is packed according to GOST 1510-60 in barrels and cans It is applied in an unheated state with a trowel or rag; when heated to a temperature of 85-115°C, by dipping, with a brush, swab and by other methods
Petrolatum	60-70	Drop point, °C, not below	54		
Ceresin of all grades (except grade 57)	4	Slipping temperature, °C, not below	48		
KI-7 additive	1	Acid number, mgKOH per g	0.55-1.0		
2. Gun lubricant, GOST 3005-61					
Cylinder oil 11	35-25	Light brown to dark brown grease		For preservation of outer and inner surfaces of mechanism parts and joints during prolonged storage if the temperature of the articles does not exceed 30-35°C. It is replaced by PVK	It is packed according to GOST 1510-60 in barrels and cans. It is applied in the same way as lubricant PVK
Petrolatum PK	60-70	Drop points, °C, not below	50		
Ceresin (except grade 57	5	Slipping temperature (actual), °C	30-35		
Sodium hydroxide	0.02	Kinematic viscosity at 60°C, cSt, not less than	40		

		Acid number, mg KOH per g, not more than	0.3		
3. Lubricant SKhK, GOST 11069-64					
Petroleum oil with a viscosity at 100°C of 9-13 cST	10	Brown to dark brown thick grease		For protection against corrosion of outer surfaces of metal parts of agricultural machines, tractors and other mechanisms during storage in the open	It is packed according to GOST 1510-60 in barrels. It is applied in a hot (melted) state by dippling, spraying, with a brush or rag
MNI-3 additive PSs, PS and PK	3	Drop point, °C, not below	54		
	Remainder to 100%	Slipping temperature, °C not below	48		
		Acid number, mg KOH per g	0.5-1.0		
4. Lubricant GOI-54p, GOST 3276-63					
Ceresin grades 75 and 80	23	Yellow grease		For lubricating the mechanisms of machines and instruments which operate in the open air and protecting metal surfaces against corrosion It can be replaced by lubricant GOI-54 without additive MNI-7 at product storage and operating temperatures below +30°C	It is packed according to GOST 1510-60 in tin cans with a capacity of up to 20 l It is applied in a cold state with a trowel or rag, with a stauffer lubricator and other methods, or in melted form, heated to a temperature of not above 105°C by dipping cold metal articles in it
MNI-7 additive*	1	Drop point, °C, not below	60		
MVP oil	Remainder to 100%	Slipping temperature, °C, not below	48		
		Acid number, mg KOH per g	0.6-1.0		

*The lubricant is also prepared without additive at the user's request.

5. Protective compound (lubricant PP-96/5), GOST 4113-48

Petrolatum PK and PS	95	Light brown to dark brown grease		For protecting metal products with roughly finished surfaces against corrosion during storage in covered storehouses and containers For preserving wood. It can be replaced by lubricants SKhK and PVK	It is packed according to GOST 1510-60. It is applied only in a melted state by dipping
All grades of paraffin (except match)	5	Drop point, °C, not below	55		
Sodium hydroxide, not more than	0.02	Slipping temperature, °C, not below	35-40		
		Acid number, mg KOH per g, not more than	0.28		
		Does not decrepitate at temperature, °C	-40		

6. Technical vaseline (lubricant UN), GOST 782-60

Lubricant is obtained by fusing in any proportions petrolatums, paraffins, ceresins, industrial oils, cylinder oil 11, still residues of instrument oils, heavy paraffins and ozocerite distillates		Light brown to dark brown grease without lumps		For protecting non-crucial metal articles against corrosion during storage. It is replaced by lubricants SKhK, PVK, gun	It is packed according to GOST 1510-60. It is applied in a melted state by dipping or with a brush and without heating – with a rag, trowel or by other methods
		Drop point, °C, not below	54		
		Slipping temperature, °C, not below	30-35		
		Kinematic viscosity at 70°C, cSt, not less than	27		
		Acid number, mg KOH per g, not more than	0.28		

7. Anti-corrosion lubricant ZhE, TU MPS No. 07-68

Cylinder oil 11	75	Drop point, °C, not below	60	For coating carrier cables of electrified railroads for protection against corrosion	It is packed in barrels with a capacity of up to 100 kg It is applied by smearing
Ceresin	25	Penetration at 25°C	200-240		
Sodium hydroxide, not more than	0.3	Reaction	Weakly alkaline		

8. Preservation lubricant TsIATIN-215, GOST 8882-58

Oxidized petrolatum	37	Uniform dark brown to black grease		In the form of a water emulsion for impregnating phosphate coating of steel parkerized articles to improve protection against atmospheric corrosion	It is packed in tin cans with a capacity of up to 1 kg. It is used in the form of a 12-15% water emulsion. It is applied by dipping, spraying or with brushes
Sodium hydroxide	On calculation to complete saponification	Penetration at 25°C	200-300		
		Water-emulsion stability: in 1 h oil is released, %, no more than	2		
Industrial oil 12	Remainder to 100%	Free base, %	0.7-1.5		
		Water, %, not more than	5.6		

9. Lubricant TsIATIM-205, GOST 8551-57

Ceresin	43-47	White to light cream colored uniform oily paste. Slight granularity permitted		For protection against caking of threaded connections of pipe lines and motor armatures which operate in the temperature range from −40 to +50°C in aggressive media. For packing and preservation of mechanisms operating in contact with acids, bases, alcohols and oxidizers	It is packed in tin cans with a capacity of 20 *l*. It is applied by smearing without melting
Mixture of 85% medical vaseline and 15% perfume oils	57-53	Drop point, °C, not below	65		
		Acid number, mg KOH per g, not more than	0.05		

Liquid anti-corrosion lubricants

10. Liquid gun lubricant RZh, GOST 9811-61

20 or 20B industrial oil	45	Mobile liquid oil, dark brown which easily spreads on a metal surface		For normal operation of rifle mechanisms at temperature to −50°C and for protecting it against corrosion during operation and for cleaning after firing under field conditions. It protects steel well against corrosion	It is packed in tin cans with a capacity of up to 20 *l*. It is applied with a rag, by saturation with the lubricant or by sprinkling
T-1 fuel	50				
Vinypol VB	3.5				
Additive MNI-5 or MNI-3	1.25	Kinematic viscosity, cSt at +50°C, not below	6.0		
		at −50°C, not above	1500		
		Pour point, °C, not above	−60		
		Acid number, mg KOH per g, not more than	0.3-0.7		

11. Gun lubricant (VO), GOST 3045-51

Cylinder oil 11 (light)	97.5-98.0	Thick liquid of little mobility; when observed in transient light it is light brown to dark brown		For lubricating rifle mechanisms and brief protection of metal parts against corrosion at temperatures above +5°C. It is replaced by lubricant RZh	It is packed in tin cans with a capacity of up to 20 *l* and wooden barrels. It is applied with a rag
Ceresin of all grades (except grade 57)	2.5-2.0	Kinematic viscosity, not less than			
Sodium hydroxide, not more than	0.02	at 50°C	65		
		at 100°C	10		
		Reaction of lubricant	Neutral or weakly alkaline		

12. Neftegaz-203 lubricant, grade A, MRTU 12N No. 78-64

Calcium sulfonate concentrate in industrial oil 12	88	Thick slightly mobile dark brown to black oil		For protecting outer surfaces of metal articles and mechanisms against corrosion in the absence of the direct effect of atmospheric precipitates	It is packed in 100 *l* iron casks. The unheated lubricant is applied with a brush; heated to 60-100°C by dipping, spraying
Oxidized petrolatum	12	Flash point (in open crucible), °C, not below	180		
		Kinematic viscosity at 100°C, cSt	25-50		
		Alkalinity, mg KOH per g, not less than	4		

13. Neftegaz-203 lubricant, grade B, MRTU 12N No. 78-64

Calcium sulfonate concentrate in 12 or 20 industrial oil	40	Dark brown mobile liquid		For protection of inner components and surfaces of pumps and motors against corrosion in the absence of the direct action of atmospheric precipitates	It is packed in 100 *l* iron casks. Lubricant heated to 50-80°C is applied with a brush or by spraying
Oxidized petrolatum	10	Flash point (in open crucible), °C, not below	170		
12 or 20 industrial oil	50	Kinematic viscosity at 100°C, cSt	10-15		
		Alkalinity, mg KOH per g, not less than	2		

14. Neftegaz-203 Lubricant, grade C, MRTU 12N No. 78-64

Calcium sulfonate concentrate in 12 or 20 industrial oil	40	Brown liquid oil		For protecting internal surfaces of pumps and motors against corrosion	It is packed in 100 *l* iron casks. It is poured into the working units of motors instead of working oil; it is applied by spraying or dipping
Oxidized petrolatum	10	Flash point (in open crucible), °C, not below	150		
Transformer oil	50	Kinematic viscosity at 50°C, cSt	25-33		
		Alkalinity, mg KOH per g, not less than	2		

15. Neftegaz-204, MRTU 12N No. 69-63

Nitrated petroleum oil	60-70	Brown to black oily liquid, transparent in a thin layer, without lumps and abrasive particles		For preservation of agricultural machines, spare parts, mechanisms and other articles made of ferrous and non-ferrous metals during storage and transportaion in the absence of the direct effect of atmospheric precipitates	It is packed in 100 *l* iron casks. It is applied by any method (with a brush, by spraying or dipping) at ordinary temperature and heated to 50-80°C
Pyropolymer (petroleum residues obtained during pyrolysis)	20-15				
Oxidized petrolatum	20-15	Kinematic viscosity at 100°C, cSt	80-160		
		Flash point (in open crucible), °C, not below	140		
		Ash content, %	0.3-0.5		

16. Neftegaz-204u lubricant, MRTY 12N No. 69-63

Nitrated petroleum oil	70-60	Brown to black oily liquid, transparent in a thin layer, without lumps and abrasive particles		For the same purposes as Neftegaz-204 lubricant. It can be used under conditions of the brief effect of atmospheric precipitates	The same
Oxidized petrolatum	17-20	Kinematic viscosity at 100°C, cSt	15-20		
Paraffin	5-8	Flash point (in open crucible), °C, not below	140		
Aluminum soap of synthetic fatty acids	8-12	Bound and free bases (with bromphenol blue indicator), mg KOH per g, not less than	1.0		
		Water	Absent		
		Mechanican impurities, %, not more than	1.0		

17. Preservative lubricant X-15, GOST 9185-59

Oxidized petrolatum	1.3	Uniform viscous oily liquid of dark brown color		For preservation of airplane engines and their components	It is packed in 20 *l* containers. It is applied by pouring into the engine housing with subsequent removal of the excess, by dipping and by spray-in-
Additive TsIATIM-339	2.5				
Sa-45 rubber	1	Pour point, °C, not above	-15		
Lithium hydroxide	On calculation to complete saponification	Kinematic viscosity at 100°C, cSt	15-22		
		Stability of water emulsion: oil given off in 1 h, %, not more than	2		
Transformer oil, not more than	40	Free base, %, not more than	0.1		
MS-20 oil	Remainder to 100°				

