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LUBRICATING AND PROTECTIVE MATERIALS

by

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ABSTRACT: ~~This~~ monograph presents the basic properties, test and preparative methods, and ~~also~~ applications ~~for~~ lubricant and protective paints and lacquers required in the railroad industry. Compared with the second edition, this edition provides additional information on synthetic oils, greases, new synthetic polymeric paints and lacquers, and also detergents and polishing compositions. The monograph was approved by the State Administration for Educational Institutions of the Ministry of Transport as a textbook for rail transport technical schools and can be used by a wide range of workers who are connected with painting and lubrication of rolling stock.

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English translation: 140 pages.

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SAMZOCHNYYE I ZASHCHITNYYE MATERIALY

Izdaniye tret'ye
pererabotannoye i dopolnennoye

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TABLE OF CONTENTS

PART ONE. Lubricants

PART TWO. Protective Materials

In the book there are given basic properties, methods of production and testing and also order of application of lubricants and protective varnish and paint materials used in railroad car economy. As compared to second the third publication of book is supplemented by information on synthetic lubricating oils, grease lubricants, new synthetic polymer varnish and paint materials, and also cleansing agents and polishing pastes.

Book is approved for central administration by educational institutions of Ministry of Railroads (MPS) as a textbook for technical schools of railroad transportation and can be used by a wide circle of railroad workers, connected with painting and lubrication of rolling stock.

INTRODUCTION

Application of lubricants and paint and varnish materials was started in very ancient times.

Many milleniums ago for adornment of dwellings and prolonged preservation of articles pigments were used and it was known that surfaces lubricated by fatty products slide and are rolled easier than unlubricated.

Lubricants and varnish and paint materials started to be applied especially widely in the past century, when there appeared the necessity of lubricating the axles of wheels of railroad cars, locomotives, steam engines, machines, and also of painting rolling stock, buildings, bridges, and other constructions, which in turn required creation of a wide assortment of corresponding materials.

Systematic study of processes of friction and the role of lubricants in them gave scientific basis for the search and selection of necessary lubricating materials. Priority in the development of teaching the role of lubricants and production of lubricating oils from petroleum belongs to representatives of Russian science — the creator of hydrodynamic theory of friction N. P. Petrov and the great chemist D. I. Mendeleyev.

The study of paints occupied the great scientist M. V. Lomonosov, and also many other Russian researchers. D. I. Mendeleyev created a new form of varnish and paint nitrocellulose materials, which are widely applied at present.

The universal usage of natural drying oils, natural and synthetic resins, bitumens, and also production of polychromatic pigments from minerals and creation of organic dyes led to the development of science of varnish and paint materials.

Lubricants and varnish and paint materials possess a considerable community of properties:

basically are organic compounds, which in initial form can be in liquid or solid state;

able to form thin, but sufficiently durable films on surface of metals and other materials;

are intended for extension of service life of machines, mechanisms and different articles.

At the same time they essentially differ from each other with respect to many properties and assignment.

Lubricating materials, forming undrying films, are applied mainly in friction units for easing of shift of frictional elements and decrease of their wear, and also protection from corrosion and other damages, reducing their service life.

Part of the lubricating materials (protective lubricants) is used for protection of metallic articles from corrosion in period of storage in storehouses or during preservation.

Varnish and paint materials in contrast to lubricants will form drying films. These materials are intended for protection of buildings and constructions from aggressive actions of environment (metallic articles and constructions — from corrosion, wooden — from rotting, stone — from weathering, etc.). Paint gives a beautiful view and required color to constructions and mechanisms and promotes safeguard of necessary sanitary and hygienic conditions.

On the correct selection, rational application of lubricating materials, and standard organization of lubricating economy to a considerable degree depends effective usage of rolling stock and equipment of railroads.

During selection of lubricants for mechanism or unit of friction special attention is paid to its viscous-mechanical and anticorrosion properties. Increase of viscosity, for example, of axle oil in boxes of railroad cars of a train strengthens the resistance to rotation of wheels and leads to increase of power expenditure by the locomotive. Such dependence is approximately observed in rolling stock equipped with boxes with roller bearings.

Application in railroad-car boxes of lubricating materials of high quality contributes to:

decrease of wear of frictional surfaces;

elimination of cases of dry friction, and also damage of bearings, and in connection with this increase of safety control of movement of trains;

lowering of resistance when starting the stock from a place and with its movement, by which there is attained large fuel or electric energy economy on locomotive;

travel at high speeds;

easing of operating conditions of coupling equipment and therefore the possibility of driving trains of great weight.

Railroads are the biggest consumer of lubricants and varnish and paint materials. To ensure normal operation of only rolling stock there are consumed hundreds of thousands of tons of high-quality axle oils, grease lubricants, and varnish and paint materials yearly.

In connection with this the correct use and the strictest saving of lubricants and varnish and paint materials in the railway industry have paramount value.

Varnish and paint materials are destroyed with time under the influence of rain, snow, hail, hoarfrost, fog, smoke, sand, dust, solar rays, and mechanical influences, which leads to corrosion of metal and rotting of wood if the paint is not renewed in good time.

In railroad cars because of damage of protective coatings the most characteristic corrosion defects are destruction of roof along ridges and welds, supports in places of contact with wood, and metal facing of floor. In isothermal railroad cars the destruction of such facing with insufficient protection can occur at the rate of 0.14-0.16, and in passenger cars — 0.08-0.10 mm/year with respect to thickness of metal. Frames of railroad cars with detachable body are damaged especially strongly, where destruction for passenger cars can reach 0.2-0.3, and for isothermal — 0.3-0.6 mm/year.

Corrosion of parts of rolling stock is a result of chemical or electrochemical processes.

In tank cars, and also reserviors for acids, oil products, and dry gases it occurs as a result of dissolution or oxidation of metal (chemical process).

Metal parts, touching electrolytes (water, solutions of acids, alkalis, and salts), atmosphere of air, etc., corrode due to electrochemical processes, theory of which is developed by Soviet scientists V. A. Kistyakovskiy, N. A. Izgaryshev, G. V. Akimov, and others. Especially dangerous are damages induced by simultaneous influence of corrosion and mechanical factors. Such damages are called corrosion fatigue.

In the Soviet Union, including railroad transportion, to questions of the struggle with metal corrosion and wood rotting there is allotted much attention. Considerable successes in this struggle are attained thanks to transactions of Soviet scientists Ye. N. Orlov, A. A. Sapozhnikov, I. A. Tselikov, A. Ya. Drinberg, G. S. Petrov, V. S. Kiselev, S. G. Vedenkin, and others.

Reliable contemporary means of protecting parts from corrosion, rotting, and wear are, along with natural, many new synthetic varnish and paint materials and lubricating oils. For production and use of these new materials there are developed highly productive technological processes with wide application of various mechanisms, equipment, and attachments. Mastering of synthetic paints and lubricants, their correct selection and use will enable us to extend the service life of rolling stock and many parts of equipment.

In this textbook there is given necessary information on technology of producing corresponding lubricants and protective materials, and also on their rational application in railroad car economy.

Third publication is revised and supplemented in connection with changes of conditions of usage of rolling stock occurring in recent years (increase of speeds, loads, and nonstop runs), and also in view of the rapid development of chemical industry in our country. In it there is considerably expanded information on synthetic lubricating oils, grease lubricants, and improving lubricating oils of chemical additions to them (additives); there are shown means of mechanization of reduction of lubricating and protective materials; there is given information on new synthetic polymer varnish and paint materials; there is added a section on washing agents and polishing pastes, applied when equipping railroad cars in process of operation.

Textbook is compiled in accordance with program of course "Lubricating and protective materials" for technical schools of railroad transportion.

PART ONE

LUBRICANTS

C H A P T E R I

FRICTION: BASIC PROPERTIES OF LUBRICANTS

§ 1. Concepts of Friction

Friction — special type of interaction of solids, appearing on contact surfaces and appearing during their relative motion on each other in the form of resisting forces, called frictional forces. Friction depends on many reasons and is caused by mechanical and energy resistance, and also by molecular attraction.

Surface of any part, experiencing friction, is not ideally smooth, but consists of a great number of cavities and protrusions, amounts of which after machining or grinding usually oscillate within limits from 0.01 to 0.0001 mm. Engagement of protrusions of one frictional surface against protrusions of another creates mechanical resistance to relative movement of these surfaces (Fig. 1).

Fig. 1. Diagram of contact of rough surfaces in magnified form.

At points a of direct contact of surfaces there appear, furthermore, forces of molecular attraction, very great, but effective in radius of thousandths of a micron (0.000001 mm). Under action of these forces the molecules of one surface are so strongly attracted to molecules of the other that destruction of bond frequently occurs not along the line of contact, but between molecules of one surface. This creates resistance to molecular cohesion.

In the process of friction of solids there occurs absorption of mechanical energy by microvolumes of surface layer, as a result of which in frictional surfaces there appears change of electric potentials. This indicates the presence of power component — resistance, combined with elementary electrical processes in common value of friction. Specific gravity of some component or another in value of frictional force can be noticably changed depending upon cleanness of treatment of frictional surfaces. With increase of cleanness of treatment, i.e., in proportion to decrease of protrusions and roughness of surface, their resistance to mechanical engagement decreases, but because of increase of number of points of contact the resistance to molecular attraction increases.

Everything stated pertains to a case when frictional surfaces are clean, dry, and nothing separates them. If, however, there is a thin film of liquid on them or they are completely separated by a layer of lubricant, then conditions of friction are changed in principle, and value of frictional force is decreased.

Friction is frequently used in technology as a useful factor for production of braking action (brake shoes and bands, check nuts, etc.) or in case of movement of locomotives and motor vehicles, carried out due to friction between rim of wheels and surface along which they roll (rails, asphalt). However, in many cases friction is harmful. First, on surmounting forces of friction there is expended part of the energy produced and imparted to body, graphic example of which can be gradual reduction of flight path (orbit) of artificial earth satellites, occurring especially due to their friction against rarefied gas in upper layers of the earth's atmosphere. Secondly, friction leads to wear of frictional surfaces, involving change of dimensions of parts and distrubance of normal operation of mechanisms.

§ 2. Types of Friction

For development of laws of friction and their use in technology we classify friction according to kinematic criterion, and also depending upon presence and thickness of lubricant film.

With respect to kinematic criterion we distinguish 4 types of friction: static, sliding, rotating, and rolling.

Static friction is with the absence of motion or at minute speeds of relative shift of surfaces.

Sliding friction is that friction with which the same point of surface of one body contacts new points of surface of another body during their mutual shift.

Rotating friction is a variety of sliding friction. When rotating, all points located in plane of contact of two bodies circumscribe concentric circumferences with the center, coinciding with pivoting axis.

Rolling friction is caused during rolling of one body by another, during which relative speed of points of contact of surfaces of both bodies is equal to zero, and points of contact change all the time.

Depending upon presence and thickness of lubricating film friction occurs dry, liquid, threshold, and mixed.

Dry is that friction with which between frictional surfaces there is no film of liquid, oxides, or similar materials to them. Static, sliding, and rotating friction conforms to generalized law, which is expressed by the following formula, offered by Prof. B. V. Deryagin:

$$F=f(P+Sp_0). \qquad (1)$$

where F – frictional force in kgf; P – normal load in kgf; S – area of true contact (at points of contact of both surfaces) in cm^2; f – true coefficient of friction; p_0 – specific pressure of molecular cohesion, depending on nature of touching surfaces, in kgf/cm^2.

From formula (1) it follows that at load P, equal to zero, frictional force does not disappear, since there remains force fSp_0, generated by molecular cohesion.

With very large loads, many times exceeding force of molecular cohesion, formula (1) takes the form in which it was offered as early as 1699 by Amonton,

$$F=fP. \qquad (2)$$

Coefficient of friction f = F/P is an abstract quantity, showing the connection between frictional force and normal load. It depends basically on material of frictional surfaces, which is clear from the following data.

Coefficients of sliding friction
for ground surfaces

Mild steel on steel.........	0.14
Cast iron on cast iron......	0.16
Bronze on bronze.....	0.20
Mild steel on bronze........	0.18
Cast iron on bronze........	0.21

Rolling friction in principle differs from the first three kinematic varieties. It appears during rolling of spheric or cylindrical bodies. If touching bodies are absolutely solid, then their contact would be carried out accordingly at point or on a straight line. However, all materials to some measure are elastic are deformed and during rolling of one body by another (Fig. 2). Therefore, for rolling of body to it there should be applied moment

$$M = QR, \qquad (3)$$

equal to moment of resistance

$$M_{\text{сопр}} = Pf'. \qquad (4)$$

where Q — force necessary for rolling of body, applied in its center, in kgf; R — radius of sphere or cylinder in m; P — normal load on rolled body in kgf.

With respect to analogy with sliding friction the coefficient of rolling friction

$$f' = \frac{M_{\text{сопр}}}{P} = \frac{QR}{P}, \qquad (5)$$

i.e., it is equal to value of arm, on which force P is applied, or to radius of dimple formed on support surface under the rolled body, and has linear measurement. Energy losses on rolling friction in comparable conditions are 15-20 times less than losses on sliding friction.

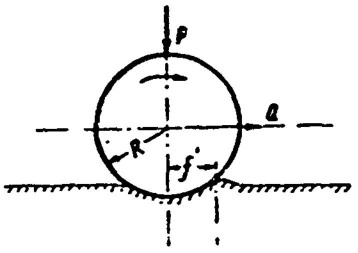


Fig. 2. Diagram of formation of resistance during rolling of elastic bodies.

Liquid friction is that friction at which frictional surfaces are completely separated by liquid (lubricant) and do not touch at any point, and friction occurs between layers of liquid. In process of liquid friction wear of frictional surfaces is eliminated because of absence of their contact. Therefore, from a technical point of view the creation of liquid friction in machines and mechanisms is advantageous. However, for its realization it is necessary that the lubricant separating frictional surfaces would possess special properties, and frictional parts would be of strictly determined form and operate in a definite range of loads and speeds.

Threshold friction is that friction at which frictional surfaces are separated by a very thin layer of lubricant, thickness is one or several rows of molecules, i.e., of order 0.01-0.10 μm (0.00001-0.0001 mm). Such thin layer of lubricant can be held securely on frictional surfaces only at certain chemical affinity of lubricating fluid and frictional surface. Ability of lubricating fluid to durably adhere to frictional surfaces and to consolidate their molecules near them, creating a so-called oriented consolidated layer (Fig. 3), is usually called oiliness. This property is determined by approximately the same physical and chemical regularities as wettability of liquids.

In usual mechanisms the height of roughness of frictional surfaces is 0.01-0.0001 mm. Consequently, values of protrusions are equal to or greater than thickness of film, forming due to oiliness, ensuring threshold friction. Therefore, threshold friction can occur practically purely only in small precise

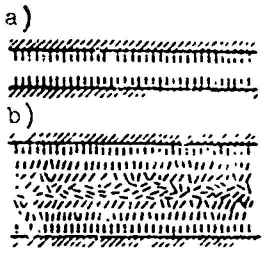


Fig. 3. Diagram of structure of oil layer: a) arrangement (orientation) of molecules in lubricant film at the surface of solid metallic bodies (on sections of surface with threshold friction); b) arrangement of molecules in thick oil layer (at liquid friction).

mechanisms (for example, watches) with very small and well fitted frictional surfaces.

In a considerable part of mechanisms and machines, especially in periods of their start, stop, or change of operating conditions, there is carried out <u>mixed</u> friction. With this type of friction part of the surface points touches directly and between them there occurs dry friction; in the part of points where surfaces approach to distance on the order of thousandths of a millimeter, there occurs friction, but on the remaining surface — liquid friction.

§ 3. <u>Basic Properties of Lubricating Materials and Hydrodynamic Theory of Lubrication</u>

It was stated above that for production of liquid friction the lubricant separating frictional surfaces should possess special properties. The first of these properties is oiliness, by virtue of which molecules of lubricant are durably held on frictional surface. These molecules, thanks to cohesion with other molecules of lubricant, attract them and tighten the gap between frictional surfaces. Internal friction of liquid, appearing with shift of its molecules under action of external force, is called viscosity. Viscosity is the second important property of any lubricating material. Depending upon method of its determination we distinguish absolute viscosity (dynamic and kinematic) and relative (arbitrary).

Depending upon the purpose, for which it is necessary to know the value of viscosity of liquid, it is defined in technical or physical units. Furthermore, in connection with the introduction into use in the Soviet Union of international system of units (All Union Governement Standard 9867-61) viscosity can be expressed both in this system and in that applied earlier.

Dynamic viscosity, or coefficient η of internal friction of liquid, is resisting force exerted by liquid to such shift of its particles, at which 2 layers of liquid with area 1 cm^2, located at 1 cm distance are shifted relative to each other under the influence of external force in 1 dyn at a rate of 1 cm/s.

Physical unit of dynamic viscosity is a poise. It has the following dimension:

$$1 \text{ poise} = \text{dyne}\,\frac{\text{s}}{\text{cm}^2} = \frac{\text{g-cm}}{\text{s}^2}\cdot\frac{\text{s}}{\text{cm}^2} = \frac{\text{g}}{\text{cm}\cdot\text{s}}.$$

Frequently in technical calculations for convenience there is used technical unit of dynamic viscosity $\frac{\text{kgf}\cdot\text{s}}{\text{m}^2}$. Between physical and technical units of dynamic viscosity there exists the following dependence:

$$1\,\frac{\text{kgf}\cdot\text{s}}{\text{m}^2} = 98.1 \text{ poise};\quad 1 \text{ poise} = 0.0102\,\frac{\text{kgf}\cdot\text{s}}{\text{m}^2}$$

According to the international system unit of measurement of dynamic viscosity is equal to Newton-second on a square meter and is designated by

$$\frac{1\ \mathrm{N}\cdot 1\ \mathrm{s}}{1\ \mathrm{m}^2},$$

where N — value of force with dimension

$$\frac{1\mathrm{kfg}\cdot 1\ \mathrm{m}}{1\ \mathrm{s}^2}.$$

Relationship between units of dynamic viscosity in the international unit system [SI](СИ) and old is equal to: 1 poise = 0.1 $\mathrm{N}\cdot\mathrm{s}/\mathrm{m}^2$.

However, at present there are still not developed methods of determination of force, dynamic and kinematic viscosity by international system of units (SI).

For unit of kinematic viscosity there is accepted Stokes, equal to value of relation of dynamic viscosity of liquid η to its density ρ at the same temperature. Stokes is expressed in the following units:

$$\frac{\mathrm{g}}{\mathrm{cm}\cdot\mathrm{s}} : \frac{\mathrm{g}}{\mathrm{cm}^3} = \frac{\mathrm{cm}^2}{\mathrm{s}}$$

In laboratory practice is used value centistoke (cSt), equal to 1/100 Stokes.

Unit of kinematic viscosity in international system of units is equal to a square meter per second and is designated by m^2/s.

Besides values of viscosity, expressed in absolute units, viscosity is sometimes measured in arbitrary units by different methods. In USSR for this there is accepted arbitrary viscosity [VU](ВУ) method according to GOST 6258-52, where viscosity is expressed by dimensionless relation of time of outflow of tested liquid through standardized opening at temperature of experiment to time of outflow of the same volume of water at 20°C.

Conversion of values of viscosity from arbitrary units into centistokes and conversely is produced by tables and formulas, placed in Appendex 2 for GOST 33-53. Furthermore, conversion can be produced by approximate formula

$$\nu_t = 10^{-4}\left(0{,}0731\,BY_t - \frac{0{,}0631}{BY_t}\right)\ \mathrm{m}^2/\mathrm{s},$$

where VU_t — value of arbitrary viscosity at temperature of experiment; ν_t — kinematic viscosity in cSt at the same temperature.

Viscosity of many liquids, lubricating oils in particular, is decreased with increase of temperature, and is increased with lowering of temperature. Degree of change of viscosity from temperature is different for various liquids.

For lubricating oils of petroleum origin the viscosity can be determined at any temperature, if its values at any two temperatures are known. For this there exists standard formula

$$\lg\lg(\nu_t + 0{,}8) = A + B\lg T,$$

where ν_t — viscosity in cSt at temperature t°C; T — absolute temperature, corresponding to t°C; A and B — constants for given oil.

By substituting known values of oil viscosity at any two temperatures in formula, we solve obtained equations as a system of two equations with two unknowns with respect to A and B. Having obtained values of these coefficients, we can determine viscosity of given oil at any assigned temperature.

For all mineral lubricating oils the viscosity, increasing with reduction of temperature, becomes so great that oil ceases to flow and loses mobility, and consequently also lubricating properties. This moment for each oil is determined by its solidification temperature.

Effect of viscosity of lubricating fluid on value of friction of conjugate surfaces and the difference between dry and liquid friction were investigated and proven for the first time by the prominent Russian scientist Prof. N. P. Petrov in 1883. Prof. N. P. Petrov established that in a case when journal and bearing are completely separated by a layer of lubricant, friction occurs in this layer and conforms to laws of hydrodynamics. Therefore, science of friction of well lubricated bodies acquired the name hydrodynamic theory of lubrication. In process of development this theory was turned into orderly, mathematically founded, and experimentally confirmed teaching.

In accordance with hydrodynamic theory of lubrication the coefficient of liquid friction is equal to (with some simplification)

$$\mu = \frac{\eta v}{h p_m}, \qquad (6)$$

where η – viscosity of lubricating material in kgf·s/m^2; v – speed of relative slip of frictional surfaces in m/s; h – thickness of layer of lubricant in m; p_m – average specific pressure in layer of lubricant in kgf/m^2.

Here and further in all formulas there are used dimensions in the earlier applied system of units in view of the absence of methods of determination of values of Newton, dynamic and kinematic viscosity, joule, watt, and others in international system of units (SI).

At comparison of formulas (1) and (6) of coefficients of dry and liquid friction it is clear that between them there exists a fundamental difference: if coefficient of dry friction depends only upon load, material and degree of cleanness of treatment of frictional surfaces, then coefficient of purely liquid friction is a function of lubricant viscosity, speed, geometric dimensions of frictional surfaces, determining thickness of layer of lubricant, and load, but does not depend on material of frictional surfaces.

For normal operation of frictional units of railroad cars (boxes, sliders, etc.), lubricating oils, besides oiliness and viscosity necessary for given unit, should satisfy another series of requirements. In oil the volatile parts should not be more than permissible, content of which is determined by flash temperature. At a considerable quantity of them oil in the process of operation in a box can be changed intensely and worsened. Content of water in oil should not exceed a very insignificant established norm since when water gets into oil the capillary conductivity and elasticity of padding materials, pads, and rollers are impaired. Furthermore, there is possible the appearance of corroding action of water on metal parts and increase of coefficient of friction. When water gets into axle oil in winter time it freezes and draws the pad downwards, by which normal supply of lubricant is disturbed.

Contamination of oil by different solid inclusions (mechanical impurities) also considerably worsens operating conditions of bearings. With thickness of lubricant film 5-10 μm even insignificant sand grain, getting between frictional surfaces, will destroy them; this can be accompanied by considerable temperature rise and fusion of babbit. Furthermore, mechanical impurities, filling pores in padding material and coolers of bearings, disturb the regular supply of oil under bearing.

Water-soluble acids and alkalis are inadmissible in lubricating oils because they, as a rule, cause corrosion destruction of metal parts.

In certain frictional units, in which it is difficult to organize continuous supply of lubricant or the lubricant should operate for a long time without replenishment and not flow out (for example, boxes of railroad cars with roller bearings or automatic brake devices), we apply not liquid oils, but thickened grease lubricants. The latter should have density (consistency) that is the most suitable for given of frictional unit so that lubricant would not flow out of bearing and at the same time would not create too much resistance. Besides it is important that all necessary properties of lubricant be preserved without change during the period of its prolonged operation.

Consistency of lubricant is determined on a special instrument — penetrometer and is expressed by penetration number. Degree of impermissible dilution of lubricant from increase of temperature is estimated by temperature of dropfall. Value of resistance, which the lubricant creates in frictional units of rolling stock, in the end determines amount of energy expended by locomotive. Therefore, it is important to estimate value of resistance created by lubricant. For evaluation of changes of properties of lubricant, occurring in process of its prolonged operation, there are methods of determination of mechanical stability of grease lubricants.

§ 4. Elementary Calculation Formulas of Lubricant Layer of Bearings

On the basis of hydrodynamic theory of lubrication there are developed methods of calculation of bearings for different operating conditions. These methods permit determining the geometric dimensions, allowable loads, temperature of bearings at different operating conditions, and also permits selecting optimum viscosity of lubricant. In practice of operation of rolling stock, in particular railroad cars, it is rarely necessary to collide with designing of bearings and selection of oil viscosity. Therefore, here there are brought out only those approximate formulas by which it is possible to tentatively check correctness of application of oil in given unit, permissibility of loads, and other factors.

In order to check permissibility of loads on bearing there can be used the formula for determination of specific pressure. Under specific pressure we understand the load per unit of area of friction surface. Moreover, in calculation we take projection of part of cylinder, embraced by the bearing, to horizontal plane. Consequently, in order to determine specific pressure, it is necessary to divide the load, arriving on the entire bearing, by the area obtained from multiplication of length of bearing by length of chord, corresponding to angle of contact of journal by the bearing.

Value of specific pressure is equal to

$$p_m = \frac{d^2\eta\omega}{3{,}84\,h\,(D-d)}\ \text{kgf/m}^2 \tag{7}$$

where η — absolutely viscosity of oil in kgf·s/m^2; D — diameter of hollow of bearing in m; d — diameter of journal of axle in m; h — minimum thickness of lubricant layer in m; ω — angular velocity in 1/s.

Diametrial clearance (D - d) for railroad-car axle bearings with scraping of them along journal and as a result of prolonged running is usually equal to 0.10 to 0.15 mm.

Minimum thickness of lubricant layer h to ensure liquid friction should be greater than total roughness of bearing and axle journal. Journals of railroad-car axles after machining have roughness with height 10-20 μm. Value of roughness for well fitted journals is within limits from 1 to 4 μm and their surface has almost mirror smoothness. As a result of surface damages roughness, starting from 30-40 μm are already noticeable to the eye in the form of dark spots, slight scratches, etc. During normal operation for fitted bearings and journals the total roughness of frictional surfaces is 5-8 μm, and minimum thickness of lubricant layer, ensuring liquid friction, is equal to 6-9 μm (0.000006-0.000009 m).

Angular velocity, entering formula (7), is calculated from expression ω = 0.1047 n, where n — number of revolutions of shaft.

In operation cases are possible when it is necessary to check whether viscosity of lubricating oil applied in given unit of machine or in box of railroad car is sufficient. For this there can be used formula

$$\eta = \frac{3{,}65\,P\,(D-d)\,h}{d^4\,\frac{l}{d}\,n}, \tag{8}$$

where η — sought absolute viscosity of oil in kgf·s/m^2; P — load on bearing in kgf; (D - d) — diametral clearance in m; d — diameter of journal of axle in m; h — thickness of lubricant layer in m; l — length of bearing in m; n — speed of rotation of axle of wheel in r/min.

In formula (8) all values can be found by direct measurement or from the above considerations. Number of revolutions of axle (wheel) of railroad car can be easily calculated by known speed of train, by using expression

$$n = \frac{vk}{60},$$

where v — speed of train in km/h; k — coefficient, equal to 318.5 r/km for wheels of railroad car of 1,000 mm diameter and 353.4 r/km — 900 mm diameter.

For checking the temperature of oil layer at various conditions of operation there can be applied formula

$$t_{м}^{\circ} = t_{в}^{\circ} + 2.6\sqrt{\frac{Pn^3\eta}{9\,600\,a^3\,\frac{l}{d}}}, \tag{9}$$

where t_{B}^{o} — temperature of external air in ^{o}C; P — load on bearing in kgf; n — speed of rotation of axle of wheel in r/min; η — absolute viscosity of oil in kgf·s/m^2; l — length of bearing in m; d — diameter of journal of axle in m; a — coefficient of heat removal.

Construction of bearing and axle, on which it rests, and also box (bushing), encircling frictional unit, has considerable effect on conditions of heat removal, forming as a result of friction. A large role in heat removal is played also by external operating conditions of frictional unit (constant temperature and insignificant humidity, for example, in subway, rain, frost, or wind — on roads of the north). On the basis of experiments there are established approximate values of coefficient of heat removal for various constructions of bearings at different conditions of operation, given in Table 1 (for speeds 90 and 110 km/h coefficient a is obtained by means of extrapolation of empirical curve).

Table 1

Speed in km/h	Coefficient of a	Speed in km/h	Coefficient of a
10,8	4,8	43,2	9,2
14,4	5,5	54,0	10,2
21,6	6,6	72,0	11,7
28,8	7,6	90,0	12,8
36,0	8,4	110,0	13,4

By knowing coefficient of heat removal, dimensions of bearing and axle journal, load on axle, and viscosity of oil, lubricating the bearing, it is possible by formula (9) to determine temperature of oil layer between bearing and journal of axle at any temperature of external air and any speed of railroad car.

Under operating conditions there can also be encountered the necessity of checking thickness of lubricant layer between journal of axle and bearing and to establish whether it is possible to ensure liquid friction at assigned speed and lubricant.

For determination of thickness of lubricant layer the following formula can be used:

$$h = \frac{d\eta\omega}{3.81\bar{p}_m\psi}. \qquad (10)$$

where h — thickness of lubricant layer in m; d — diameter of journal of axle in m; η — absolute viscosity of oil in kgf·s/cm^2; ω — angular velocity in 1/s; p_m — specific pressure in lubricant layer in kgf/cm^2; ψ — relative gap, representing relation of diametral clearance to diameter of journal:

$$\psi = \frac{D-d}{d}.$$

All values of formula (10) can be measured directly or determined by the above-mentioned means.

Questions for Self-check.

1. What is friction and as a result of what does it appear?

2. In what cases are friction harmful and in what useful?

3. What does the fundamental distinction between coefficients of sliding and rolling friction consist of?

4. What is viscosity of liquid and in what units is it expressed?

5. What is oiliness and what is its role in process of lubrication?

6. How will the presence of oil with high solidification temperature in boxes of railroad cars be reflected on movement of train in winter?

7. What properties are important to evaluate in grease lubricants?

CHAPTER II

PRODUCTS FOR MANUFACTURE OF LUBRICATING MATERIALS

§ 1. Petroleum-Basic Raw Material for Producing Lubricating Materials

Petroleum is the basic raw material for production of lubricating oils. It is known from long ago, but its usage for industrial purposes started only about 100 years ago.

Contemporary development of economy, transportation, and defense of any country is inconceivable without products of refining of petroleum gasoline, kerosene, petroleum naphtha, diesel fuel, lubricating oils, and many other products. Production of the majority of plastics, as many synthetic materials, is also now based chiefly on the use of products of petroleum and gas refining.

In spite of the fact that petroleum acquired huge value in technology and economics, the question of its origin at present is not solved finally and a number of scientists hold different theories.

There exist two basic theories of the origin of petroleum. Theory of mineral origin, proposed by D. I. Mendeleyev, explains the formation of petroleum by interaction of carbides of iron and other metals with steam in the depth of the earth under conditions of high temperatures and pressures. According to the theory of organic origin of petroleum the parent substance of its formation are decomposition products of different plants and animal organisms. These products in early geological eras were accumulated in sedimentary deposits of coastal maritime zones, were covered by silt, sand, and other rocks, were decomposed without access of air, and petroleum and combustible gases were formed. During this disintegration of organic products was assisted by bacteria and radiation of radioactive substances.

USSR has huge reserves of petroleum available. During the years of Soviet power works are conducted continuously on prospecting of petroleum deposits and the development of petroleum, gas, and oil-chemical industry.

Largest petroleum deposits in USSR are located now not only in the Caucasus (Baku, Grozny, Maikop, and other petroleum regions), but also in many other regions and republics of our country: between the Volga and Urals, in western Kazakhstan (Emba petroleum-bearing region), in western Siberia, in a number of regions of the Ukraine, in central Asian republics, in the Far East (Sakhalin, Kamchatka), north (Ukhta), etc.

Growth of output of petroleum in USSR (Fig. 4) and its huge value for the national economy are clearly reflected in materials of XX-XXII congresses of the CPSU and in decisions of May (1958) and February (1964) Plenums of Central Committee of the Communist party of the Soviet Union, from which it is clear that in 1958,

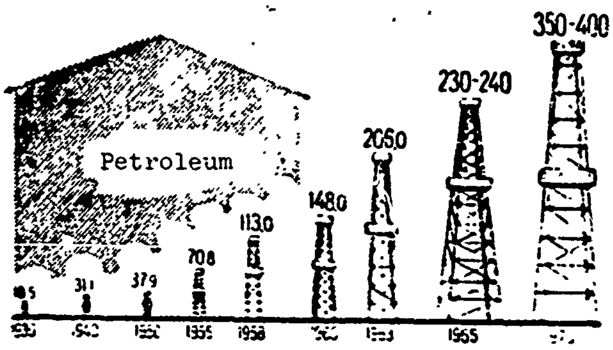


Fig. 4. Growth of output of oil in USSR (in millions of tons with respect to yea:s).

i.e., at the beginning of the current seven-year plan, in USSR there was extracted 113 million tons of petroleum, which is approximately 12.5 times greater than 1913 output. In 1963 the output of petroleum increased to 206 million tons, and in 1965 it will compose not less than 230-240 million tons.

Petroleum is obtained basically through bore holes (Fig. 5), sometimes having considerable depth (more than 6,000 m). From holes the petroleum is pumped with special depth pumps. Sometimes it proceeds to the earth's surface under pressure of gases by gravity flow (gusher output) and is collected by special equipment. Soviet scientists developed new more improved methods of drilling of wells with the aid of hydraulic and electric drills and others.

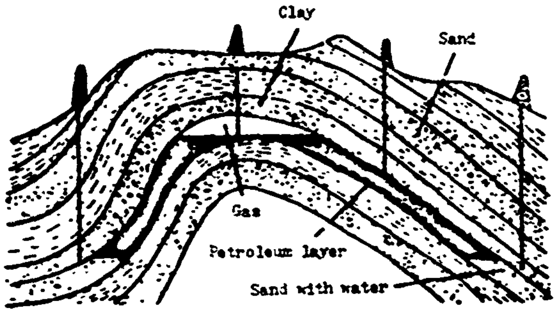


Fig. 5. Cutaway of petroleum deposit with bore holes.

Petroleum of different deposits considerably differ from each other both by composition, and their physical and chemical properties. Generally petroleum is a combustible oily liquid, possessing a characteristic odor, something like the odor of kerosene, with different mobility from liquid to thick tarry with specific gravity in most cases less than one (0.75-1.0).