18. Preservative lubricants K-17 and K-17n (K-19). GOST 10877-64

Oxidized petrolatum	2.5	Dark brown viscous oily liquid		For preserving of internal parts of engines and protection of articles and mechanisms stored under cover against atmospheric corrosion Lubricant K-17n before use is mixed for uniform distribution of the sodium nitrite	It is packed in 20 l containers; lubricant K-17 in containers with a narrow neck; lubricant K-17n in containers with a wide neck. It is applied by pouring into the engine housing with subsequent removal of the excess, by dipping and spraying
Lithium hydroxide	By calculation	Kinematic viscosity at 100°C, cSt	15-22		
		Pour point, °C, not above	-20		
SK-45 rubber	1	Free organic acids, %, not more than	1.0		
Additive TsIATIM-339	2.5	Water and free alkali	Absent		
Additive PMSYa	10				
Diphenylamine	0.3				
Transformer oil, no more than	40				
MS-20 oil	Remainder to 100%	Ash content, %	1.3-2.5		
Lubricant K-17n is composed of					
lubricant PMSYa (instead of 10%)	2				
sodium nitrite	2				

19. Protective lubricant SP-3 (59ts), GOST 5702-51

Oleic acid Triethanolamine Transformer oil (without additive)	10 6 Remainder to 100%	Uniform liquid lubricant Stability of emulsion at 20°C for 24 h Test for steel and aluminum corrosion	Does not separate Does not cause corrosion	For treating internal surfaces of engines which operate on fuel containing ethyl fluid for purposes of protection against corrosion	It is packed in 20 l containers. It is applied by pouring into the engine housing with subsequent removal of the excess

20. Lubricant NZ-25, STU-36-13-660-61

Technical oleic acid Triethanolamine 20 or 20B industrial oil	10.5 4.5 Remainder to 100%	Stability of emulsion at 40°C for 24 h Test for steel corrosion	Does not separate Does not cause corrosion	For preparing water emulsion of fluid which operates in water systems of accumulator stations	It is packed in 20 l containers

Cable Lubricants

21. Cable lubricant for steel cables, MRTU 12N No. 87-64

Cylinder oil 11	75-82	Dark brown to black uniform semi-liquid mass		For lubricating steel cables operating on wood alloy	It is packed according to GOST 1510-60 in 20 *l* tin plate containers and wooden barrels with a capacity of 100 and 200 *l*. It is applied in melted form by dipping and smearing
Ozocerite raw material	25-18	Kinematic viscosity at 100°C, cSt	9.4		

22. Cable lubricant NNZ-3 TU NZ 42-64

Synthetic ceresin	8	Smooth black grease. Finely granular texture is permitted		For lubricating steel cables and impregnating center of steel cable	It is packed according to GOST 1510-60 in kraft bags. It is applied in melted form by dipping
Wool fat	10	Drop point, °C, not below	65		
BN-3 bitumen	25	Abrasive impurities and water	Absent		
Cylinder oil 11	10	Does not decrepitate on cables with a bend at a temperature of, °C	-15		
Copper naphthenate	3	Test for steel corrosion	Passes		
Polyisobutylene with molecular weight of 20,000	1				
Petrolatum	Remainder to 100%				

23. Industrial cable lubricant IK (cable grease), GOST 5570-50

Petrolatum	40	Uniform dark brown to black grease		For lubricating steel cables to decrease abrasion and protect against corrosion	It is packed according to GOST 1510-60 in plywood drums. Saturation of steel cables by dipping in melted lubricant, lubrication of cables with brushes
Petroleum bitumen	10	Drop point, °C, not below	40		
Pine rosin	10	Specific viscosity at 100°, VU degrees	1.4-2.5		
Graphite P	3				
Oily tar of grade L or petroleum residue of direct distillation	Remainder to 100%				

24. Cable lubricant 33 "T," MRTU 12N No. 31-63

Grate T oily tar	36	Smooth uniform (without lumps) black grease; fine grain structure without phase separation is permitted		For lubricating steel cables	The same
Oxidized petrolatum	25				
Ozocerite-standard grade not below 67	20	Drop point, °C, not below	60		
Tallow oil, saponified with lime milk	10	Water soluble acids, bases and abrasives	Absent		
Octol	9	Water, %, not more than	0.5		
		Test for corrosion of metal plates	Passes		

General Purpose and Automotive Anti-Friction Lubricants

85. Synthetic grease — press-grease S, GOST 4366-64

Calcium soaps of synthetic fatty acids, not less than	9	Uniform paste (without lumps) of up to dark brown color		For lubricating rolling and slipping bearings as well as other friction joints of mechanisms which operate at temperatures from —40 to +50°C. Water resistant lubricant	It is packed according to GOST 1510-60. It is applied in a heated state by smearing
Industrial oil with kinematic viscosity of 17-33 cSt at 50°C and with a pour point of not above —15°C		Tensile strength at 50°C, gf/cm², not less than	1.0		
		Effective viscosity at 0°C, poise, not more than	1000		
		Free bases, %, not more than	0.2		
		Free organic acids and mechanical impurities	Absent		
	Remainder to 100%	Water, %, not more than	2.5		
		Test for steel and copper corrosion	Passes		

26. Synthetic grease – grease S (USs-automobile lubricant), GOST 4366-64

Calcium soaps of synthetic fatty acids, not less than	12	Uniform paste (without lumps) of up to dark brown color		For lubricating rolling and slipping bearings as well as other friction joints, automobile wheel naves and rollers of caterpillar tractors which operate at temperatures from −30 to +65°C. Water resistant lubricant	The same
Industrial oil with kinematic viscosity of 17-33 cSt at 50° C and with a pour point of not above −15°C	Remainder to 100%	Tensile strength at 50°C, gf/cm², not less than	2.0		
		Effective viscosity at 0°C, poise, not more than	2000		
		Free bases, %, not more than	0.2		
		Free organic acids and mechanical impurities	Absent		
		Water, %, not more than	2.5		
		Test for steel and copper corrosion	Passes		

27. US-1 universal average melting lubricant (fatty press-grease) GOST 1033-51

Calcium soaps of cottonseed oil	9	Light yellow to cark brown uniform paste		For lubricating the bearings of tractors and other mechanisms which operate at temperatures no higher than 40-50°C	It is packed according to GOST 1510-60. It is used without melting. It is applied by smearing
20, 20V, 45 and other oils with a viscosity of 38-52 cSt at 50°C	Remainder to 100%	Drop point, °C, not below	75		
		Penetration at 25°C	330-355		
		Free bases, %, not more than	0.1		
		Mechanical impurities, %, not more than	0.3		
		Water, %, not more than	1.5		

28. US-2 universal average melting lubricant (fatty grease L), GOST 1033-51

Calcium soaps of cottonseed oil, not less than	11	Light yellow to dark brown uniform paste		For the same purposes as lubricant US-1 at temperatures no higher than 50°C	It is packed according to GOST 1510-60. It is used without melting. It is applied by smearing.
Industrial oils with a viscosity of 17-40 cSt at 50°C	Remainder to 100%	Drop point, °C, not below	75		
		Penetration at 25°C	230-290		
		Free bases, %, not more than	0.2		
		Mechanical impurities, %, not more than	0.4		
		Water, %, not more than	2		

29. US-3 universal average melting lubricant (fatty grease T), GOST 1033-51

Calcium soaps of cottonseed oil, not less than	18	Light yellow to dark brown uniform paste		For the same purposes as lubricant US-1 at temperature no higher than 70°C	The same
Industrail oils with a viscosity of 27-52 cSt at 50°C	Remainder to 100%	Drop point, °C, not below	90		
		Penetration at 25°C	150-220		
		Free bases, % not more than	0.2		
		Mechanical impurities, %, not more than	0.4		
		Water, %, not more than	3		

30. UTs-1 synthetic universal high melting lubricant (synthetic konstalin), GOST 5703-51

Sodium soaps of synthetic fatty acids, not less than	14	Dark brown uniform paste		For lubricating the friction joints of tractors, municipal transportation, industrial and other mechanisms at temperatures of up to 115°C without direct contact of the lubricant with water. At temperatures below -20°C, not recommended	The same
Mineral oils with viscosity of 19-45 cSt at 50°C	Remainder to 100%	Drop point, °C, not below	130		
		Penetration at 25°C	225-275		
		Water, %, not more than	0.5		

31. UTs-2 synthetic universal high melting lubricant (synthetic konstalin), GOST 5703-51

Sodium soaps of synthetic fatty acids, not less than	16	Dark brown uniform paste		It is used as a general purpose high temperature lubricant for lubricating friction joints of mechanisms operating at temperatures of up to 135°C	The same
Mineral oils (mixture) with viscosity of 19-53 cSt at 50°C	Remainder to 100%	Drop point, °C, not below	150		
		Penetration at 25°C	175-225		
		Water, %, not more than	0.5		

32. UT-1 universal high melting lubricant (fatty konstalin), GOST 1957-52

Sodium soap of natural fats (castor oil and others)	18-20	Uniform paste (without lumps) from light yellow to dark brown color		For same purposes as lubricant UTs-1	It is packed according to GOST 1510-60. It is used without melting. It is applied by smearing
Industrial oil with a viscosity of 19-45 cSt at 50°C	Remainder to 100%	Drop point, °C, not below	130		
		Penetration at 25°C	225-275		
		Free bases, %, not more than	0.2		
		Water, %, not more than	0.5		
		Ash content, %	4		
		Test for steel and copper corrosion	Passes		

33. UT-2 universal high melting lubricant (fatty konstalin), GOST 1957-52

Sodium soap of natural fats including castor oil	18-20	Uniform paste (without lumps) from light yellow to dark brown color		For same purposes as lubricant UTs-2	The same
Industrial oil with viscosity of 19-53 cSt at 50°C	Remainder to 100%	Drop point, °C, not below	150		
		Penetration at 25°C	175-225		
		Water, %, not more than	0.5		

34. Fatty lubricant 1-13, GOST 1631-61

Technical castor oil	21	Uniform paste (without lumps) from light yellow to dark brown color		For lubricating roller and ball bearings of wheel naves, water pumps, primary shaft of automobile gear box, roller bearings of electrical motors and generators	It is packed in 20 *l* jars and cans. It is used without melting
Air construction lime (on conversion to CaO)	0.5	Drop point, °C, not below	120		
Sodium hydroxide	From calculation to complete saponification of fats	Viscosity at 0°C and rate of deformation 10 s^{-1}	5000		
		Tensile strength at 80°C, gf/cm^2, not less than	1.5		
		Water, %, not more than	0.75		
Mineral oil (mixture) with viscosity at 50°C of not less than 19 cSt and with pour point no higher than −38°C		Free base (on conversion to NaOH), %, not more than	0.2		
	Remainder of 100%				

35. 1-13s Synthetic lubricant, MRTU 12N, No. 120-64

Mixture of 50 industrial oil and AU axle oil thickened with sodium-calcium soaps of synthetic fatty acids	Uniform paste (without lumps) of dark brown color		For same purposes as lubricant 1-13	The same
	Drop point, °C, not below	120		
	Viscosity of 0°C and average rate gradient 10 s^{-1}, poise, not more than	3200		
	Colloidal stability, %, not more than	5.0		

36. YaNZ-2 automobile lubricant, GOST 9432-60

Synthetic fatty acids	15	Uniform light yellow to dark brown paste		For lubricating bearings of wheel naves, water pumps and worm shaft of automobile gear box and other mechanisms in which lubricant 1-13 and grease are used	It is packed in 20 *l* jars and cans. It is used without metlting
Water soluble carbonic acids with acid number of not less than 110 mg KOH per g	0.75	Drop point, °C, not below	150		
Sodium sulfonate	0.7	Viscosity, poise, at 0°C and average gradient of rate of deformation 10 s^{-1}, not more than	2000		
Building lime (on conversion to CaC)	0.5	Same at +50°C and 100 s^{-1}, not more than	35		
Technical sodium hydroxide	To complete fat saponification	Tensile strength at 50°C, gf/cm^2, not less than	1.8		
		Water, %, not more than	0.5		
12 industrial oil	Remainder of 100%				

37. Automobile lubricant for AM forward drive bridge (Cardan), GOST 5730-51

Technical hydrogenated fat	8	Uniform long-fibered dark paste		For lubricating swivel pin of forward drive bridge of automobiles (Cardan joints)	It is packed according to GOST 1510-60 in 20 *l* tin cans. It is used without melting
Cottonseed oil	2	Drop point, °C, not below	115		
Technical castor oil	3	Penetration at 25°C	220-270		
Caustic	3	Water, %, not more than	0.75		
Pine rosin	4				
AK-10 oil	10				
AK-15 oil	70				

38. LZ-31 lubricant, MRTU 38-1-161-65

Lithium stearate	19	Light yellow to brown uniform paste	For lubricating automobile closed rolling bearings	It is packed according to GOST 1510-60. It is applied without melting by cementing
Chlordiphenyl (chlorinated biphenyl)	10	Drop point, °C, not below 185		
Diphenylamine	0.2	Dynamic viscosity, poise:		
Synthetic oil	Remainder of 100%	at gradient of rate of displacement 100 s^{-1} and 50°C, not more than 100		
		At gradient of rate of displacement 10 s^{-1} and 0°C, not more than 2800		
		Tensile strength at 50°C, gf/cm^2, not less than 3.0		
		Colloidal stability at 50°C, not more than 14		
		Test for corrosion:		
		on steel: Passes		
		on brass: Turning green is permitted		
		mechanical impurities: Absent		

39. Lubricant for vacuum and pneumatic windshield wipers, MRTU 12N No. 76-64

Aluminum stearate AU axle oil	15 85	Uniform transparent paste (without clots) from yellow to brown color	For lubricating pistons and housing of vacuum and pneumatic AS windshield wipers	It is packed in 20 l cans. It is applied without melting by smearing
		Drop point, °C, not below	75	
		Penetration at 25°C	300-360	
		50°C, not more than	380	
		Syneresis at 50°C, not more than	6.0	
		Testing of protective properties (at 20°C, 10 days) on brass	Irridescence is permitted	
		On zinc alluminum alloy	Tarnishing is permitted	

40. ATE lubricant for ball bearings of motor and tractor electrical equipment, TU 424-54

Industrial oil with viscosity of 28.4-51.4 cSt at 50°C, thickened with sodium soap of hydrogenated fat		Smooth uniform paste of weakly fibrous structure, broken off short, from light yellow to brown color	For lubricating ball bearings of automobile and tractor magnetos and generators	It is packed according to GOST 1510-60. It is used without melting
		Drop point, °C, not below	140	
		Penetration at 25°C	175-225	
		Syneresis at 50°C	250	
		Syneresis at 75°C	300	
		Water, %, not more than	0.2	

41. Lubricant No. 158, MRTU 12N No. 139-64

MS-20 oil thickened with lithium-calcium soaps of stearic acid with addition of 2% phthalocyanin (copper complex)		Dark blue uniform paste		In bearings of Moskvich and Volga automobile generators and combine generators	It is packed according to GOST 1510-60 in 20 *l* cans and in tubes weighing 40-50 g. It is used without melting
		Drop point, °C, not below	125		
		Penetration at 25°C	280-360		
		Free bases, %, not more than	0.1		
		Free organic acids	Absent		
		Water	Traces		

42. USSA graphite lubricant, GOST 3333-55

Calcium soap of synthetic fatty acids	12	Uniform dark brown to black paste		For lubricating springs and cables of automobile brakes, tractor suspension and undercarriage, as well as rough heavily loaded gears and mechanisms (winches, open cog wheels of rolling mills, etc.)	It is packed in 200 and 100 *l* barrels. It is applied by smearing without melting
Graphite P	10	Drop point, °C, not below	77		
Cylinder oil 11	Remainder to 100%	Penetration at 25°C	250		
		Colloidal stability, %, not more than	5		
		Water, %, not more than	3		

43. Industrial lubricants for rolling mills IP1-L (summer), IP1-Z (winter), GOST 3257-53

Cottonseed oil, including sulfured	11	Uniform light yellow to dark brown paste		For lubricating bearings of rolling mills with centralized lubricant supply	It is packed in barrels with a capacity of not more than 200 l. It is applied without melting
Hydrogenated fat	3	Drop point, °C, not below:			
Air construction lime (on conversion to CaO)	2	IP1-L	80		
		IP1-Z	75		
Sodium hydroxide	From calculation to complete saponification of fats	Penetration at 25°C:			
		IP1-L	260-310		
		IP1-Z	310-350		
		Sulfur, %, not less than	0.3		
		Water, %, not more than	2		
Cylinder oil 11	Remainder to 100%				

44. Industrial lubricant for rolling mills IP-2, GOST 6708-53

Oxidized petrolatum	43	Dark brown to black thick paste		For lubricating open journals of rolling mill shafts	It is packed according to GOST 1510-60. It is used without melting
Sodium hydroxide	To complete fat saponification	Drop point, °C, nct below	170		
		Penetration at 25°C	50-100		
		Water, &, not more than	0.2		
Motor and tractor transmission oil	Remainder to 100%				

45. 59tsS lubricant (from sulfurous raw material), MRTU 12N No. 89-64

Oleic acid	11	Uniform liquid; it can give off precipitates; upon shaking it again becomes uniform		For preparing emulsion fluid used for cooling rolling mills	It is packed in cans with a capacity of no more than 20 *l*. It is used for preparing technological cooling emulsion by mixing with water
Triethanolamine	5				
Transformer oil, derived from sulfur-containing petroleums and hydropurified (without additives)	Remainder to 100%	Corrosive effect at 20°C in 24 h	Passes		
		Stability of emulsion at 20°C for 24 h	Does not separate		

46. IT textile lubricant, GOST 4952-49

Technical hydrogenated fat	11	Uniform slightly fibrous mass from white to light yellow color; when rubbed between fingers it gives a short break		For lubricating the wheels of textile torsion machines	It is packed according to GOST 1510-60 in 20 *l* tin cans and 100 and 200 *l* wooden barrels. It is used without melting
Sodium hydroxide	To complete fat saponification				
Perfume oil	Remainder to 100%	Drop point, °C, not below	100		
		Penetration at 25°C	275-325		

47. IR rotary lubricant, GOST 4874-49

Aluminum stearate	14	Smooth uniform vaseline-like masses (without lumps and clots) from light brown to dark brown in color; it is transparent in a thin layer		For lubricating bearings of rotary machines	It is packed in 20 *l* metal containers. It is applied without melting
MS-20 and MK-22 aviation oil	86	Drop point, °C, not below	95		
		Penetration at 25°C	275-350		
		Ash content, %	1.8		

48. Red's lubricant, MRTU 12N No. 64-63

Aluminum oleate	8	Thick uniform mass		For lubricating bearings of electric immersion pumps and protecting electric motors against the penetration of ground water	It is packed in 20 *l* metal containers. It is applied without melting by smearing
SK-45 synthetic rubber	1	Drop point, °C, not below	45-65		
MK-22 aviation or 52 cylinder oil (lubricating oil for steam engine cylinders	Remainder to 100%				

49. Industrial metallurgical lubricant No. 10, GOST 8804-58

Cottonseed oil	11	Uniform light yellow to dark brown paste		For lubricating the bearings and other friction parts of metallurgical equipment which operate at increased loads and average speeds	It is packed in barrels with a capacity of no more than 200 *l*. It is applied without melting
Technical hydrogenated fat	11	Drop point, °C, not below	90		
Building air lime	5.2	Penetration at 25°C	200-260		
Sodium hydroxide	0.2	Water, %, not more than	1.0		
Technical oleic acid	1				
20B industrial oil	10				
Cylinder oil 11	Remainder to 100%				

50. Lubricant LZ-142, TU TNZ No. 120-62

Triethylene glycolic ester of C_{17-20} fraction of synthetic fatty acids		Light yellow to dark brown uniform lubricant		For cold rolling of steels and alloys; it is used in pure form and in the form of a dispersion or emulsion (with the addition of an emulsifier). It is a complete substitute for palm and castor oils and rolling lubricants prepared on a natural fat base	It is packed according to GOST 1510-60 in 20 *l* drums or tin cans
		Drop point, °C, not below	45		
		Evaporability at 150°C in 30 min, %, not more than	7.0		
		Saponification number, mg KOH per g	140-180		
		Water, %, not more than	1.0		

61. Lubricant No. 137, GOST 9974-62

Castor oil	3.7	Brown to dark brown uniform paste		It is used in friction joints which operate at high temperatures in manual and automatic thick lubricant systems which service the bearings of furnace roller conveyers, the belts of agglomerating machines, lifting cranes, open-hearth furnace cranes and mechanisms of hot mills which do not come into contact with water	It is packed according to GOST 1510-60. It is used without melting
Stearin	3.5				
Pine rosin	0.7				
Sodium hydroxide	From calculation to complete saponification of fats	Viscosity at 0°C and average gradient of rate of deformation of 100 s^{-1}	2800		
		Drop point, °C, not below	145		
38 cylinder oil	20	Penetration at 25°C	325-365		
MK-22 oil	Remainder to 100%	Free bases, %, not more than	0.3		
		Free organic acids and mechanical impurities	Absent		
		Water, %, not more than	0.4		
		Mechanical impurities	Absent		
		Test for steel corrosion	Passes		