Solidification temperature of petroleum also depends on its chemical composition and, as a rule, will be higher, the greater the solid hydrocarbons contained in it (paraffin and cerezine). Solidification temperature of different petroleums is usually within limits from +11 to -40°C.

Temperature of flash and ignition of products of petroleum refining (even without taking into account gasolines, flashing and inflammable at very low-minus-temperatures) oscillates in wide limits — from 28°C (for kerosene) to 300°C (for cylinder oils). Heat of petroleum combustion is 10,300-11,000 kcal/kg (42,000-46,000 kJ).

§ 2. Chemical Composition of Petroleum and Its Basic Properties

Regarding chemical composition petroleum is extraordinarily complicated and consists of a large number of various organic compounds. Composition of petroleum includes mainly carbon (84-85%) and hydrogen (12-14%). Other chemical elements (oxygen, nitrogen, and sulfur) are contained in it in quantities rarely exceeding 5%. In conformity with this basic compounds entering the composition of petroleum are hydrocarbons, i.e., compounds consisting of carbon and hydrogen.

Petroleum is basically a mixture of hydrocarbons of paraffin (methane), naphthenic, and aromatic series. The simplest representative of methane hydrocarbons is the gas methand CH_4, each molecule of which (Fig. 6a) consists of one atom of carbon, joined with four atoms of hydrogen. Molecule of following ethane C_2H_6 (Fig. 6b) with respect to complexity of hydrocarbon constructed in the form of a chain, consisting of two atoms of carbon, connected with six atoms of hydrogen. Further there is propane, hydrocarbon chain of which consists of three atoms of carbon, then — butane, pentane, hexane, octane C_8H_{18} (Fig. 6c), etc.

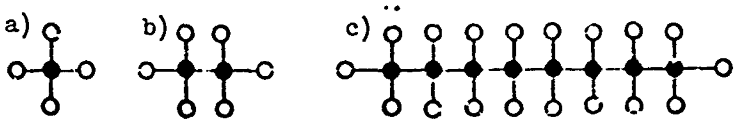


Fig. 6. Structure of molecules of saturated hydrocarbons (here and in Figs. 7-11 black circles — atoms of carbon, white — atoms of hydrogen): a) methane; b) ethane; c) octane.

With further development of chain it is possible to approach saturated methane hydrocarbons with a very large number of atoms.

Construction of methane hydrocarbons in expanded chain, when the extreme atom of hydrogen is replaced in it every time, is called normal structure. If however one or several atoms of hydrogen, standing in middle of chain, will be subjected to substitution, then such structure of hydrocarbons is called isostructure, and hydrocarbons — isomers (Fig. 7).

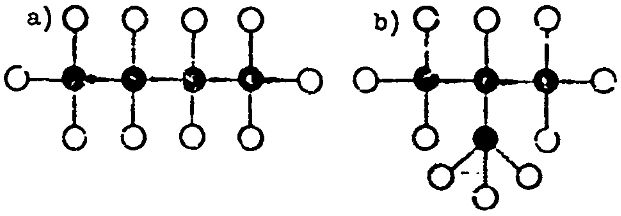


Fig. 7. Structure of molecules of normal butane and its isomer: a) normal butane; b) isobutane.

Regarding chemical composition (quantity of carbon and hydrogen atoms) normal butane or other hydrocarbon does not differ from its isomer, however their physical properties will be somewhat different due to nonuniform structure of their molecules.

Besides hydrocarbons, molecules of which are long open chains, there exist molecule of annular cyclic structure. They primarily include hydrocarbons of naphthenic series, which are contained in great quantity in petroleum. In the composition of petroleums there are mainly pentanaphthene C_5H_{10} (Fig. 8a) and

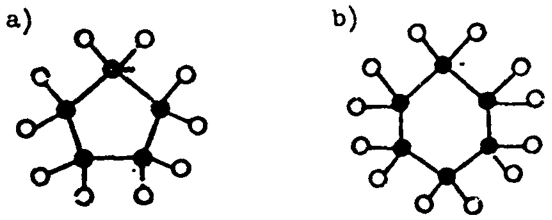


Fig. 8. Structure of molecules of naphthenic hydrocarbons: a) pentanaphthene; b) hexanaphthene.

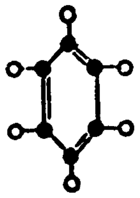


Fig. 9. Structure of molecule of aromatic hydrocarbon — benzene.

and hexanaphthene C_6H_{12} (Fig. 8b). General chemical formula of hydrocarbons of naphthenic series can be represented in the form of C_nH_{2n}. These hydrocarbons are saturated similar to methane, since all 4 valences of each carbon in their particle are saturated by hydrogen or by valence of neighboring carbon atoms. In naphthenic hydrocarbons the hydrogen atoms can be replaced by methyl group or other groups and can form homologic series.

The other group of cyclic hydrocarbons includes aromatic, or benezene, called so by the name of the simplest hydrocarbon of this series — benzene C_6H_6 (Fig. 9). General chemical formula of aromatic hydrocarbons has the form of C_nH_{2n-6}. Consequently, in their molecule there is found the least amount of hydrogen atoms of all the examined series. These hydrocarbons, similar to naphthenic, have annular structure with six-membered nucleus, as can be seen on Fig. 9. Benzene differs from six-membered naphthene by the presence of three double bonds in its nucleus and by the fact that with each atom of carbon there are bound not 2, but only 1 atom of hydrogen.

Many are in petroleums and more complex compounds, in which hydrocarbons of the three shown forms (Figs. 10 and 11) are bound together in different combinations.

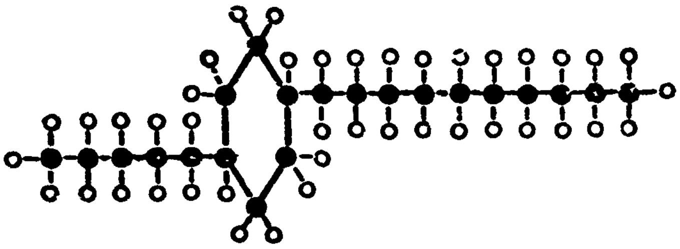


Fig. 10. Structure of naphthenic hydrocarbon with lateral paraffin chains.

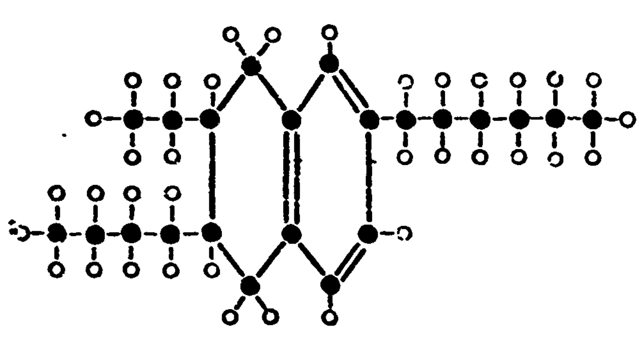


Fig. 11. Structure of naphthenic and aromatic rings with lateral paraffin chains.

Quality of different oil products in many respects depends on which of the hydrocarbons are contained in them in the greatest quantity. Thus, for example, in lubricating oils the presence of aromatic and solid paraffin hydrocarbons is undesirable for the reason that the first of them at large content are inclined to coke formation, and the second increase solidification temperature of petroleum.

Petroleums in which oil fractions consist of liquid naphthenic and paraffin hydrocarbons, and also naphthene-paraffin compounds, usually pertain to the category of oil and from them are produced lubricating oils.

Hydrocarbons, containing from one to four carbon atoms in a molecule, in usual conditions are gases, which are widely used both for everyday needs and for purpose of their refining into more complex chemical compounds.

Liquid hydrocarbons, entering the composition of gasoline, kerosene, and diesel fuel, as a rule have from 5 to 20 carbon atoms. Mineral lubricating oils consist of hydrocarbons with number of carbon atoms approximately from 20 to 70.

Main mass of petroleum composed of liquid hydrocarbons; they are the crude from which we produce gasoline, kerosene, and lubricating oils. Depending upon which hydrocarbons are predominant, petroleums are subdivided into 6 classes: methane, methane-naphthenic, naphthenic, methane-naphthene-aromatic, naphthene-aromatic, and aromatic.

Heating oil can be divided into separate parts (fraction) with different boiling point. On this is based the process of petroleum distillation. For example, with heating to 200°C from petroleum there are driven off the most volatile mixtures of hydrocarbons with small specific gravity – gasoline-ligroin fractions. In proportion to increase of distillation temperature to 300-360°C there are driven off heavier kerosene and solar oil fractions. Remainder of oil after distillation of gasoline-kerosene and solar oil fractions from it is called black oil.

Black oil is the basic product, from which with further distillation we obtain lubricating oils.

§ 3. Petroleum Refining

Concept on Petroleum Distillation and Production of Lubricating Oils From It

All the extracted petroleum is subjected to refining, as a result of which from it we obtain different valuable products: gasoline, kerosene, and lubricating oils. Certain (mainly gaseous) products of refining serve as initial crude for production of synthetic oils and resins, varnishes, artificial fibers, rubber, plastics, etc.

Lubricating oils, as also lighter oil products (gasoline, kerosene, etc.), are obtained during fractional distillation of petroleum. Process of petroleum distillation is carried out on tubular distillation units and usually consists of two basic stages.

In the first stage (Fig. 12a) from petroleum there are distilled light oil products, evaporating at a temperature up to 360°C (gasoline, kerosene, and light solar oils). After distillation of these products from petroleum there remains black oil.

Depending upon quality the black oil can be applied directly as lubricant, which rarely occurs in practice, or will be subjected to further refining (distillation) into lubricating oils (black oils of petroleums), or is used for cracking-process (splitting of coarse molecules of hydrocarbons into fine parts).

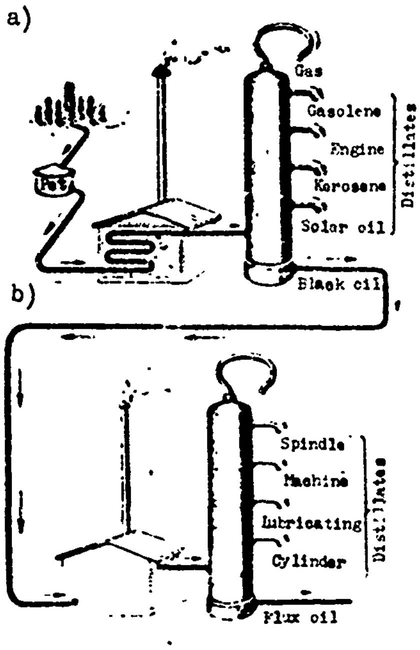


Fig. 12. Diagram of petroleum distillation.

In the second stage (Fig. 12b) by means of further distillation of black oils of oily petroleum under vacuum at temperature up to $400^{\circ}C$ we obtain valuable lubricating oils: spindle, machine, lubricating, cylinder, etc.

After distillation of part or all of oil fractions from black oil we obtain a thick dark product, called flux oil or asphalt. From flux oil and asphalt of high-quality oily petroleums by means of removal of surplus resins and other harmful inpurities we produce residual cylinder oils (visconsine and vapor) and certain aviation oils. Asphalts of less qualitative (tarry) petroleums are used for production of petroleum bitumens.

Tublar units on which black oil is distilled are fully automated and are equipped with devices for creation of deep vacuum. Vacuum distillation is based on the known law of physics about the fact that at reduced pressures (in vacuum) liquids, evaporate at lower temperatures. This permits eliminating the possibility of decomposition of hydrocarbons, entering the composition of black oils. On powerful tubular units with deep vacuum up to 90% different fractions can be distilled from oil.

Concept on Purification of Lubricating Oils

Fractions (distillates) of lubricating oils obtained as a result of distillation of black oil in most cases are not directly suitable for use. They have to be purified from harmful impurities contained in them: resins, asphaltenes, naphthenic acids, corrosion-active sulfides, and so forth. Removal of these impurities is carried out by various methods.

Basic method of purification of oils is treatment of distillates by sulfuric acid, bleaching clays, or selective solvents.

With sulfuric acid purification on special units (Fig. 13) the oil is mixed in tank 1 with a strong sulfuric acid, entering from small tank 5. Acid, interacting with unsaturated and tarry matters, and also partially with aromatic hydrocarbons, will form acid asphalt, which settles on conical bottom of tank and then is removed.

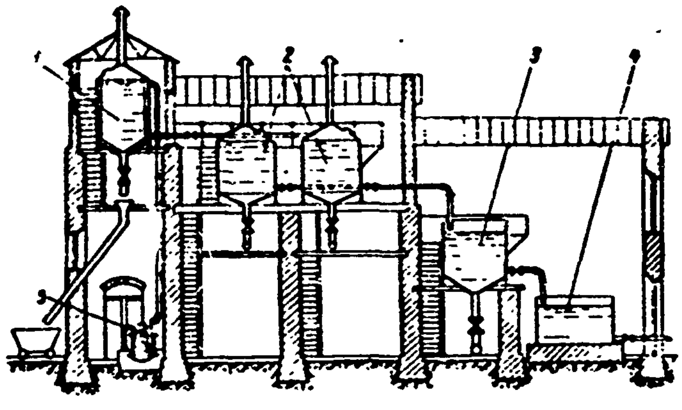


Fig. 13. Unit for purification of oils by sulfuric acid.

Oil asphalt released from acid enters tanks 2, where it is neutralized by alkali (caustic soda). Caustic soda also enters into reaction with naphthenic acids, forming naphthene soap (alkaline naphthenate). Alkaline naphthenate and sodium sulfate settle on the bottom of tank and are removed from it. Oil in tank 3 is washed from residue of caustic soda with water and is dried in additional tank 4 by blowing warm air through it or by preheating and creation of vacuum above it. Certain lubricating oils are purified only by alkali. Such oils are called leached.

Industrial, motor, and other critical oils, purified by acid-alkali method, are additionally, exposed to deeper purification by bleaching clays. Process of purification involves mixing of oil with finely pulverized bleaching clay and subsequent filtration on special filter presses. Acid-alkali purification, augmented by purification with clays, carried the name of acid-clay or acid-contact purification.

More improved method of purification of oils, having received wide propagation in the last few years, is selective purification. This purification permits separating harmful substances from distillates, while not similarly involving sulfuric acid purification of useful component parts of lubricating oil.

During selective purification the oil is mixed with one of the solvents (nitrobenzene, furfurole, propane, phenol, and others), able to dissolve in itself a specific part of undesirably hydrocarbons and not dissolving the remaining part of oil. After such treatment 2 layers are formed: upper — purified oil with impurity of some quantity of solvent and lower — solvent with harmful impurities removed from oil or conversely. After separation of these layers and distillation of applied solvent from them there is obtained purified oil and the part (extract) cleaned from it. Extract is applied just as often as lubricating oil for mechanisms which operate in special conditions.

Selective method is also applied for deparaffination and deasphalting of oils.

One of the essential merits of selective purification is also considerable improvement of temperature-viscous properties of oils. Removal of harmful sulfides from oils is carried out by means of their treatment at elevated temperature and pressure-hydrogen (method of hydrofining). Sulfur when combined with hydrogen forms gas hydrogen sulfide, which removes this harmful impurity with itself.

Type of applied purification of oils is designated usually in GOST arbitrary indices: for example, oil [AC_{Π}-5] (AS_{Π}-5) is automotive, selective purification, with additive; oil AK_{Π}-5 is a similar oil, but acid purification, etc.

§ 4. Synthetic Lubricating Oils

Lubricating oils can be produced not only by direct petroleum distillation, but also by means of synthesis (compound).

Synthetic lubricating oils are obtained by synthesis from the simplest unsaturated hydrocarbons or in the form of complex compounds, in which carbon or hydrogen, entering molecule of hydrocarbons, can be replaced by other elements (silicon, fluorine, etc.).

The simplest diagram of production of lubricating oils from ethylene gas is shown in Fig. 14. This process consists in the fact that ethylene, separated in the form of gaseous by product during cracking of petroleum, is set in a special autoclave under pressure 10-15 at (sometimes at normal pressure) and is heated to 200°C, thanks to which in the presence of catalysts from the simplest molecules there will be formed more complex liquid molecules (polyethylenes) with number of carbon atoms from 20 and more. From simple gaseous molecules of ethylene there is formed more complex molecules of new liquid hydrocarbons, which can be used as lubricating oils.

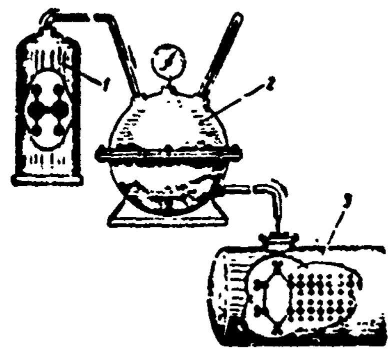


Fig. 14. Diagram of production of synthetic oil from ethylene: 1 — cylinder with ethylene; 2 — autoclave; 3 — ta for synthetic oil.

Similar to ethylene for synthesis of lubricating oils there can also be used other unsaturated hydrocarbon gases and liquids, which permits obtaining synthetic lubricating oils with various properties.

Production of synthetic oils can also go by means of replacement of hydrogen atoms, entering the composition of molecules of hydrocarbons (Fig. 15a), with atoms of fluorine. During this there is obtained a new compound carbon tetrafluorides (Fig. 15b), which in contrast to usual hydrocarbon oils withstand high temperature (up to 500°C) and are not oxidized. One more type of lubricating oil received considerable propagation, named silicone fluids. During their manufacture silicon oxide is introduced into hydrocarbon molecule (Fig. 16).

Silicone oils possess a number of properties which usual lubricating oils do not have: they withstand high temperature, are resistant to oxidation, are frost-resistant, and change their viscosity considerably less with change of temperature, which is especially important for many constructions of railroad transportion.

Advantages of synthetic lubricants permitted replacing usual lubricants by them in a number of mechanisms.

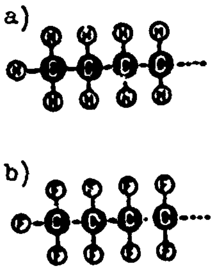


Fig. 15. Structure of molecules: a) hydrocarbon; b) carbon tetrafluoride.

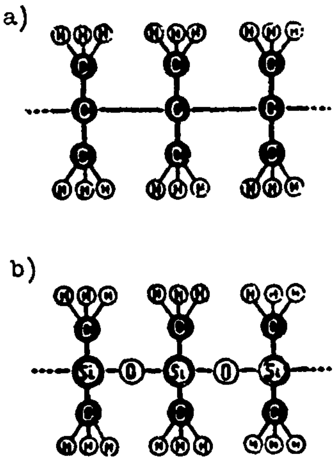


Fig. 16. Structure of molecules: a) hydrocarbon; b) silicone.

§ 5. Lubricating Greases

Along with lubricating oils grease lubricants have wide application in many frictional units. These lubricants are plastic colloidal systems with respect to composition are a mixture — allow of mineral or synthetic oils with thickeners.

In contrast to lubricating oils grease lubricants are stagant salvelike materials of various consistency.

Lubricating oils flow quite rapidly from frictional surfaces under action of their own weight or under the influence of centrifugal and inertial forces of moving parts, which is especially perceptible at high temperatures, speeds, and loads. Therefore, it is not always possible to apply them.

One of the main conditions of successful application of oils is their continuous supply to frictional units. However, in many machines and mechanisms there are such frictional units which are not continuously lubricated by oil, since frequent access to them is either hampered, is impossible, and equipment of them with oil-feeding devices is complicated and unprofitable. In such cases lubricating oils are replaced by grease lubricants.

Grease lubricants are applied in many constructions and parts of machines and mechanisms (ball and roller bearings, automatic brakes, geared and worm drives, various kinds of joints, etc.). Region of their application is continuously expanded.

In usual conditions grease lubricant behaves similar to a solid, does not change its shape, and does not spread over the surface. When a load is applied to it, it changes its shape and starts to flow similar to lubricating oil. With removal of load the lubricant as if congeals, preserving shape and position, which were given to it under load, and is durably held on part, not flowing from it.

This is a very important property of grease lubricants. Considering it, grease lubricants began to be widely used in hard-to-reach frictional units of machines and mechanisms and in constructions which are slightly hermetically sealed or are not hermetically sealed at all.

Besides the shown, grease lubricants have the following advantages:

a) lower expenditure n lubricating materials and maintenance of mechanisms, since losses are less and less frequent replacement of lubricant is possible.

b) are not thrown, do not flow from frictional units, and improve their hermetic sealing. This ensures cleanness of work stations and prevents damage of production (for example, in the textile industry);

c) most lubricants have wider temperature range of application than lubricating oils;

d) as a rule, possess best adhesion (adherence) as compared to oils. Therefore, probability of baring of lubricated surfaces when stopping machines is decreased. Constant presence of lubricant on frictional surfaces contributes to lowering of wear, especially at moments of touching, and also to protection of parts from corrosion (if lubricant is nonhygroscopic);

e) give possibility of use of highly worn mechanisms;

f) are irreplaceable for units in which lubricant is filled only during their assembly (automatic brake devices, ball and roller bearings, etc.).

With respect to their assignment grease lubricants are divided into antifriction, intended for lubrication of frictional parts, and protective, applied for protection of metal articles from corrosion and for impregnation of leather articles (tallowed compositions) for the purpose of giving them softness, air — and water tightness, and increase of service life.

Grease lubricants (ointments) are prepared from various lubricating oils and thickening products. As thickeners we use soap (salt of highest fatty natural and synthetic acids) or nonsoap solid organic products (ceresin, paraffin, wax), and sometimes mineral products (finely dispersed clay).

Depending upon type of applied thickener (Fig. 17) grease lubricants are subdivided into the following group:

lime-base, thickened with calcium (lime) soaps, named cup greases;

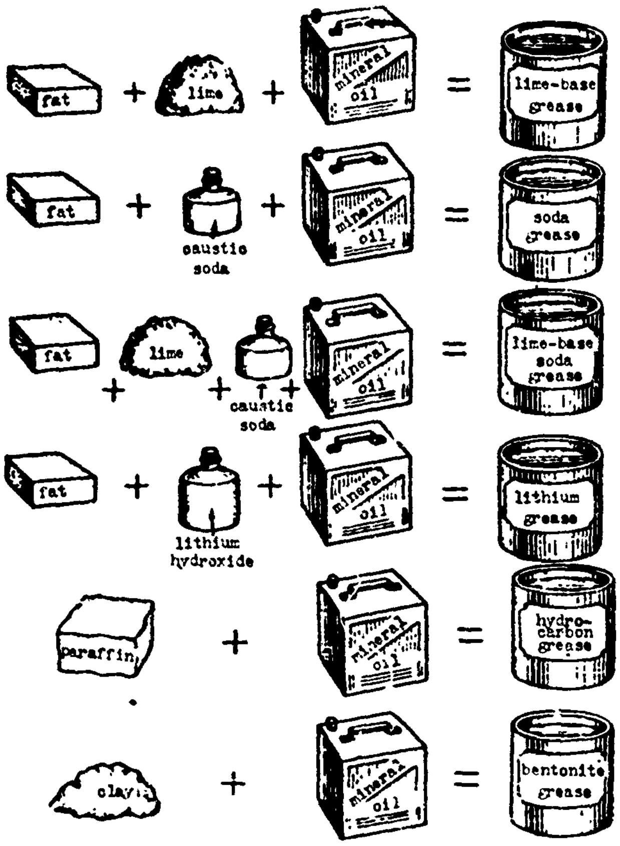


Fig. 17. Component parts of grease lubricants.

soda, thickened with soda soaps (konstalin, [ZhT] (ЖТ) and [ZhA] (ЖА) lubricants – railroad braking and antiemergency);

lime-base soda, thickened with a mixture of lime and soda soap (lubricants 1-13, [1-LZ] (1-ЛЗ), and others);

lithium, aluminum, barium, and others thickened with soaps of these metals or their mixtures;

with nonsoap hydrocarbon thickeners (with wax, ceresin, paraffin, and so forth) – vaseline, gun lubricant, and others;

thickened with special finely dispersed clays.

Soda lubricants have a rather high temperature of dropfall (higher than 100°C), but are very sensitive to moisture (are dissolved and are washed away by it). Therefore, they should be applied on mechanisms operating in conditions of the absence of dampness.

Line-base lubricants are moistureproof, but their temperature of fusion is lower than for soda (65-90°C). Besides this, they have a tendency to dilute at intense mixing.

An average position among these lubricants is occupied by lubricants of mixed soda-lime base, which includes lubricant 1-LZ, applied now in boxes with roller bearings.

Soda and lime-base lubricants are gradually displaced by lithium lubricants. In them there can be combined good properties: high melting point (150-180°C), frost-resistance, water tightness, and anticorrosivity.

Grease lubricants, made on nonsoap organic thickeners, are mainly protective (preservative) lubricants and their melting temperature at present usually does not exceed 50-60°C. Lubricants thickened with clays pass only the stage of experimental application.

Inasmuch as basic mass of antifriction grease lubricant compose lubricants, thickened with soaps, as examples below there are cited characteristic reactions of formation of such thickeners from various fatty acids:

$$1)\ \underset{\text{oleic acid}}{C_{17}H_{33}COOH} + \underset{\text{caustic soda}}{NaOH} = \underset{\text{sodium soap of oleic acid}}{C_{17}H_{33}COONa} + \underset{\text{water}}{H_2O};$$

$$2)\ \underset{\text{stearic acid}}{2C_{17}H_{35}COOH} + \underset{\text{slaked lime}}{Ca(OH)_2} = \underset{\text{lime soap of stearic acid (calcium stearte)}}{(C_{17}H_{35}COO)_2Ca} + \underset{\text{water}}{2H_2O.}$$

$$3)\ \underset{\text{stearic acid}}{C_{17}H_{35}COOH} + \underset{\text{lithium hydroxide}}{LiOH} = \underset{\text{lithium soap of stearic acid}}{C_{17}H_{35}COOLi} + \underset{\text{water}}{H_2O}$$

Not all soaps utilized during manufacture of grease lubricants can obtain the shown reactions of direct saponification. In such cases they resort to reactions of double replacement decomposition.

Reaction of formation of lead soap goes in the following way.

At first we obtain soda soap by direct saponification

$$RCOOH + NaOH \rightarrow RCOONa + H_2O.$$

Then, in order to produce lead soap, we create conditions for interaction of soda soap with lead salt. During the second reaction from obtained soda soap lead forces out sodium and remains in its place:

$$2RCOONa + Pb(CH_3COO)_2 \cdot 3H_2O \rightarrow$$
$$\rightarrow \underset{\text{lead soap}}{(RCOO)_2Pb} + \underset{\text{sodium acetate}}{2CH_3COONa} + \underset{\text{water}}{3H_2O.}$$

Second product during this reaction is sodium acetate. This water-soluble soda salt of acetic acid, which is removed from lead soap by multiple water washings.

Alumium soap, applied in production of grease lubricants, is also formed at reaction of double replacement decomposition.

Process of manufacture – boiling of grease lubricants – is carried out in special installations by approximately the following diagram (Fig. 18). Into boiler 5 of installation there is loaded mineral oil and melted fats or fatty acids, which are heated and thoroughly mixed, then into this mixture there is gradually poured a solution of alkali (caustic soda – for soda lubricants, lime – for lime-base, lithium hydroxide – for lithium, etc.). During interaction of fats and alkali there are formed soaps, thickening the mineral oil, as a result of which there is obtained a salvelike mixture of desirable consistency. Process with

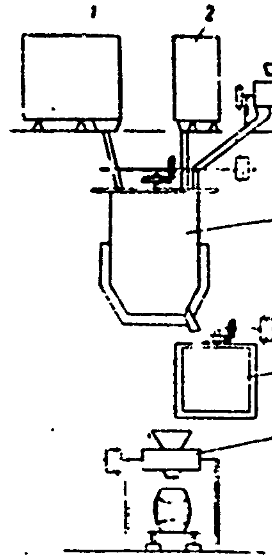


Fig. 18. Diagram of installation for boiling of lime-base grease lubricants: 1 — tank for mineral oil; 2 — tank for fat; 3 — tank for lime; 4 — tank for milk of lime; 5 — cooking boiler with mixer; 6 — cooling boiler; 7 — rollers.

which the soap prepared beforehand is dissolved in oil in the same boiler is considered more improved. In these cases the process of boiling lubricants with soap thickeners is similar to process of manufacture of hydrocarbon lubricants (with paraffin and ceresin) and amounts to thorough mixing — fusion of components entering the lubricant. For imparting of high homogeneity to sodium, and often to other lubricants, after boiling and cooling they pass through rollers 7 or other apparatuses.

Our industry produces about 100 types of different grease lubricants from hard to very soft. As mineral oils, these lubricants are divided into two groups: a) special assignment (motor, aircraft, railroad, etc.) and b) commonly used.

A large part of the grease lubricants applied in railroad-car economy pertains to the first group (for automatic brakes, roller bearings, antiemergency).

Along with this general-usage — mass grease lubricants (cup greases and konstalins) have considerably application. Cup greases are moisture-proof and are applied in frictional units of industrial mechanisms (machines, mechanical tool, and others), and also in trucks and tractors. Konstalins, as grease, are used in frictional units various mechanisms, but during their operation under conditions of elevated temperatures and low humidity, and also in tractors and streetcars.

The number of special grease lubricants (besides railroad-car) also includes a number of lubricants of highly specialized assignment: a) low-temperature — for special mechanisms operating at very low temperatures (to -80°C); b) instrument — on synthetic oils; c) high-temperature — for mechanisms operating at elevated temperatures; d) for crude mechanisms; e) transmission; f) railway (locomotive), and others.

§ 6. Solid and Other Lubricating Materials

Along with lubricating oils and grease lubricants as lubricating materials we also use some solids. They first of all include graphite of good quality. Graphite, having laminar — petal structure, consists of scales, which slide easily on each other. Frictional surfaces, covered with a thin layer of graphite, become ideally smooth, since all their irregularities are filled with graphite. With friction of such surfaces slip of metal on metal is replaced by slip of graphite on graphite. While film of graphite is preserved on frictional surfaces, graphitized surface works reliably, without wear and burrs. Graphite is applied both in dry form, preliminarily applied by thin layer on frictional part, and in the form of well crushed impurity (dimensions of particles to 2 3 μm) to lubricating oils and grease lubricants.

At present much attention is allotted to hard lubricating substance — bisulfide (MoS_2), which is still more effective than graphite. Lubricating molybdenum bisulfide is a greyish-black glittery powder of very good crushing (particles with dimension less than 1 μm). It is applied, as graphite, in dry form, in the form of paste, mixed on mineral oil, or in the form of impurity to oils and grease lubricants. However, molybdenum bisulfide is insufficiently durably held on surface of metal and is easily precipitated in oil.

Solid lubricating materials are applied not only in stressed, but also in usual frictional units. Presence of molybdenum bisulfide in oils and lubricants promotes easier starting of mechanisms lubricated by them, improves smoothness of their movement, and increases service life.

Of the number of lubricating materials applied in railroad-car economy, graphite is contained in antiemergency lubricant. It is applied also in grease lubricants, utilized in road economy. Molybdenum bisulfide is tested as an additive in diesel locomotive oils and certain lubricants for roller bearings.

The number of other materials, which are applied as lubricating, include usual air, utilized in mechanism operating at very high r/min — 100,000 r/min and more. Essence of the process of air lubrication is the same as liquid lubrication. Forced air is attracted by the surface of shaft in clearance between shaft and bearing and forms an elastic pad, separating the shaft from support. It is attempted to apply certain molten metals and melts of certain salts for lubricating purposes under conditions of very high temperatures.

§ 7. Additives to Lubricating Materials

Appearance of new machines and mechanisms with increasing powers, high specific loads, and speeds required different lubricating oils and lubricants, possessing improved properties. Methods of increase of quality of lubricating oils by means of selection of high-quality oils, improvement of technology of their refining, and application of improved methods of purification, applied before, are no longer in a position to satisfy these increasing requirements.

One of the most reliable methods of increase of quality of lubricating materials is the introduction into their composition of small quantities from 0.003 to 10% special substances, able to sharply improve necessary properties of oils and lubricants.

The numerous additives with respect to their assignment can be divided into:

a) antioxidizing, retarding oxidation of oils and lubricants (phenylnaphthylamines, diphenylamine, additive [VTI-1] (ВТИ-1), and others), they can include deactivators — substances neutralizing the catalytical action of metals on oxidation of lubricants.

b) anticorrosion, preventing corrosion on lubricated frictional surfaces (sodium benzoate, tributylphosphite, lanolin, additives [VNII NP-360] (ВНИИ НП-360) and [AzNII-4] (АзНИИ-4), and others). Their action is based on the ability to form durable protective films on the surface of metals and alloys;

c) extreme-pressure, and antiwear, reducing wear and also the probability of scores of frictional metal surfaces (molybdenum disulfide, complex compounds, containing sulfur, chlorine, and phosphorus along with organic radicals, and others);

d) improving vicous-temperature properties of lubricating materials (polyisobutylene, vinipol, santopur, paraflow, voltol, AzNII depressor, and others);

e) increasing the oiliness of lubricating materials and strength of their films (vegetable and animal oils, especially in sulphurized form, and others);

f) antifoaming, eliminating foaming of oils (additive [PMS-200A] (ПМС-200А);

g) washing (anticarbon), decreasing carbon formation and lacquer deposit in engines;

h) complex, improving several properties of lubricating materials simultaneously.

Presence of additives in lubricating materials is specified usually in GOST and is noted by arbitrary indices: for example, index [Dp-8] (Дп-8) designates diesel oil with viscosity 8 cSt at 100°C, containing additive.

In some lubricating materials, applied in railroad transportion, – anti-emergency lubricant ZhA, lubricant for gears in electrically operated structure, diesel (diesel locomotive) oil, lubricant for roller bearings (1-IZ), there are also contained additives. In the next few years additives will undoubtedly receive still greater propagation.

§ 8. Classification of Lubricating Materials

Lubricating materials are classified according to the following basic criteria: origin, physical state, and basic areas of application.

With respect to origin lubricating materials are divided into animal-vegetable and mineral.

The number of animal-vegetable materials includes animal fats (beef and pork fat, bone fat, etc.) and vegetable oils (castor, cotton seed, rapeseed, sunflower, coconut, and others).