Special Lubricants

62. ST airplane engine high melting lubricant (NK-50), GOST 5573-50

MK-22 oil thickened with sodium soap of fatty acids with the addition of colloidal graphite		Black uniform oily paste		For lubricating hot friction parts of aviation engines (valves, yokes) and other airplane parts	It is packed according to GOST 1510-60 in 1-2 *l* containers. It is applied by smearing without melting
		Penetration at 25°C	200		
		Syneresis at 50°C, not more than	170-225		
		Ash content, %	6		
		Water, %, not more than	7		
		Free bases, %, not more than	0.3		
		Testing for corrosion on steel, bronze and aluminum	0.15		
			Passes		

53. Lubricant No. 9, MRTU 12N No. 77-64

Technical stearin	15.55	Light yellow to dark brown smooth paste		For lubricating the friction joints and mechanisms of aviation technology: covered gear drives and worm gears of reducers, low-speed circuits and certain instruments; in bearings with linear velocities of not more than 20 m/s and specific loads of no more than 25 kgf/mm²; for preservation of these articles for a period of up to 1 year	It is packed in 1 l beakers. It is applied without melting by smearing
Lead monoxide	2.95	Drop point, °C, not below	92		
Barium hydroxide	To complete fat saponification	Penetration: at +25°C, not less than	330		
		at +75°C, not more than	370		
MVP oil	Remainder to 100%	at −60°C, not less than	45		
		Syneresis at 50°C, %, not more than	3.0		
		Testing for corrosion of copper	Passes		

54. AMS-1 lubricant, GOST [illegible]-52

Aluminum oleostearate	12	Uniform dark paste		For lubricating mechanisms which operate in water or in contact with it to protect them against corrosion; in friction joints of some ship mechanisms	It is packed in tin cans with a capacity of 20 l. It is applied by smearing without melting
52 cylinder oil (lubricating oil for steam engines)	Remainder to 100%	Drop point, °C, not below	85		
		Penetration at 25°C	300-350		

55. AMS-3 lubricant, GOST 2712-52

Aluminum oleostearate	20	Uniform dark paste		For same purposes as lubricant AMS-1	The same
52 cylinder oil (lubricating oil for steam engines)	Remainder to 100%	Drop point, °C, not below	95		
		Penetration at 25°C	200-250		

56. MS-70 lubricant, GOST 3762-61

Technical stearin	8	Brown to dark brown uniform paste (without lumps and granules), transparent in a thin layer; produces a small whisker upon rubbing between fingers		For spherical distillates, gears and worm gears of mechanisms which are in contact with sea water. For joints which operate at temperatures from −45 to +50°C, which work on slipping and rolling friction with linear velocities of not more than 15 m/s and specific loads of no more than 26 kgf/mm²; for preservation of these articles for a period of up to 2 years. Its application on copper alloys is not recommended	The same
Barium hydroxide	To complete stearin saponification				
Aluminum stearate	5				
Ceresin 80	5				
Polyisobutylene with molecular weight of 135,000-225,000	0.008-0.01	Drop point, °C, not below	80		
MVP oil	Remainder to 100%	Viscosity at 0°C and average gradient of rate of deformation of 10 s^{-1}, poise, not more than	2000		
		Penetration at 20°C	210-275		
		Tensile strength at 50°C, gf/cm², not less than	2		
		Water, %, not more than	0.1		
		Testing of protective properties on steel	Passes		

57. Lubricant PRGC, MRTU 12N NO. 88-64

Ceresin of grade 80	2.5	Nonuniform semi-liquid black mixture which separates during storage		For operation of heavily loaded high high-speed reducers at a temperature from −50° to +50°C. In a quiet state the lubricant separates; it is mixed during operation of the reducer	It is packed in 20 l containers. It is poured into the reducer. The lubricant is carefully mixed before filling the reducer
Fused lead stearate	2.5				
Aluminum distearate fused with MVP oil	0.5	Residual shear stress at −50°C, gf/cm², not more than	15		
Copper naphthenate	0.5	Individual oils in centrifuging, %			
Paraoxydiphenylamine	0.02		15-35		
Diphenylamine	0.08				
Dry grades S-1 and S-2 colloidal graphite preparations	12.5				
Industrail oil for high-speed mechanisms (velosite)	Remainder to 100%				

59. ZhD-1 locomotive connecting rod lubricant, TU MPS TsTCh No. 01-64

Hydrogenated fat	18.0-22.0	Brown to almost black very thick plastic paste		For lubricating pins of crankshafts at connecting rod bearings with floating sleeves. It can be replaced by lubricant ZhD-1ts	It is packed in wooden containers with a capacity of no more than 40 kg. It is used without melting
Tar grease	9.0-5.0	Drop point, °C, not below	100		
Sodium hydroxide	To complete fat saponification	Penetration: at 25°C	35-70		
		at 75°C	75-95		
		Water, %, not more than	7		
Automotive summer transmission oil	Remainder to 100%	Free bases, %, not more than	1.2		

59. ZhD-1p locomotive connecting rod lubricant, TU MPS TsTCh No. 01-64

Technical hydrogenated fat	2.5-3.0	Very thick dark brown to black plastic paste		For lubricating connecting rod bearings equipped with floating sleeves. It can be replaced by lubricant ZhD-1	The same
Tar grease	2.5-3.0	Drop point, °C, not below	100		
Oxidized petrolatum	28-34	Penetration: at 25°C	30-50		
Sodium hydroxide	To complete fat saponification	at 75°C	60-95		
		Water, %, not more than	0.5		
		Free bases, %, not more than	0.6		
Summer automotive transmission oil (nigrol)	Remainder to 100%				

60. ZhD-2 locomotive connecting rod lubricant, TU MPS TsTCh No. 01-58

Technical hydrogenated fat	13.5-15.5	Brown to almost black very thick paste		For lubricating connecting rod slitted and sleeve bearings of locomotives. It is sensitive to water. It can be replaced by konstalin and lubricant ZhD-1	It is packed in wooden barrels with a capacity of no more than 200 kg and in wooden crates with a capacity of no more than 40 kg. It is used without melting
Tar grease	5.5-4.5	Drop point, °C, not below	100		
Sodium hydroxide	To complete fat saponification	Penetration at 25°C	90-130		
		at 75°C	130-170		
		Water, %, not more than	5.5		
Summer automotive transmission oil (nigrol)	Remainder to 100%	Free bases, %, not more than	1.0		

61. ZhD-2p locomotive connecting rod lubricant, TU MPS TsTCh No. 01-58

Technical hydrogenated fat	2.5-3.0	Very thick dark brown to black plastic paste		For lubricating connecting rod pins. It can be replaced by lubricant ZhD-2	The same
Tar grease	2.5-3.0	Drop point, °C, not below	100		
Oxidized petrolatum	24-25	Penetration: at 25°C	50-75		
Sodium hydroxide	To complete fat saponification	at 75°C, not more than	120		
		Water, %, not more than	Traces		
Summer automotive transmission oil (nigrol)	Remainder to 100%	Free bases, %, not more than	0.6		

62. Sulfured lubricants for locomotives -- summer (L) and winter (Z), TU MPS TsTCh No. 06-64

1. Summer (L)					
Summer automotive transmission oil (nigrol)	67	Dark brown to black uniform mass		For lubricating the gear transmission of traction electric engines of locomotives	It is packed in iron barrels with a capacity of no more than 200 *l*. It is applied without melting
Konstalin	30	Water, %, not more than	0.2		
Sulfur	3	Sulfur, %	2.8-3.0		
2. Winter (Z)		Ash content, %	3.0		
Summer automotive transmission oil (nigrol)	87	Pour point, °C, not above			
Konstalin	10	summer	-5		
Sulfur	3	winter	-20		

63. ZhA anti-emergency coach lubricant, TU MPS TsTTs No. 03-64

Mixture of water insoluble naphthenic acids -soap-oil	10.5	Thick oily uniform paste (without clots and condensations) from dark brown to black in color		In coach axle boxes to prevent their uncoupling due to combustion of axle journals at stations which do not conform to technical inspection points	It is packed in iron containers with a capacity of up to 25 kg or in 50-100 *l* wooden barrels. It is applied without melting
Graphite P	5-7	Drop point, °C, not below	100		
Industrial oil	Remainder to 100%	Penetration at 25°C	200-275		
		Water, %, not more than	1.0		
		Ash content, %	10.0		

64. ZhK locomctive connecting link lubricant, TU MPS TsTCh No. 02-54

1st formula Technical hydrogenated fat	10-12	Brown to dark brown, almost black smooth uniform paste (without clots and condensations)	For lubricating the bearings of link mechanisms, spring suspension couplings, fire box bearings and other locomotive parts which are adapted for use of plastic grease-like lubricants. It can be replaced by press-grease S	It is packed in barrels with a capacity of no more than 200 l. It is applied without melting
Sodium hydroxide	To complete fat saponification			
Industrial oil with a viscosity at 50°C of 38-52 cSt	Remainder to 100%			
2nd formula Tar grease	7-12			
Sodium hydroxide	To complete fat saponification			
Industrial oil with a viscosity at 50°C of 38-52 cSt	Remainder to 100%			

Drop point, °C, not below	100
Penetration: at 25°C	270-325
at 50°C not below	340
Water, %, not more than	3
Free bases, %, not more than	0.8

65. ZhB locomotive axle box lubricant, TU MPS TsTCh No. 01-64

Technical hydrogenated fat	18.5-22.5	Brown to dark brown, almost black very thick plastic grease		For lubricating the journals of the driving and coupling axles of locomotive axle boxes of the FDp and FD series. It can be replaced by lubricant ZhD-1 lubricant	It is packaged in the form of bars. It is packed in wooden crates with a capacity of no more than 40 kg. It is applied without melting
Tar grease	9.0-5.0				
Sodium hydroxide	To complete fat saponification	Drop point, °C, not below	100		
		Penetration: at 25°C	25-40		
		at 75°C	50-65		
		Water, %, not more than	7		
Summer automotive transmission oil (nigrol)	Remainder to 100%	Free bases, %, not more than	1.2		

66. M-1 metro lubricant, MRTU 12N No. 81-64

Synthetic fatty acids	55	Light brown to dark brown uniform grease (without lumps and clots)		For lubricating the motor axle bearings of subway rolling stock which operate at a temperature of up to 75°C	It is packed according to GOST 1510-60. It is used without melting
Sodium hydroxide	To complete fat saponification	Drop point, °C, not below	120		
		Penetration: at 25°C	110-130		
45 and 50 industrial oils	Remainder to 100%	at 75°C, not more than	250		
		Free bases, %, not more than	0.2		
		Water, %, not more than	1.0		

67. M-2 metro lubricant, MRTU 12H No. 81-64

Synthetic fatty acids	35	Light brown to dark brown uniform grease (without lumps and clots)		For same purposes as lubricant M-1
Sodium hydroxide	To complete fat saponification	Drop point, °C, not below	120	
45 and 50 industrial oils		Penetration: at 25°C	160-190	
		at 75°C, not more than	250	
	Remainder to 100%	Water, %, not more than	1.0	

68. 1-LZ (improved 1-13) lubricant, MRTU 12H No. 118-64

Technical castor oil	20	Soft uniform grease (without lumps)		For lubricating roller bearings used in the axle boxes of railroad rolling stock	The same
Air construction lime (on conversion to CaO)	0.5	Drop point, °C, not below	125		
Sodium hydroxide	To complete fat saponification	Penetration at 25°C	220-260		
		Water, %, not more than	0.75		
		Tensile strength at 50°C, gf/cm², not less than	2.4		
Diphenylamine	0.5				
Mixture of AU axle and 50 industrial oils	Remainder to 100%				

69. Lubricant KV(UTM), GOST 2931-51

Technical castor oil	5	White to light brown grease-like mass		It is used in aviation, in railroad transport, in trolley, bus and trolley-bus yards in mechanisms for opening automatic doors and other joints of transport machines. It has low water resistance	It is packed in 20 *l* tin cans and 100 and 200 *l* wooden barrels. It is used without melting
Animal fat, technical or hydrogenated fat	5	Drop point, °C, not below	120		
Sodium hydroxide	To complete fat saponification	Tensile strength at 50°C, gf/cm^2, not less than	2.5-3.5		
		Penetration not less than			
		at −10°C	130		
		at −50°C	45		
Industrial oil for high-speed mechanisms I, (Kazan) or transformer oil	Remainder to 100%	Syneresis at 50°C, not more than	6		
		Usable at temperatures, °C	from +100°C to −60°C		

70. ZhR track lubricant, TU MPS No. 08-58

Oxidized petrolatum	6	Grayish-black thick uniform grease (without clost and condensations)		For lubricating the rails in the curved segments of railraod tracks	It is packed in 20 *l* tin cans and 100 and 200 *l* wooden barrels. It is used without melting
Tar grease	6				
Sodium hydroxide	To complete fat saponification	Drop point, °C, not below	110		
		Penetration at 25°C	270-325		
45V industrial oil	78	Free bases, %, not more than	0.4-0.8		
Grade B powdered graphite	10	Syneresis, %, not more than	2.0		

71. ZhT (4a) brake lubricant, TU MPS TsTCh No. 04-60

Castor oil	7-7.5	Light yellow to light brown grease like smooth uniform lubricant		For lubricating metal, leather and rubber parts of automatic brakes of railroad rolling stock. It can be repdaced by lubricant TsIATIM-201	It is packed in cans with a capacity of not more than 20 kg. It is applied without melting
Ceresin	to 0.5				
Technical fat	7-7.5				
Sodium hydroxide	To complete fat saponification	Drop point, °C, not below	120		
		Penetration: at 25°C	290-340		
		at -50°C, not below	45		
Industrial oil for high-speed L mechanisms (velosite)	Remainder to 100%	Free bases, %, not more than	0.1		
		Syneresis, %, not more than	5.0		

72. Dry graphite lubricant SGS-0, TU MPS TsTCh No. 9-64

Indene-coumaranone resin	35-39	Black powder	For lubricating contact plates of pantographs of electric locomotives and motorized coaches of electric sections and electric trains	It is packed in tin cans with a capacity of up to 25 *l*. It is applied in a melted state by hand. It is periodically renewed
Powdered graphite	61-65			

73. Dry graphite lubricant SGS-D, TU MPS TsTCh No. 9-64

Indecene-coumaranone resin	12-15	Black powder, suspended in solution of coumaranone resin in solvent	For reinforcing layer of SGS-0 lubricant in case it is painted	It is packed in 20 *l* tin cans. It is applied with a brush in a cold state
Powdered graphite	28-32			
Solvent	Remainder to 100%			

74. Grease compound 12 (PS-12), TU MPS No. 06-64

1st formula		Uniform cream to brown smooth grease	Greasing and pregreasing the sleeves of air distributors and pneumatic apparatus of electric rolling stock	It is packed in tin cans with a capacity of no more than 20 *l*. The greasing is carried out with melted lubricant
Polymerized castor oil	88			
Grades B, G and D paraffin	6			
Ceresin	6			
2nd formula				
Polymerized castor oil	88			
Beeswax	12			

Drop point, °C, not below	53
Conventional viscosity at 70°C, °VC	7-10
Acid number, mg KOH per g, not more than	6
Solubility in gasoline with heating	Complete

75. Grease compound 40 (PS-40), TU NPS No. 05-64

1st formula		Cream to light brown thick smooth uniform grease		For greasing and pregreasing the sleeves of air distributors and pneumatic apparatus of electric rolling stock	It is packed in tin cans with a capacity of no more than 20 *l*. The greasing is carried out with melted lubricant
Polymerized castor oil	88				
Grades B, G and D paraffin	6	Drop point, °C, not below	49		
Ceresin	6				
2nd formula		Conventional viscosity at 70°C, °VC	4.5-7.0		
Polymerized castor oil	60	Acid number, mg KOH per g, not more than	6		
Grades B, G and D paraffin	14	Solubility in gasoline with heating	Complete		
Hydrogenated fat	20				

76. Lubricant GMS, TU 351-53

Lubricant 1-13	54	Black grease	For lubricating the cover plates of rail junctions and the ends of rails to provide steady electrical conductance in the rail junctions	It is packed in tin cans with a capacity of up to 20 *l*. Packing in plywood drums is permitted. It is applied without melting
Grade B graphite II	46			

77. Lubricant 2TsKP, Standard N-620

Ceresin 80	25	Soft light yellow grease		For lubricating friction surfaces of components and threaded connections of directing screws with small gaps in the connections (from 5 to 20 μ); gears and pinions and screw joints working under small loads. It provides operation of instrument joints at temperatures from −40 to +45°C	It is packed in tin jars with a capacity of up to 2 kg. It is applied without melting by smearing
Petrolatum	5	Drop point, °C, not below	60		
MVP oil	70	Penetration at 25°C	278-311		
		Colloidal stability, %, not more than	6		

78. Lubricant 3TsKP, Standard N-620

Ceresin 80	30	Light yellow soft grease		For lubricating fricton surfaces of components and threaded connectionsof directing and hoisting screws with average gaps in the connections (from 20 to 50 μ and small loads; gears and pinions and screw joints working under small loads; ocular and objective threads with average-size gaps in the connections. It provides operation of instrument joints at temperatures from −40 to +45°C	The same
Petrolatum	5	Drop point, °C, not below	60		
MVP oil	65	Penetration at 25°C	211-277		
		Colloidal stability, %, not more than	4		

79. Lubricant 4TsKP, Standard-620

Ceresin 80	35	Thick yellow grease		For lubricating the friction surfaces of components and threaded connections with large gaps in the connections (above 50 μ) and small loads, including ocular and objective threads, ball and socket, pinion and screw joints which operate under small loads, nonfriction surfaces inside instruments for protection against shedding in the optics. It provides operation of instruments at temperatures from —40 to +45°C	It is packed in tin jars with a capacity of up to 2 kg. It is applied without melting by smearing
Petrolatum	5				
MVP oil	60	Drop point, °C, not below	60		
		Penetration at 25°C	180-210		
		Colloidal stability, %, not more than	3		

80. Ball and socket graphite lubricants G, Standard N-620

Lubricant 1G		Thick black grease		For lubricating heavily loaded joints of optical mechanical instruments with gaps: 1G – above 0.05 mm 2G – up to 0.02 mm 3G – from 0.02 to 0.05 mm 4G – above 0.05 mm	The same
Lubricant 3TsKP	50	Limits of operation, °C	From +50 to –40		
Graphite S-1	50				
Lubricant 2G		Light black grease			
Lubricant 2TsKP	95				
Graphite S-1	5	Limits of operation, °C	From +50 to –40		
		Colloidal stability, %, not more than	7		
		Black grease			
Lubricant 3G		Limits of operation, °C	From +50 to –35		
Lubricant 3TsKP	85				
Graphite S-1	15	Colloidal stability, %, not more than	5		
Lubricant 4G		Black grease			
Lubricant 4TsKP	95	Limits of operation, °C	From +60 to –35		
Graphite S-1	5	Colloidal stability, %, not more than	4		
		Drop point of all lubricants, °C, not below	60		

81. Lubricant 2SK, Standard N-620

Ceresin 80	20	Light yellow soft grease		For lubricating carriers containing optical components which have threaded grids in instruments which are subjected during operation to great accelerations and shock stresses. It provides operation of instrument joints at temperatures from –40 to +45°C	The same
Natural rubber	3	Drop point, °C, not below	60		
MS-14 oil	5	Penetration at 25°C	280-310		
MVP oil	72	Colloidal stability, %, not more than	5		

82. Lubricant 4SK, Standard N-620

Ceresin 80	50	Thick yellow grease (mastic)		For sealing the lids of the heads of optical instruments It is suitable for use at temperatures from −40 to +45°C	It is packed in tin jars with a capacity of up to 2 kg. It is applied without melting by smearing
Natural rubber	5	Drop point, °C, not below	60		
MS-14 oil	20				
MVP oil	25				

83. Lubricant OKB-122-7-5, MRTU 38-1-230-66

Ceresin	5	Light yellow vaseline-like grease		For lubricating friction couples of aviation and other instruments which operate without changing the lubricant for a long time at temperatures from −70 to +80°C	It is packed in tin jars with a capacity of up to 1 l. It is used without melting
MS-14 oil	22	Drop point, °C, not below	140		
Lithium stearate	5	Syneresis at 50°C in 48 h, %, not more than	4		
Ethylpolysiloxane liquid	68	Evaporability at 50°C in 100 h in a 0.1 mm layer, %, not more than	3.5		
		Free bases, %, not more than	0.03		
		Drop point, °C, not below	−70		
		Test for corrosion of steel, brass and D1-T alloy	Passes		