Up to the second half of the past century as lubricants there were applied basically only fatty substances of animal and vegetable origin. These products, being good lubricating materials, have however a number of significant deficiencies. At elevated temperatures under the influence of oxygen and light vegetable oils and animal fats are rapidly oxidized and decomposed, and during prolonged storage are spoiled and lose their primary properties. Besides this, limitedness of resources of animal and vegetable fats, their increasing consumption for food purposes, soap production, oil boiling, and their higher considerably cost as compared to mineral oils make their application as lubricating materials economically unprofitable. Therefore, their production and application at present is almost completely discontinued.

High-quality mineral lubricating oils from petroleum were produced for the first time in Russia in 1876, whereas in other countries there still were no concepts on their production. These oils rapidly displaced other types of lubricants from use and became the basic lubricating materials.

Mineral (petroleum) lubricating oils with respect to technological criteria of their production are subdivided into the following groups:

1) distillate, obtained by means of distillation of black oil;

2) residual, obtained in the form of residuum after distillation of part of oil fractions (flux oil, asphalt) from black oil;

3) mixed (compound), obtained by mixing of distillate and residual oils or mineral oils with a small amount of vegetable oils;

4) emulsion, prepared in the form of emulsion consisting of mineral oil, water, and additives, which prevent stratification of emulsions;

5) synthetic, obtained by chemical synthesis of gaseous hydrocarbons or with the inclusion into composition of the other last compounds (silicon, fluoride, and others).

Regarding physical state lubricating materials are divided into liquid oils and salvelike (grease) lubricants.

Great variety of operating conditions of different machine parts and mechanisms causes the necessity for separate parts of machines to have their own type of lubricant, possessing specific physical and chemical properties. In connection with this by industry there is produced a large assortment (more than 200 designations) of lubricating oils and grease lubricants, intended for different purposes.

All lubricating materials can be split into several groups, each of which encompasses lubricants that are similar with respect to conditions of their application, and consequently, with respect to their properties.

Thus, liquid lubricating materials are conditionally divided into 6 groups:

1) for mechanical equipment of various enterprises — industrial oils (light, medium, and heavy);

2) for internal-combustion engines (motor oils) — automobile, tractor, aviation, diesel;

3) for special mechanisms — transmission, marine, axle;

4) for piston steam engines — cylinder;

5) for steam and water turbines — turbine;

6) for air compressors, air-blowing, and refrigerating machines — compressor.

For grease lubricants there are applied two basic classifications: according to area of application and kind of thickener. Regarding area of application they are divided into the following basic classes:

1) antifriction lubricants, lowering friction and wear of frictional parts;

2) frictional lubricants, increasing friction for preventing slip; such lubricants are necessary for lubrication of pulleys of belt drives, transmission, etc.;

3) protective (protection) lubricants, protecting parts from corrosion;

4) dispersive lubricants, promoting fit of frictional surfaces of parts.

Large part of lubricants pertains to the antifriction class. Many antifriction lubricants, besides decrease of friction also possess good protective properties and can simultaneously serve for other purposes. Such lubricants are called universal.

According to the character of thickener grease lubricants can be split into two groups:

a) with soap thickeners. Here there enter soda, lime-base, soda-lime, aluminum, barium, lithium, lead, and others;

b) with unsaponifiable thickener. They include lubricants prepared on hydrocarbon thickeners: ceresin, paraffin, petrolatum.

Questions for Self-check.

1. What basic properties does petroleum possess and what is its role in technology?

2. What is the chemical nature of petroleum and what compounds does it consist of?

3. What types of hydrocarbons enter into compositions of petroleum?

4. How is petroleum refined in oil-refining plants?

5. What are grease lubricants, how are they obtained, and what properties do they possess?

6. For what are additives applied to lubricating materials and what value

do they have?

7. By what criterial are lubricating materials classified?

CHAPTER III

LUBRICATING MATERIALS, APPLIED IN RAILROAD TRANSPORTATION

§ 1. Railway Lubricating Materials

Lubricating materials applied in railway economy according to assignment are divided into the following group:

1) axle oils for lubrication of plain bearings of passenger and cargo railroad cars;

2) lubricants for roller and ball bearings;

3) automatic brake lubricants for valves, pistons of air-distributors and brake cylinders, and also grease compositions for impregnation of leather packings of automatic brakes;

4) antiemergency railway lubricant;

5) other lubricating materials.

Axle Oils

For lubrication of axle journals of wheels with plain bearings we apply axle oils of three grades: [L, Z, and S] (Л, З, and С) (summer, winter, and northern respectively).

Axle oils of grades L and Z are pure black oil from nonparaffinaceous oils or a mixture of it with various distillate oils. Oil of grade S is prepared from low-viscosity distillates of oily petroleums, congealing at low temperature, and is intended for pouring into railroad-car boxes on railways of the north under conditions of especially low temperatures.

Externally the axle oils are an oily liquid of dark color with a specific petroleum odor.

During lubrication of axle journals of passenger and isothermal railroad cars to ensure high reliability of operation into oils we sometimes add salvelike products – so-called thickeners: commercial vaseline, petrolatum, and cup grease. Amount of these thickeners permitted is: in winter lubricant 5% cup grease, and in summer 15% vaseline or petrolatum and 5% grease.

Basic physical and chemical properties of axle oils are given in Table 2 according to (GOST 610-48).

Table 2

Designation of physical and chemical properties	Grade of oil		
	L (summer)	Z (winter)	S (northern)
Viscosity at 50°C:			
kinematic in cSt...........	36-52	20-25	12-14
conditional in °VU.........	5.0-7.0	3.0-3.5	2.0-2.2
Dynamic viscosity in pieze, not more than:			
at 0°C.....................	—	—	2
at -35°C...................	—	—	120
at -50°C...................	—	—	2500
Content in %:			
water-soluble acids and alkalis..................	Absence		
mechanical impurities not more than................	0.07	0.05	0.04
water not more than........	0.4	0.3	0.1
Temperature in °C:			
burst in open crucible not below................	135	130	125
congelation not above......	-15	-40	-55

Roller Bearing Lubricants

Operating conditions of railroad-car boxes with roller bearings and plain bearings are different; therefore, grease lubricant is applied for lubrication of the first.

Grease lubricant should be chemically neutral, made from high-quality mineral oil. In lubricant there is not allowed content of unsaponifiable fatty substances, since they can be decomposed and form organic acids, capable of leading to corrosion of metal of roller bearings. Such lubricant should not thicken at low temperatures and melted with increase of temperature in box. Furthermore, lubricant should not be stratified (i.e., oil should not be emanated from it both during its operation. Also its structure and consistency should remain constant in process of service of lubricant in box. Ability of lubricant to keep these properties constant during prolonged operation is called its mechanical stability.

It is especially important that lubricant for roller bearings for the purpose of decrease of friction does not have fibrous structure, i.e., when triturating between fingers it does not give a pulling fiber ("whisker").

For lubrication of roller bearings in boxes of railroad cars and a number of locomotives there is applied grease lubricant [1-LZ] (1-ЛЗ) (improved variant of lubricant 1-13), containing antioxidant additive (diphenylamine).

Lubricant 1-LZ has the following basic properties.

Basic properties of lubricant 1-LZ
roller bearings

Appearance...............	homogeneous soft ointment without lumps
Color....................	light yellow
Ultimate strength at 80°C in g/cm²...............	2.4-3.5
Temperature of dropfall in °C not lower than....	130

All analyses of grease lubricants are produced by the plant-producer or at their receipt by the consumer. Working lubricants, as a rule, are not analyzed.

Lubricants for Automatic Brakes

Quality and correct application of lubricants and grease compositions in many respects determine the exactness of action of automatic brakes, especially in winter. For lubrication of leather collars, cups, and also gate valves, bushings, valves, their seats and rings we apply antifreeze grease lubricant [TsIATIM-201] (ЦИАТИМ-201) and [ZhT] (ЖТ) (4a). The composition of lubricant TsIATIM-201 includes mineral oil with low solidification temperature (≈85%) and lithium stearate (≈15%). Lubricant ZhT is prepared from mineral and castor oils, ceresin, commercial fat, and caustic soda.

For greasing (impregnation) of leather collars of air-distributors there is applied grease composition No. 12, consisting of florisin (specially treated castor oil) – 88% and beeswax or ceresin (mineral wax) – 12%.

For impregnation of larger leather collars of brake cylinders and linings there is applied grease composition No. 40. It consists of florisin – about 60% and a mixture of solid organic substances (wax or ceresin, commercial fat, and paraffin) – about 40%

Grease compositions regarding their external properties at room temperature represent a plastic (consistent) mass. Basic physical and chemical properties of lubricant and grease compositions for automatic brakes are given in Table 3.

Table 3

Designation of physico-chemical properties	Brake lubricant ZhT (4a) Ministry of Railroads Specification (TU MPs) 04-64	Grease lubricant TsIATIM-201 GOST 6267-59	Grease Compositions TU MPS 05-64	
			No. 12	No. 40
Color............	From light yellow to light brown	From light yellow to dark yellow	From cream to brown	From cream to light brown
Appearance.......	From light yellow to light brown	Soft homogeneous ointment	Homogeneous smooth ointment	Thick homogeneous smooth ointment
Temperature of dropfall in °C not below........	120	170	53	49
Penetration at 25°C.............	290-340	270-320	-	-
Penetration at 50°C.............	45	-	-	-
Content of mechanical impurities.............	None	None	Not more than 0.1%	Not more than 0.1%
Solubility in gasoline during heating..........	-	-	Total	Total
Conditional viscosity in °VU at 70°C..........	-	-	7-10	4.5-7.0

Antiemergency Lubricants

For removal of excessive heating of railroad-car boxes with plain bearings we apply antiemergency grease lubricant [ZhA] (ЖА).

The composition of lubricant ZhA includes acidol (naphthenic acids), axle oil, graphite lube, and sodium hydroxide. The latter is introduced into lubricant in the process of its boiling for saponification of acidol and is scarcely contained in free form in lubricant.

Graphite lube is in lubricant in the form of particles of microscopic value. These particles pass through the finest clearances between frictional surfaces and are densely deposited in cavities (Fig. 19). In a certain time the rough metallic surface is turned into mirror-smooth graphitized, and wear of frictional surfaces is sharply decreased.

Fig. 19. Unevenness of surface of metal, filled with graphite.

This is explained by the fact that stickiness (oiliness) of lubricating oils with respect to graphite and graphitized surfaces is considerably greater than with respect to pure metals.

Externally lubricant ZhA is a very sticky thick ointment of dark brown color. Its temperature of dropfall is not less than 100°C, penetration at 25°C 200-275, content of water not more than 1%, not less than 5% graphite lube in it.

With the aid of antiemergency lubricant it is possible to bring the defective railroad car with hot box to the nearest repair point, while not unhitching from train. However, antiemergency lubricants cannot correct deficiencies of frictional surfaces, due to which the heating was formed. They only stop further increase of bearing temperature and somewhat decrease heating.

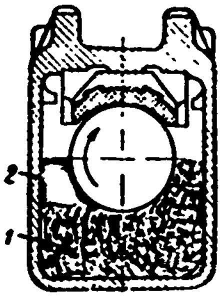


Fig. 20. Box filled with antiemergency lubricant: 1 – lining; 2 – antiemergency lubricant.

At normal state of frictional surfaces the excess viscosity of thickened axle oil leads to undesirable increase of tractive force, contamination of lining, etc. Therefore, in spite of the positive role which antiemergency lubricant plays in the struggle with uncouplings of railroad cars because of heating of boxes, its application is impermissible in cases when there is no necessity in this.

During use of antiemergency lubricant it is necessary to observe the following rules:

a) application of such lubricant is permitted only at intermediate stations between points of technical inspection;

b) filling of box with antiemergency lubricant is permitted by the train crew, accompanying the train;

c) on the cover of each defective box filled with antiemergency lubricant there should be clearly marked 2 crosses with chalk.

Reservicing of railroad-car boxes with antiemergency lubricant is carried out in the following way.

After inspection of hot box and axle journal, and also establishment of possibility of further safe movement of railroad car, the lining in box is straightened, and excess liquid lubricant is removed. From the bolster box the bolster is removed and is replaced by lining. After that on the lining on one side of the journal, opposite the direction of movement of the train, along its entire length there is poured antiemergency lubricant (Fig. 20) in a quantity 200-300 g for a box of two-axle railroad car and approximately 400 g for box of four-axle railroad car.

Lubricant for Other Parts of Railroad Car

During repair and formation of passenger and freight trains it is necessary to lubricate the following railroad-car parts with axle oil: articulations of cradle and rollers of spring suspension, box guides, brake screw, rollers of brake linkage, springs of buffer boxes. Sliders and thrust bearings during assembly of railroad car after repair are lubricated with thick lubricant of composition: graphite 50%, grease 25%, and machine oil 25%.

For railroad passenger cars along the line there are lubricated box guides and articulations of cradle suspension; these frictional parts on local railways are lubricated once a day. For lubrication of all these units there is applied seasonal axle oil.

Protective (Anticorrosion) Lubricants

For protection of metal articles and equipment from corrosion during their storage or perservation in railroad transportation there are applied lubricating materials shown in Table 4.

Table 4

Designation of lubricants	Assignment	Method of application
	Liquid lubricants	
Mineral oils: machine, axle, oilgas 203, and others	For short (1-2 months) intraplant or shop protection in the stage of treatment or storage of metal articles; for protection of high-quality metal during storage and transportation	By dipping of parts, by sputtering or lubrication of their surfaces
	Grease lubricants (ointments)	
Commercial vaseline (GOST 782-59); gun lubricant (GOST 3005-51); lubricant PP 95/5 (GOST 4112-48), lubricant PVK (GOST 10586-63), and lubricant SKhK (GOST 1199-64)	For protection of frictional mechanisms and also other parts, and also bearings during storage and transportation; duration of protection from 6 to 24 months	Dipping of thoroughly cleaned parts in melted lubricant, by sputtering it, or by lubrication of surfaces with melted lubricant by brushes
	Grease lubricants of special assignment	
Lubricants GOI$_{\text{п}}$-54 (GOST 3276-63) and AF-70 (GOST 2967-52)	For lubrication of frictional units of different instruments	By dipping of thoroughly cleaned parts in melted lubricant or by lubrication of surfaces with melted lubricant by brushes

The group of protective lubricants also includes special liquid and grease lubricants for preservation of internal-combustion engines and turbines, for protection of small arms (rifle lubricants), and also rope grease, missile lubricant, and lubricant for protection of metal surfaces in contact with sea water [AMS] (AMC). For these purposes we often use certain antifriction lubricants (cup greases, TsIATIM-201 and others).

One should constantly consider that only waterproof antifriction lubricants can replace anticorrosion lubricants when necessary. Water-soluble grease lubricants, thickened with soda and soda-lime soaps (konstalin, lubricant 1-13, and others), do not possess sufficient protective properties and should not be used for such purposes. This deficiency of soda and soda-lime lubricants is one of the causes of appearance of corrosion in mechanisms where they are applied, especially on conserved parts, when we try to apply such lubricants as protective.

Conditions of Interchangeability of Lubricants

In critical mechanisms of rolling stock (brakes, boxes, etc.) it is not recommended to replace the applicable lubricant until it is firmly established that the new lubricant exceeds the applied in all respects. In other mechanisms the temporary replacement of one type of lubricant by another is possible, but there should also be considered operating condition of mechanism and quality of the replacing lubricant. In interchangeable liquid lubricants there should be close viscosity, degree of purification, and in certain cases – chemical composition and solidification temperature. Only in this case will there be no unnecessary resistances in machines (which can cause more viscous oil) and will there not appear accelerated wear, caused by less viscous oil or oil contaminated by abrasives. For grease lubricants these conditions of interchangeability are preserved, but, besides this, their temperatures of dropfall (softening) should also be closed.

§ 2. Lubricating Materials of General Assignment

Besides the basic freight and passenger cars, on the network of railroads there are operated various special railroad cars, having every kind of devices and units requiring special lubricants. They include primarily railroad cars of trains with machine cooling and electric heating (refrigerator), railroad cars with devices for tilting of bodies, etc. Furthermore, in railway depot and repair shops there is a large amount of machine-tool equipment, load-lifting mechanisms, electrical equipment, and also a fleet of motor vehicles. All these devices, machines, and mechanisms also require special lubricating materials.

Below there are cited brief characteristics of lubricating oils used most in railway economy.

Industrial Oils

Industrial oils include those which are used for varous machines and mechanisms operating basically at room temperature and in the absence of direct contact with steam, hot air, and gasses.

Industrial oils consist of three groups: light, medium, and heavy; the basic characteristic during selection of the necessary type of these oils is their viscosity. In Table 5 there are given basic characteristics of industrial oils.

Table 5

Designation of oils	Kinematic viscosity at 50°C in cSt	Assignment
	Light	
Velosite L (GOST 1840-51) Vaseline T (GOST 1840-51)	4.0-5.1 5.1-8.5	For lubrication of frictional units, high speed lightly loaded machines, mechanisms, etc., operating at from 5 to 10 thousand r/min

Table 5 (continued)

Designation of oils	Kinematic viscosity at 50°C in cSt	Assignment
Instrument MVP (frost proof) GOST 1805-51	6.3-8.5	For lubrication of measuring instruments and filling of oil-pneumatic devices
Solar oil (unpurified) GOST 1666-51	5.0-9.0	As tempering and coolant liquid, in exceptional cases as a short-term substitute of velosite and vasoline oil
	Medium	
Industrial 12 (spindle 2) GOST 1707-51	10-14	For lubrication of frictional units of machines and mechanisms of average power, operating at from 1.5 to 5 thousand r/min
Industrial 20 (spindle 3) GOST 1707-51	17-23	
IS-20 (GOST 8675-62)	17-23	Substitute of spindle 3 oil and as tempering liquid
Industrial 30 (machine L) GOST 1707-51	27-33	For lubrication of basic stock of machines and mechanisms, operating in average conditions and at up to 1.5 thousand r/min
Industrial 45 (machine S) GOST 1707-51	38-52	
IS-45 (GOST 8675-62)	38-52	
Industrial 50 (machine SU) GOST 1707-51	42-58	For lubrication of frictional units of mechanisms operating above a load over 25 kgf/cm^2 and at speeds less than 1 m/c
	Heavy	
Cylinder 2, light (GOST 1841-51	9-13 at 100°C	For lubrication of mechanisms operating with large loads and low speeds.

Compressor Oils

Compressor oils are used for lubrication of piston and rotary compressors and blowers.

There are two grades of compressor oils: 12 (M) and 19 (T). Their difference involves various level of viscosity (11-14 cSt at 100°C for oil 12 and 17-21 cSt for oil 19), and also flash point (216 and 242°C respectively). A less viscous oil with lower flash point is applied in compressors with low compression ration of air, i.e., at lower temperatures, and more viscous oil 19 is used at high compression ratios and higher temperatures.

Automotive and Tractor Oils

The most comonly used automotive and tractor oils include motor oils: 6 (oil AK-6), 10 (oil AK-10), 15 (oil AK-15), and also oil of grades [AKZ-6] (AK3-6) and AKZ-10. Figures 6, 10, and 15 in grades of oils show their limiting viscosity in centistokes at 100°C.

With selection of motor oil according to its viscosity, besides engine performance, it is necessary to consider temperature-climatic conditions of its operation.

Motor oil 6 is intended for winter lubrication of automotive carburetor engines of all types (except [ZIL-110] (ЗИЛ-110). Motor oil from sour crude oils is equivalent to it. Motor oil 15 is used for lubrication of carburetor tractor engines in the summer.

Oil [AKZ$_{п}$-6] (АКЗ$_{п}$-6) is intended for lubrication of automotive engines under conditions of northern regions in the winter. Oil AKZ$_{п}$-10 is universal and can be applied for new and slightly worn motor vehicle engines all year.

Special automotive oils with additive (GOST 3829-51) are used for highly overloaded engines of ZIL-110 and other types of motor vehicles analogous to it. For an engine with raised compression ration ([GAZ-51] (ГАЗ-51), ZIL-150, and others) there is recommended automotive oil also with additive (GOST 5303-50).

Diesel Oils

Depending upon construction and heat release rate various oils are applied for diesel engines. In motors of refrigerated railroad cars there is applied oil [DS$_{п}$-11] (ДС$_{п}$-11) (GOST 8581-57) with the following characteristics.

Characteristic of Oil DS$_{п}$-11

Kinematic viscosity at 100°C	10.5-11.5 cSt.
Acid number per 1 g oil	Not more than 0.02 mg KOH up to introduction of additive
Coking capacity up to introduction of additive.	Not more than 0.3%
Ash content up to introduction of additive	Not more than 0.005%
Ash content with additive	Not less than 0.3%.

Cylinder Oils

Cylinder oils are used for lubrication of mechanisms of piston steam engines: locomotive, portable, and stationary.

A number of parts of steam engines operates in heavy conditions at direct contact with steam. Operating conditions of oils in steam engines, working with steam super heated to 350-500°C, are especially heavy. Therefore, expecially high requirements are imposed on cylinder oils for these mechanisms.

In steam engines, working with saturated steam, it is recommended to apply the following types of oils:

a) cylinder oil 2 (cylinder 11) for lubrication of machines operating with vapor pressure up to 5 at. It can be replaced by compressor oil M and axle L;

b) viscosine (cylinder 24) for lubrication of cylinders of steam engines, operating with vapor pressure up to 16 at. It can be replaced by summer transmission motor oil (GOST 542-50) or a mixture of oily cup grease with machine oil;

c) distillate cylinder oil 6 and residual — steam engine cylinder oil (GOST 6411-52), for lubricating steam engines operating with superheated steam.

Besides the enumerated oils, for lubrication of steam engines operating with superheated steam in the summer there are used emulsions of these oils, which are stabilized mechanical mixture of water and oil.

Application of emulsions permits decreasing the expenditure of valuable cylinder oils to 40-50%.

Special lubricating oils

The group of special lubricating oils is composed of turbine, transformer, transmission, and other oils.

Turbine oils are intended for lubrication and cooling of bearings of steam and hydraulic turbines, and also electric generators. In a large part of contemporary installations the control system is filled with these oils. Turbine oils of grades [22p(L), 30(UT), 57(T)] (22п(Л), 30(УТ), 57(Т)) and turboreduction gear oils (GOST 32-53) are the most commonly used.

Transformer oil is applied in electrical engineering as insulating and heat-transfer medium. It is used in transformers, rheostats, switches, and other devices.

Transmission oils are applied in gear drives to axles of locomotives and units of rolling stock (local electric and diesel trains) self-propelled from electric motors, hydraulic drives, etc. The most widely spread of these oils are transmission motor oil (niger oil) according to GOST 542-50 and sulphurized lubricant according to [TU TsTCh MPS 06-64] (ТУ ЦТЧ МПС 06-64).

§. 3. Methods of Feeding Lubricant to Frictional Surfaces

Selection of method of feeding the lubricant to places of friction depends on a number of factors: kind of applied lubricant, construction of lubricated unit, etc.

Liquid oils can be fed to place of friction by forcing them along tubes to some fixed point or by using capillary conductivity of wicks. Lubricated units with grease lubricants are most frequently filled by means of stuffing or pressing with special presses and only periodically there is added partially emanating lubricant to it.

Plain bearings of railroad-car boxes operate in heavy conditions. Housing of boxes, in which they are placed, are insufficiently sealed. When the train is running bearings experience blows on rail joints and swithches. Frequent stops of railroad cars worsen conditions of hydrodynamic friction. Therefore, to ensure satisfactory operation of bearings it is necessary to feed a large amount of oil to them. Such feeding is carried out lined ends, rollers, or bolsters. Both ends, and rollers constitute a large quantity of wicks with highly developed capillary network, during which the ends are packed in lower part of box, and in rollers they fill the internal part of nap cloth sack. These materials almost completely fill the space between axle journal and bottom of box and soak up all the oil.

Bolsters, represented by nap pads, fastened on a spring frame with wicks descending to the bottom of box, ensure uniform feed of oil to more than one fourth the surface of journal. Quantity of oil fed by them in a unit of time is 2-3 times less than by lining or rollers; however, it is sufficient for satisfactory operation of bearings.

Bolster materials, pressed to journal for feeding of oil, create little additional resistance to its rotation. Therefore, it is more advantageous that the axle journal simply be immersed in oil, being bathed in it. With this there will be ensured the most abundant supply of oil under the bearing, while not causing additional resistance. Wide application of such a system of oil supply has not been received at present because of creation of proper packings in box, preventing oil from emanating.

Overwhelming majority of remaining lubricated parts of railroad cars perform only periodic reciprocating or oscillatory motions and do not require a specially organized lubricant supply.

§ 4. Organization of Rational Usage of Lubricating Materials

Causes and Criteria of Aging of Lubricating Materials

Lubricating materials in process of operation in frictional units of machines and mechanisms are contaminated by different foreign impurities (sand and dust in box), and also by wear products of frictional parts (metal dust and shavings, products of corrosion). Furthermore, water gets in through different loosenesses in lubricated unit (in the form of rain or snow), which is mixed with lubricant. Under influence of oxygen of the air lubricant is oxidized and changes its physical chemistry properties. One of the results of oxidation and partial evaporation of lighter parts (fractions) of oil is increase of its viscosity.

Contamination and various influences worsen the quality of oil and lead to change of its properties. Besides precise laboratory methods of evaluation of changes occurring in lubricant, they can be determined by external criteria.

External criteria of aging of axle oil are: darkening, which indicates oxidation and sometimes contamination of oil; loss of transparency, showing the presence of water or a large amount of very fine contaminations (dust, cement, etc.) in oil, presence of solid particles, felt when rubbing the oil between fingers. External criterion of aging of grease lubricants is change of color. Depending upon type of lubricant and character of changes occurring in it, aging can cause its brightening or darkening. Change of color can occur also from irrigation and contamination of lubricant by impurities and from oxidation of the oil entering its composition. Dilution of lubricant occurs from sharp change of its initial structure, which can also be the cause of separation of oil from it (syneresis of lubricant).

These changes worsen the lubricating ability of oils and lubricants and are some of the reasons by which their periodic replacement is necessary.

Periodicity of Application of Seasonal Oils

Besides cases when it is necessary to replace oil because of strong contamination or irrigation, it is periodically changed in connection with seasonal changes of the weather.

Temperature of external air on network of roads of the Soviet Union oscillates from -60°C on roads of the north and the Far East in winter to +50°C on Central Asian roads in the summer. This leads to considerable change of oil viscosity in box. At present there is still no railroad-car axle oil which could operate satisfactorily the whole year.

Summer oil, having solidification temperature -15°C, congeals at very great frosts and cannot be fed to axle journal by bolster materials. Furthermore, with as little as insignificant lowering of temperature summer oil creats great resistance in axle bearings, causing overexpenditure of electric power or fuel by the locomotive. Oil with very small viscosity (for example, axle of grade S) in summer time on southern roads cannot create a good oil wedge between axle journal and bearing [which can be calculated by formula (8) or (10)]. As a result liquid friction will not be carried out, bearing will be extremely heated, which can lead to fusion of babbit.

So that axle oil could operate the whole year without replacement, its viscosity should be changed as little as possible with oscillations of temperature, and its solidification temperature should be as low as possible. It is possible to attain such change of properties of mineral oil by means of introduction to it of small additions of special chemical substances — so-called additives.

Development of chemical industry in our country will enable us in the future to produce all-seasonal oil. But until the appearance of such oils for decrease of resistane of railroad cars when starting from a place and during movement, i.e., for achievement of greatest possible saving of energy it is necessary to apply oils and lubricants that are specially intended for the given season. Seasonal replacement of oils prevents failures and extraordinary repair of railroad cars appearing because of incorrect application of lubricating materials.

To ensure normal operating conditions frictional units it is necessary to constantly watch so that there is sufficient quantity of lubricant in them. In railway economy for this there is set the order by which at all points of technical inspection of railroad cars the inspectors should uncover and inspect boxes with plain bearings and add oil to them when lacking.

Organization of Storage of Lubricating Materials

Safety and possibility of timely addition or replacement of lubricant, and also bolster materials, are ensured by organization of storehouses of lubricating materials in the depot and at points of technical inspection. For each material there is a separate tank for storage and a tank of smaller capacity for distribution, since delivery of materials from a large tank is hampered and is combined with danger of its contamination.

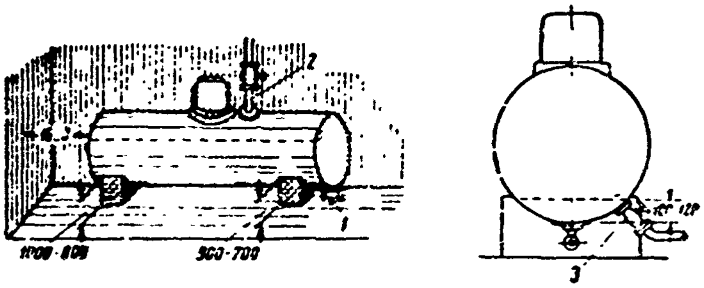


Fig. 21. Tank for oil storage: 1 — drain cock; 2 — filling pipe; 3 — distributing cock.

In the storehouse of lubricating materials there should be several (3-4) tanks (boilers, cisterns, etc.) for oil storage, located in such a manner that the oil in them could be poured from arriving cisterns by gravity flow. Usually such reservoirs are established in an underground location.

Each tank (Fig. 21) should necessarily have a drain cock 1 at a lower point for removal of settling water and mud. In order to eliminate the possibility of products of sediments getting into issued oil, cock 3 should be 100-120 mm higher than the drain cock.

For heating of oil the tanks are equipped with coils (spirally bent pipes), through which steam is passed. When emptying the tank and for its preparation for filling with a new batch of oil it is necessary to: pour all residue from it; wash, and then wipe it thoroughly with rags or waste; simultaneously thoroughly inspect and test the heating coil with steam, eliminate leakage of steam, since the least admission into coil leads to condensation of vapor in oil and to irrigation of the latter. In order to avoid entry of water, dust, etc., covers of tanks should be tightly closed and locked by a lock.

During entry of new batch of oil its grade should be set by documents so that it would be possible to pour it into an empty tank or in a tank with the same type of oil. Draining of oil should be produced in such a manner that the possibility of impurities and moisture getting into it would be eliminated. For this when draining from cisterns it is recommended to apply closed spouts or special flexible hoses, tightly secured at draining nozzle of cistern and the intake opening of tank, and when draining from barrels — direct rolling of them or to pouring hold (hatch) of tank after thorough removal of dust, dirt, and so forth from them. Tank is filled with axle oil to a level 200-250 mm lower than the upper edge of tank, after which on the latter there is applied a light oil paint stencil with date of purification, and next to it — a stencil indicating grade of stored lubricant and date of draining.

Grease lubricants should, as a rule, be stored in a tightly plugged container, in which they were admitted from the plant-producer. Scoops and shovels, intended for transfer of lubricants at delivery, should also be stored in a clean covered container.

Organization of Deliver of Lubricating Materials

Axle oils of all grades, located in tanks for storage and delivery, are freed from water and impurities which get in them during transportation and draining by means of preheating and sediment. In the period of application of summer axle oil it can be issued without preliminary preheating. Winter axle oil in a number of cases should be heated, especially during frosts lower than -25°C.

Preheating for sediment of axle oils is produced: summer — to 80°C, winter — to 70, and northern — to 60°C with holding at such temperature not less than an hour. During sedimentation lowering of temperature is allowed to +10°C. After sedimentation the residue descends through the drain cock, and oil can be pumped into distributing tanks, from which it is poured into oil cans and other small containers.

At large junction stations, where there is great consumption of oil, for reduction of time and expenditures for transportation the oil is fed from storehouse by compressed air along pipeline to distributing towers, installed on intertrack spaces of station (Fig. 22). Pipes of oil-lines are buried in the earth, serving as a thermal insulation layer, and the towers are warmed. Grease lubricants, servicing of which is not produced, on tracks, are issued only in the depot.

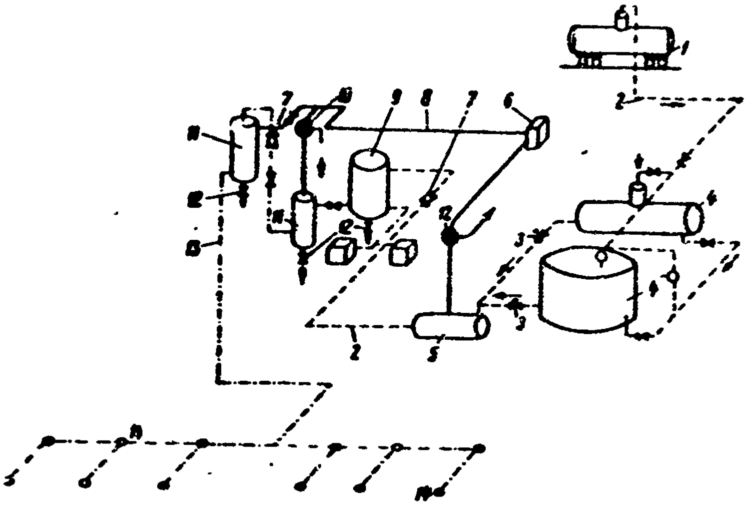


Fig. 22. Diagram of pneumatic feeding of oil at station yard: 1 — cistern with oil; 2 — pipeline for feeding oil into tanks; 3 — check valves; 4 — oil storage tank; 5 — oil-air tank; 6 — compressor; 7 — pump; 8 — compressed air pipeline; 9 — tank for sedimentation of oil; 10 — cocks for discharge of air; 11 — distributing tank; 12 — drain cocks; 13 — pipeline of feeding lubricant into yard for distributing towers; 14 — distributing towers.

Preparation of Padding Materials for Usage

Padding materials should correspond to technical conditions set by MPS for waste, rollers, and bolsters, should be clean and preliminarily impregnated with the same oil that will be poured into box. Before impregnation the padding materials are dried in a drying cabinet at temperature 60-70°C for not less than 3 h. After drying they are cleansed of dust and fines by shaking and separation on sorting tables. From the waste there is removed primarily metallic dust and shavings, sand, and also cotton, paper, silk trimmings, ropes, and short threads with less than 15 cm length.

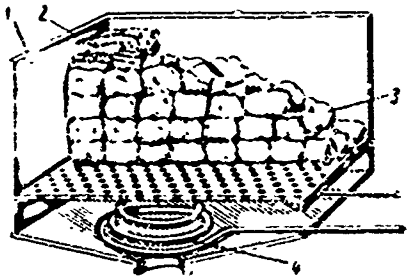


Fig. 23. Impregnating tank with padding waste and bolsters: 1 – tank; 2 – bolsters; 3 – padding waste; 4 – heating coil.

Rollers, waste and bolsters prepared for impregnation are loaded into impregnating tank (Fig. 23), filled with settled lubricant, heated to a temperature not higher than 65°C for summer oil, 60°C for winter, and 55°C for northern. Bolsters are packed on top of waste and rollers in 1 or 2 rows, if impregnation of rollers, waste, and bolsters is produced in one tank. After loading of padding materials the shown temperature of oil in tank is kept 2 h. Then heating of lubricant is ceased, and the loaded materials remain in oil another 4 h.

Impregnated materials are extracted from tank and are packed on a screen for runoff of excess oil, after which they are ready for use.

For production of all these operations at the railroad depot there are special waste impregnating points. Typical of such a point is shown on Fig. 24.

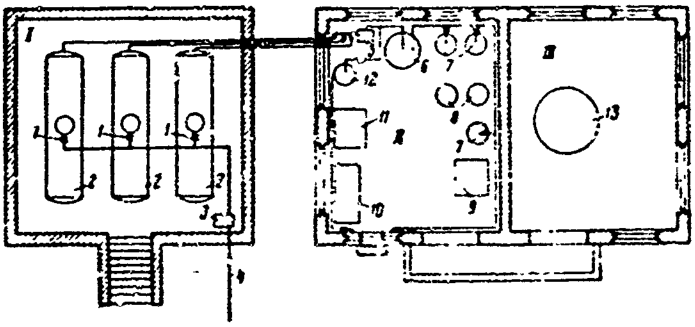


Fig. 24. Waste impregnating point: I – lubricant storehouse; II – impregnating section; III – boiler room; 1 – shutoff valve; 2 – tanks for oil storage; 3 – pump; 4 – pipe for draining of oil from cistern; 5 – pump for transfer of oil from tanks of storehouse to settling tanks of impregnating section; 6 – settling tank; 7 – impregnating tanks for waste and bolsters; 8 – distributing tanks of impregnated padding materials; 9 – drying cabinet; 10 – box for dry padding materials; 11 – steel for sorting the padding materials; 12 – distributing tank for purified oil; 13 – boiler.

Servicing and Refilling of Boxes of Railroad Cars with Lubricating and Padding Materials

Before servicing with padding material and oil each bushing should be cleansed of dust, mud, oil residue, inspected, and if it is required, repaired. Besides special attention should be turned to tightness of box covers and dust washers. Irreparable box covers should be replaced.

When filling the boxes with waste or rollers, and also in case of failure or looseness of dust washers near the latter there should be placed packing braids, tightly interwoven from padding waste. Padding from waste is laid into box in three parts: at first there is packed braid, then – main part of lining, filling all the space under axle journal (this lining is packed under the journal, and from the sides it should reach a height of up to 1/3 its diameter), third part of lining is laid in front section of box in one piece, coiled in the form of a drum, reaching the level of the center of axle journal. When servicing boxes with rollers we pack braid on the dust washer, and then 4-6 rollers across the axle journal depending upon the type of box.

Bolster, placed in the box, should have dimensions corresponding to type of axle.

After stacking the padding material in the box there is poured oil on the end and sides of journal in such quantity that when depressing the padding material by a hook the oil would slightly emerge from it, but would not overflow through the window of box. In bolster boxes the oil should be filled to the level of the lower edge of bolster brush.

Autumn reservicing of boxes of railroad cars with plain bearings from summer oil to winter is produced on all railroads in the period from 20 September to 20 October. Reservicing consists in the fact that at points of railroad having sufficient technical means and personnel available, from the boxes there is removed padding material into a special vessel and it is shipped to the waste impregnating point for regeneration. Residue of summer oil are scooped from boxes, collected, and shipped for regeneration, after which the boxes are refilled with winter oil. With reservicing of boxes on the frame of the railroad car there is placed a stencil with indication of date and point of reservicing.

On a number of roads with especially cold climate, enumerated in special instruction of MPS, from 15 November to 1 March there is applied oil S (northern). Transition to this oil is carried out without reservicing by means of its addition to boxes. During this the delivery from storehouses and distributing of winter oil at this period is ceased.

On railroads of the north with very severe frosts there is applied a mixture of axle oils with 10% low-congealing tractor kerosene. This mixture, prepared with strict observance of conditions of fire safety, is added to the box on the entire section of railroad with large frosts.

In the spring (starting from 1 April) all railroads produce sanitation repair of boxes and their transfer to summer oil. With this all malfunctions of box are removed. Replacement of padding material is produced in case of its high contamination or disrepair of bolsters. Upon completion of operations into the boxes there is poured summer axle oil and on frame of railroad car there is placed a stencil with indication of date and point of sanitation repair.

Grease lubricant applied in boxes with roller bearings serves the whole year around regardless of season. Its replacement in accordance with technical instructions of MPS is produced during complete inspection of bearings, and also during intermediate inspection in cases when with external inspection and triturating between fingers there is revealed contamination of lubricant.

Standards of Consumption of Lubricating and Padding Materials for Railroad Cars

Issued lubricating materials should be strictly considered. Primary registration document is a requirement signed by a responsible official person. Furthermore, at each point of drain and deliver of axle oils there are kept account journals of entry and consumption of axle oils.

Consumption of axle lubricants and padding materials for boxes of railroad cars according to MPS norms is given in Table 6.

Table 6

Type of consumption of lubricating materials	Standards of consumption		
	axle oil in kg	bolster brushes in pieces	padding waste in kg
Plant and depot repair of freight cars — on 1 car................................	40.0	1.6	6.4
Current repair of freight cars:			
a) preparation of cars for loading — on 1 considered car of average daily loading............................	0.7	0.01	0.04
b) on a run of 1,000 <u>railroad-axial-km</u>...	0.5	0.004	0.0015
Plant and depot repair of passenger cars on 1 car................................	40.0	4.0	4.0
Current repair of passenger cars:			
a) on each railroad car per year.........	120.0	2.0	9.0
b) on a run of 1,000 <u>railroad axial-km</u>...	0.5	0.005	0.05
Reservicing of boxes to seasonal lubricants on the average of 1 considered railroad car of working yard.........................	8.0	0.06	0.5

In order to economically expend lubricant and padding materials it is necessary to correctly apply these materials, to seek new, improved, and rational methods of care of boxes, to widely spread and introduce operational experience of the best lubricators.

For saving of lubricants and padding materials workers of box lubricating economy should observe the following rules:

a) store lubricants and padding materials in clean, serviceable, and tightly closed container, which will prevent possible contamination and losses during distribution, and also delivery to trains and filling of boxes;

b) do not permit o[illegible]lling of boxes with lubricant;

c) do not mix various grades of lubricants, and also do not burn them and padding materials on fires, in torches, and furnaces;

d) during complete refilling of boxes or partial replacement of poor quality lining thoroughly collect all the contaminated working lubricant, padding waste, and bolsters. It is necessary to pile contaminated material removed from boxes in separate tanks or buckets with tightly closed covers, and then to transfer to reclaiming points for purification;

e) add lubricant only to those boxes in which it is insufficient.

Furthermore, it is recommended to widely practice inspection of transit trains without complete filling of boxes with lubricant. In these cases it is required to expecially thoroughly check the condition of each box, its parts, and quality of servicing, while producing necessary repair of lining and addition of lubricant only in those boxes in which malfunctions were removed (replacement of bearing, bolster, etc.).

§ 5. Collection, Storage, and Reclaiming of Sludge Oils and Padding Materials

Collection of Sludge Oils

Sludge lubricating oils are oils losing the necessary performance figures in process of usage and also oils working for the period prescribed for them. Sludge oil is unfit for further usage, but by means of its reclaiming it is possible to again restore it to a state suitable for application.

Standard of collection of sludge axle lubricating oils, considering their considerable losses along the way, is set at a quantity not less than 10% with respect to consumed oil. For many of the other oils (motor oil, machine, spindle, transformer, turbine) standard of collection is set at a quantity from 25 to 40%.

Collection and storage of sludge oils should be produced separately by groups. Oils are poured into collectors, tanks, or reservoirs specially adapted for each group and grade of oils.

Sludge oils are drained into specially designated buckets, cans, and pans by hand pumps, guns, etc., depending upon character of mechanism and system of feeding of oil for lubrication. Vessels and implements for collection and transfer of oils to place of storage should be kept clean. Sludge oils, held by wiping material, lining of boxes, are extracted by squeezing, centrifuging, or by other method.

Reclaiming of Sludge Oils

Water and mechanical impurities in most cases are in sludge axle oils in suspension and are precipitated at calm state with passage of time. One sedimentation does not permit completely freeing oil from solid foreign impurities; therefore the first and the simplest method of reclaiming of oils is a combination of sedimentation with filtration. In some cases (with the presence of equipment) there is applied centrifuging.

Quality of reclaimed oil is checked by laboratory analysis. Regarding physical chemistry properties the reclaimed oil should be close to fresh.

According to technical conditions of MPS axle oil [L] (Л) after reclaiming should have the physical chemistry properties shown in Table 7. When reclaiming motor, diesel, and other oils, besides the named methods there are applied distilling of fuel, purification by bleaching clays, leaching, addition of additives, and other methods.

Table 7

Designation of physical chemistry properties	Axle oil L	
	reclaimed	fresh (for comparison)
Flash temperature in open crucible in ^{o}C not lower than	100	135
Conditional viscosity in ^{o}VU at $50^{o}C$	3.5-7.0	5.0-7.0
Content in % not more than:		
mechanical impurities	0.1	0.07
water	0.4	0.4

Reclaiming of Padding

Dirty padding waste, rollers, and bolster brushes before purification and restoration are sorted and loaded into washing tank in such a manner that they freely float in oil heated to 70-75°C. In 10-15 min the purified materials are rinsed intensively several times and are removed to a metal screen of washing tank for runoff of oil. Further removal of oil from them is produced by pneumatic or hand presses or in centrifuges. Squeezed materials are transferred to a table for separation and scutching, in the process of which mechanical impurities are removed. All these operations are repeated twice. After purification the short threads are removed from padding waste.

All the enumerated operations were produced manually. In view of their very great labor-consuming nature, and also harmfulness to health of workers in a number of railroads there is introduced mechanization of these processes with different structural layouts of machines and devices. Good results are obtained from the application of a machine for washing padding materials with a four-bladed working wheel (Fig. 25). The shaft of wheel is displaced relative to axis of washing bath at 40 mm, as a result of which between the blade and wall of bath at a height of 410 mm from the bottom there is a clearance which permits the padding material to pass freely into washing liquid. On the blade surfaces there are installed screens for improvement of quality of washing of material.

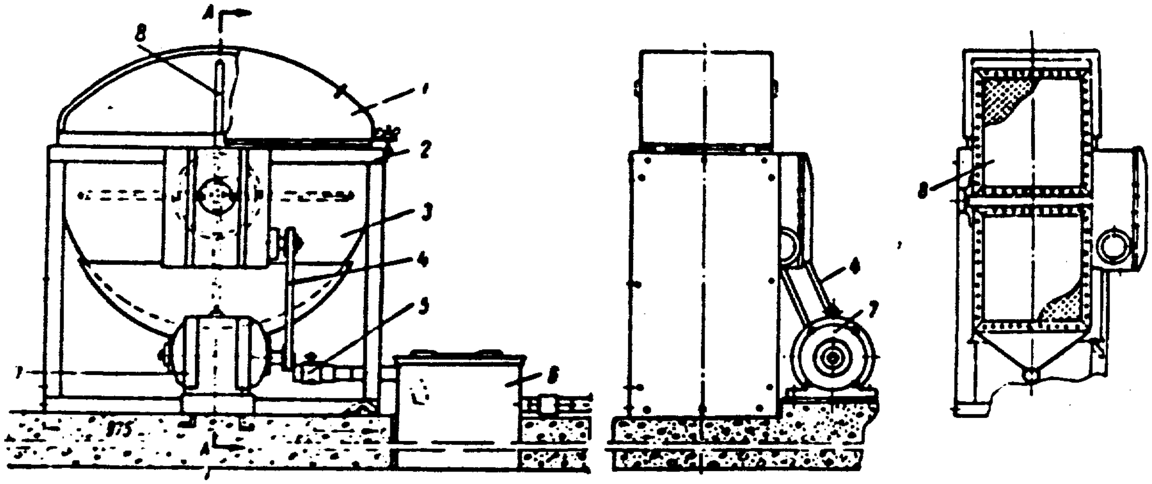


Fig. 25. Washing machine with four-bladed working wheel: 1 — cover; 2 — housing; 3 — drum; 4 — belt drive; 5 — shutoff valve; 6 — settling tank; 7 — electic motor; 8 — four-blade wheel.

Washing bath has a pipe for filling with heated lubricant, temperature of which in working process is maintained by steam jacket of bath. Dirty lubricant from the bath enters the sump collector and is removed through the drain pipe.

Subsequent scattering after washing of padding material and removal of mechanical impurities and fines from it are successfully carried out by a vibration machine, designed in one of the railway depots.

Vibration machine (Fig. 26) consists of mobile screen 2, which by means of springs and coupling bolts is installed elastically on frame 4 of machine. Vertical reciprocating motions of screen are received from cock 3 by a special vibrator (pusher) 5. Front wall of housing of machine is made sliding, consisting of two doors: lower 6 is metal, opened according to need for inspection and repair of air-distributing mechanism, and upper 1 is from glass or transparent plastic. This permits watching the course of scattering of padding waste. Cock is fastened by eight bolts to the frame, which in turn is welded to housing of machine.

For escape of vapors of lubricant during scattering of lining, and also dust and fine particles during treatment of new lining, to the vibration machine there is connected a draw pipe, combined with the overall ventilation network of reclaiming and waste-impregnating points.

Both machines permit treating 30-40 kg of padding material in 5-7 min.

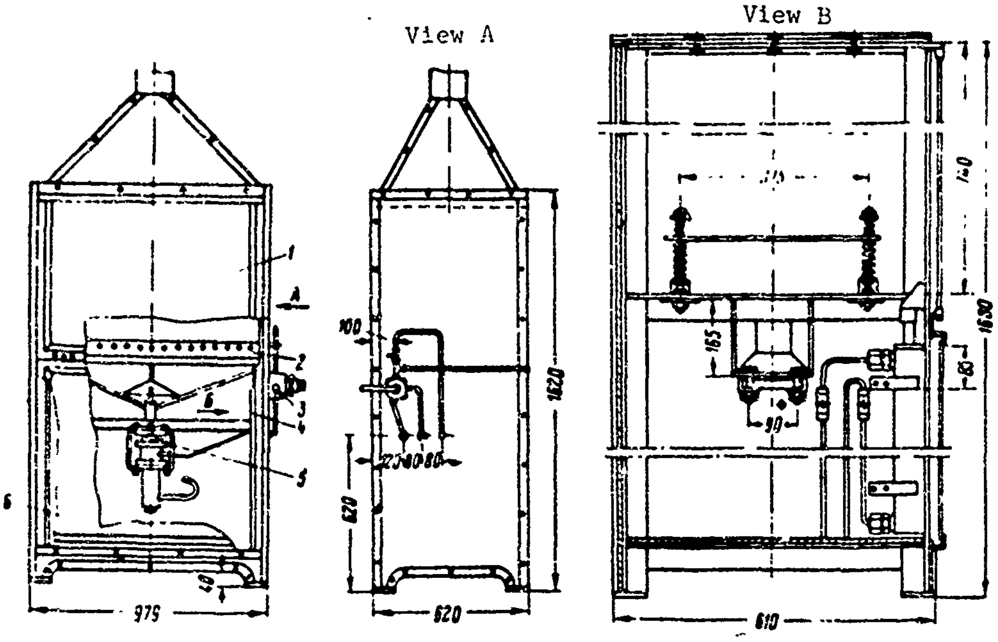


Fig. 26. Vibration machine for scattering of padding material

Rollers and bolster brushes in case of loss of needed shape by them or the presence of holes and wornness are repaired in accordance with special instructions.

Fireproof Measures During Storage and Analysis of Lubricating Materials

Lubricating materials pertain to the category of fuels; therefore, during their storage and application there should be observed all the necessary measures of fire safety.

In oil storehouses, reclaiming, laboratories, and other similar locations the use of open fire is prohibited without observance of a number of special conditions.

Preheating of oils by fire or electricity, especially during the manufacture of mixture of winter oils with tractor kerosene, should be produced in tanks having a water jacket. In all places of storage, delivery, and reclaiming of lubricating materials there should be a sufficient amount of fire-extinguishers, sand, felting, and other means of quenching fire.

Moist or slightly oiled compacted padding waste can ignite during prolonged storage in a large quantity in open air. Therefore, prolonged storage of such waste in an uncovered container, and also scattering and accumulation of oily waste are impermissible on the territory of oil storehouses, reclaiming and distributing points.

When conducting analyses of lubricating materials in the laboratory and during their transfer into glass vessel the measures of precaution should be intensive. Pouring and measuring the quantity of petroleum products during their analysis are possible only with heating instruments turned off. In a laboratory location it is permitted to store not more than 2-3 liters of inflammable petroleum products and reagents (gasoline, benzene, ether, etc.).

Practice shows that fires appear most frequently because of carelessness in the work. Therefore, in all cases of handling of petroleum products the necessary operations should be fulfilled without hurry, cautiously, and very accurately.

Questions for Self-check.

1. What basic lubricating materials are applied in railway economy?

2. What is the basic difference between axle oils L, Z, and S and for what are they intended?

3. With what are roller bearings lubricated in boxes of railroad cars?

4. What lubricants and for what purpose are applied in automatic brakes?

5. What are antiemergency lubricants and in what cases can they be applied?

6. By what is established the order of transfer of boxes of railroad cars from one oil to another?

7. What is accepted order of draining, storage, and delivery of oils and lubricating materials?

8. What oils and how are applied in winter time in especially cold regions?

9. How are axle oils and padding materials reclaimed?

CHAPTER IV

TESTING OF LUBRICATING MATERIALS

§ 1. Assignment of Chemical-Technical Laboratories of Railway Transportation

The introduction to railway transportation of powerful and high speed electric locomotives; diesel locomotives, diesel trains, improved railroad cars, and many other machines and mechanisms requires rapid mastery of new technology and high culture in the organization of continuously growing material economy of railroads.

One of the most important conditions, contributing to rational use of material resources and to increase of life and reliability of rolling stock and transport constructions, is the continuous control of quality of the numerous materials (metal, fuel, lubricants, paints, etc.) entering railway transportation.

For carrying out such control on the entire network of railroads there are organized chemical-technical road and plant laboratories, and also laboratories at locomotive and railroad-car depots.

Materials entering railroad transportation are tested in laboratories with respect to norms shown in standards or technical conditions on each type of material. Only after testing and establishment of qualitative conformity of material to standard can the head or chief engineer of corresponding organization (depot, plant) give the consent for its application. Tests should be conducted by strictly adhering to standard methods.

Besides qualified personnel each chemical-technical laboratory for carrying out needed analyses should have:

standard and regularly checked instruments and equipment;

corresponding reagents, materials, and vessels;

correctly selected samples of materials, subject to analysis, and a plant certificate on each batch of admitted material;

effective standards or technical conditions for materials to be analysized and standard methods of analysis of different materials.

During test of lubricating materials there should primarily be determined in accordance with requirements of standards for lubricating oils: kinematic or conditional viscosity, temperature of flash and ignition, solidification temperature, percentage of mechanical impurities, presence of water-soluble (mineral) acids and alkalis, quantitative content of water, and for grease lubricants: penetration, viscosity, temperature of dropfall, acid value, percentage of mechanical impurities and water, ultimate strength, mechanical stability.

§ 2. Sampling

Observance of rules of sampling of lubricating materials for analysis has important value. An incorrectly chosen sample makes all subsequent work of laboratory useless regarding testing of lubricant and does not permit obtaining actual characteristics of material. Therefore, sample of lubricant should be selected only by a well instructed laboratory worker.

It is necessary to select samples in clean and dry vessels. Liquid lubricating materials should be placed in glass bottles with tightly closed stopper; grease lubricants and oils with high viscosity — in wide-necked glass or tin beakers with tightly closed covers. Sampling of lubricating materials is produced according to GOST 2517-60.

Before sampling we thoroughly inspect the condition of packing (marking, serviceability, etc.), from which we have to take the material. Samples from a small container are withdrawn in places guarded from dust and atmospheric precipitation. Surface around stoppers, cover, and bottoms is rubbed with rags before opening.

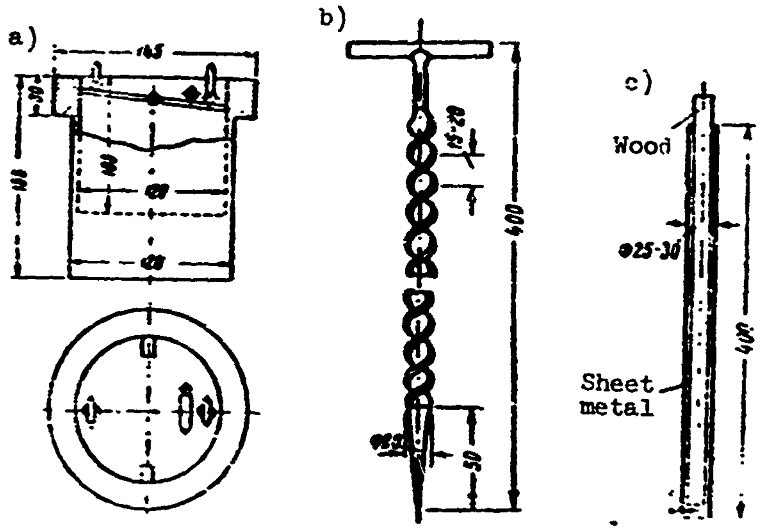


Fig. 27. Samplers: a) for liquid petroleum products; b) helical probe for grease lubricants; c) piston probe for grease lubricants.

Samplers (Fig. 27) and other equipment for sampling should be clean and dry. On each bottle and beaker with sample there is glued a label with instruction:

designation of product and its grade or type;

designation of plant-producer or base from which the product was admitted;

number of batch (or numbers of cisterns, barrels, etc.), from which sample is taken;

date of sampling.

§ 3. Determination of Kinematic and Conditional Viscosity of Oils

Viscosity of lubricating oils is standardized in units of kinematic viscosity (in stokes or centistokes) or in units of conditional viscosity (in degrees of [VU] (ВУ)). Methods of their determination are cited below.

Determination of Kinematic Viscosity
(GOST 33-53)

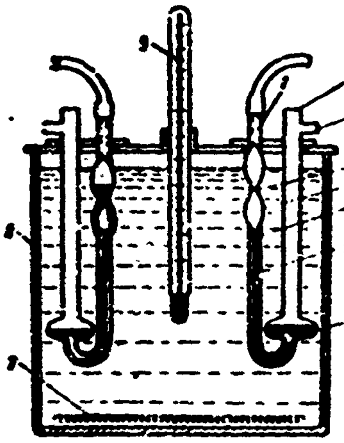


Fig. 28. Pinkevich viscosimeters, placed in water thermostat.

For determination of kinematic viscosity there are applied glass Pinkevich viscosimeters (Fig. 28). Viscosimeters are glass U-shaped tubes with three expansions 4 and 6, in the narrow elbow of which there is soldered capillary 5 with 75 mm length. Diameters of capillaries in the assembly of such viscosimeters are from 0.4 to 4 mm.

Kinematic viscosity of oils is determined in the following order:

1) we select a clean and dry viscosimeter with diameter of capillary at which time of outflow of liquid composes 300 ± 180 s;

2) on side outlet 3 of viscosimeter we put a rubber tube, overturn the viscosimeter, and plunge elbow 1 into beaker with tested oil. Having squeezed by finger the opening of wide elbow 2, with the aid of a rubber tube we such oil into narrow elbow 1 of viscosimeter to graduation b on capillary. After this the viscosimeter is turned back to normal position, rubber tube is removed from side outlet 3, and it is slipped on elbow 1, as shown on Fig. 28;

3) we install viscosimeter in thermostat 8 with heating coil 7 in such a manner that upper graduation a would be below the water level, and held 15 min. at temperature 50 ± 0.1°C, measured by thermometer 9;

4) while not removing viscosimeter from the thermostat, with the aid of rubber tube we suck oil higher than graduation a between expansions, watching so that bubbles of air were not formed in it;

5) lowering the rubber tube, we watch the flow of oil: we switch on the stop watch when its level reaches upper graduation a, and stop it when level of oil passes graduation b. Having recorded the time noted by stop watch, testing _ repeated 3-5 times more.

Arithmetic mean time of flow of oil in seconds t is multiplied by constant of viscosimeter C, given in its certificate and expressed in cSt/s. The obtained product gives value of kinematic viscosity of oil in centistokes $\nu_{50} = Ct$.

Use of this formula also facilitates selection of viscosimeter, produced according to 1 of this method.

Determination of Conditional Viscosity (GOST 6258-52)

Conditional viscosity of lubricating and vegetable oils is determined with the aid of viscosimeter of VU type (Fig. 29).

Essence of carrying out this test involves determination of time (in seconds) of outflow of 200 ml of tested oil from instrument at prescribed temperature and referring the obtained time to water equivalent of viscosimeter. Water equivalent of the given viscosimeter is the name for time of outflow of 200 ml of distilled water from it 20°C, which should be equal to 51 ± 1 s.

Conditional viscosity of tested product VU is calculated by formula

$$BY = \frac{T}{T_{20}^{H_2O}},$$

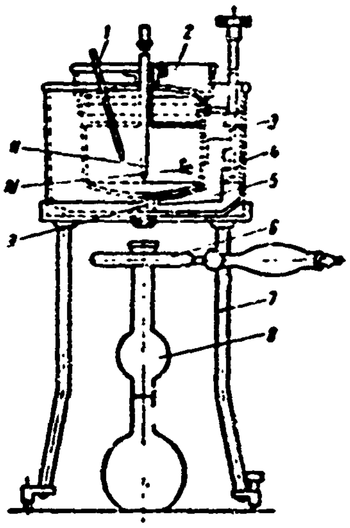


Fig. 29. Viscosimeter of VU type for determination of conditional viscosity: 1 — thermometer; 2 — cover with openings for thermometer and closing plug; 3 — reservoir for oil to be tested; 4 — reservoir-thermostat for maintaining prescribed temperature; 5 — mixer for mixing the liquid in reservoir-thermostat; 6 — collar burner; 7 — tripod; 8 — retort; 9 — drain opening; 10 — pins-indices of level; 11 — wooden closing plug.

where T — time of outflow of tested oil at a prescribed temperature in s;

$T_{20}^{H_2O}$ — water equivalent of viscosimeter in s.

Resulting value of conditional viscosity is defined as arithmetic mean of two and more measurements.

§ 4. Determination of Flash and Ignition Temperature of Oils

Flash point is such temperature at which vapors of oil evaporated during heating will form a mixture with ambient air, flashing when brought into contact with flame (but right here dying out). Ignition temperature is a higher temperature, at which oil, flashing when brought into contact with flame, continues to burn not less than 5 s. These temperatures are determined according to GOST 4333-48 in the instrument shown on Fig. 30.

Lowered flash and ignition temperatures indicate the presence in lubricating oils of low-boiling products of distillation and correspondingly their raised volatility and inflammability.

During preparation of experiment the product to be tested is powered into internal preliminarily washed and heated metal crucible 2 with height 47 mm, diameter at the top 64 mm and at the bottom 36 mm, in such a manner that the level of liquid was 12 mm from edge of crucible for oils with flash up to 210°C inclusively and 18 mm for oils with flash higher than 210°C. Correctness of filling of crucible is checked by a gage. Then the crucible with oil is placed in metal sand bath 1 with height 45 mm and diameter over 100 mm, which is set in ring of holder 4. Instrument is placed in a darkened place, where there is no noticeable movement of air. In the internal crucible there is installed thermometer 3 in a strictly vertical position in such a manner that the mercury ball was in the center of tested oil.

After assembly of instrument we approach the determination of flash point in the following order:

1) instrument is heated by flame of gas burner or Bartel lamp. Heating is conducted at first in such a manner that the rate of temperature climb was 10°C per minute, and in the range from 40°C to the expected flash point the rate is limited to 4°C per minute;

2) testing is started from 10°C to the expected flash point, for which through each 2°C of temperature rise we slowly draw the flame of igniting attachment 5 (representing a glass or metal tube with diameter of outlet for gas in 1 mm) along the edge of crucible at a distance of about 10-14 mm from surface of oil and parallel to it. Length of flame of igniting attachment during this should be 3-4 mm; time of advance of flame from one edge to another 2-3 s. In cases of absence of gas a splinter or wick in a metal or glass mounting, having the shown length of flame, can serve as igniting attachment.

For the flash point we take the temperature recorded by thermometer at the appearance of the first blue flame above part or above the entire surface of tested product.

When it is necessary to simultaneously determine the ignition temperature, we continue to heat the tested product at a rate of 4°C per minute. During this every

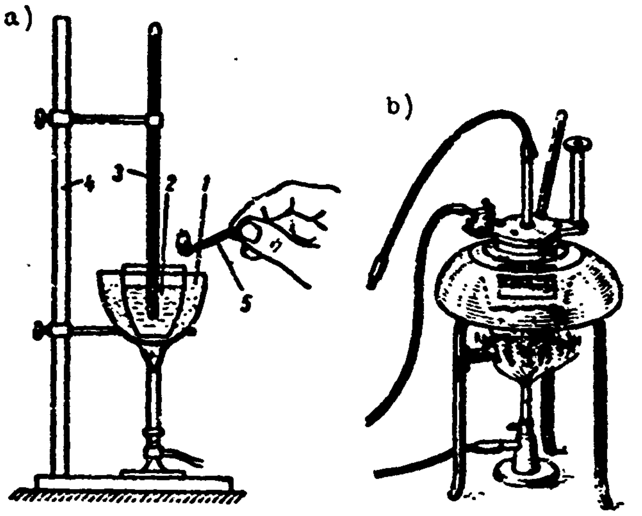


Fig. 30. Instrument for determination of flash point: a) in open crucible; b) in closed crucible.

2°C we draw the flame of igniting attachment horizontally above the surface of crucible until the tested product ingnites and burns not less than 5 s. For ignition temperature we take the temperature shown at this instant by the thermometer.

After determination of flash or ignition temperature heating of instrument is ceased, thermometer is removed, and burning product is extinguished by covering the crucible with a metal plate.

For fuels and certain oils the flash point is determined in an instrument (Fig. 30b) with covered crucible (GOST 6356-52).

§ 5. Determination of Solidification Temperature of Oils

Solidification temperature of oil is the name for that temperature at which oil thickens so much that when inclining the test tube with oil at 45° angle and holding it in such position for a minute the level of it remains motionless. For axle oils this index is especially important as characterizing the lower temperature limit of their efficiency.

Solidification temperature of oil is determined according to GOST 1533-42 in a special instrument (Fig. 31). As cooling mixture we apply: for temperature not lower than -15°C a mixture of ice and table salt, and for temperature lower than -15°C a mixture of dry ice (solid carbon dioxide) with denaturated alcohol or gasoline. Determination of solidification point is produced in the following order. In test tube 2 we pour preliminarily dehydrated oil to be tested 1 to a height of 30 mm (to annular mark) and with the help of a stopper we fasten thermometer 4 into it in such a manner that the mercury ball would be in the middle of oil. Then the test tube with oil and thermometer are placed into water bath, heated to temperature 50 ± 1°, and held in it until oil reaches temperature of bath.

After that the test tube is removed from bath, wiped and with the help of a stopper is fastened in middle of test tube-sleeve 3. The assembled instrument is secured in vertical position in holder of support and left at room temperature until the product is cooled to temperature 35 ± 5°C. Then the instrument is placed in cooling mixture 5, temperature of which should be 5°C lower than assumed solidification point of tested oil. Temperature of cooling mixture is maintained with accuracy to 1°C.

When the thermometer shows temperature of possible solidification of tested oil (specified by norms), the instrument is inclined at 45° angle and left in such position for a minute, after which it is carefully, but rapidly removed, wiped and there is determined whether meniscus of tested oil was displaced. If it was displaced, then the test tube is removed from sleeve and the whole experiment is repeated, lowering the temperature of cooling mixture 4°C below the preceding, and until meniscus of tested oil ceases to be displaced.

After finding the boundary of solidification the experiment is repeated, increasing the temperature 2°C. Even if at this temperature the meniscus will not be displaced, it is recorded as solidification point of tested oil.

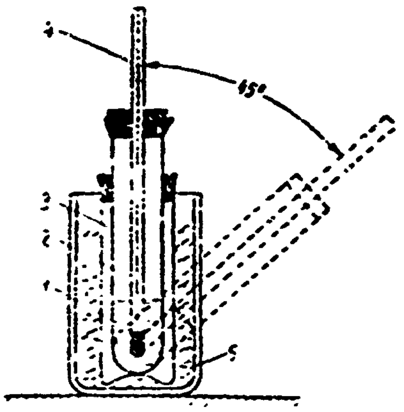


Fig. 31. Instrument for determination of solidification temperature of lubricating oils.

§ 6. Determination of Content of Mechanical Impurities, Water-Soluble Acids, Alkalis, and Water

Determination of Content of Mechanical Impurities in Lubricating Oils (GOST 6370-59)

Mechanical impurities in lubricating oils are considered all substances found in them in the form of deposit or in suspension. Their presence is qualitatively revealed by deposit on bottom of vessel from the sample of oil, by oily spot on paper, or in examining a drop of oil on a glass (especially through a magnifier with four-power magnification).

For quantitative determination of mechanical impurities the sample of tested oil (25-100 g) is dissolved in a 2-6-fold volume of heated grade [B-70] (Б-70) gasoline, gasoline-solvent, or benzene (for dark, unpurified oils), after which the obtained solution is passed through a filter and is thoroughly washed on the filter by the same solvent. With this on the filter there are precipitated all mechanical impurities, content of which is determined by weighing. Percentage of mechanical impurities serves as an index of degree of contamination of oil.

Determination of Content of Mechanical Impurities in Grease Lubricants

Mechanical impurities in grease lubricants are those substances which contaminate it. Their quantity is expressed in percents.

Content of these impurities is determined (according to GOST 1036-50) by means of extraction of lubricant in a Soxhlet apparatus by alcohol benzene mixture. Substances, contaminating lubricant, do not pass into extract and fall into deposit, which is washed on the filter by hot distilled water.

Method is used for determination of mechanical contaminations which get into lubricant during its production, usage, and storage. We also apply it for determination of content of substances, which are specially introduced into lubricant as solid additives-filters (graphite, molybdenum disulfide, and others).