84. Lubricant OKB-122-7, MRTU 38-1-230-66

Ceresin	15	Light yellow vaseline-like grease		For lubricating different instruments and joints of radio electronic apparatus operating at temperatures from −70 to +120°C	The same
MS-14 oil	25				
Lithium stearate	5	Drop point, °C, not below	160		
Ethylpolysiloxane liquid	55	Syneresis at 50°C in 48 h, %, not more than	2.5		
		Evaporability at 50°C in 100 h in a 0.1 mm layer, %, not more th than	3.5		
		Solidification point, °C, not above	-70		

85. Lubricant OKB-122-8, MRTU 38-1-230-66

Ceresin	25	Light yellow vaseline-like grease		For lubricating instruments operating at temperatures from −60 to +60°C. It can be replaced by lubricant OXB-122-7-5	The same
MS-14 oil	11.5				
Ethylpolysiloxane liquid	63.5	Drop point, °C, not below	70		
		Syneresis at 50°C in 48 h, %, not more than	4		
		Solidification point, °C, not above	-70		

86. *Lubricant OKB-122-12, MRTU 38-1-230-66*

[illegible]resin	5	Light yellow vaseline-like grease		For lubricating instruments operating at high specific loads, velocities of 25,000 r/min and temperatures from −70 to +110°C	It is packed in tin jars with a capacity of up to 1 l. It is used without melting
MVP oil	40				
Polysiloxane liquid	40	Drop point, °C, not below	150		
Sodium soap of shale oil	15	Syneresis at 50°C in 48 h, %, not more than	1.5		
		Evaporability at 50°C in 100 h in a 0.1 mm layer, %, not more than	3		
		Free bases, %, not more than	0.15		
		Solidification point, °C, not above	−70		

87. *Lubricant TsIATIM-201, GOST 6267-59*

Technical stearin	11	Light yellow to dark yellow uniform grease (without lumps)		For lubricating instruments and mechanisms operating with low shear strength at temperatures from −60 to +120°C	The same
Lithium hydroxide	On calculation to complete saponification	Viscosity at −50°C and gradient of rate of deformation of 10 s^{-1}, poise, not more than	11,000		
Diphenylamine	0.3	Tensile strength at 50°C, gf/cm^2, not less than	2.5		
MVP instrument oil	Remainder to 100%	Drop point, °C, not below	170		
		Evaporability at 120°C, 1 h, %, not more than	25		
		Penetration at 25°C	270-320		
		Colloidal stability %, not more than	30		
		Free bases, %, not more than	0.1		
		Water and mechanical impurities	Absent		

88. Lubricant TsIATIM-202, GOST 11,110-64

Technical stearin	6.5	Yellow to light brown uniform lubricating grease		For lubricating high-speed ball bearings of mechanisms which operate in a temperature range from –50 to 150°C; it provides their operation for 500 h at rates of revolution of 30,000 r/min	The same
Castor oil	1.4				
Lithium hydroxide	To complete fat saponification	Drop point, °C, not below	170		
		Testing for corrosion of copper plates at 100°C for 24 h	A slight change in color is permitted		
Diphenylamine	0.3				
Transformer oil	20				
MS-14 oil	70	Viscosity at –30°C and gradient of rate of deformation of 10 s^{-1}, poise, not more than	15,000		
		Tensile strength at 50°C, gf/cm^2, not less than	1.2		
		Free bases, %, not more than	0.1		
		Content of mechanical impurities in 1 ml of lubricant			
		a) with diameter from 0.025 to 0.075 mm, not more than	1500		
		b) with diameter of more than 0.075 mm	Absent		
		Water and free organic acids	Absent		

89. *Lubricant TsIATIM-203, GOST 8773-58*

Technical stearin	6	Dark brown greases with smooth structure		For lubricating mechanisms operating at high specific loads at temperatures from −60 to +120°C	It is packed in tin jars with a capacity of up to 1 *l*. It is used without melting
Sulfured hydrogenated sperm whale fat	4	Drop point, °C, not below	150		
Sulfured acidol	3	Viscosity at −30°C and gradient of rate of deformation of 10 s^{-1}, poise, not more than	15,000		
Lithium hydroxide	By calculation				
Triphenylphosphate	0.5	Tensile strength at 50°C, gf/cm^2, not less than	2.5		
Transformer oil thickened with vinypol to viscosity of 11.4-15.2 cSt at 50°C	Remainder to 100%	Colloidal stability, %, not more than	15		

90. Lubricant TsIATIN-221, GOST 9433-60

Silico-organic liquid (lubricant No. 3) thickened with calcium stearate stabilized with calcium acetate with diphenylamine added	Light yellow to light brown uniform grease with smooth structure		For lubricating friction joints and coupled metal-metal and metal-rubber surfaces of mechanisms which operate in the temperature range from −60 to +150°C in aggressive media. It provides operation of product joints in the temperature range from +50 to −40°C after six years of storage in heated warehouses and 6 months under field conditions without direct effect of atmospheric precipitates and the sun's rays	It is packed in jars with a capacity of up to 1 *l* and in 100 g tubes. It is applied without melting
	Drop point, °C, not below	200		
	Viscosity at −50°C and gradient of rate of deformation of 10 s^{-1}, poise, not more than	8000		
	Tensile strength at 50°C, gf/cm^2, not less than	2		
	Penetration at 25°C	280-360		
	Colloidal stability, %, not more than	7.0		
	Free bases, %, not more than	0.08		
	Water and mechanical impurities	Absent		

Hermetic Sealing Lubricants

91. Vacuum lubricant, GOST 9645-61

Natural rubber	15	Yellow to dark brown uniform sticky grease with structure	For sealing movable glass and metal joints of vacuum equipment	It is packed according to GOST 1510-60 in 100 g tubes, glass jars with screw-on lids and in tin cans with a capacity of 100, 250, 500 and 1000 g
Ceresin of all grades (except grade 57)	20	Drop point, °C, not below 50		
Mineral oil with a viscosity of [illegible]-120 cSt at 50°C and with a flash point of no lower than 234°C	Remainder to 100%			

92. MGS sealing lubricant, MRTU 12N No. 91-64

Barium soap of stearic acid	4[illegible]	Gray vaseline-like mass		For sealing gaskets, stopcocks and threaded joints of pipe lines along which alcohol, glycerin, water and air are pumped, as well as for lubricating ball bearings which operate with a very variable number of revolutions at velocities of up to 6000 r/min	It is packed in tin cans. It is applied without melting
Transformer oil	Remainder to 100%	Drop point, °C, not below	110		
		Penetration:			
		at 25°C	260-330		
		at 75°C, not more than	360		
		at 60°C, not more than	40		

93. Liner (VK) lubricant, GOST 5078-49

Sodium soap of hydrogenated fat	16	Dark uniform oily grease		For lubricating joinable surfaces of steel pipes and the threads of articles which are subjected during operating to periodic heating to a temperature of 200-300°C. It provides a thin joint of connected surfaces and screwing of lubricated threads at temperatures to -40°C. It protects lubricated joints against corrosion well	It is packed in 20 l tin cans. It is applied without heating by smearing
Graphite P	17	Drop point, °C, not below	150		
Industrial oil 20	Remainder to 100%	Penetration at 25°C	220-270		
		Free bases, %, not more than	0.1		
		Free organic acids	Absent		
		Water	Absent		

94. Projectile (VS) lubricant, GOST 3260-54

Terminal castor oil	8	Light yellow to light brown uniform grease		For lubricating the threads of articles stored up to 10 years at temperatures from −50 to +40°C (point under fuse and empty bushings of shells and mines)	It is packed in barrels with a capacity of up to 200 *l* and in cans with a capacity of up to 20 *l*. It is applied without heating and melting
Technical hydrogenated fat	8	Drop point, °C, not below	70		
Building lime	From calculation to complete saponification	Penetration at 25°C	230-280		
		Free bases, %, not more than	0.2		
		Free organic acids	Absent		
Industrial oil for high-speed L mechanisms (velosite) with a pour point no lower than −35°C	Remainder to 100%	Mechanical impurities, %, not more than	0.3		
		Ash content, % not more than	2.0		
		Water, %, no more than	2.0		

95. Gasoline resistant (BU) lubricant, GOST 7171-54

Zinc soap of castor oil	30	Uniform light yellow to dark brown paste		For sealing joints of gasoline pipes, hermetic sealing of stopcocks and threaded joints of engine fuel and oil systems; it is used in aviation. At low temperatures it is diluted with ethyl alcohol (up to 25% is added)	It is packed in 20 *l* tin cans. It is applied by smearing
Glycerin	4	Drop point, °C, not below	55		
Technical castor oil, oxidized	Remainder to 100%	Penetration at 25°C	130-200		
		Solubility in mixture of 85% gasoline and 15% benzene, %, not more than	20		
		Water, %	0.3-2.0		

96. Pump lubricant, MRTU 12N No. 98-64

Oxidized castor oil	57.7	Dark gray to black uniform grease-like oily sticky mass		For packing and hermetic sealing of air-hydraulic pumps which pump mineral oil and water-glycerin-alcohol mixtures; for lubricating bearings of oil-transferring pumps and other apparatus. It provides operation of special pumps at temperatures from -60 to 130°C	It is packed in 20 *l* tin cans. It is applied by smearing and by filling lubricators with a gun
Dry grades S-1 and S-2 colloidal graphite preparations	42.0	Drop point, °C, not below	140		
Lithium stearate	0.3	Penetration at 25°C	300-350		
		Solubility in MVP oil and liquid steol M at 50°C	Does not dissolve		

97. LZ-188, lubricant, TU TNZ No. 123-62

AU axle oil	50.4	Light yellow to dark yellow grease		For packing and hermetic sealing of spigots of gas mains. It provides air-tightness of stopcocks at pressures up to 40 at and temperatures from -30 to 130°C	It is packed according to GOST 1510-60. It is applied without melting by smearing
MS-20 oil	16.8				
Castor oil	10.5	Drop point, °C, not below	140		
Technical stearin	7.1	Penetration at 25°C	240-320		
Rosin	0.7				
Sodium hydroxide	2.4	Free bases, %, not more than	0.2		
Potassium hydroxide	0.5	Test for corrosion on steel for 72 h	Passes		
Ground mica	11.6				

98. Sealing lubricant No. 15, TU NP No. 26-62

Bakinskiy PK petrolatum	40	Thick brown grease		For lubricating the plugs of switch cocks and chokes of braking devices which operate at temperatures from −50 to +55°C	It is packed in tin cans with a capacity of up to 1 *l*. It is applied by smearing
Ceresin grades 75 and 80	35	Drop point, °C, not below	60		
Special petroleum oil (260-320° C fraction)	25	Penetration: at +25°C, not below	135		
		at −50°C, not below	65		
		Water soluble acids and bases	Absent		
		Water	Absent		
		Mechanical impurities, %, not more than	0.02		