Qualitative Determination of Water-Soluble Acids and Alkalis in Lubricating Oils and Preservative Grease Lubricants (GOST 6307-60)

When carrying out this analysis for oils there are necessary: separatory funnel 1 (Fig. 32) 250-300 ml, support 2 with three test tubes of white glass, methyl orange solution (0.2 g in 1,000 ml of distilled water), solution of phenolphthalein (1 g per 100 ml 96% alcohol) in droppers with pipettes 3, and distilled water. For high-viscous oil products solvent is necessary also (gasoline of grade B-70 or gasoline-solvent), checked for neutrality.

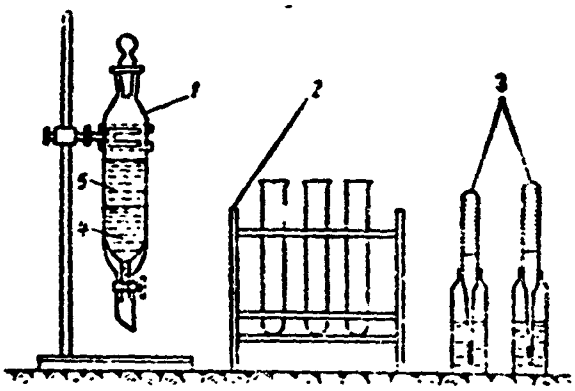


Fig. 32. Equipment for determination of water-soluble acids and alkalis in oils.

Test is conducted in the following order. Sample of oil is thoroughly agitated for 3 min in a phial, filled not more than 3/4 capacity. Viscous and paraffinaceous oils are preliminarily heated to 40-50°C. After that from it is removed a sample for analysis in quantity 50 ml and it is heated in a clean vessel to 70-80°C.

Heated sample is poured into separatory funnel and agitated for 5 min together with 50 ml of distilled water checked for neutrality, heated to 70-80°C. After that the separatory funnel is placed in support. After 10-30 min the mixture is divided into layer of oil 5 and layer of aqueous extract 4.

Aqueous extract is poured into two test tubes (1-2 ml in each). In the first test tube we add two drops of methyl orange solution (rose coloring of solution indicates the presence of water-soluble acids in oil product), in the second test tube we add 3 drops of phenolphthalein (coloring of solution indicates the presence of alkali in product).

During test of preservative grease lubricants (thickened with ceresin or paraffin) we hold the following order: from the surface of tested sample with a spatula we remove and discard the upper layer, and then in several places (not less than three) we take samples (in approximately equal quantities) that are not near the walls of vessel. Samples are put together in a porcelain cup and thoroughly mixed. Total weight of sample should be about 50 g. Then into cup we pour 50 ml of distilled water checked for neutrality, and boil the content until complete melting of lubricant and then 5 min more, while energetically mixing the melted lubricant in water. After that we cool the content of the cup to room temperature and carefully remove aqueous extract from it (by draining or pipette) into two test tubes, 1-2 ml in each. We proceed further with aqueous extracts just as with extractions from oil, and with the aid of solutions of methyl orange and phenolphthalein we determine qualitative presence or the absence of water-soluble acids and alkalis in lubricant.

Determination of Water Content in Lubricating Oils and Grease Lubricants

Presence of water in lubricating materials lowers their anticorrosion and antifriction properties. Therefore it is not permitted to apply materials containing water in a quantity greater than permissible by GOST.

Quantitative determination of water content in lubricating materials is produced by distilling it from mixture of tested material with solvent (GOST 2477-44 and 1044-41).

Instrument for determination of water content in lubricating materials (Fig. 33a) consists of metal or glass retort 2 with a short neck, glass collector-trap 3, and glass reflux condenser 4. Glass collector-trap is a cylindrical test tube graduated in 10 ml with conical lower part and a soldered drain tube. Instrument is set up with the aid of support 5 and tripod 1; heating is produced by gas burner 6 or an electric bulb heater.

As solvents we apply:

a) for determination of water in lubricating oils – tractor petroleum naphtha (GOST 2109-46), "Rubber" gasoline (GOST 443-56), or gasoline of direct distillation, from which fractions, evaporating at temperatures to 80°C are driven off;

b) for determination of water in grease lubricants – gasoline with beginning of boiling not lower than 90°C and end of boiling not higher than 150°C or tractor petroleum naphtha. Solvents before use should be dehydrated by dry calcium chloride and filtered.

Test is conducted in the following order. Sample of analyzed lubricating oil is well mixed and is agitated in phial for 5 min, not more than 3/4 of its capacity. Viscous and paraffinaceous oils are preheated to 40-50°C.

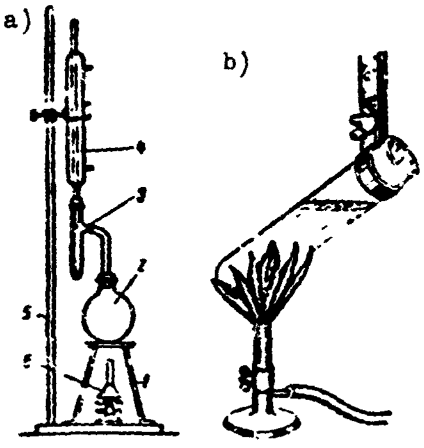


Fig. 33. Instrument for determination of quantitative content of water in oil and lubricants and the position of test tube during qualitative determination of presence of water in oil.

Into well dried retort we pour 100 g of tested oil with accuracy of 0.1 g, there add 100 ml of solvent, and thoroughly mix. It is permitted to measure low-viscosity oil in retort by volume. Suspension of oil in this case will be equal to its specific gravity, multiplied by 100. With this measuring vessel (without washing) we measure and pour into retort 100 ml of solvent, which will wash residue of oil from walls of cylinder. For preventing vigorous boiling into retort we throw several pieces of dry pumice, faience, or glass capillaries.

Retort with the aid of stopper is connected with collector-trap, and the latter – with condenser, and we grease their compounds with collodion in order to avoid admission of vapors. We switch on the heater, and after the mixture boils we conduct distillation in such a manner that from the slanted cut end of condenser 2-4 drops per second would fall into collector-trap.

Distillation is stopped when volume of water in collector ceases to be increased and the upper layer of solvent appears absolutely transparent. Time of distillation should compose not more than an hour. After cooling of retort the apparatus is disassembled.

Content of water in percent by weight is calculated by formula

$$W_{acc} = \frac{V \cdot 100}{p},$$

where V — volume of water in collector in ml;
p — suspension of lubricant in g.

When quantity of water in collector-trap appear less than 0.025 ml (half of lower graduation), it is considered that there are only traces of water in lubricant.

Determination of water content by this method in grease lubricants differs from the shown order by the following: sample of tested grease lubricant is thoroughly mixed with a clean dry spatula, after which into predried retort of instrument 20-25 g of this lubricant with accuracy to 0.1 g is weighed out on technochemical scales; 150 ml of solvent is poured into retort, during which for soda lubricants one should take only gasoline of the above-indicated quality, and for all remaining lubricants any of the given solvents.

In other respects the experiment and calculation are conducted the same as in case of determination of water content in lubricating oils.

The qualitative presence of water in oil can also be verified by a simpler method. For this it is necessary to heat oil in a glass test tube to a temperature higher than 100°C (but not higher than 150°C). If in oil there is contained even a very small amount of water, then the oil will foam, characteristic audible crackling begins, and the test tube will shudder. The simplest diagram of such determination is shown of Fig. 33b. Its conduction is more exactly according to GOST 1547-42 when heating is conducted not on open fire, but in an oil bath.

§ 7. Determination of Penetration of Grease Lubricants

Consistency (degree of density) of lubricants is determined with the aid of penetrometer (Fig. 34). This index is characterized by number of penetration, representing the depth of submersion of standard cone into tested sample of lubricant for 5 s, expressed in tenths of a millimeter.

The greater the number of penetration, the softer is the grease lubricant.

Order for determination of penetration of grease lubricants according to GOST 5346-50 is the following.

Metal beaker 1 (Fig. 35) of mixer is filled with lubricant to be tested. With this it is necessary to see that air cavities do not remain in it. Then the beaker is tightly closed by screw-on cover 3 and is placed in thermostat for an hour at outlined testing temperature.

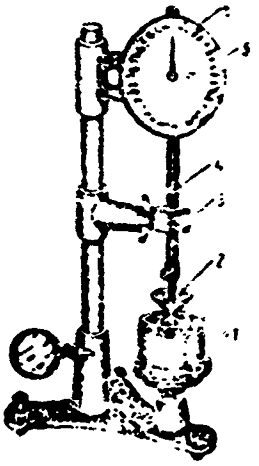


Fig. 34. Penetrometer.

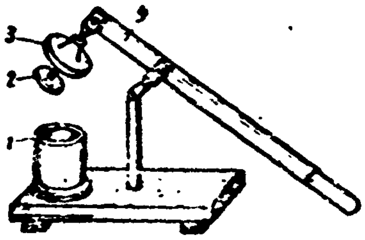


Fig. 35. Mixer for penetrometer.

The heated beaker to required temperature is fastened on support of mixer and lubricant is mixed, while lifting and lowering handle 4 of mixer with agitator 2 60 times per minute.

After mixing the beaker with lubricant is again held in thermostat for 15 min at 25°C and 30 min, if testing is conducted at a higher temperature, after which the cover is removed from beaker, surface of lubricant is levelled thoroughly by a knife or spatula, and it is placed on table of penetrometer 1 (see Fig. 34). In order to hold temperature of lubricant at the assigned level during testing, it is necessary to place the beaker with lubricant on table of instrument together with a water or another bath, in which the prescribed temperature is maintained during the entire experiment. Hard grease lubricants are not mixed, but are placed in the form of a rectangular piece into a metal box, which is also preliminarily placed into bath for an hour at the outline testing temperature.

Cone of penetrometer 2 is set so that its point would only touch the surface of lubricant and so that during submersion it would not graze the beaker walls, after which rack 4 of instrument is lowered to contact plunger, in which the cone is fastened, and pointer of dial is set on zero. Simultaneously with the right hand we press push button 3 of instrument, and with the left start a stop watch, making it possible to immerse cone into lubricant. In 5 s we release the push button and simultaneously halt the stop watch.

Rack of instrument is lowered to contact plunger and we record how many graduations pointer 6 on dial 5 moved during this. Number of graduations will also give penetration number of tested lubricant. Then the cone is lifted to initial position, wiped with cotton, moistened in gasoline, surface of lubricant is levelled and test is repeated 4 more times. For penetration index we take arithmetic mean of five determinations.

Penetration of lubricant, determined at minus temperatures, can definitely characterize its frost-resistance.

§ 8. Determination of Temperature of Dropfall of Grease Lubricants

Temperature of dropfall of grease lubricants is that temperature at which there occurs softening and fall of the first drop of lubricant from capsule of instrument, heated in strictly determined conditions (GOST 6793-53). Temperature of dropfall is indicated by upper temperature limit of application (efficiency) of lubricant. Lubricant will not be melted and flow from frictional unit if its temperature is 15-20°C below temperature of dropfall of lubricant.

Instrument for determination of temperature of dropfall of grease lubricants (Fig. 36) consists of special thermometer 1, in lower part of which there is fastened glass capsule 3 with tested lubricant, having an opening, test tube 2 with 40-45 mm diameter and 180-200 mm length, beaker 4 and agitator 5.

Temperature of dropfall of grease lubricants is determined in the following order.

Tested lubricant, from which the upper layer is preliminarily removed, is tightly cemented into glass capsules with a spatula; surplus of it is cut from upper part of capsule with a knife. Capsules with lubricant are inserted in a metal case in such a manner that the upper end of it rested in beads or brads of instrument. A certain quantity of lubricant, squeezed from opening of capsule during this by bulb of thermometer, should be carefully removed with a knife.

On the bottom of test tube there is placed a white paper circle, replaceable after each determination. Thermometer with capsule is secured in the test tube with the aid of a plug in such a manner that the lower edge of capsule was at distance of 25 mm from the bottom of test tube. Test tube is placed in vertical position in beaker, filled with water or light oil with flash point not lower than 180°C to a level of 120-150 mm from bottom of beaker.

We heat water or oil in the beaker with continuous mixing in such a manner that thermometer readings, starting from a temperature 20°C below the expected point of fusion, were increased at the rate of 1°C per minute.

The temperature at which the first drop of tested lubricant falls from the lower opening of capsule will be the temperature of dropfall. If lubricant does not form drops, but is extended from capsule in the form of a column, for temperature of dropfall we take that at which the extended column of lubricant touches the bottom of test tube.

Allowable divergence between parallel determinations should be not more than 1°C.

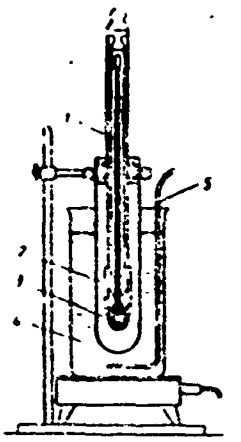


Fig. 36. Instrument for determination of temperature of dropfall of grease lubricants.

§ 9. Determination of Acid Value of Grease Lubricants

Acid value characterizes the content of free organic acids in grease lubricants thickened with soaps. It is determined according to GOST 6707-57 and consists of the following.

In conical retort with an accuracy of 0.1 g we take suspension of 4-5 g of tested lubricant. During test of dark and difficultly soluble lubricants we take smaller suspension 1-1.5 g with an accuracy of 0.0004 g. In another conical retort we pour 30 ml of light gasoline of direct distilling and 20 ml 60% ethyl alcohol. We close the retort by a plug with condenser inserted in it and boil the mixture for 5 min with continuous mixing. Into the hot alcohol-gasoline mixture we add 3-4 drops of phenolphthalein and at continuous mixing neutralize with 0.1 normal (n) alcohol solution of caustic alkali until the appearance of a slightly rose color.

After that the neutralized hot alcohol-gasoline mixture is poured into retort with suspension of lubricant, retort is closed with a condenser inserted in it, and content is boiled while mixing until dissolution of lubricant.

After complete dissolution of lubricant we continue to boil the mixture 5 minutes more. Then we seal the upper end of tube of condenser with cotton and cool the mixture to room temperature. To the cooled retort with lubricant and neutralized solvent we add 3-4 drops more of phenolphthalein and in case the contents do not obtain pink color immediately, titrate it with 0.1 n of alcohol solution of caustic alkali until the appearance of slightly pink color. Appearance of pink coloring at the moment of introduction of phenolphthalein shows that lubricant does not contain free organic acids, but contains free alkali.

Acid value K of tested lubricant in mg of [KON] (KOH) per 1 g of lubricant is calculated by formula

$$K = \frac{V \cdot 0.00561 \cdot 1000}{G} = \frac{5.61\,V}{G}\,,$$

where V — volume of alcohol solution of caustic alkali (in coversion to exactly 0.1 n solution) expended on titration in ml; 0.00561 — quantity of caustic alkali corresponding to 1 ml exactly of 0.1 n solution of hydrochloric acid, in g; 1,000 — coefficient for conversion of 1 g into mg; G — suspension of tested lubricant in g.

§ 10. Determination of Viscosity of Grease Lubricants

Grease lubricants in contrast to oils are not flowing materials, but materials obtaining fluidity under the influence of pressure. Therefore, with determination of viscosity the grease lubricant should press through a capillary tube of definite section. Viscosity of grease lubricant is variable even at constant temperature, depending on its rate of deformation. Therefore, when determining viscosity it is necessary to know not only the temperature, at which it was determined, but also the speed at which the lubricant was pressed through capillary. Such viscosity is called effective.

Viscosity of grease lubricants is determined according to GOST 7163-54 on automatic capillary viscosimeter (instrument [AKV-2] (AKB-2)), shown on Fig. 37. Essence of determination of viscosity of grease lubricants involves the following.

With the aid of rod 1 lubricant from chamber of instrument 2 at a specific temperature, created by thermostat, is pressed through calibrated capillary tube 3. Rod is brought into action by preliminarily compressed tared spring 4. In the beginning at full compression of spring the lubricant is pressed at great speed. Then in proportion to the spring becoming lax the pressure weakens and rate of outflow of lubricant is decreased.

Values of spring pressure and outflow velocity of lubricant during the entire experiment are automatically traced by a pencil in the form of a curve on tape, installed on revolving drum 5.

By curve or curves, obtained at different temperatures by means of simple calculation, given in GOST 7163-54, we find viscosity of lubricant in poises at different outflow velocities of it from capillary.

Determination of effective viscosity of grease lubricants is more complicated than determination of their penetration, and requires more time for mastering this method. At the same time viscosity of grease lubricant is a more reliable and promising index of operational properties of lubricant than penetration.

By using effective viscosity, one can determine pumping quality of lubricant for frictional units and starting properties of it for lubricated mechanisms.

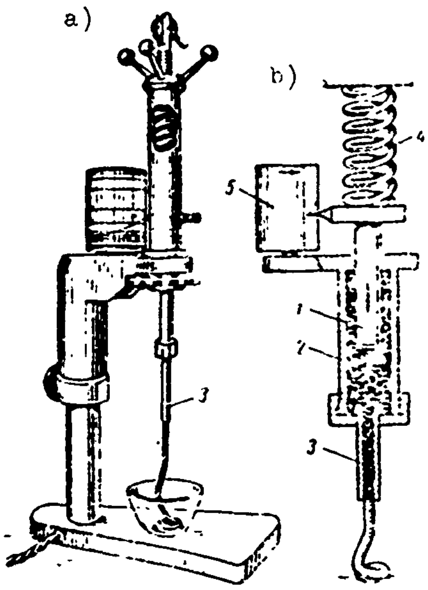


Fig. 37. AKV-2 automatic capillary viscosimeter for determination of effective viscosity of grease lubricants: a) overall view; b) diagram.

§ 11. Determination of Ultimate Strength of Grease Lubricants

Ultimate strength of grease lubricants, called shear stress limit, is that minimum force (in g/cm^2) which it is necessary to apply to lubricant in order to change its shape and to shift one layer of lubricant relative to another. Lubricant with low strength will not be held in frictional units, will be rejected from moving parts, and slip from vertical surfaces.

Lubricant with high strength will create increased resistances for shift of parts of frictional unit.

Therefore, while determining ultimate strength of lubricants, one should bear in mind its optimum value. Ultimate strength of lubricants is lowered with increase of temperature. It is determined according to GOST 7143-54 on a K-2 plastometer (Fig. 38).

Order of carrying out this test is the following. Metal capillary 1 with internal screw thread is filled with lubrication to be tested 2. After this the lower part of capillary is connected by a tube with oil tank 3, having a manometer; its upper part remains open. Oil tank and tube are filled with low-viscosity oil. Capillary with tested lubricant is heated with the aid of electric plate 4 or cooled

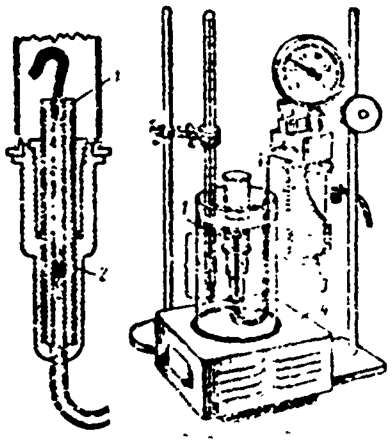


Fig. 38. K-2 plastometer for determination of ultimate strength of grease lubricants.

to prescribed temperature. Then we switch on the electric furnace, heating the tank with oil, and watch the manometer. Rate of increase of pressure in system should be not more than 0.05 kgf/cm^2 per 1 min when using long capillary (l = 100 mm) and 0.05 per 2 min when using short capillary (l = 50 mm). Rate of increase of pressure is regulated by lifting or lowering the electric furnace along the tank with oil.

After pressure in system, having reached a certain maximum, starts to be reduced, which characterizes shift of lubricant, experiment ceases.

Maximum pressure is recorded with accuracy of 0.01 kgf/cm^2. Ultimate strength of tested lubricant τ in gf/cm^2 is calculated by formula

$$\tau = \frac{pr}{2l}\ 1000,$$

where p — maximum pressure in kgf/cm^2; r — radius of capillary in cm; l — length of capillary in cm.

For result of tests we take arithmetic mean of two determinations.

§ 12. Determination of Mechanical Stability of Grease Lubricants

Mechanical stability of grease lubricants is their ability under conditions of storage or intense mixing to preserve their consistency and viscosity without changes or with small changes. Lubricants, strongly diluting or hardening in conditions of storage or under the influence of mixing, are not mechanically stable and cannot ensure normal operation in frictional units. There is no standard method for determination of this index. In practice for these purposes we most frequently use method of stirring of grease lubricants in a mixer from penetrometer (see Fig. 35).

Comparison of value of penetration of lubricant in its initial stage (after lifting and lowering of handle of mixer 60 times for 1 min) with changed penetration after 10,000 cycles of such mixing permits indicating the degree of mechanical stability of grease lubricants.

§ 13. Other Methods of Testing Lubricating Materials

Besides the above described basic methods of testing of lubricating materials, there is still a considerable amount of methods of testing them with respect to other indices. All of them are expounded in the collection "Methods of testing of petroleum products," issued and supplemented periodically by Standartigiz. This collection is a reference aid of each laboratory for analysis of lubricating materials.

The number of methods which can be additionally encountered in practice of laboratory check of railroad-car lubricating materials should include:

1) determination of acidity — acid value (organic acidity) of oils (GOST 5985-59);

2) determination of ash content of oils (GOST 1461-59);

3) determination of color of oils (GOST 2667-52);

4) determination of coking capacity of oils (GOST 5987-51);

5) corrosion testing of oils and grease lubricant, (GOST 2917-45 and 5757-51);

6) testing of grease lubricants for thermal and chemical stability (GOST 1631-61); and also colloidal stability (GOST 7142-54) and several other methods.

Questions for Self-Check.

1. What conditions should be observed during sampling of oils and lubricants for analysis?

2. What basic properties characterize quality and grade of lubricating oils?

3. What order of determination of kinematic and conditional viscosity of oils is set and what is the practical value of this determination?

4. How are flash, ignition, and solidification temperatures of lubricating oils determined and what is the practical value of these determinations for axle oils?

5. What foreign impurities can be in lubricating oils? What is the order of determination of these impurities and their effect on lubricated parts?

6. What basic properties characterize quality and grade of grease lubricants?

7. How is degree of density of grease lubricants determined?

8. What is the order of determination of temperature of dropfall of grease lubricants and the value of this index for brake lubricant and greased compositions?

PART TWO

PROTECTIVE MATERIALS

CHAPTER V

GENERAL CONCEPTS ON PROTECTIVE MATERIALS

§ 1. Corrosion of Metals

Corrosion of metal in atmospheric conditions is an electrochemical process, which can be expressed in the following way. On the surface of metal (steel), having various structural heterogeneities, with the precence of moisture there appear local electrical currents (microcurrents), forming a trace element. In this element (Fig. 39) segment of pure iron 1 will be anode, and segment 2 of foreign inclusion or more electropositive structural heterogeneity — cathode.

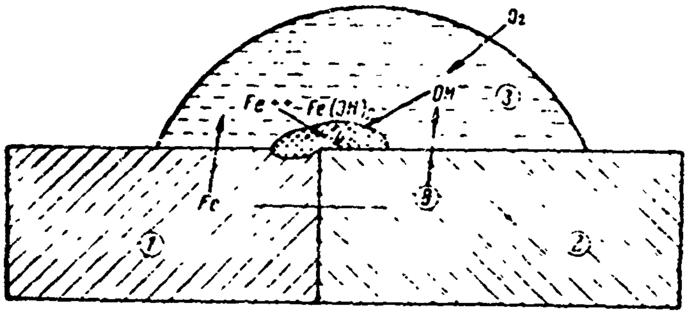


Fig. 39. Electrochemical process of metal corrosion: 1 — anode zone; 2 — cathode zone; 3 — electrolyte — drop of moisture; 4 — products of corrosion — rust; θ — electron.

As a result of the reaction flowing in trace element the iron at anode will be changed into solution

$$\mathrm{Fe} - \mathrm{Fe}^{\cdot\cdot} n\,\mathrm{H_2O} + 2\theta,$$

whereas at the cathode under action of supply of atmospheric oxygen the following reaction will occur:

$$2\theta + \frac{1}{2}\mathrm{O_2} \xrightarrow{\mathrm{H_2O}} 2\mathrm{OH}^-.$$

In solution (zone 3) the iron will be oxidized

$$\mathrm{Fe} + 2\mathrm{OH} - \mathrm{Fe(OH)_2} \rightarrow \mathrm{FeO}\cdot\mathrm{H_2O}$$

with formation of rust subsequently in zone 4, composition of which can be represented by the following formula:

$$x\,FeO\,y\,Fe_2O_3\,z\,H_2O.$$

Appearance of the first areas of corrosion and the appearance of rust sharply accelerate the corrosion process, since rust, being electropositive with respect to iron, acts analogously to electropositive heterogeneities of metal.

Corrosion practically always appears when some metal touches another, since on the surface of metals there is almost always a layer of condensed moisture, playing the role of electrolyte in element.

Corrosion rate of various metals is different and is dependent on value of electrode potential. The latter depends on properties of the metal itself and liquid (electrolyte), in which it is located, and also on concentration of ions of this metal in it. Certain metals, for example, zinc, iron, aluminum, cadmium, tin, and others, having negative electrode potential with respect to hydrogen, potential of which is equal to zero, are called electronegative metals. Others, for example, copper, silver, platinum, having positive electrode potential, are called electropositive.

Electronegative metals in solutions of their salts behave similar to that which was analyzed on an example of iron. As the property of electronegative metals to be sent into solution their own positively charged ions are used in technology for protection of different constructions from corrosion. This method of protection from corrosion is called protector, and electronegative metals utilized for this — protectors.

With submersion of electropositive metals (platinum, copper, and others) into solution of their own salts there will take place phenomena that is opposite to the above described.

That metal, which in the formed galvanic cell is anode, is subjected to corrosion. For example, if copper sheets are riveted by aluminum rivets, then in a short time the aluminum rivets will start to corrode and will drop out.

With flow of reaction of corrosion the abundant wetting of metal by water or deposits is not necessary, since along with sea corrosion, occuring under a thick film of moisture, damp corrosion under a thin film of moisture or condensate, ensuring easy access of oxygen to corroding metal flows considerably more intensively.

In view of sharp daily temperature drops and increase of relative humidity of external air, and also the penetration of air through wooden partitions of railroad car walls, dew falls on surface of metal or moisture is condensed, which assists corrosion.

Content of gases (products of fuel combustion and others) in atmosphere strongly accelerates the process of corrosion. Thus, in conditions of a locomotive depot corrosion of steel flows 3 times more intense than under conditions of an industrial region, and 9 times as compared to a rural area.

Contaminations getting on metal surfaces of railroad car — slag, scale from locomotives, dust, mud, metallic particles from brake shoes, and also contact with transported loads — salt brines in isothermal railroad cars, chemicals in tank, coal and ore in gondola cars, etc., intensify the process of corrosion. Some of these contaminations (coal, ore) absorb moisture from the atmosphere and create areas of corrosion around themselves, during contact with metal being areas of formation of a number of new microgalvanic cells, in which these contaminations are cathodes, and metal around them anode, subjected to additional destruction. Other forms of contaminations (acids, salt brines) increase the electrical conductivity of film of moisture settled on metal or by their raised chemical activity accelerate the process of corrosion.

Table 8

Designation of parts and units of railroad cars	Corrosion rate on depth in mm/year	
Passenger cars		
Floor from internal side	0.075-0.20	
Walls from internal side	0.04-0.075	
Ceiling from internal side	0.01-0.04	
Floor from external side	0.05-0.08	
Pipes of heating network	1.0	
Small water tank	0.67	
Radiator pipes	0.5-0.63	
Walls and bottoms of air-heater	0.4-0.5	
Lower housing of boiler	0.72	
Chimneys	0.67	
Coal box	0.61	
Four-axle freight cars	Gondola cars	Box cars
End beams (buffer beams)	0.20-0.45	0-0.20
Pin beams	0.10-0.30	0-0.20
Intermediate beams	0.05-0.25	—
Spinal beams	0.05-0.25	0-0.20
Lateral channel beams	--	0.10-0.25
Supports	0-0.20	0-0.15
Door frame	0.10-0.35	0-0.15
Isothermal railroad cars (with wall pockets)	[illegible]	[illegible]
Spinal beams	0.15-0.40	0.12-0.16
Lateral beams (lower fastening region)	0.06-0.13	0.02-0.04
Pin beams	0.16-0.32	0.13-0.30
End beams	0.15-0.27	0.08-0.22
Transverse beams	0.16-0.30	0.14-0.60
Floor	0.40-0.60	—
Sulfuric acid tanks (from internal side)		
Front bottom	0.6-2.0	
Upper plate	0.5-2.0	
Lateral plate	0.7-2.0	
Lower plate	0,5-1.3	
Cap	1.0-1.6	

Intensity of development of corrosion of railroad cars g. 40) depends both on weather effects and the influences of transported cargoes, and to a considerable degree on structural design of separate units of railroad cars. Corrosion rate for a number of parts of rolling stock is given in Table 8. Typical corrosional damages of railroad cars, cause of which are structural shapes of units and parts, include the following:

through damages of recesses of corrugated floor;

destruction of ridges of corrugated floor in places of contact with moistened mipor;

corrosion in places of loose fitting of elements to each other, for example, vertical supports of end walls of isothermal railroad cars, overhead corrugations of passenger and other railroad cars;

Fig. 40. Through corrosional destruction of corrugated floor of railroad car after a period of 5-6 years.

injury in places of contact of metal with wood;

corrosion along perimeter of beading of window frames;

through destructions in zones of weld seams;

corrosion in closed spaces of longitudinal box beams of passenger cars;

corrosion of sections subjected to variable bends, etc.

Metal bodies, frame, carriages, and frames of railroad cars experience considerable cyclic variable load during movement of trains. The latter represent an intense alternating dynamic load, which, besides cracks of fatigue character, with simultaneous influence of corrosion factors causes development in structures of such dangerous damage as corrosion fatigue cracks (Fig. 41) and corrosion cracking (Fig. 42).

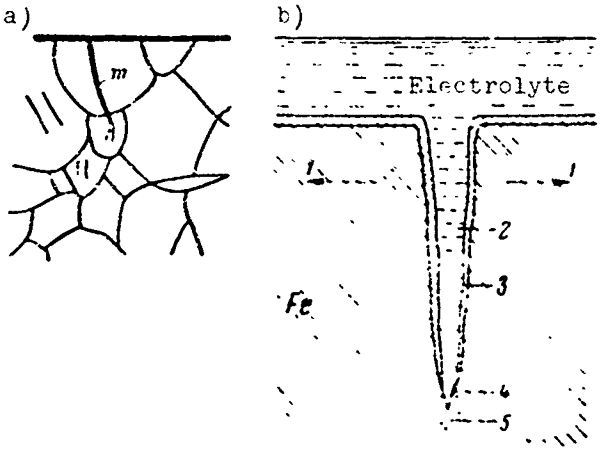


Fig. 41. Diagrams of fatigue and corrosion-fatigue breakdown of metal: a) diagram of formation of fatigue microcrack; b) diagram of corrosion-fatigue microcrack; m — microcrack with shear lines on end; 1 — direction of basic tensile stresses; 2 — primary crack, filled with electrolyte and products of corrosion; 3 — protective film — cathode of corrosion pair; 4 — travelling point of crack — anode of corrosion pair; 5 — maximum stressed region of metal (zone of preexisting imperfection).

Lowering of intensity of these damages can be attained by application of metallic or varnish and paint coating (Fig. 43) on surface of steel or aluminum articles.

Sufficiently reliable and the most practicable method of protection of metal surfaces of rolling stock and railroad structures from corrosion, and also protection of wooden parts from the destroying action of environment, is application of varnish and paint coatings on them.

Fig. 42. View of corrosion cracking of steel structures: a) external view; b) cross section (microphotography).

§ 2. Protective Varnish and Paint Materials

For protection of metals from corrosion, wood from rotting, and giving a pleasant appearance to various articles, railroad cars, and locomotives, and also for satisfaction of sanitary-hygienic conditions we apply varnish and paint coatings on them.

Varnishes and drying oils, paints and enamels are liquid high-molecular organic materials, which, being applied on surface of an article, harden with passage of time, forming films (protective coatings), durably gripping the painted surface.

On articles we usually apply a multilayer system of coatings, in which corresponding types of varnish and paint materials fulfill definite tasks.

a) Primers, applied directly on metal or wood, serve for formation of a layer which provides high adhesion (sticking) to painted surface and to subsequent layers of coating; they should possess high waterproofness and anticorrosion resistance. On wood besides primers we apply mordants, which serve for coloring of wood materials to imitate various types of wood.

b) Puttys are intended for levelling off of painted surface and for filling pores of wood.

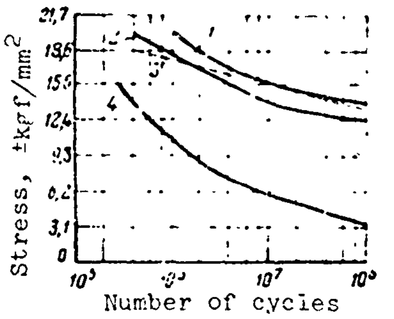


Fig. 43. Graphics of the effect of painting of surface on fatigue strength of aluminum alloy in various media: 1 and 2 – in air; 3 and 4 – in 3% solution of common salt; 1 and 3 – painted samples; 2 and 4 – unpainted samples.

c) Coatings – paints, enamels, varnishes – provide weatherproofness, resistance to the influence of various media and mechanical factors, and also aesthetic decorative finishing, providing proper sanitary-hygienic state of article, railroad car, etc.

Depending upon quality of finishing and assignment the coatings are distinguished by their appearance (class of coating), by conditions of usage (group of coating), and by materials.

In railway economy there is applied a large number of various varnish and paint materials. For production of the latter as raw material and semi-finished products there are used film-forming substances (oil, resin), pigments, plasticizers, solvents, and others. Raw material sources for production of numerous synthetic varnish and paint materials and their component parts are petroleum and petroleum gases (Fig. 44), coal (Fig. 45), and wood (Fig. 46).

For priming of metal units and parts of railroad cars of all types we apply primers – glyptal No. 138, [GF-020](ГФ-020), phenol [FL-03k](ФЛ-03к), [FL-013] (ФЛ-013), vinyl-perchloride [KhS-010](XC-010), KhS-025, or oil from iron-oxide red paint on oksol drying oil, and for internal surfaces of metal body of all-metal passenger and isothermal railroad cars – lead-oxide red paint on natural linseed oil. For painting freight cars (box, gondola, flat cars, etc.) we apply oil paints on drying oil of glyptal, pentaphthalic, or oksol, vinyl-perchloride enamels and water-emulsion paints (for wooden surfaces). For painting isothermal railroad cars we apply oil paints of various colors, water-emulsion paints, acrylic enamels, and others. For painting tanks there are applied various vinyl-perchloride and copolymer enamels, and also oil paints. Passenger cars are painted with glyptal, pentaphthalic, and also phenol and urea-formaldehyde (carbamide) enamels. Furniture of these cars is varnished with oleoresinous, nitrocellulose, polyester, alkyd-styrene, alcholhshellac, and other varnishes.

Furthermore, for painting passenger cars alkyd-melamine, polyester acrylate, alkyd-acrylic, alkyd-phenol enamels and varnishes are promising.

Certain varnish and paint materials have a specific special purpose assignment. Chemically stable vinyl-perchloride, and also acid-resistant enamels and varnishes are applied for painting of lead storage batteries; epoxy enamels and enamels on chlorinated rubber and cyclorubber – for painting alkaline storage batteries. Paints based on bakelite varnish are used for painting tanks-dilators of air-heaters; acrylic primer and enamels – for painting internal surfaces of water tanks; polyurethane primer and enamels – for gasoline-resistant coatings, and silicone (polysiloxan) varnishes and enamels – for heat resistant coatings.

In order to become well acquainted with areas of application and conditions of applying varnish and paint materials, it is necessary to study these materials.

Varnish and paint materials are produced by means of corresponding processing of component parts entering them – binding, pigments, solvents, plasticizers, etc.

Production diagram of basic types of varnish and paint materials from initial raw material is presented on Fig. 47.

Basic quality of varnish and paint material is determined by binder entering it (oil, resin, latex) and therefore they are named according to these binders: oil, glyptal, vinyl-perchloride, polyvinyl acetate, etc.

As any organic compound the binder consists of carbon, hydrogen, oxygen, and in certain cases with addition of nitrogen, chlorine, fluorine, silicon, and other elements.

GRAPHIC NOT REPRODUCIBLE

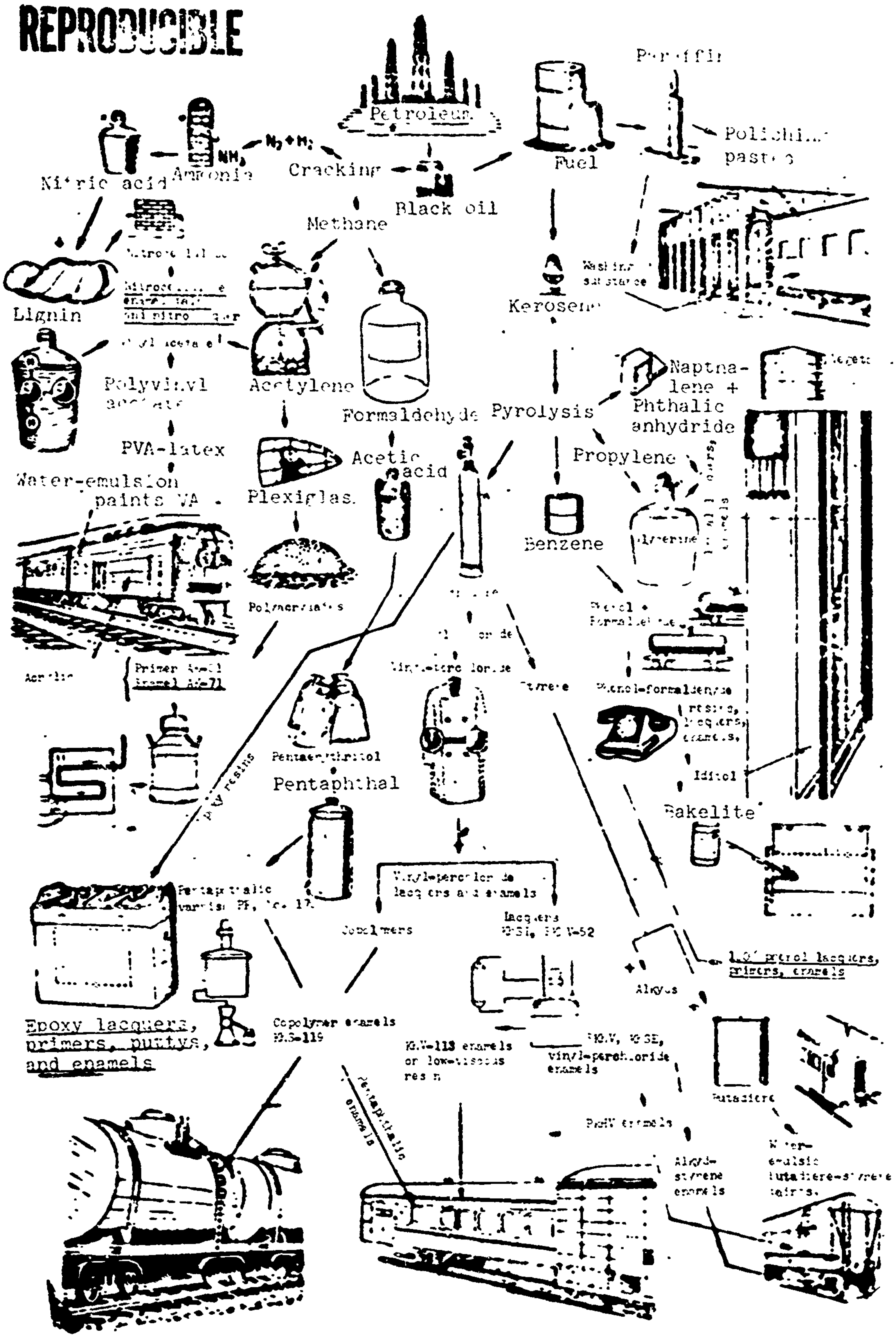


Fig. 44. Production diagram of varnish and paint, auxiliary, and other protective materials from petroleum and petroleum gases.

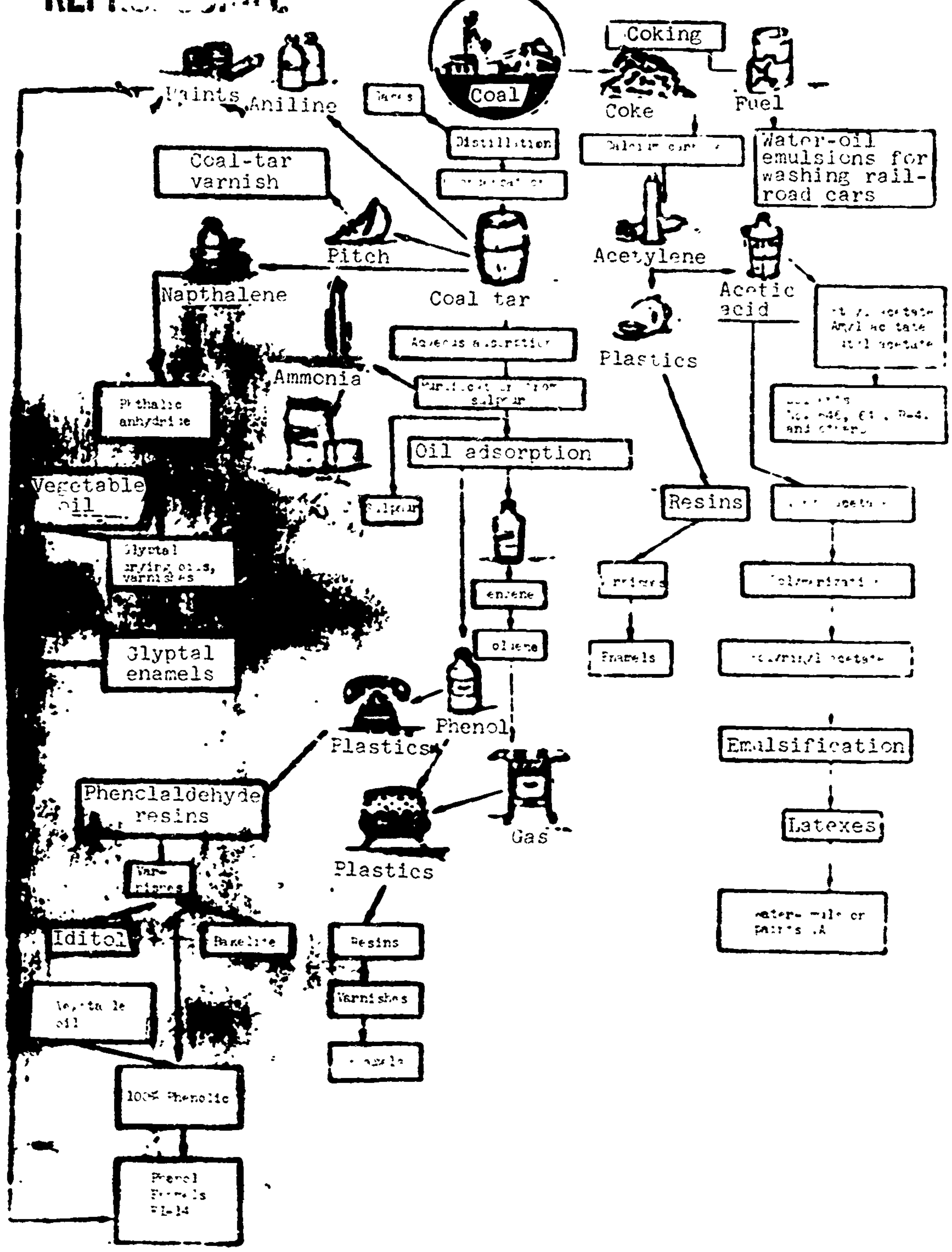


Fig. 45. Production diagram of varnish and paint materials from coal.

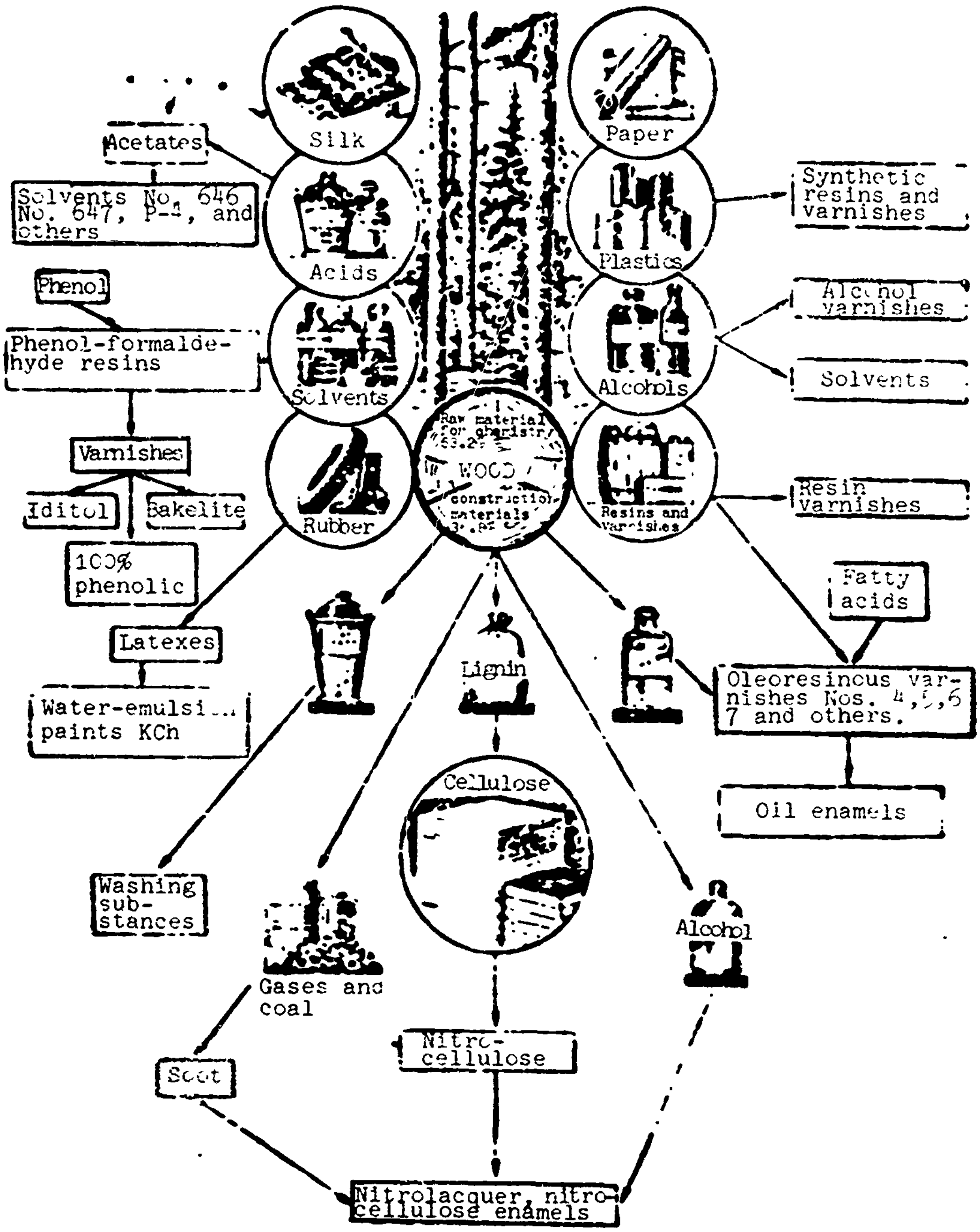


Fig. 46. Production diagram of varnishes, paints, washing, and polishing agents from wood.

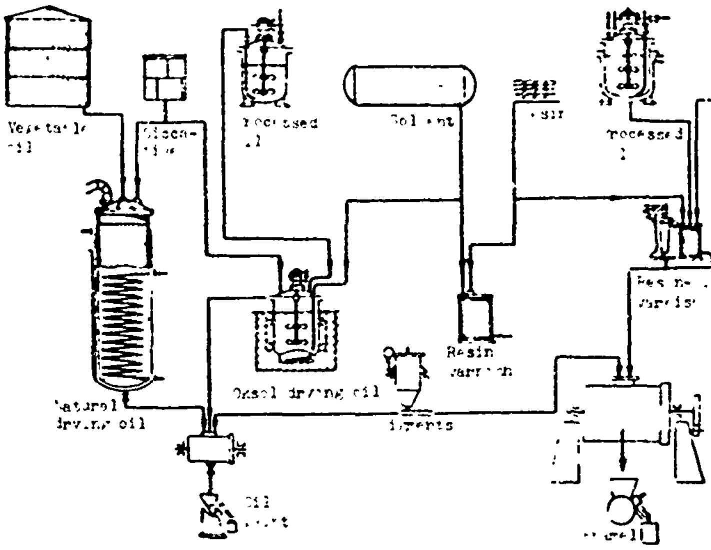


Fig. 47. Production diagram of basic types of varnish and paint materials from initial raw material.

Its properties depend on elements entering its composition and on the structure of molecule formed by these elements.

Structure of molecules of any paint, enamel, or varnish is very complicated and for simplification of study of properties of these materials we determine properties of initial materials (raw material — oils, fatty acids, resins, monomers), pigments, solvents, plasticizers, and conditions of their processing.

Varnish and paint coatings have many advantages over other types of protective coverings (metallization, protection by oxide films, and so forth). Varnish or paint is easily applied on an object and closes all pores, found on its surface well. Any machines and constructions, even those as bulky as railroad cars, can be covered by paint without special technical difficulties. Varnish and paint coatings are very cheap, do not change properties of painting materials, and are a reliable method of protection of metal from corrosion and wood from rotting.

§ 3. Mechanism of Formation of Paint Films

Oils, drying oils, varnishes, paints or enamels, applied on surface, dry. With this there occurs reaction of autoxidation, flowing under the direct influence of atmospheric oxygen. Oxygen is added along place of double bonds of unsaturated compounds (acids of oils), possessing great free energy. The more the double bonds, the more energetically oxygen is added and the faster it dries.

Absorption of oxygen by oil occurs intensively only in a thin layer of film, i.e., with the presence of large surface of contact with air. Oxidation of oil is an exothermic (flowing with heat liberation) process, which can lead to self-ignition of oil (in oiled waste).

During oxidation of oil as a result of reaction of oxygen with fatty acids there will be formed low-molecular acids, which are volatilized from film. Absorption of atmospheric oxygen by film is accompanied by increase of its weight by the value of difference between weight of added oxygen and weight of evaporated decomposition products. This value, called oxygen number, for example reaches 10-12% for linseed and 14-15% for lumang oils.

Process of drying of oil films can be divided into a number of stages: self-oxidation (autooxidation) → activation and formation of "initiator" → copolymerization or oxidizing copolymerization, leading to cross-linking of molecules, with formation of copolymer, determining transition of liquid film into solid state (linoxyn).

In films containing solvents in the initial stage of drying there occurs evaporation of solvent. In films of resinous, nitrocellulose, vinyl-perchloride, and other polymerization materials the process of drying involves evaporation of solvent with formation of a solid film of coating. In oleoresinous coatings and in films based on condensation resins besides the evaporation process of solvent there flow processes of oxidation and copolymerization.

While films based on urea- or melamine-formaldehyde resins are drying there occurs process of condensation polymerization, as a result of which due to two molecules, from which there will be formed film former, water or other low-molecular is separated, and between molecules there appears chemical bond with formation of a solid film.

If the process of drying of such materials as styrene or vinyl chloride is activated by corresponding catalysts, then reaction of polymerization flows and molecules are connected with each other, forming long chains, transformed during this into solid films.

Processes of drying (hardening) of so-called chemically active materials, such as epoxy, polyurethane, resol, phenol-formaldehyde, flow due to reaction with hardners, added to primer, varnish, or enamel directly before application on surface to be painted. As hardeners for these coatings we apply amines, polybasic aciss, etc., compounds containing mobile atoms of hydrogen, which as a result of chemical interaction transform resins of linear structure into infusible and insoluble compounds.

Processes of drying are intensified with increase of temperature (hot drying) and depend to a considerable degree on the affect of light, exchange of air, and humidity of medium.

§ 4. Basic Properties of Varnish and Paint Materials and Their Films

Properties of each varnish and paint material depend on the individual qualities of raw materials entering it, chemical interactions between them and other processes, occuring during its manufacture.

Varnish and paint materials and their component parts should possess a number of specific physical chemistry properties which provide life of coating, its preservation in various operational conditions, and a beautiful external decorative view of the coated object. For control of these properties we apply special instruments.

Binding Substances

Color of varnish and paint materials is determined mainly by color of pigment entering it. However, the color of binder entering it can also greatly affect the color of varnish and paint coating. The color of binder has especially important value during the manufacture of light paints and enamels, and also varnish coatings applied on top of the paint or directly on wood.

For determination of color of drying oil or varnish there is applied an iodometric scale, which consists of number of solutions of different quantities of iodine in 1/10N-aqueous solution of potassium iodide, which have different color.

Viscosity permits indicating the quality of binder and suitability of material for application on surface. Too thick products are difficult to apply with a uniform layer, too liquid products give a very thin film and flow from vertical surfaces while drying. Viscosity of varnish and paint materials is considered satisfactory if it does not hamper their application on surface.

During investigation of varnish and paint materials we usually determine their conditional or relative viscosity. For this purpose we use instruments called viscosimeters ([VZ-4](ВЗ-4), [VU](ВУ), VZ-1, of [NIILK](НИИЛК), which are distinguished by diameter of opening for outflow of liquid.

We distinguish initial viscosity in state of delivery and working viscosity; the latter is selected depending upon method of application: with application by brush the viscosity is equal to 35-40 s for VZ-4, spraying — 25-30, dipping — 15-20, in electrical field — 18-25 s.

Time of drying is the basic index of all film-forming materials. Drying is the process at which liquid varnish and paint product, applied by a thin layer on surface, hardens and is turned into film.

We distinguish two basic stages of drying: "from dust" and practical. Drying "from dust" is that stage when on varnish and paint material there is formed the finest surface film, preventing adhesion to it of lycopodium powder or other light mineral, and also dust. Practical, or complete, drying is the stage of termination of drying process when a solid film is formed over the entire thickness of applied material.

Content of solvent is characteristic for drying oils, into composition of which there enters solvent, and all varnishes, paints, and enamels. Solvent content is determined by its distillation in a special apparatus or drying of sample.

Iodine number characterizes the tendency of oils and resins to dry. It shows what quantity of iodine in grams is able to join 110 g of oil or resin, treated by a specially prepared solution of iodine.

Iodine number determines content of unsaturated organic compounds in oils and resins, determining the ability of oils and resins to dry. With increase of content of unsaturated compounds, and iodine number accordingly, the drying rate of oils and resins is increased. Iodine number of linseed oil is 175, cottonseed — 101-116.

Acid number characterizes quantity of free fatty and resinous acids not connected with glycerine, contained in oil. With considerable content of free fatty and resinous acids in oil its quality worsens (oil turns rancid). Acid number shows the quantity of milligrams of caustic alkali, which is required for neutralization of free (fatty and resinous) acids, found in 1 g of oil or resin.

Acidity or neutrality, and also alkalinity of solutions of paint and its separate components (pigments, solvents, etc.) are characterized also by concentration of hydrogen ions pH in solution or water extract. Neutrality of solution is characterized by value pH, equal to 6-7; acidity — value less than 6, and alkalinity — value greater than 7.

Saponification number permits indicating the quantity of all acids (bound and free) contained in oil.

Index of light refraction (refractive index) has large value during establishment of quality of oils, drying oils, solvents, and resins. Value of light refraction index by fats depends on the chemical structure of fatty acids entering their composition, and turns out to be higher, the richer oil is with unsaturated acids. Refractive index is determined by refractometer.

Transparency of varnish and paint materials is determined after settling of product in a narrow measuring glass for 24 h. During this there is also established sediment in percent (by volume) of deposit settled on bottom of container.

Pigments

Color of varnish and paint materials is explained by their ability to absorb or to reflect light waves of defined length.

Light rays with wavelength from 750 to 400 mμ are perceived by retina of the eye in the form of specific colors.

White, or daylight, consists of oscillations of waves of different length. With reflection of all light waves the object seems white, and during absorption of all light waves — black. Objects reflecting color of one wave are perceived as colored in this color. Color of all colored pigments is determined by comparison with a special standard or by card file of color standards [GIPI-4](ГИПИ-4), and also by [KNO-2](КНО-2) or KNO-4 colorimeter, and white — by white color scale.

Characteristics of color depending upon wavelength and frequency of oscillations are represented in Table 9, where there is also shown classification of color by card file of color standards GIPI-4.

Table 9

Wavelength in $m\mu$	Frequency (number of oscillations per second)	Color	Numeration of shades by cards file GIPI-4
760—620	$460 \cdot 10^{12}$	Red	1—99
620—585	$490 \cdot 10^{12}$	Orange	100—199
585—550	$530 \cdot 10^{12}$	Yellow	200—299
550—510	$580 \cdot 10^{12}$	Green	300—399
510—490	$625 \cdot 10^{12}$	Light Blue	400—499
490—450	$670 \cdot 10^{12}$	Blue	
450—390	$730 \cdot 10^{12}$	Violet	500—599
—	—	White	800—820
—	—	Gray and others	900—999
—	—	Black	821—840

Specific gravity of different pigments oscillates within wide limits from 8.6-9.4 for lead-oxide red paint to 1-1.3 for organic dyes.

Oil-absorption power. If to a certain quantity of dry pigment we add oil with continuous stirring, then at first after addition of the first drops of oil the pigment remains a free-flowing body. Further addition of oil leads to formation of separate lumps and, finally, after addition of one drop of oil the entire mass of pigment is turned into paste — thick milled paint.

Quantity of oil that is expended for production of thick milled paste from 100 g of dry pigment is called by oil-absorption value of I type. With subsequent addition of oil to thick paste it attains paint consistency, i.e., a state when it can be easily applied on surface. Quantity of oil necessary for production of paint of paint consistency from 100 g of dry pigment, is called oil-absorption value of II type. Oil-absorption value of I and II type is expressed in percent. There is no dependency between them.

Refractive index of pigments indicates their covering power. The greater the difference between refractive index of pigment and binder, the more covering power of pigment. For example, chalk in water conceals, since refractive index of chalk is 1.52, and water 1.332, in oil chalk does not conceal, since refractive index of linseed oil is 1.479.

Dyeing power, or intensity, is the name for the ability of certain pigments to change their color when mixing with other pigments. For example, if to 100 g of carbon black we add 5 g zinc whites, then the color of carbon black will not be changed; if however to 100 g of zinc whites we add 5 g of soot, then the color of whites will be sharply changed and will become dark-gray. Carbon black is intense pigment, white — nonintense.

Dyeing power is expressed in grams of pigment, which it is necessary to add to some other pigment for production of paint of a specific color shade.

Body, or covering power of pigment or paint is the name of its property to cover (to paint) primer during painting of article in such a manner that there does not occur translucence of primer through the layer of pigment or paint. Body is expressed in grams of pigment or paint that it is necessary to expend in order to cover the colored field or checker board of white and black bands or squares in conversion to area in 1 m^2.

Shape of grains and value of particles (grind) of pigment. The majority of pigments are finely crystalline substances with different shape form and value of grains – crystals. Shape of crystals of pigment characterizes its properties, for example, titanium whites – titanium dioxide – of rutile grade possess high weatherproofness and have shape of grain that is different from titanium dioxide of anatase grade, which is unstable in atmospheric conditions.

In practical work during dilution of paints and when painting the dimension of particles (dispersiveness, or degree of grind) of pigments has great value. Fineness of grind strengthens the fundamental tone of pigment and its brightness; covering power and intensity of pigment also depend on its grind. Value of particles can be measured by micrometer or determined by method of sifting, and also by "wedge" method by means of filling up a wedge with graduations from 1 to 150 microns.

For pigments applied in primes the most important index is their anticorrosion resistance.

Varnish and Paint Films

Thickness of films affects quality and life of coatings. Too thin film can be easily permeable for moisture, gases, etc. Too thick film, particularly putty and, resinous varnishes, is inclined to cracking. Thickness of films is determined by thickness gages (Fig. 48). Along with thickness the continuity of covering, determined by [ED-5](ЭД-5) flaw detector is important.

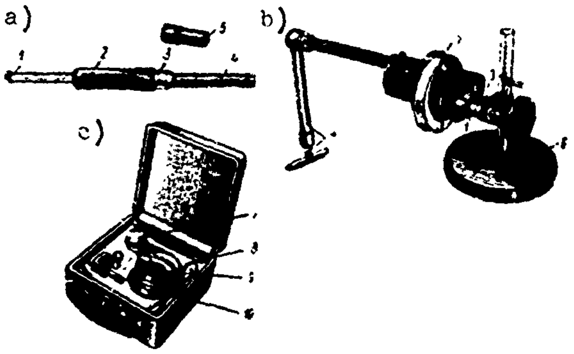


Fig. 48. Instruments for testing varnish and paint coatings (films): a) ITP-1 thickness gage; b) MT-2 thickness gage; c) ED-5 flaw detector; 1 – scale; 2 – body; 3 – vernier; 4 – guide tube with magnet; 5 – cap; 6 – support; 7 – glass weighing bottle; 8 – brush; 9 – galvanometer; 10 – clamp.

Luster, or gloss. Majority of varnish and paint coverings after drying should form a glossy film. For lacquers and enamels this ability is expressed to a greater degree than for oil paints. Evaluation of character of gloss produce by a luster gage.

Flexibility – elasticity – of films is especially important in coverings applied for external painting of railroad cars, since these coverings on the travel line are subjected to temperature effects and dynamic oscillations, causing stress in metal and film, which can lead to its cracking.

Hardness of film characterizes the mechanical strength of varnish and paint coating. Conditional hardness of varnish and paint films is determined on a pendulum apparatus. Hardness of film can also characterize time of complete drying of varnish and paint coating.

Impact resistance. Varnish and paint coatings can be subjected to impacts, leading to their deformation. Film experiencing impact should not be peeled from surface, cracked, or destroyed. A film that is resistant to action of impacts is more long-lasting. Impact resistance of varnish and paint films is determined by force necessary for damage of film.

Tensile and elongation strength is determined on special devices.

Water-resistance, heat-resistance, and oil-resistance are determined in corresponding media with recording of change of state of film in them.

Inclination of films to aging is established by means of artificial aging under action of heating for prolonged time with subsequent check of change of their mechanical properties.

Adhesion – cohesiveness – characterizes adhesive strength of film to surface and is determined by special instruments.

Weather resistance according to GOST 6992-60 is determined after test of coatings in atmospheric conditions, recording change of state of coatings (Fig. 49).

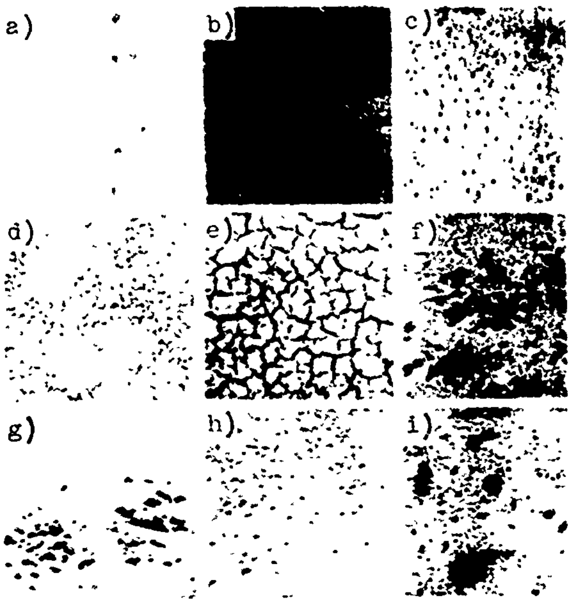


Fig. 49. Damage of paint films in atmospheric conditions: a) chalking; b) weathering; c) fines; d) network; e) cracking; f) peeling; g) swelling; h) bubbles; i) rusting.

All properties of varnish and paint materials and raw material for their manufacture are shown in corresponding standards and reference books.

Questions for Self-check.

1. What does the process of corrosion consist of?
2. What are the types of corrosion damages of parts of railroad cars?
3. What factors contribute to development of corrosion?
4. What basic assignment do protective coatings have?

5. What types of protective coatings are applied in railway economy?

6. For what are varnish and paint protective materials intended in railway economy and how are they classified?

7. What does the mechanism of formation of paint films consist of?

8. What properties characterize varnish and paint materials and their films?

CHAPTER VI

RAW MATERIAL AND SEMIFINISHED PRODUCTS FOR VARNISH AND PAINT MATERIALS

§ 1. Binding Materials

Vegetable and Cod-Liver Oils

Basic form of raw material applied for manufacture of drying oils and oil varnishes are vegetable and cod-liver oils.

Oils (fats) are represented by esters, into composition of which enters trihydric alcohol-glycerine ($CH_2OH-CHOH-CH_2OH$) and different fatty acids, containing a large number of carbon atoms in hydrocarbon chain (from 15 and more).

In accordance with the presence in molecule of fatty acids of hydrocarbon chains with single or double bond these acids are subdivided into saturated and unsaturated. Saturated fatty acids (myristic, palmitic, stearic, and others) have general formula $C_nH_{2n}O_2$, which shows that all bonds of these acids are filled. In unsaturated acids oleic $C_nH_{2n-2}O_2$, linoleic $C_nH_{2n-4}O_2$, and linolenic $C_nH_{2n-6}O_2$ in hydrocarbon chain 2, 4, and 6 hydrogen atoms respectively are not enough for total saturation, i.e., they have a number of double (-CH = CH-) bonds.

Vegetable oils are divided into drying, semidrying, and nondrying.

Drying oils contain linoleic, linolenic, and other unsaturated acids. During application of these oils in a thin layer on a surface they are oxidized by atmospheric oxygen and are turned into solid products, forming a dense surface film (linoxyn). Drying oils include linseed, tung, and hempseed.

Semidrying oils contain linoleic and oleic acids and will form a film with weak tackiness only after prolonged time (14-18 days). Such oils include: sunflower, soybean, cameline, poppy seed, and others.

Nondrying oils contain basically oleic acid and saturated fatty acids. With application on surface they do not dry. Such oils include: conttonseed, castor, olive, and others.

All vegetable oils are dissolved well in chloroform, gasoline, turpentine, and other solvents. They are not mixed with water and, having less specific gravity than for water, emerge on its surface. Interacting with alkalis, fatty acids of vegetable oils will form salts, called soaps.

Besides the shown component parts, vegetable oils can also contain a number of impurities: mucous and albumin substances (0.06-0.25%), coloring substances, water (0.05-0.3%), ash (0.2%).

Vegetable oils are obtained from seeds of various plants. Thus, linseed, hempseed, sunflower, cottonseed, soybean are extracted from seeds of flax, hemp, sunflower, cotton plant, soya respectively; cameline oil – from seeds of yearly plant Lactarius deliciosus; tung – from nuts of a tung oil tree, and castor – from seeds of castor plant.

Below there are cited brief characteristics of vegetable oils and animal fats, applied for manufacture of drying oils and oil varnishes.

Oils. Linseed oil is the basic material for manufacture of drying oils and varnishes. Oil is obtained by hot or cold pressing under a hydraulic press. During hot pressing the crushed linseed is preliminarily overburnt. With this occurs partial decomposition of organic substance, as a result of which oil acquires a dark color. During cold pressing oil is obtained lighter, but its yield decreases. Drying of linseed oil at temperature 18°C occurs in approximately seven days.

Depending upon method of treatment oil is divided into refined and unrefined.

Tung oil is poisonous and absolutely unfit for food.

In production of oil varnishes tung oil is very valuable, since it gives a quick-drying, hard, and durable film. However, damp or incorrectly treated oil gives a dull and wrinkled film.

Hempseed oil is very wide-spread and is often applied instead of linseed oil for manufacture of drying oils and varnishes. Process of obtaining hempseed oil is the same as linseed.

Oil has a greenish nuance: the higher is the heating of hempseeds before pressing, the darker the oil is produced. Hempseed oil is comparatively easily bleached. Bleached oil has some advantage over linseed, since it does not change the nuance of white paints. Linseed oil gives a yellowish color to it.

Sunflower oil receives a color from light yellow to dark yellow depending upon method of processing of seeds. The oil has a pleasant odor and taste; it is used mainly in food.