99. No. 1 sealing lubricant, VTU 473-53

Ceresin 80	Parts by weight	Solid brown mass		For sealing gaskets, regulating valves and level gages which come into contact with chlorine and chemicals at temperatures from 23 to 52°C	It is packed according to GOST 1510-60. It is applied by smearing
Paraffin	18	Drop point, °C, not below	45		
Petrolatum	10				
Potassium hydroxide	68				
	0.16				

100. No. 2 sealing lubricant, VTU 473-53

Sodium soap in fish oil	Parts by weight: 58	Solid soap Drop point, °C, not below	85	For sealing gaskets, regulating valves and other joints which come into contact with natural and industrial gases, gasoline, petroleum and organic solvents within temperatures from 17-80°C	It is packed according to GOST 1510-60. It is used as a cement or impregnation
Sodium soap in hydrogenated whale oil	14				
Glycerin	23				
Ground mica	7				

101. No. 3 sealing lubricant, VTU 473-53

Sodium soap in hydrogenated fat	Parts by weight: 36	Light brown to dark brown grease Drop point, °C, not below	100	For sealing gaskets, regulating valves and other joints which come into contact with natural and industrial gases at a temperature of 7-97°C	It is packed according to GOST 1510-60. It is used without melting
Industrial oil	58				
Ground mica	2.0				

102. No. 4 sealing lubricant, VTU 473-53

Calcium soap in castor oil	55	Light brown thick sticky grease Drop point, °C, not below	75	For sealing gaskets, regulating valves and other joints which come into contact with water and oil mixtures; for drains at high pressures and temperature of 4-85°C	It is packed in crates. It is used without heating
Technical castor oil	30				
Mountain wax (montan wax) or a mixture of ceresin with beeswax	10				

103. No. 5 sealing lubricant, VTU 473-53

Aluminum soap in montan wax	Parts by weight: 64	Thick sticky grease		For sealing gaskets, regulating valves and level gages which come into contact with hot petrcleum, gases, bitumens and live steam at temperatures of 176-260°C	It is packed in crates. It is used without melting. It is applied by smearing
Technical castor oil	33	Drop point, °C, not below	120		
Ground mica	8				

104. Lubricant No. 54, RTU RSFSR NP 28-62

Technical castor oil	19	Dark gray almost solid mass		For sealing cork stopcocks with pneumatic drive mechanisms which operate in hydrocarbon media (benzene, kerosene); provides air-tightness of stopcocks in "closed" position at temperatures from −10 to +100°C	It is supplied in the form of briquets with a weight of up to 100 kg, wrapped in parchment paper
Sodium hydroxide	0.6	Drop point, °C, not below	120		
Building air lime	1.9	Penetration at 25°C, not below	150		
Laminated graphite	6.0	Test for steel corrosion	Passes		
Ground mica	35				
Oxidized castor oil	Remainder to 100%				

105. Lubricant for gas cocks, MRTU 12N No. 97-64

Castor oil saponified with calcium oxide	97	Dark yellow thick grease		For lubricating stopcocks installed in gas lines. It is replaced by lubricant LZ-188	It is packed according to GOST 1510-60. It is applied without melting by smearing
Water	3	Drop point, °C, not below	60		
		Penetration at 25°C (without mixing), within (stipulated upon ordering): a)	45-70		
		b)	90-115		
		Water, %, no more than	3.5		
		Test for steel corrosion	Passes		

106. Lubricant for threaded joints, MRTU 12N No. 103-64

MVP oil	14	Dark yellow thick grease		For hermetic sealing of threaded joints of drive pipes used in the petroleum extracting industry	It is packed in 2-3 *l* tin cans, grooved around the edges. It is applied by smearing without melting
Graphite P	18	Penetration at 20°C (without mixing)	280-400		
Lead powder	29				
Copper powder	4				
Zinc dust	12				
Composition base: aluminum stearate (20%) 50 04 45 industrial oil (80%)	Remainder to 100%	Maximum shear strength at 30°C, gf/cm^2, gf/cm^2, not more than	120		

107. ZZK-2u protective adhesive cement, MRTU 38-1-201-66

Aluminum soaps of C_{16}-C_{18}	18	Dark brown uniform thick mass		For hermetic sealing of seams of various machines and cabins during prolonged storage	It is packed in 20 *l* tin cans. It is applied with a spatula without melting
Petrolatum	26	Drop point, °C, not below	100		
SK-45 synthetic rubber	0.5	Penetration at 25°C	40-60		
12 industrial oil	1.9	Test for copper corrosion	Passes		
52 cylinder oil (lubricating oil for steam engines)	Remainder to 100%	Water	Absent		

Vaselines

108. Medical vaseline, GOST 3582-52

Mixture obtained by fusing purified petrolatum sulfate with medicinal oil or with a mixture of perfume and medicinal oils	White or yellow odorless uniform stretched grease with short threads. When smeared on glass produces a uniform nonslipping and nondecrepitating film		For medical purposes — lubrication of skin and preparation of various therapeutic pastes, creams, greases, pomades, rouge, etc. In the textile industry for preparation of emulsion compounds used in wetting silk fabrics	It is packed in 20 *l* tin cans or in wooden barrels with a capacity of not more than 200 *l*
	Drop point, °C, not below	37-50		
	Viscosity at 60°C, cSt, not less than	16.0		
	Acid number, mg KOH per g	0.28		
	Fats, resins, sulfur compounds, water and foreign substances	Absent		

109. Medicinal vaseline for agriculture, MRTU 12N No. 116-64

It is prepared by fusing paraffin or petrolatum with highly purified mineral oil	White to light brown uniform grease (without lumps) without kerosene odor		For lubricating animal udders and during artificial insemination	The same
	Drop point, °C, not below	37-50		
	Acid number, mg KOH per g	0.28		

Lubricants for Leather

110. Leather emulsifying paste, GOST 5344-50

SZhK sodium soap	35-40	Light yellow to brown uniform paste-like mass		For emulsifying fatty mixture used in lubricating leathers	It is packed according to GOST 1510-60
Unsaponified residue of oxidized substance, not more than	15	pH of 2% emulsion	7-8.2		
Water, not more than	20	Stability of 5% emulsion: oil given off in 2 h, %, not more than	1		
20 or 20B industrial oil	Remainder to 100%				

111. Munitions lubricant, GOST 2649-52

Mineral oil with viscosity at 50°C of not less than 19 cSt	40	Yellow to dark brown uniform grease		For protecting metal components of munitions against corrosion and for softening leather parts of munitions	It is packed in 100 l wooden barrels. It is applied without melting
Grades I and II whale oil	20	Drop point, °C, not below	45		
Petrolatum	Remainder to 100%	Viscosity at 60°C, cSt, not less than	30		
		Test for steel corrosion	Passes		

Instrument Lubricating Oils

OKB-122 instrument lubricating oils are mixtures of silico-organic liquids and mineral oils of a high degree of purity. They are used for lubricating instrument bearings and friction joints which operate at low temperatures and for the preparation of low-temperature OKB-122 instrument oils. Five grades are produced (see Table 12.30).

TABLE 12.30

Properties of Instrument Oils

1 Показатели	2 Марка масла				
	ОКБ-122-2	ОКБ-122-4	ОКБ-122-7	ОКБ-122-14	ОКБ-122-18
3 Плотность ρ_4^{20}	0.930–0.940	0.940–0.960	0.960–0.970	0.970–0.980	0.960–0.980
4 Вязкость кинематическая при 50° С, сст	11–14	11–14	18–23	22.5–28.5	19–25
5 Температура вспышки (в открытом тигле), °С, не ниже	160	160	170	170	170
6 Температура застывания, °С, не выше	–65	–70	–70	–70	–70
7 Кислотное число, мг КОН на 1 г, не более	0.2	0.2	0.25	0.25	0.25
8 Вода	9 Отсутствует				

1) Properties; 2) grades of oil; 3) density ρ_4^{20}; 4) kinematic viscosity at 50°C, cSt; 5) flash point (in open crucible), °C, not below; 6) pour point, °C, not above; 7) acid number, mg KOH per g, not more than; 8) water; 9) absent.

Oils and Lubricants for Clockworks

Special oils and lubricants are used for lubricating clockworks and instruments analogous to them. The principal lubricating oils and their properties are presented in Table 12.31. The oils MPB-12, MZP-6, MTs-3 and MChM-5 are used for clockworks operating under ordinary conditions; for mechanisms which operate in the open air at low temperatures the oils MN-30, MN-45 and MN-60 are used. For clocks designed for operation in countries with a tropical climate, the oils MChT-3 and MPT-2 which contain an antiseptic which prevents the development in them of the spores of various fungous organisms and microorganisms (bacteria) are used. These oils are tested for moisture resistance and chemical stability by the method set forth in GOST 7934-56.

TABLE 12 31

Properties of the Principal Lubricating Oils for Clock Mechanisms

Properties, units of measurement	Clock oils, GOST 7935-56			Krasnodarskiy SNKh oil TU 13-58	Low temperature clock oils, GOST 8781-58			Clock oils for use in countries with tropical climates, STU 25-734-62	
	MPV-12	MZP-6	MTs-3	MChM-5	MN-30	MN-45	MN-60	MChT-3	MPT-3
Principal components	Mixture of fats with esters		Mixture of fats with mineral oils	Mixture of fats with esters					
Principal purpose	For lubricating wristwatches, the connections of electric meters, hydrometeorological and other scientific instruments, camera mechanisms, etc.		For lubricating large clocks, tachometers, kymographs, etc.	For small clocks of the "Zarya" type	For clocks and instruments operating at low temperatures				
External appearance, color	Uniform transparent yellow or light brown liquid			Yellow to light brown transparent oil	Uniform transparent yellow or light brown liquid			Uniform transparent yellow liquid	
Specific viscosity at 20°C	-	-	-	6.5-7.5	-	-	-	-	-
Ratio of specific viscosity at 20°C to viscosity at 50°C, not above	-	-	-	2.8	-	-	-	-	-

TABLE 12.31 (Cont'd)

Kinematic viscosity, cSt									
at +50°C	19-22	23-26	26-30	-	22-23	15-16	11-12	22-25	30-35
at +20°C	-	-	-	-	76-80	47-50	33-35		
Dynamic viscosity, poise, not more than:									
at -30°C	-	-	-	-	30.0	Not standardized		-	-
at -50°C	-	-	-	-	Not standardized	100.0	Not standardized	-	-
at -60°C	-	-	-	-	Not standardized		33.0	-	-
Increase in viscosity during oxidation in a thin layer, %, not more than	3.0	4.0	2.0	2.0	1.0	1.0	1.0	-	-
Acid number, mg KOH per g of oil, not more than	0.18	0.18	0.18	0.30	0.30	0.25	0.30	0.25	0.25
Evaporability, %, not more than	0.20	0.20	0.20	0.18	0.20	0.20	0.20	0.20	0.20
Wettability, %, not more than	0.5	0.5	0.5	1.0	0.50	0.65	0.75	1.0	1.0
Mechanical impurities and water				Absent					
Water soluble acids and bases				Absent					
Pour point, °C, not above	-20	-20	-15	-25	-40	-52	-67	-18	-15