In recent years sunflower oil has been widely applied in the varnish and paint industry for manufacture of glyptal and pentaphthalic bases and thick milled white paints. White paints, milled in sunflower oil and separated by linseed drying oil, preserve their white color a long time. Dried film of sunflower oil is melted at temperature 86-90°C.

Soybean oil reminds us of sunflower. Color of oil is yellow with a reddish-brown nuance, odor is specific. Film of drying oil from soybean oil is inclined to subsequently soften and is easily abraded. Processing of oil improves the quality of drying oil.

Cameline oil has a golden yellow color, is distinguished by sharp unique taste and odor, and foams intensely during heating; oil of hot pressing is greenish-brown.

Cameline oil is applied during manufacture of drying oils in a mixture with linseed or hempseed oil within limits up to 40%. In view of the fact that cameline oil contains ethereal oils, composition of which includes sulfur, preparation of lead-oxide paints on its drying oil is not recommended, since there will be formed lead-sulfide, causing blackening of paint.

Cottonseed oil in raw state has a reddish-brown color. Raw cottonseed oil is subjected to alkaline purification in oil mills, after which it acquires a golden yellow color and is applied in the food industry. Cottonseed oil cannot be applied as an independent film forming material without special treatment due to its poor drying ability. At present it is widely applied during the manufacture of glyptal bases for drying oils and varnishes after corresponding processing, and also in soap production.

Castor oil possesses high viscosity; at 20°C its viscosity is 20 times more than that of linseed oil. At low temperatures viscosity is considerably increased, which hampers transportation of oil.

Regarding its chemical composition castor oil is highly distinguished from other oils. It is not inclined to oxidation in a thin layer, due to which a hard film will not form.

Castor oil was applied in the varnish and paint industry only as a plasticizer in the production of nitrocellulose and alcohol varnishes.

However, recently as a result of special treatment of ricinoleic acid and its transformation into unsaturated acid, similar to linoleic, castor oil is applied as raw material for manufacture of varnishes and drying oils.

Cod-liver oils. Additional raw materials for manufacture of drying oils and varnishes are cod-liver oil and marine animal fat (whales, walruses, etc.).

Cod-liver oil can be applied as binder only after separation of part of saturated fatty acids, entering its composition in a large quantity. Usually in the varnish and paint industry there are applied so-called commerical fats, i.e., products obtained by rendering, pressing, or extraction of waste of fish or special raw material (sardines codfish, dolphin, walruses, seals, and whales).

Oil Refining

For production of varnishes and drying oils, and also milling paints and enamels there are mainly applied not raw vegetable oils, but oils subjected to some preliminary treatment: refining, polymerization, oxidation, interesterification, or esterification.

Refined oil. Vegetable oils contain mucin, phosphatides, and other impurities, which have to be removed from oil in order to avoid damage of varnish or enamel.

Mucin is removed by heating of oil to 230-240°C, at which it is coagulated and falls into deposit. However, such high-temperature heating of oil is not always convenient and more often for this purpose we apply bleaching of oil at 130-140°C with bleaching clays (Glukhov kaolin, gumbrine, floridin, etc.), which absorb mucin. For removal of phosphatides mainly from semidrying oils we produce hydration of them. For this into heated oil there is fed up to 50% water and then 0.5-0.75% table salt. Phosphatides, dissolved in water, fall into deposit with addition of salt. Aqueous layer is removed with deposited phosphatides and oil is dried.

Vegetable oil treated thus is called refined (varnish) oil.

Polymerized oil. For varnishes an important component part is heat-bodied oil, mainly polymerized. For polymerization there is applied varnish (bleached) oil.

Polymerization is the process of connecting molecules of unsaturated organic compounds into long chains or a ring. Polymerization of oils is conducted at high temperatures: linseed at 300-315°C, sunflower at 270, soybean at 260, tung at 250-260°C in atmosphere of inert gas (CO_2).

The most widely spread densification is to viscosity 12, 40, or 43°, which corresponds to viscosity of solution of heat-bodied oil in white spirit 1:1, 6, 10, and 11°.

Polymerized oils are distinguished by increased specific gravity, high viscosity, stickiness, ability to stretch into thread, and presence of green fluorescence (light effect). These oils have a light nuance and do not darken white pigments; they are not dissolved in a number of solvents and will not form oil spots on paper.

Oxidized oil. Oxidation of oil is produced with blowing of stream of air through it. Viscosity of oil during oxidation can be 50-60 times more than viscosity of initial oil. In process of oxidation oil at first brightens considerably due to destruction of its coloring components. Subsequently, when degree of oxidation, characterized by viscosity of oil, becomes considerable, darkening of oil starts. Oxidized oil dries faster than crude oil.

Interesterified oil. For production of synthetic varnishes and drying oils we use not crude oil, basically containing triglycerides of oils, i.e., esters, in which glycerine joined 3 fatty acids, but their refining products, containing two or one molecules of fatty acid respectively (diglycerides and monoglycerides). For production of diglycerides and monoglycerides we conduct interesterification of varnish oil. For this vegetable oil is treated with glycerine at 180-240°C and we obtain diglycerides, and with surplus (over 25%) glycerine-monoglycerides.

Esterification. Under esterification we understand the reaction of interaction of alcohols of various atomicity with acids. Reaction of esterification s reversible and the reverse reaction is called saponification (splitting).

In case of vegetable oils the process of esterification is conducted with fatty acids emanated from oils.

§ 2. Resins and Esters of Cellulose

Natural Resins

Conifers and other trees with a deep cut (tapping) emanate liquid resin — turpentine. During distillation of spirits of turpentine and other volatile substances from crude turpenting we obtain natural, or true, resin, for example, rosin. In a number of places (for example in the Baltic states) we obtain such resins which have remained a millenium in the earth, and we obtain so-called copals, which include amber and other resins.

Rosin is the most widely-spread natural resin. Rosin is used in large quantities in the varnish and paint industry in the form of its refining products. Products of refining of rosin (so-called prepared rosin resins) — resinates — are salts of resinous acids of rosin and heavy metals (manganese, lead, cobalt, calcium, zinc, and others), and ester gums are obtained during interaction of rosin with polyatomic alcohols — glycerine, pentaerythrite, and others.

Shellac is a product of refining of natural stick lac material, represented by a resinous excretion of special insects on branches of certain tropical plants.

Depending upon treatment shellac can be light, yellow, and orange.

All types of shellac are hard and are dissolved well in alcohols — ethyl, methyl, and others, and also in alkalis.

Copals are mineral resins of vegetable origin. Their composition includes mainly resinous acids and esters of these acids. Copals are dissolved in oil only after melting and distillation of volatile part, comprising from 15 to 35%.

Recently copal resins have been applied in varnish and paint industry in limited quantity, since artificial resins have replaced them.

Asphalts are natural mineral resin, formed as a result of processes of oxidation of petroleum, coming out of the depth of the earth to the surface. Asphalts are solids or viscous liquids of dark brown or black color.

In the Soviet Union there have been uncovered a number of asphalt deposits. The following types of asphalts have the greatest value:

1) Pechora — a solid substance with softening point 107-145°C;

2) Shugurov — contains up to 30% sulfer, its melting point is not higher than 100°C, it is used for manufacture of varnishes of average quality;

3) Bakhilov — regarding its quality and properties it is equivalent to Shugarov;

4) Sadki — has softening point from 140 to 220°C, is joined with oil within limits of 30-35%.

Asphalts are obtained also in the Caucasus, Transcaucasus, Central Asia, and other regions of our country.

Natural asphalts are widely applied in the varnish and paint industry.

Asphalts are very waterproof, are not dissolved in alcohols, alkalis, are almost dissolved in hydrogen sulfide, and are difficultly saponified in alkali media.

Pitches. During dry distillation, pyrolysis, cracking, and other methods of refining oil, coal, and various organic substances we produce solid or semisolid resins of black color, fusible, and for the most part brittle, called pitches. The most widespread are coal-tar pitches, obtained with various methods of processing of coal. Depending upon method of production they are divided into gas, coke, gas producing and low-temperature pitches.

Coal-tar pitches, being active antiseptics, are widely applied in railroad tie impregnating plants, and also during manufacture of Ruberoid, roofing paper, and other roofing materials. After corresponding treatment coal-tar pitch is used in the varnish and paint industry as varnish, known under name of Kuzbass varnish.

Petroleum bitumens are obtained from petroleum by means of distillation, blowing with air at high temperatures, and purification of certain distillates of oil by sulfuric acid.

The majority of black asphalt varnishes are prepared on the basis of petroleum bitumens. With respect to softening point petroleum bitumens are divided into the corresponding grades: I, II, III, IV, and V.

Synthetic Resins

Synthetic resins are organic compounds with great molecular weight; they pertain to the number of high-molecular compounds, or polymers.

Molecules of polymers (macromolecules) consist of a chain of uniform or various-type molecules of monomers or elementary particles joined together by chemical bonds.

Macromolecules can have linear or space structure.

Synthetic resins are dissolved well in organic solvents, are melted, are combined with oils and natural resins, and also with other component parts of varnish or enamel. Coatings based on synthetic resins possess adhesion ability, hardness and elasticity, resistance to mechanical, thermal, and chemical influences, weather resistance, and several other specific properties.

Resins are obtained from monomers by reactions of polycondensation or polymerization. Polycondensation is accompanied by formation of byproducts — water, hydrogen chloride, etc. Byproducts will not be formed during polymerization.

Polycondensation resins. Alkyd resins are produced during interaction of polyatomic alcohols with polybasic acids. As polyatomic alcohols we apply glycerine and pentaerythrite. Furthermore, it is possible to use alcohols: trimethylolethane, trimethylolpropane, xylitol, sorbitol, mannitol.

From polybasic acids we most frequently apply dibasic orthophthalic acid in the form of its phthalic anhydride. We also apply isophthalic and terephthalic acids.

Alkyd resins are subdivided into unmodified, modified with rosin, modified with vegetable oils or the highest fatty acids.

During interaction of phthalic anhydride with glycerine we obtain so-called glyptals.

Unmodified glyptal resins have high acid numbers, weak water-resistance, and therefore are not applied as protective coverings. They possess good electrical insulating properties and are applied as electrical insulating varnishes.

During modification of glyptals by resinous acids, contained in rosin, we obtain modified glyptals, applied for manufacture of certain nitrolacquers, nitroenamels, and nitroprimers.

Varnishes and enamels obtained from glyptal resins, modified with vegetable oils or the highest fatty acids, are the most widespread in railway economy.

During interaction of phthalic anhydride with pentaerythrite we obtain pentaphthals. They have advantages over glyptals; varnishes and enamels based on them dry faster than glyptal with cold drying and will form more water-resistant and weather-resistant coatings.

Polyesters. During interaction of dibasic acids and diatomic alcohols we obtain complex polyesters, which are used for production of varnishes for furniture and colored enamels for wood. At combination of polyesters with acrylates we obtain polyster acrylate varnishes and enamels of hot drying, which are very promising for painting railroad passenger cars.

Phenolaldehyde resins. Phenolaldehyde, or phenol, resins are the products of polycondensation of phenols (phenol, cresol, paratertiary butyl phenol, and others) and aldehydes (mainly formaldehyde) with the addition of modifying substances or without them.

The most widespread of these resins are novolak (iditol), resol (bakelite), and hundred-percent. Hundred-percent phenolic resins are combined with oils and alkyd resins, are dissolved in aromatic and aliphatic hydrocarbons. They are solid, brittle in fracture, transparent, from yellow to dark brown in color, with melting point from 53 to 75°C, and content of free phenol up to 4%.

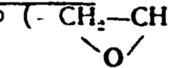
During modification of phenol-formaldehyde resins by rosin we obtain so-called artificial copals; during their modification by vegetable oils and mixed esters of resinous and fatty acids we obtain a large number of various resins, applied for varnishes and enamels of cold and hot drying.

Urea- and melamine-formaldehyde resins are obtained as a result of polycondensation of urea or melamine with formaldehyde and are represented by transparent colorless products.

For use of these resins in varnish and paint materials we esterify them with butyl alcohol; after this they are combined well with all solvents and alkyd resins.

Urea- and melamine-formaldehyde resins are used for producing high-quality varnishes and enamels of hot drying.

Epoxy resins. During interaction of substances, containing or able to form epoxy group $(-\underset{\diagdown\mathrm{O}\diagup}{\mathrm{CH_2{-}CH}}-)$, with polyatomic phenols and polyatomic alcohols there are obtained epoxy resins, which possess high elasticity, good adhesion, and color stability.



Epoxy resins are delivered in the form of solid products or in the form of solutions in xylene and toluene.

Silicone resins, or polyorganosiloxanes, are polymers, basic chain of which consists of alternated atoms of silicon and oxygen, remaining valences of silicon are replaced by other compounds.

Depending upon initial raw material and method of manufacture polyorganosiloxanes are produced in the form of liquids, plastics, or resins. They represent products from colorless to dark brown color, and are well soluble in orgainc solvents. During heating they pass into infusible and insoluble state. Polyorganosiloxanes possess raised heat-resistance (up to 400-600°C), high electrical insulating properties, elasticity, water-resistance, gas and oil resistance and several other valuable properties.

Polymerization resins. Vinyl-perchloride resins are products of repeated chlorination of polyvinyl chloride resin. During this the content of chlorine is increased from 56 to 62-65%.

Vinyl-perchloride resins are dissolved in acetates, ketones, chlorinated and aromatic hydrocarbons; they possess good water-resistance, chemical stability, gas and oil resistance, weather resistance, relative frost-resistance, and incombustibility. Resins are combined well with oils, alkyd and other resins and plasticizers. With heating above 100°C their decomposition starts with dehydroclorination, accompanied with yellowing and later blackening of resin. Such blackening also occurs under action of ultraviolet rays of light. In order to avoid this, resins are stabilized by epoxy resins, cadmium salts, strontium, etc.

Vinyl-perchloride resins are divided with respect to viscosity of 1% solutions of them in dichlorethane into high-viscosity and low-viscosity.

On the basis of high-viscosity resin there are produced enamels of brands [PKhV, KhV, KhSE] (ПХВ, ХВ, ХСЭ), and others, and on the basis of low-viscosity resin — brand KhV-113.

Copolymers of vinyl chloride with vinylidene chloride. During joint polymerization of vinyl chloride $CH_2 = CHCl$ and vinylidene chloride $CH_2 = CCl_2$ there are produced copolymers, which possess good solubility in solvents. Externally this is a fine-grained powder of from white to yellow color. While heating resin is softened, changing into viscous mass, and at temperature 120-145°C is decomposed. Copolymer is used for manufacture of enamels and varnishes of brands [KhS, VKhE] (ХС, ВХЭ), and others.

Copolymers of vinyl chloride with vinyl butyl ester and methylacrylate. During joint polymerization of vinyl chloride with vinyl butyl ester in a water-emulsion medium with the presence of initiator and emulsifier we produce copolymer of brand [SKhB-70] (СХБ-70). During joint polymerization of three monomers — vinyl chloride, vinyl butyl ester, and methyl acrylate — with the presence of initiator and emulsifier we produce copolymer of brand [SKhBM-10] (СХБМ-10).

These copolymers are represented by fine white powder, dissolved well in aromatic hydrocarbons, butyl acetate, and acetone, combined well with alkyd and other resins.

Copolymers permit obtaining solutions in acid of 20% concentration instead of 10% concentration in a mixture of solvents for vinyl-perchloride resins on high-viscosity resin. Copolymers with methyl acrylate possess high viscosity and better adhesion than without methyl acrylate.

Copolymers of vinyl chloride with vinyl acetate are produced with joint polymerization of the shown monomers. For improvement of compatibility of copolymer with oils and other resins it is partially saponified by alkali.

These copolymers are produced under brands A-15 and A-15-0. They represent white (A-15) or yellow (A-15-0) powder, are completely soluble in acetone with chlorine content from 47.5 to 52.5%. These copolymers are used for producing varnishes and enamels of brands KhS, KhV, and also in dispersed state in plastisols and organosols.

Polyvinyl butyral is produced by means of interaction of polyvinyl alcohol with oil aldehyde. It has limited compatibility with other resins, will combine with small quantities of phenol, urea- or melamine-formaldehyde resins, and also with nitrocellulose, shellac, and spirit-soluble copal.

Polyvinyl butyral will dissolve completely in rectified alcohol, and also in ketones, esters, and in a mixture of alcohols with aromatic hydrocarbons. Polyvinyl butyral is used for parkerizing primers, and also combined with other resins for gas and oil resistant coatings.

Polyacrylic resins are polymers of acrylic ($CH_2 = CHCOOH$) and methacrylic [$CH_2 = C(CH_3)COOH$] acids or their derivatives.

Such polymers form products with various properties from soft elastomers with elongation more than 1,000% over hard plastics. All of them are colorless and colorfast, do not darken while aging, possess good adhesion, and heat-resistance (up to 175°C).

Polyacrylic resins are used for coatings in the form of solutions (varnishes and pigmented enamels) and aqueous emulsions (latexes).

Oil-styrene and alkyd-styrene resins. During copolymerization of styrene with vegetable oils or alkyd resins we obtain oil-styrene or alkyd-styrene resins respectively. From these resins there are produced varnishes for furniture and enamels of various assignment.

Polyurethanes are products of interaction of diisocyanates with biatomic alcohols (glycols) or triatomic alcohol (glycerine). Drying or hardening of mixtures occurs with addition of catalysts – cobalt salts, etc. In view of high reactivity of mixtures their viability composes 6-8 h; after that solidification sets in, finished by gelatination. Polyurethanes are dissolved in ketones and esters, and are combined with a small quantity of aromatic hydrocarbons.

Rubbers. Natural and many synthetic rubbers are not applied for varnish and paint coatings in view of their poor solubility, low concentration of solutions, difficulty of application, and drying. Certain solutions of rubbers, including chlorinated rubber and cyclorubber, and also latexes base on copolymers find application.

Chlorinated rubber is produced by means of chlorination of natural or synthetic rubbers in medium of chlorinated hydrocarbons. Chlorinated rubbers are fine grained light powders from white to yellowish color. They are dissolved in benzene, toluene, acetone, and acetates. They are combined with polyester, phenol, vinyl-perchloride resins, and a number of plasticizers. All pigments, except lead-oxide red paint and chromium oxide, can be combined with chlorinated rubber.

Cyclorubber is produced with treatment of benzene solution of natural rubber by halide compounds of metals, for example, tin chloride or titanium tetrachloride. Cyclorubber is harder than natural rubber, it is a white powder, soluble in aliphatic and aromatic hydrocarbons, and possesses limited compatibility with other resins, oils, and plasticizers.

Polymers of fluroine derivatives of ethylene-fluoroplastics. The number of fluoroplastics includes polytetrafuoroethylene – fluoroplastic-4 and polychlorotrifluoroethylene – fluoroplastic-3.

Fluoroplastics are heat-resistant, chemically stable, and possess good dielectric properties.

Fluoroplastic-4 is absolutely insoluble in organic solvents; fluoroplastic-3 is dissolved while heating in aromatic hydrocarbons and carbon tetrachloride. Fluoroplastic-3 can be applied on surface in the form of a suspension with subsequent drying and hardening of coating.

Fluoroplastics-3 and -4 were checked as protective coverings for containers and cisterns, transporting concentrated sulfuric acids and acid melange. Fluoroplastic-4 turned out to be absolutely stable in these conditions, but its application is limited because of complexity of application and gluing to metal surface of cistern. For containers there can be used fluoroplastic-3, applied in the form of suspension, dried at temperature 180°C, and hardened to an absolutely solid state.

Nitrocellulose and Other Esters of Cellulose

During treatment of cellulose (cotton, wood, etc.) by nitric acid in the presence of sulfuric acid we obtain nitrocellulose with various nitrogen content. Depending upon nitrogen content we distinguish esters with 11-12% nitrogen, called colloxylin, with 12-12.5% — pyrocollodion, and with 12.5-13.9% — pyroxylin.

In the varnish and paint industry there is applied nitrocellulose, known under the name of varnish colloxylin.

Nitrocellulose is destroyed under the influence of concentrated acids and alkalis, and is decomposed under the action of heat and light.

In spite of a number of deficiencies (combustibility, low heat-resistance, and insufficient colorfastness), colloxylin possesses good physical and mechanical properties, transparency, water-resistance, combinability with plasticizers and resins, and also solubility in many solvents. It is widely applied in production of various types of nitrolacquers, nitroenamels, nitroprimers, and nitrocellulose puttys.

Besides nitrocellulose (ester of nitric acid), ethylcellulose (ester of ethyl chloride), alkali cellulose, and others.

§ 3. Placticizers and Adhesive Substances

Plasticizers (softeners). Films of certain varnishes (nitrocellulose, vinylperchloride, divinyl acetylene, resinous, and others) are brittle and are insufficiently elastic. For improvement of properties of these films there are added so-called plasticizers, or softeners, to them.

Plasticizers are high-boiling liquids with low vapor pressure and insignificant volatility. Plasticizers should be easily dissolved or mixed with varnish bases, preserved in film after drying, and should ensure its plasticity.

Along with this plasticizers should satisfy the following requirements:

a) possess low melting point;

b) dissolve (gelatinize) varnishes and their component parts well (resins, oils, esters of cellulose, etc.),

c) be combined with usual solvents and pigments;

d) be colorless or lightly colored and not have odor;

e) be neutral, chemically stable, and not be decomposed during prolonged storage with emanation of acids and other harmful substances for metal;

f) possess resistance to action of light and atmospheric influences, should not be hygroscopic;

g) have sufficiently high ignition temperature and should lower combustibility of varnish film;

h) be preserved in coatings a long time.

Properties of basic plasticizers are described below.

Tricresylphosphate — colorless liquid without odor. Plasticizes nitrocellulose and vinyl chloride polymers well. Low colorfastness of tricresylphosphate makes it unfit for light coatings.

Tributylphosphate – colorless liquid. Is applied in the production of varnishes and enamels intended for production of coatings that are resistant to action of low temperatures and ultraviolet rays. Application of tributylphosphate is limited due to its high volatility.

Triphenyl phosphate – white crystal substance without odor. Is dissolved in majority of usually applied solvents for varnishes, is not dissolved in water and petroleum hydrocarbons. It is practically nonvolatile and imparts high plastic properties to coatings. Has reduced colorfastness. Is used for obtaining of varnishes and enamels based on nitrocellulose and mainly cellulose acetate.

Dibutyl phthalate – colorless liquid without odor. Gelatinizes nitrocelluloses and simple esters of cellulose, vinyl chloride, and acrylic polymers well. Is applied mainly in production of nitrocellulose varnishes and enamels. Gives to films and coatings good physical and mechanical properties, preserved during aging, and also good color fastness and satisfactory frost-resistance. For nitrolacquers and enamels it is applied chiefly in a mixture with castor oil.

Castor oil is applied as plasticizer inproduction of nitrocellulose varnishes and enamels. Castor oil added in considerable quantities during heating of nitrocellulose film is emanated (sweats). For elimination of this deficiency it is applied in a mixture with digutyl phthalate. Castor oil is dissolved well in alcohol, insoluble in gasoline, petroleum ester, and mineral oils.

Casterol – product obtained from castor oil by means of prolonged heating to 200-270°C and subsequent blowing with air at 80-130°C. It is an oily liquid with very slight odor. Is applied as plasticizer for nitrocellulose mainly in a mixture with dibutyl phthalate. Nitrocellulose films, containing casterol, are considerably more frost-resistant and more waterproof than a film with castor oil. Casterol is dissolved well in usual solvents and diluents, is mixed with other plasticizers in any ratio.

Clorinated biphenyl (chlorphen) is dyphenyl polychloride. It is applied mainly in production of varnishes and enamels based on vinyl-perchloride resin and chlorinated rubber, with which it is combined in considerable quantity. Clorinated biphenyl possesses resistance to alkalis and acids. It pertains to the number of insufficiently frost-resistant plasticizers.

Adhesive substances are applied as film-forming substances in flue, casein, and emulsion paints and putty (filling) materials, and also for a number of special operations (gilding, gluing of Lincrust or Relin, etc.).

As adhesive substances there are used glues of animal, vegetable, and mineral origin, and also certain resins (shellac, rosin, and others).

Glues of origin animal include carpenter's, hide, bone, fish, casein, gelatin, albumin, gluten, and vegetable origin – starch, dextrins, gums, pectin, vegetable glue stock, sulfite liquor. Mineral adhesive substances include lime and soluble glass.

Synthetic glues are not applied as film-formers.

§ 4. Solvents and Diluents

Varnish and paint materials produced by plants, have viscosity that does not always correspond to conditions of their application on surface. Furthermore, certain varnish and paint materials thicken during prolonged storage. Depending upon method of application (spraying, dipping, pouring, painting in electrical field, brush, and others) there are required materials of different viscosity.

For bringing varnish and paint materials to working viscosity there are applied various solvents, diluents, and thinners. Dilution of varnish and paint materials with inappropriate solvents (diluents, thinners) can lead to coagulation, gelatinization, or other undesirable consequences, and to spoilage of varnish and paint coating on articles (whitening, dulling, shagreen, etc.).

Solvents are volatile organic liquids, dissolving resins, oils, plasticizers in production process of varnishes, enamels, and serving also for dilution of the latter during their application on surface.

We distinguish active solvents and diluents (thinners) and their mixtures – compound solvents.

Solvents directly dissolve binding substances and change them into solution. Diluents (thinners) are substances which dissolve film-forming materials into a mixture with active solvent, during which the content of diluent in mixture can reach up to 80%. After application of coating the solvents are volatilized.

Solvents should possess the following properties:

a) should not contain mechanical and coloring impruities, and also impurities of free inorganic acids, alkalis, water, and not act decompcsingly on the remaining components of varnish and paint material;

b) easily and completely dissolve all nonvolatile substances of varnishes, be mixed well with them and other solvents, be voltalized from film rapidly without residuum in process of its formation;

c) be minimum toxic, not have irritating odor and odor that is kept for a long time in film;

d) have high flash and ignition temperature;

e) be nonhygroscopic, neutral, and stable during storage.

Below are described characteristics of solvents applied in railway economy.

Aliphatic hydrocarbons. White spirit (gasoline-solvent for varnish and paint industry) is a light, transparent liquid, having odor similar to gasoline. Is applied as solvent of oil varnishes, drying oils, and the majority of varnish resins. White spirit is obtained with petroleum distillation. Its dissolving ability is somewhat lower than turpentine.

Ligroin is obtained during petroleum refining and is a light transparent liquid, applied in the varnish and paint industry in a mixture with other solvents. In pure form it sometimes replaces white spirit.

Gasoline is product of petroleum refining, is a transparent, colorless liquid, evaporating in air without residuum and criteria of an oily spot. Gasoline is applied as solvent during manufacture of quick-drying oil varnishes and paints, and also for formation of a uniform film when painting with oil and varnish paints by dipping method.

Petroleum hydrocarbons possess cyclicity of their structure and extraordinarily great constancy. Of the petroleum hydrocarbons there is applied only tetralin and decalin for dissolution of oils, resins, and waxes oxidized to high viscosity.

Aromatic hydrocarbons. Basic raw material for production of aromatic hydrocarbons is coal tar, obtained with coking of coal and products of pyrolysis of petroleum.

Benzene is a colorless, transparent liquid, not soluble in water. It dissolves the majority of oil, resinous-oil, alkyd resins, and also many simple and complex esters of cellulose well. Benzene is very toxic, it is recommended to work with it in special chambers with intake-exhaust ventilation; with the absence of chambers it is necessary to don respirators.

Toluene is a colorless, transparent liquid, dissolving oil, resinous-oil, alkyd, and other varnish and paint bases well. It dissolves ethylcellulose, resinous esters, but does not dissolve shellac, and esters of cellulose; however it is applied as their diluent. Toluene is less toxic than bezene.

Xylene is a colorless, transparent liquid, obtained in the process of rectification of fractions of raw benzene. It is a good solvent for oil, resinous-oil, alkyd, and other artificial varnish bases, but does not dissolve esters of cellulose. Xylene is mixed with petroleum hydrocarbons and with all solvents of esters of cellulose.

Xylene fraction is obtained during rectification of xylene in the form of mixtures of different solvents, which received designations: heavy and light solvents, dissolving resins and resinous-oil bases well.

Solvent is a colorless or yellow colored liquid, consisting of a mixture of aromatic hydrocarbons of benzene series (toluene, xylene, trimethylbenzene). Solvent is obtained in process of purification and rectification of raw benzene. In it there is allowed a small quantity of petroleum paraffin hydrocarbons.

Chlorinated hydrocarbons. During treatment of hydrocarbons by chlorine there are obtained various solvents, which are used for dissolution of nitrocellulose, vinyl-perchloride resins, and also fats and oils.

Dichlorethane is obtained during interaction of ethylene with chlorine. It is a colorless difficultly inflammable liquid with an odor similar to chloroform. Dichlorethahe well dissolves fats and many resins, nitrocellulose and vinyl-perchloride varnishes well.

Chlorobenzene is a colorless liquid with a slight odor of almond. Chlorobenzene is obtained by chlorination of benzene in the presence of catalysts — iron and aluminum. Chlorobenzene dissolves many resins.

Spirits of turpentine. The best solvent of oil bases, resinous-oil varnishes, and varnish paints is turpentine. Turpentine is a mixture of terpenes and it is called turpentine oil.

Regarding method of production, turpentine is divided into gum, resinified, and wood-tar.

Gum turpentine is obtained from oleoresin of conifers, consisting of rosin and liquid part of turpentine. After treatment of turpentine by steam distillation there is obtained solid resin — rosin and liquid part — gum turpenting. Gum turpentine is sometimes called gum spirits of turpentine, or turpentine oil.

Resinified turpentine is produced from conifer wood — tar-impregnated wood. Tar-impregnated wood is crushed into fine chips and is processed by steam, alkali, or extraction method. Depending upon method of production resinified turpentine is called steam-distilled or extracted.

Wood-tar turpentine is obtained by dry distillation of tar-impregnated wood and depending upon technology of production and distillation carries the name of furnace or boiler. With respect to their qualities resinified and wood-tar turpentines are considerably worse than gum.

Alcohols are applied as solvent for spirit varnishes and spirit-soluble resins: shellac, copal, turpentine, and component of solvents and diluents of nitrocellulose, vinyl-perchloride, and other synthetic varnish bases.

Methyl, or wood, alcohol (methanol) is a colorless liquid with a unique odor. Methyl alcohol is poisonous; therefore its application is limited.

Ethyl alcohol is a colorless, transparent liquid with a characteristic wine odor. It is produced by means of fermentation of starch-containing or sugary substances or by means of hydrolysis of wood. Ethyl alcohol is hygroscopic, is mixed well with water. It is widely applied as solvent during manufacture of spirit varnishes and as diluents for preparation of mixed solvents.

Isopropyl alcohol is obtained by reduction of acetone by hydrogen in the presence of catalysts, it is mixed well with water and organic solvents. Isopropyl alcohol is a substitute of ethyl alcohol in production.

Butyl alcohol (butanol) is a colorless liquid with an odor of alcohol and fusel oil. Is produced with fermentation of cereal grains. Is used for nitrolacquers, alcohol and oil varnishes. It assists decrease of surface tension and improvement of bottling of oil and other varnishes.

Ethers are obtained during chemical interaction of molecules of alcohols in the presence of concentrated sulfuric acid. Ethers of glycol (otherwise called polyglycols); methylglycol, ethylglycol, butylglycol, and others received the greatest propagation. Polyglycols are almost entirely not smelling liquids with very high dissolving ability. They dissolve nitrocellulose, and also oils and resins well.

Esters are obtained during chemical interaction between molecules of alcohol and organic acid. This process occurring with this is called esterification.

Ethylacetate is a neutral liquid with a sweet fruit odor. Ethylacetate is obtained by direct esterification of ethyl alcohol with acetic acid. Ethylacetate is the best average-boiling solvent and therefore is widely applied in the production of nitrolacquers. It does not dissolve nitrocellulose, but with addition of 15-20% ethyl alcohol dissolution occurs normally.

Ethylacetate easily dissolves greases and oils, and also is mixed well with hydrocarbons and usual solvents in any ratios.

Amylacetate is a transparent, colorless liquid with odor of a pear. Amylacetate is obtained during interaction of acetic acid and amyl alcohol (from fusel oil), with this there is produced chemically pure and technical amylacetate. It is intended for dissolution of nitrolacquers, nitroenamels, and compound solvents.

Normal butylacetate is a neutral colorless liquid with pleasant odor. Is obtained by direct esterification of butyl alcohol by acetic acid. Butylacetate is widely used for dissolution of nitrocellulose. Butylacetate in combination with a small quantity of butyl alcohol gives especially good results. Butylacetate is non-toxic and has a less sharp odor. It is a good solvent of phenol-formaldehyde resins, coumarone resins, resinates of calcium, zinc, and manganese. With addition of about 20% butyl alcohol it dissolves high-polymerized phthalic-glycerine resins well. It is mixed with castor, linseed, and other oils, and with hydrocarbons.

Aldehydes and ketones. Alcohols are easily oxidized under action of various oxidizers, being turned into aldehydes. During oxidation of methyl alcohol is obtained methanal or formaldehyde, which is one of the basic products for production of resins. With dry distillation of wood along with acetic acid and wood alcohol there is emanated acetone, which is one of the basic solvents for various types of varnishes and enamels.

Compound solvents, recommended for different groups of varnish and paint materials, are mixtures of simple solvents.

To such mixtures there are appropriated brands or numbers, for example: [RDV] (РДВ), [R-4] (Р-4), [R-5] (Р-5), No. 646, No. 647, No. 649, etc.

All these mixtures are highly volatile, homogeneous, transparent, colorless liquids or with a slightly yellowish nuance. They should not contain moisture, mechanical impurities, and mineral oils.

When mixing solvents and mixtures for dilution with lacquers, enamels, and other varnish and paint materials they should have full compatibility without coagulation, stratification, curdling, or suspended matter, and obtained films should be homogeneous, without whitish spots, whitening, and other defects.

§ 5. Pigments, Dyes, and Fillers

Paints or enamels are obtained by mixing oil, drying oil, varnish, or other binding materials with coloring substances, which are divided into on pigments and dyes.

Pigments

Pigments in contrast to dyes are not dissolved in water and binder, in which they are located in the form of suspension or finely ground paste. Pigments are of inorganic and organic origin. Inorgainc pigments have the greatest practical application.

Pigments and dyes are classified according to their color.