TABLE 12.31 (Cont'd)

Temperature at which mobility of oil is retained, °C, not above	-	-	-	-	-30	-45	-60	-	-
Test for corrosive aggressiveness on steel and brass (according to OOST 7934-56)		Pass				Pass; darkening of brass to light brown color is permitted			

TABLE 12.32

Clock and Instrument Lubricating Greases

Properties, units of measurement	Plastic lubricants			Colloidal lubricants, VTU NIICasprom 1212-62		
	RS-1	PS-4	RST-3, STU 25-734-62	KS-20	KS-22	KS-25
Principle components	Petroleum oil with addition of bone oil			Suspension of MoS_2 in mineral oil	Suspension of MoS_2 in oil	Suspension of MoS_2 in oil
Principle purpose	For lubricating clock plant and conveyer mechanisms and lever gears of miniature instruments	For lubricating clock springs	For lubricating mechanisms operating in countries with tropical climate	For lubricating instruments and technical clocks		
External appearance, color	Uniform (without lumps and unthickened oil) grease-like mass; on melting – uniform transparent liquid		Uniform (without lumps and unthickened oil) grease-like mass	Black oily liquid; phase separation is permitted with the condition that the uniformity of the suspension is reestablished upon mixing		
Kinematic viscosity, cSt						
at 50°C	–	32-36	–	–	–	–
at 70°C	15-19	15-18	15-19			
Dynamic viscosity at 20°C, poise	–	–	–	2.0-2.5	2.2-3.0	1.8-2.0

TABLE 12.32 (Cont'd)

Drop point, °C	39-45	-	39-45	-	-	-
Pour point, °C, not above	-	-	-	-65	-65	-25
Acid number, mg KOH per g, not more than	0.8	0.4	0.8	0.20	0.20	0.15
Water soluble acids and bases			Absent			
Evaporability, %	Absent		-	Not above 0.10	Not above 0.10	Not above 0.07
Wettability	Absent		-	-	-	-
Mechanical impurities and water			Absent			
Colloidal stability at 3000 r/min (according to GOST 7934-56, Section IV)	-	Withstand 30 min	-	-	-	-
Test for corrosive aggressiveness on steel and brass plates (according to GOST 7934-56, Sec. V)			Passes			
Content of molybdenum disulfide, %, not less than	-	-	-	15	15	15
Test for degree of dispersion: settling, min, not less than	-	-	-	60	30	15
Microbiological resistance at temperature of 30°C for 21 days, %, not less than	-	-	100	-	-	-

TABLE 12.33

Epilams – Liquids for Treating Components of Clock Mechanisms to Prevent Spreading of Lubricating Oils (VTU NIIChasprom)

Properties	Grades		
	EN-3	EN-4s	EN-5s
External appearance, color	Mobile transparent colorless liquid	Mobile transparent yellow or light brown liquid	
Fractional composition: 97% distilled at temperature, °C, not above	100	80	80
Acid number, mg KOH per g	0.06-0.10	0.06-0.10	0.06-0.10
Refractive index at 20°C, not above	1.3890	1.3700	1.4590
Test on steel polished plate	Complete evaporation of liquid; slight white deposit remains at site of evaporated drop		
Test for corrosive agressiveness on steel and brass plates, three days at room temperature	Traces of corrosion absent		
Water soluble acids and bases	Absent		
Mechanical impurities and water	Absent		

The principal properties of clock and instrument lubricating greases, general purpose RS-1 and PS-4 and RST-3 for instrument and clock mechanisms intended for operation in countries with a tropical climate are presented in Table 12.32; the latter contains an antiseptic additive.

The colloidal lubricants KS-20, KS-22 and KS-25 are designed for lubricating mechanisms in which great abrasion of the friction components is possible. They all contain about 15% of finely ground molybdenum disulfide which decreases friction and abrasion of the friction components.

The quality indexes of epilams – liquids used for treating the components of instruments and clock mechanisms to prevent spreading of the oils and lubricants from the friction joints are presented in Table 12.33.

5. THE COMPATIBILITY OF LUBRICANTS OF DIFFERENT COMPOSITION

The compatibility of lubricants is of great practical importance since during the operation and storage of mechines and mechanisms it is frequently necessary to solve the problem of the pos-

sibility of replacing one lubricant by another, while it is not always possible to remove the first without complete dismantling of the joint, which can lead to impairment of normal operation and even damage to the article. Moreover, the dismantling and assembly of complex modern machines and instruments is expensive and requires the expenditure of skilled labor, whereas replacement of the lubricant without dismantling joints and mechanisms of machines usually is not difficult and can be performed by the people who operate them.

Hydrocarbon lubricants almost without exception can be coalesced and combined in unmelted form; mixtures of them do not separate upon cooling. The mixing of such lubricants as gun, technical vaseline, PVK, SKhK, etc., as well as the addition to them of an additional amount of thickening agents (which is sometimes practiced for the purpose of increasing the drop point, increasing the thickness, eliminating slipping, etc.), although it is possible, is not recommended. The formulas of lubricants PVK, SKhK and GOI-54p have been well developed and tested; there is no need to add more ceresin or oxidized petroleum products to them. It is sometimes expedient to mix gun lubricant with PVK lubricants, fusing them in equal amounts, for example, if it is necessary to use the available store of gun lubricant and the mixture will be used to protect articles against corrosion which are stored in an area with a moderate or cold climate where there is no danger of slipping of the layer at temperatures above 45°C.

When hydrocarbon lubricants prepared in different plants from different raw material are mixed the mixtures which are formed can have decreased qualitative indices. It is particularly dangerous to use such mixtures for preserving articles for prolonged storage since the mixed lubricant layer can decrepitate, peel off the covered metal and slide. This sometimes occurs due to undesirable recrystallization of solid hydrocarbons in the mixture and reduction of the volume of the lubricant during recrystallization of its components. Paraffin should not be added to hydrocarbon lubricants since it imparts to the mixture a tendency to decrepitate, especially at a low temperature. All such mixtures should be tested before use.

Lubricant GOI-54p (GOI-54) should not be mixed with gun and PVK and SKhK lubricants since in this case it loses its low temperature properties.

However, not all mixtures of hydrocarbon lubricants have decreased properties. For example, a mixture of 1 part by weight of gun lubricant and 1 part by weight of rifle lubricant (GOST 3045-51) is recommended for preserving rifles during prolonged storage. Mixtures of gun lubricant or PVK lubricant with AU axle oil are used in the operation of ship mechanisms. A mixture of 30% AU axle oil and 70% PVK lubricant possesses good protective properties.

The overwhelming majority of hydrocarbon lubricants are not compatible with saponaceous lubricants; as a rule, they damage saponaceous lubricants, considerably changing their characteristics.

The mixing of various grades of greases and of fatty grease

with synthetic is entirely possible and does not lead to any deviations in the operation of the lubricated friction joints. By mixing calcium and lithium lubricants, products with intermediate properties are obtained. A mixture of grease with lubricant TsIATIM-201 has a minimum tensile strength at a content of 75% grease in the mixture. However, it is entirely possible to mix greases with lithium lubricants. This makes it possible to replace greases having a low melting point and comparatively poor low-temperature properties with lithium lubricants which possess considerably better high and low-temperature properties. It is possible to carry out this replacement without dismantling the joints.

From mixing greases with konstalin, mixtures with poorer properties than those of the original lubricants are obtained.

The viscosity characteristics of mixtures of sodium and lithium lubricants changes monotonically with a change in composition. The addition of a small amount of konstalin to lubricant TsIATIM-201 leads to an increase in the tensile strength, while the other properties change only slightly.

The mixing of monotypic lubricants, as well as of fresh and depleted lubricants is entirely permissible. The combining of nonmonotypic lubricants, each of which separately can provide normal operating conditions, for example, of rolling bearings, is not permissible and can lead to breakdown due to flowing out and casting off of the lubricant mixture from the effect of mechanical deformation. Mixtures of lubricants 1-13 and 1-13s, TsIATIM-201 and 1-13, US-2 and 1-13s behave in this way. Loss of efficiency of the indicated nonmonotypic lubricants after their combing causes a sharp deterioration in the initial mechanical characteristics (tensile strength, effective viscosity, thixotropic properties) and an almost irreversible loss of plasticity from the effect of the mechanical deformation.

When a lubricant is added to roller and ball bearings, its mixing with the old lubricant even during intensive operation occurs very slowly. Therefore, it is necessary as far as possible to take measures to displace the old lubricant from the friction joint by pumping and other methods.

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Manuscript Page No.	Transliterated Symbols
765	ГОСТ GOST = Gosudarstvennyy obshchesoyuznyy standart = All-Union State Standard
765	ТУ = TU = technicheskiy usloviya = technical specifications
766	МИНХИГП = Moskovskiy institut neftekhimicheskoy i gazovoy promyshlennosti = Moscow Institute of the Petrochemical and Gas Industry
770	ВТИ = Vsesoyuznyy Teplotekhnicheskiy Institut = All-Union Heat Institute
771	ЦИАТИМ = TsIATIM = Tsentral'nyy nauchno-issledovatel'skiy institut aviatsionnykh topliv i masel = Central Scientific Research Institute of Aviation Fuels and Lubricants
781	МРТУ = MRTU = mezhrespublikanskiy usloviya = provisional technical specifications
816	ВНИИ НП = VNII NP = Vsesoyuznyy sauchno-issledovatel'skiy institut po pererabotke nefti i gaza i polucheniyu iskusstvennogo zhidkogo topliva = All-Union Scientific Research Institute of Oil and Gas Processing and Production of Artificial Liquid Fuel
821	МПС = MPS = Ministerstvo putey soobshcheniya = Ministry of Railroads
828	МЗ = MZ = maslo zimnee = winter oil
829	ВУ = VU = vyazkost' uslovnaya = conventional viscosity
870	НП NP = Nafte produkty = petroleum products
872	РТУ = RTU = Respublikanskiye Tekhnicheskiye Usloviya = Republican Technical Specifications
872	РСФСР = RSFSR = Rossiyskaya Sovetskaya Federativnaya Sotsialisticheskaya Respublika = Russian Soviet Federated Socialist Republic
880	НИИЧаспром = NIIChasprom = Nauchno-issledovatel'skiy institut chasovoy promyshlennosti = Scientific Research Institute of the Watch Industry