White pigments. White lead is obtained during treatment of lead – litharge oxide by acetic acid and then carbon dioxide; white lead, represented by microcrystalline particles, is very poisonous, especially in dry form, therefore it is applied only for cirtical operations.

Zinc white is finely dispersed powder of zinc oxide, obtained during sublimation of metallic zinc in muffler furnaces or zinc ores and zinc-containing raw material in special withering furnaces. These whites are easily milled with film-forming substances. With the presence of fatty acids the paste hardens.

Zinc white is colorfast, but their weather resistance is limited; withered whites exceed muffle. Whites are useful in anticorrosion primers. Color of withered whites is darker than muffle.

Lithopone white (lithopone). Lithopone is produced as a result of interaction of zinc sulfate and varium sulfide.

Lithopone is a fine white powder. It is the least colorfast of all white pigments and is not weather resistant. It is used for painting the inside of railroad cars. Lithopone contains 28% zinc compounds and 72% barium sulfate (barite).

Titanium white (titanium dioxide TiO_2) is obtained from titanium ores by means of its treatment by sulfuric acid.

Titanium dioxide possesses the best covering power of all white pigments. It is produced in the form of two crystal shapes – rutile ([R] (P), [RO] (PO)) and anatase (A, AO): rutile is weather resistant, anatase is insufficiently stable in atmosphere.

Yellow pigments. Lead chrome yellow is a mineral pigment from light lemon to orange color. It is a product of simultaneous deposition of lead chromate and sulfate.

Weather resistance or orange chrome yellows is high, the remaining chrome yellows – average. Colorfastness is average. Orange chrome yellows possess high anticorrosion properties, yellow – somewhat less.

Zinc chrome yellow is an artificial mineral pigment of light yellow color. Zinc chrome yellow is dissolved in acids, alkalis, and even water (from 2% and more); is used for primers, chiefly for light metals, since it possesses protector action.

Iron oxide yellow pigment with respect to chemical composition corresponds to $Fe_2O_3 \cdot H_2O$ and is an artificially produced finely pulverized powder of brownish-yellow color of small saturation. Colorfastness and weather resistance of this pigment are very good. It is applied as component part in green enamels instead of toxic lead chrome yellow.

Ocher is a natural pigment, having the form of fine powder from yellow to reddish-brown color.

Ocher is widely applied, in spite of dull color, because of its accessibility, cheapness, good stability to the influence of light, atmosphere, alkalis, and weak acids. Ocher is delivered in three brands: A – for artistic paints; [B] (Б) – for oil paints and enamels; [V] (B) – for glue paints with content 18, 12, and 11% iron oxide Fe_2O_3 respectively.

Red and orange pigments. Vermilion is a paint of red color of different shades; it is obtained by deposition or mixing of organic pigments with fillers: para red [NK] (HK), red pigment [S] (C), reddish pigment. As fillers we use spar, limestone, marble, or prepared chalk.

Vermilion is chalky, ordinary, and for special operations – light and dark.

Lead-oxide red paint (Pb_3O_4 or $2PbO \cdot PbO_2$) is obtained by means of heat treatment of litharge PbO in special muffle furnaces. It is a heavy orange powder, distinguished by large specific gravity and bulk density. Lead-oxide red paint is the best priming pigment on steel, since it possesses high anticorrosion properties. It is not applied for covering paints because of its unstableness in atmosphere. Quality of red lead is evaluated by quantity of ferric dioxide PbO_2. content of which should be 26%.

Basic deficiency of lead-oxide red paint is hardening of paste obtained from it, which prevents manufacture of thick milled and thin milled paints and leads to its dilution directly at working place.

Iron-oxide red paint is a natural pigment, containing not less than 73% ferric oxide Fe_2O_3, and in good grades 90% and more.

Basic properties of iron-oxide red paint depend on content of ferric oxide. Colorfastness and weather resistance are very good. It is the most commonly used pigment in railway economy both for external painting (roof of railroad cars, etc.) and as priming material for metal.

Iron-oxide red paing is of two brands: A – for oil paints and primers with content of not less than 73% ferric oxide Fe_2O_3 and B – with 63% ferric oxide.

Colcothar is a natural pigment, consisting of aluminosilicate of iron with silicon impurity; content of ferric oxide is from 20% in light colcothar to 35% in dark. Colorfastness and weather resistance of colcothar are good.

Iron-oxide red pigment is a powder of almost pure ferric oxide Fe_2O_3, produced by means of heat treatment of various salts or hydroxides of iron, possesses high colorfastness and weather resistance, high intensity and covering power, and has somewhat dull shades. Is used for all possible paints.

Blue pigments. Iron azure (milori) is the finest dark blue powder of high intensity and covering powder. Azure is resistant to weak acids, but is destroyed under action of alkalis. Colorfastness and weather resistance of azure are good. In thin layers with binder azure glazes, i.e., does not cover in usual layers with thickness 60-80 μ; it covers the surface well. Is applied in colored paints and for preparation of green paints in a mixture with chrome yellows.

Ultramarine is blue inorganic pigment. Acids destroy ultramarine with separation of H_2S, is resistant to weak alkalis. Colorfastness of ultramarine is good, and weather resistance is satisfactory. Due to destruction under influence of sulfurous gas ultramarine is not applied for paints under conditions of atmosphereic influence. Its basic application is for coloring of white paints.

Green pigments. Lead green is a mechanical mixture of lead chrome yellow and iron azure with filler in a quantity of 50-75% or without it. Weather resistance and colorfastness of greens are good.

Zinc green is a mechanical mixture of zinc chrome yellow and azure with addition of fillers or without them.

Alkali destroys green, acids change it into solution. Weather resistance and colorfastness are satisfactory. Covering power is lower than that of lead greens.

Chromic oxide Cr_2O_3 is artificial inorganic pigment, having the form of thin powder of dull green color with olive nuance. It is not dissolved in water, acids, and alkalis. It is extremely resistant to the action of light, high temperatures, and atmospheric agents. Dullness of color and high cost prevents wide application.

Gray pigments. Aluminum powder is a highly smearing pigment of silvery-gray color, crushed in the form of petals. Regarding chemical composition it is comprised of almost pure aluminum, protected from oxidation by a thin grease layer (paraffin, stearic acid). This layer assists emergence (leafing) of petals of powder in layer of varnish and paint material and their ordered arrangement by plates along the plane of paint with formation of brilliant metal-like surface; furthermore, grease layer strongly decreases possibility of spontaneous combustion of powder and explosions of it, which occur very easily when surface of particles of powder is not protected by anything.

Powder is dissolved in acids and alkalis. Colorfastness and weather resistance are good.

Powder is inclined to ignition under influence of moisture, therefore it should be guarded from moistening.

Zinc dust is a by-product when processing zinc and consists basically of finely dispersed crushed metallic zinc. It is applied during manufacture of zinc protector primer and in a mixture with other pigments for manufacture of steel color paints.

Black pigments. Carbon black is artificial pigment having the form of finely dispersed, highly smearing black powder that is soft to the touch. With respect to chemical composition carbon black almost pure carbon with small quantities (0.15%) of volatile substances and ash.

Regarding method of production the most widespread is petroleum and gas black. Petroleum black is obtained with burning of petroleum products (black oil, etc.), gas – natural gases (methane, etc.). Carbon black is not dissolved in alkalis, acids, and solvents. Covering power and intensity is higher for carbon black than for all other pigments.

In recent years the varnish and paint industry has produced new pigments, which are used for parkerizing and covering primers, paints, and enamels: potash-barium chromate, chromium phosphate, lead silicochromate, zinc tetrahydroxychromate, calcium chromate, nickel titanium, mixed pigments of brown and other colors based on titanium dioxide, oxides of iron, zinc, copper.

Organic Dyes

Organic dyes are used mainly for manufacture of cinnabar, coloring varnishes, colored enamels, and transparent colored resinous and nitrolacquers.

It is expedient to use organic dyes in pure form since with oils they dry slowly and are very expensive. Therefore, they are used together with fixing substances – substrates or fillers, as which can be aluminum hydroxide, blanc fixe, heavy spar, kaolin, chalk, and so forth.

Scarlet pigment is bright red pigment, possessing high colorfastness and good covering power. This pigment stands up against the action of water, lime, oil, alcohol, acids, and various alkalis. It is stable during heating up to 100°C.

Bordeaux pigment (naphthylamine of bordeaux) has dark Bordeaux red color. It possesses good colorfastness. It also stands up against the action of water and lime. Bordeaux pigment is dissolved well in alcohol and other solvents, but is weakly dissolved in oil; therefore, its application is very limited. Is applied during manufacture of spirit varnishes and nitrolacquers (for coatings under rose wood).

Blue monastral is a unique stable pigment of brilliant bright blue color. Its intensity is 2-3 times more than for iron azure. Covering power is extraordinarily high and reaches 4-8 g/m^2. Blue monastral is insoluble in all the usual solvents, is very stable with respect to light, atmospheric influences, heating, and the action of boiling hydrochloric acid. With respect to its properties it exceeds not only organic dyes, but also mineral pigments (azure, ultramarine). It is used for all types of enamels, in particular, it enters the composition of pentaphthalic enamels.

Green monastral is a brilliant bluish-green pigment with nuances from light green to dark green. It possesses high covering power, intensity, high resistance to light, atmospheric influences, heating, and the action of different reagents, including oxidizers and reducers.

Fillers

Fillers are applied to different mineral and organic pigments as impurities.

As fillers we apply heavy spar $BaSO_4$, light spar $CaSO_4$, chalk $CaCO_3$, talc, kaolin, asbestos, blanc fixe, limestone-shell rock, tripoli, etc.

§ 6. Desiccants, Initiators, Activators, and Solidifiers

Desiccants are liquid or dry substances, accelerating drying of raw vegetable drying and semidrying oils. Desiccants are applied as catalysts during manufacture of drying oils, oil, and other varnishes and paints.

Desiccants are obtained from salts and oxides of different metals, and also from naphthenic acids, oil (chiefly from vegetable), and resin (basically rosin). For production of desiccant there are used the following salts and oxides of metals: lead acetate (sugar of lead), lead-oxide red paint, litharge (lead-oxide), pyrolusite (manganese peroxide), manganese hydroxide, manganeseborate, cobalt acetate, and others.

With respect to their activity metals can be arranged in the following series: CO > Mn > Pb > Ni > Cu > Fe > Cd > Cr > Zn > Ba > Ca > Mg.

Desiccants themselves will not form protective film: with addition in a quantity 2-10%, depending upon type of desiccant, to vegetable drying oils (linseed, hempseed, and others) they ensure drying of the latter at 18-23°C in 24 h. Better desiccants are mixed from two-three metals, in particular, cobalt-lead-manganese, lead-manganese-calcium.

For every desiccant there is a defined optimum, i.e., limit of introduction of it into oil, ensuring the greatest drying rate. Surplus of desiccant (above optimum) causes lowering of drying rate.

Solutions of metallic salts of organic acids in solvents recieved wide application (white spirit or turpentine), i.e., liquid desiccants and solutions in oils, i.e., extracts.

Industry produces the following brands of liquid desiccants: light lead-manganese No. 63, lead-manganese dark No. 64, cobalt No. 7640, extract No. 1 light, extract No. 2 dark.

Desiccants and their solutions are transparent liquids from straw yellow to dark brown color, are dissolved well in vegetable oils.

Initiators. For drying and film-formation of polyester varnishes we add initiators to them, which are substances which form free radicals and which excite the polymerization reaction. In contrast to catalysts initiators are expended during polymerization, while entering the composition of polymer. Initiators are organic or inorganic peroxides, for example, initiators for varnishes of cold drying: benzoyl peroxide, methylethyl ketone peroxide, cyclohexanone peroxide, isopropyl benzene hydroperoxide (cumene), furoin.

Accelerators (activators). Inasmuch as decomposition of initiators occurs rapidly only at elevated temperature, for acceleration of this process without heating we introduce so-called accelerators (activators), possessing reducing properties.

As activators we apply dimethylaniline and salts of polyvalent metals soluble in hydrocarbons, in particular, naphthenate and octoat (salt of diethylcaproic acid) cobalt octoate. The salts are introduced in varnish or enamel in the form of solutions in acetone or toluene.

Decomposition of benzoyl peroxide is accelerated basically by dimethylaniline, and peroxides of cyclohexanone, methylethyl ketone, and cumene hydroperoxide — by salts of polyvalent metals (cobalt, iron).

Solidifiers. For hardening of epoxy resins at room or elevated temperature we apply solidifiers — solutions or salts of hexamethylenediamine.

Solidifier No. 1 is a 50% solution of hexamethylenediamine in ethyl alcohol. Solidifier [AE-4] (АЭ-4) (adduct No. 4) is a product of reaction of hexamethylenediamine with epoxy resin [E-40] (Э-40). Solidifier is delivered in the form of solution in organic solvents and is a transparent viscous liquid of dark yellow color. With addition in a quantity of three parts by weight per 1% epoxy group it produces hardening of resin.

For hardening of polyurethane varnishes there are applied polyisocyanates, for example, 2.4-toluylenediisocyanate. Polyisocyanates are produced by means of action of phosgene on polyamines.

2.4-toluylenediisocyanate is a transparent liquid of slightly yellow color with 98% content of basic product. When mixing it with polyester the viability of mixture composes 6-8 h, after which it thickens and gelatinizes. Therefore, components are mixed immediately before application on surface. More viable — up to two days — are mixtures of polyesters and diisocyanates with raised molecular weight, for example, urethan [DGU] (ДГУ), which is delivered in the form of 70% solution in cyclohexanone. This product is a viscous nonvolatile and nontoxic liquid of yellow color and is designed for varnishes of both hot and cold drying. Isocyanates can be applied both as solidifiers for epoxy resins and as additives for increase of chemical stability of cresol-formaldehyde varnishes.

Varnish [MCh-52] (МЧ-52) based on phenol-formaldehyde-urea resin of cold drying for wood is hardened with addition of 10% alcohol solution of Petroff contact, and MCh-26 — with addition of 3-7% solution of hydrochloric acid.

Questions for Self-Check.

1. What oils pertain to drying, semidrying, and nondrying?

2. From what products are drying oils produced?

3. What resins are used for production of varnishes?

4. What properties should resins possess?

5. What are the types of natural resins?

6. What resins are used for manufacture of oil, spirit, and black varnishes?

7. How are oleoresinous varnishes distinguished with respect to their assignment and composition?

8. Which resins pertain to condensation and which to polymerization? How do they differ from each other?

9. What are pigments? What are their basic properties?

10. What are plasticizers and what is their assignment?

11. For what purposes are solvents applied? What types are they?

CHAPTER VII

VARNISH AND PAINT MATERIALS AND COATINGS

§ 1. Drying Oils

Drying oils are film-forming material obtained by means of heat treatment of vegetable oils with addition of desiccants. With application of a thin layer of drying oil on surface it should dry in a period of not more than 24 h with formation of an elastic protective film.

Depending upon method of processing the drying oils are divided into natural, oksol type, glyptal, pentaphthalic. Furthermore, depending upon applied raw material we distinguish homogeneous, obtained from one type of raw material (for example, linseed, hempseed, sunflower, castor, etc.) or mixed from a mixture of several types of raw material (for example, linseed-sunflower, is linseed-cottonseed-castor, etc.).

Initial products for production of drying oils are not crude oils, but processed – refined, polymerized, oxidized, dehydrated, or interesterified.

Natural drying oils. Basic raw material for production of natural drying oils are linseed and hempseed oils.

There are 2 methods of producing natural drying oils, which in accordance with this are called: polymerized, oxidized.

Polymerized drying oil is obtained as a result of heating of linseed oil, containing desiccant, without access of air to 275-280°C; oxidized drying oils are obtained by means of heating and blowing of linseed or hempseed oil by air with addition of soluble desiccant at 120-145°C.

Oksol drying oils are products produced by oxidation of heated drying linseed, hempseed, or semidrying sunflower, soybean, and also cameline oil by blowing with air at 160°C in the presence of catalyst (desiccant) with subsequent addition of desiccant and dissolution in while spirit.

Glyptal drying oils are products obtained during interaction of vegetable oils, glycerine, and phthalic anhydride with addition of desiccant and subsequent dilution with white spirit.

Pentaphthalic drying oils are produced similar to glyptal, where instead of glycerine there is used pentaerythrite. Glyptal and pentaphthalic drying oils contain 45% binder, including 25-30% oils and 55% solvent.

Quick-drying oils. Basic deficiency of drying oils and paints based on them is the prolonged period of natural drying. This deficiency can be avoided by applying quick-drying oil. In normal conditions the drying time of this drying oil and paints based on it is 2-4 h. Such fast drying of drying oil occurs thanks to the introduction of specially active catalysts.

Besides the shown most widespread types of drying oils, there are produced various types of drying oils both on the basis of vegetable raw material — cottonseed drying oil, castor drying oil, xylite, xyphthalic, emulsion, and on the basis of refining of petroleum products, oil shales, natural gas, and other crude, so-called snythetic drying oils — naphthenol, carbonol, lakol, snythol, syntoxin, saline, ether saline, shale, polydiene, kukersol, ester-oil, ester-glyptal, and others.

Drying oils from vegetable raw material possess sufficiently good qualitative numbers and satisfactory stability in operating conditions, and can in certain cases be applied on a par with basic types of drying oils.

Synthetic drying oils have insufficient indices and, as a rule, insufficient stability in operational conditions; therefore, they should not be applied in railroad car construction.

§ 2. Varnishes

Varnishes are organic liquids, consisting of nonvolatile part — binder (film-forming material), dissolved in volatile part — solvent (or mixture of solvents). Varnish, applied in a thin layer on surface, dries and forms a solid brilliant or dull film. While drying from film there is volatilized solvent (or solvents) and there occurs a number of physical chemistry processes.

Depending upon processes occurring with formation of film, varnished are subdivided into 2 basic types.

Varnishes of the first type are solutions in organic solvents of natural resins or synthetic alkyd-resinous bases, and also of polycondensation resins, combined or modified with vegetable oils or fats.

These varnishes form films as a result of complex comparatively prolonged physical chemistry processes.

A peculiarity of these varnishes is irreversibility of films obtained from time. Films in the process of drying and hardening are turned into three-dimensional polymers (linoxyn) that are insoluble in organic solvents.

Varnishes of the second type are solutions of natural or synthetic polymerization resins, ester, or their mixtures in volatile solvents with the addition of plasticizers. These varnishes (so-called volatile or quick-drying) will form films immediately after volatilization of solvents.

Films of these varnishes are reversible and are dissolved in organic solvents.

Oleoresinous varnishes are products of interaction of vegetable oils with resins of vegetable or synthetic origin. In them, in contrast to drying oils, besides oil there is resinous component.

For production of oleoresinous varnishes we apply mainly a mixture of oils and fats (chiefly primarily cod-liver) and various resins.

Quality of oils and resins, their relationship, i.e., fattiness of base, and especially technology of treatment of component parts, determine the structure and property of varnish film.

Oleoresinous varnishes on a rosin base are manufactured from preparations of rosin — esters, resinates. Weather resistance of preparations of rosin is considerably lower than for other resins — copals, synthetic; therefore in oil varnishes on their base oil has a decisive influence on quality of coatings. Fattiness of rosin varnishes is higher than corresponding brands of other oil varnishes.

On the basis of rosin preparations there are manufactured the most widespread oleoresinous varnishes of brands No. 5, 6, 17, 7, 8, 74, 92a, and others.

Copal varnishes constitute an alloy of copal with vegetable oil, dissolved in volatile solvents with the addition of desiccant. The group of copal varnishes includes amber varnishes [YaK-1] (ЯК-1) and others.

Resinous varnishes are the name for solutions of resins in volatile solvents. Majority of such varnishes are prepared on alcohol, due to which they are called spirit varnishes.

With respect to quality the best resinous varnishes are shellac, among which varnishes and weak-cut shellac are distinguished. Content of resin in shellac varnishes is 30-45%, in weak-cut shellac varnishes – 15-25%.

Alkyd (synthetic polyester) varnishes. Alkyd (polyester) varnishes are produced on the basis of products of interaction of polybasic acids and polyatomic alcohols. Depending upon composition these varnishes are subdivided into glyptal and pentaphthalic.

Glyptal varnishes are obtained during interaction of phthalic anhydride and glycerine with vegetable oils. Depending upon their composition, they are divided into short-oil, medium, and long varnishes. Long varnishes are dissolved in white spirit, whereas for short-oil varnishes there are required more active solvents – solvent, xylene, etc. Introduction of rosin and its preparations into glyptal varnishes always lowers service life of coatings, although it increases brightness, hardness, and drying rate.

The most widespread varnishes on glyptal base are [5s, 5t, 6s, 6t] (5c, 5т, 6c, 6т) (brands of varnishes are the same as for oil varnishes on rosin ester), and [17f] (17ф).

Numerous glyptal varnishes are used for manufacture of primers, puttys, enamels of cold and hot drying, for example, No. 154 for manufacture of primer No. 138, No. 1 for puttys, [FV-2] (ФВ-2) and [F-PV-2] (Ф-ПВ-2) – for enamels of types [FSKh] (ФСХ) [FO] (ФО), and others. Properties of glyptal varnishes, montypic with oil varnishes based on rosin esters, are regulated by the same standards and are identical.

Pentaphthalic (modified) varnishes have considerably advantages over modified glyptal varnishes:

drying occurs faster; varnishes based on semidrying oils have higher mechanical indices of coatings; coatings with application of pentaphthal from semidrying oils have more prolonged service lives.

These advantages are explained by the structure of pentaphthals, modified with oil.

Pentaphthalic varnishes are applied in pure form, for example, No. [4s, 4t,] No. (4c, 4т,) 170, and for manufacture of enamels of brands [PF, PF-115, PF-133] (ПФ, ПФ-115, ПФ-133), and others.

Phenol-formaldehyde varnishes are produced in the form of novolaks – iditol, resols – bakelites, artificial copals, and on the basis of 100% phenolic resins.

Iditol is a solution of novolak resins in ethyl alcohol. Besides ethyl alcohol, there can be applied butyl alcohol, ethylacetate, butylacetate, acetone, cellosolve, and alcohol benzene mixture. Iditol is insoluble in benzene, toluene, xylene, and petroleum solvents. It is combined only with rosin and spirit-soluble nitrocellulose. Iditol is not combined with oils and other resins. Iditol is applied as spirit varnish and weak-cut shellac varnish in exchange for shellac varnish and weak-cut shellac varnish.

Iditol varnishes contain from 20 to 40%, and weak-cut shellac varnishes — up to 10% resin. Basic deficiency of iditol — reddening of films under action of light. Application of antioxidants, for example, oxalic acid, reduces this deficiency, but does not remove it.

A widespread group of phenol-formaldehyde varnishes are varnishes of resol type — bakelite varnishes.

Bakelite varnishes are a product of condensation of phenol with formaldehyde (in paint ratio 6:7) in the presence of alkaline catalyst. Depending upon type of applied phenol (synthetic, peat, and others), and also of cresol there are produced various grades of varnish, differing from each other also by viscosity: grade A with viscosity 50-150 s regarding [VZ-4] (ВЗ-4), grade [B — 150-300] (Б — 150-300), and grade [V — 2-10 c] (В — 2-10 с).

Varnishes on substituted phenol. Varnishes produced by means of condensation of phenol with formaldehyde (iditol, bakelite) are not combined with oils and do not possess weather resistance. Varnishes on the basis of phenol-formaldehyde resins, modified by rosin, — arificial copals (albertol) — possess only low or average resistance.

A big achievement was the creation of varnishes on so-called 100% phenolic resins — from the highest compounds (homologues) of phenol, paratertiary butyl phenol, or dimethyl phenol paracresol.

Urea-formaldehyde varnishes. Products of combination of urea-formaldehyde and alkyd resins (urea-alkyd varnishes) are used for manufacture of hot drying enamels of brand [MCh-13] (МЧ-13) of different colors, including white color and light tones. Films of these varnishes are light and hard, not yellowing with heating to 150°C, possessing high gloss, resistance to water, gasoline, and oils.

Melamine-formaldehyde varnishes like urea-formaldehyde without addition of plasticizers will form transparent, colorless, but brittle films possessing poor adhesion; therefore, they are usually combined with alkyd resins during manufacture of melamine-alkyd, urea-melamine-alkyd varnishes and enamels. Duration of hardening of melamine-alkyd varnishes and enamels is 25-40% less than urea-alkyd at the same temperature and analogous ratios. They are less inclined to yellowing while drying (conducted at a temperature higher than 150°C) than urea-alkyd varnishes and enamels; they exceed the latter with respect to resistance to action of water, alkalis, solvents, and with respect to weather resistance.

Therefore, melamine-alkyd enamels of brand [ML-12] (МЛ-12) are used for high-quality coverings of passenger cars, and enemel ML-21, No. 891, and others — for refrigerators, washing machines, sewing machines, hospital implements, kitchen implements, equipment of railroad dining cars and special railroad cars, and also for weather resistant coverings under conditions of elevated temperature and humidity (tropical climate).

On the basis of these varnishes there are manufactured enamels with drying temperature to 85°C for railroad cars and locomotives.

Polyester (furniture) varnishes. Polyester varnishes on the basis of unsaturated polyester resins are characterized by high content of film-forming substances (85-95%). Obtained films possess high luster, hardness, color fastness, heat resistance, frost-resistance, and resistance to influence of water, soap solutions, and alcohol.

Polyester varnishes are applied in one gross layer with thickness up to 200 μm, in 24 h they are ground and polished with No. 290 paste. It is recommended to apply them only for finishing of horizontal surfaces.

Polyester varnish consists of two components:

a) solution of unsaturated polyester resin in styrene with addition of accelerator;

b) peroxide catalyst (4-5% of weight of varnish).

Duration of dying of coating at temperature 18-23°C is not more than 6 h.

Silicone varnishes. On the basis of [F-9] (Ф-9) resin (polyphenyl siloxane) as binder we manufacture heat-resistant varnish [FG-9] (ФГ-9) and heat-resistant enamel F-9, obtained by means of addition of [PAK-3] (ПАК-3) or PAK-4 aluminum powder to varnish FG-9. Varnish FG-9 is widely used for painting furnaces, pipes of heating system, and other parts operating at temperatures up to 250°C, and enamel up to 500°C. For increase of elasticity and adhesion resin FG-9 is mixed with glyptal resin and is dissolved in toluene or xylene with formation of FG-9 varnish.

Besides varnish FG-9 and enamel No. 9, there are applied varnishes K-40, K-44, K-54, and others.

Vinyl-perchloride varnishes are manufactured from dry vinyl-perchloride resin. They possess a number of valuable properties: resistance to water, acids, alkalis, minerals oils, alcohols, gasolines, and other aliphatic hydrocarbons; high weather resistance, frost-resistance, incombustibility, and good dielectric properties.

Basic deficiencies of vinyl-perchloride varnishes are a specific unpleasant odor, weak adhesion to metals, absence of gloss, low elasticity, and low heat-resistance. For increase of adhesion varnishes are modified with alkyds, phenol-formaldehyde resins, and rosin derivatives, and they also are applied over alkyd and phenol primers. For increase of elasticity we add plasticizers in a quantity up to 30% of weight of resin.

With heating of films of varnishes higher than 100°C their decomposition starts, causing yellowing of film.

Varnishes on low-viscous vinyl-perchloride resin maintain all positive properties of varnishes on high-viscous resin, a number of which are considerably improved during this. For dissolution and dilution of varnishes on high-viscous resin it is necessary to apply solvent [R-4] (Р-4), containing 10-12% butylacetate, 24-26% acetone, and 60-62% toluene and xylene, and for varnishes based on low-viscous resin xylene or toluene and solvent are used with success. Coatings from varnishes on low-viscous resin possess higher gloss — 30-100 according to measure of luster of [FB-2] (ФБ-2) instead of 30-40 for varnish [KhSL] (ХСЛ) on high-viscous resin.

Varnishes on vinyl chloride copolymers. Vinyl chloride is combined well with other monomers and on the basis of products of their combined polymerization there are created copolymers with vinylidene chloride [SVKh-40] (СВХ-40), vinyl butyl ester [SKhB-70] (СХБ-70), vinyl butyl ester and methyl acrylate [SKhBM-10] (СХБМ-10), with vinly acetate [KhS-119] (ХС-119), and others.

Varnish solutions of these copolymers are of comparatively high concentration with resin content up to 20-30%. They are transparent liquids with small opalescence. Varnish films are colorless and transparent, at room temperature they dry in 2 h. In contrast to films of vinyl-perchloride varnishes they do not have any odor, are distinguished by good elasticity, large elongation (up to 300%), tensile strength (1-1.5 kgf/mm^2), satisfactory frost-resistance (to -40°C) and adhesion to metal and other materials, high resistance to action of chemical reagents, weak solutions of mineral acids, alkalis, salts, alcohols, organic acids, gasoline, mineral oils, and kerosene. While exceeding coatings on the basis of vinyl-perchloride varnishes with respect to these indices, they are inferior to the latter in weather resistance and water-resistance. Heat-resistance of films is low: at 80°C there occurs strong darkening.

In view of good elasticity and elongation varnishes are applied without plasticizers. Varnishes are combined well with a number of resins, plasticizers, and pigments, except zinc and iron, which accelerate decomposition of copolymer. On the basis of these copolymers there is developed a large group of chemically stable varnishes, primers, and enamels, which are widely used in railway economy —

for painting railroad cars which carry live fish, tanks and cisterns for gasoline, mineral oils, etc.

For increase of water-resistance of coatings based on copolymer we manufacture varnishes without stabilizer on resin [SVKh-40BS] (СВХ-40БС). For increase of adhesion to metals with cold drying we add up to 1% maleic acid to them.

Vinyl chloride copolymers with vinyl acetate can also be applied in dispersed crushed state in plastisols and organosols. Content of vinyl chloride in copolymer can be increased to 95%, having increased hardness and chemical stability of coatings accordingly.

Thanks to raised hardness varnishes and enamels based on copolymers A-15 and A-15-0 can be applied for platforms, bridges, and due to their good resistance to sea water — for underwater naval constructions and naval vessels, ferry crossings.

Varnishes based on cellulose esters. Solutions of esters of cellulose in volatile solvents, containing plasticizers and resins, are called ester cellulose varnishes, or nitrolacquers. Solutions of cellulose esters with various plasticizers and resins, and sometimes drying oils, will form films of various qualities. Property and strength of film depend on quality of basic raw material — cellulose ester.

Increase of concentration of plasticizer lowers the strength of film, increases its tensility (elasticity), and decrease hardness. Increase of concentration of resin lowers tensile strength, but increases cohesiveness of cellulose films, but soft resins, including resile and esters of rosin, lower them. Polymerization resins scarcely affect cohesiveness.

Separate components of cellulose varnish and their concentration differently affect life of cellulose films in atmospheric conditions depending upon their own weather resistance. Process of aging of ester cellulose films and coatings is closely connected both with depolymerization (disintegration) of ester of cellulose, and with destruction of introduced resin and plasticizer.

The basic factor assisting propagation of nitrolacquers in industry, is their ability to dry very rapidly. In approximately 7-15 min after application of first layer it is possible to apply the second layer of nitrolacquer.

Bituminous varnishes. Bituminous or asphalt-bituminous varnishes are solutions of asphalts, bitumens, or coal tar pitch usually in solvent, xylene fraction, benzene, turpentine, white spirit, or other solvents.

Of the number of oilless bituminous varnishes, producted by the varnish and paint industry, varnishes No. 35, 350, and 67 have the greatest propagation.

Oilless bituminous varnishes No. 35, 350, and 67 are permitted to be temporarily applied in railway transportation for painting the lower parts and undercarriages of railroad cars, components of automatic brakes, signalling and automatic block devices, internal parts of railroad cars, service and industrial locations, painted black, and also for priming the internal side of metal sheathing of railroad cars with wooden bodies.

Of the varnishes manufactured on a pitch base the most widespread is so-called Kuznetsk Basin coal-tar varnish, which is produced in two grades — A and B. On railway transportation it is permitted to apply varnish of grade A (higher quality) both in pure form and with the addition of aluminum powder. For painting constructions and structures not subjected to prolonged effect of solar rays, there can be applied bituminous-oil varnish No. 177, which is more stable as compared to varnishes No. 35, 350, and 67. Application of varnish No. 177 is permitted on railway transportation for temporarily painting locations and equipment of boiler tanks for tap water and so forth.

Divinyl acetylene varnish "Ethinol" is a byproduct during production of synthetic rubber. Externally "Ethinol" varnish is a dark-brown liquid with a sharp chlorobenzene odor.

A great deficiency of varnish on these solvents is its inclination to coagulation. Films of varnish and paints from iron-oxide red lead on its base are brittle, are unstable to impact, and possess poor adhesion.

§ 3. Oil Paints

Oil paints are produced by the industry as thick milled (pastes) or thin milled — ready to use.

Thick milled pastes are prepared by thorough mixing of dry pigments and fillers with vegetable oils, natural or heat-bodies drying oil in special mixers with subsequent repeated milling of mixture in a paint mill.

Preparation of thin milled paints is reduced to dilution of thick milled paints or crushing of pigments and fillers (or without them) and milling them with binders and solvents (or without them) in ball mills or mixers of various types.

With application of vegetable oils, natural and combined K-2, K-3 drying oils we obtain oil paints; with use of alkyd (glyptal, pentaphthalic, and others) drying oils we obtain alkyd paints. Oil and alkyd paints are prepared on only one basic pigment or for production of colored paints with its coloring by other pigments and dyes.

As fillers for oil and alkyd paints during external operations we apply talc, barite, mica, during internal — barite, chalk, anhydrite.

Below there is cited description of properties of basic oil paints.

Thick milled white lead is produced in a limited quantity. Basically it consists of dry white lead, heavy spar, and natural drying oil or raw linseed or sunflower oil. White lead are prepared in four grades, for which there are accepted arbitrary designation: 00, 0, 1 and 2. Grade No. 00 is manufactured without filler, the remaining grades contain filler. Only heavy spar is applied as filler.

White leads are very poisonous, especially in dry form. They are applied only for very responsible operations: painting of railroad constructions, bridges, viaducts, towers, and others.

Thick milled zinc whites are produced in the form of pastes, consisting of dry zinc whites or of a mixture of them with fillers (light spar, talc, and others), on natural drying oil or on vegetable oils (raw and treated) with addition of desiccant. Zinc whites are used for painting internal and external surfaces.

Thick milled lithopone whites are produced in the form of thick milled pastes, consisting of lithopone alone or a mixture of lithopone with fillers, on natural or seminatural drying oil. Whites are intended for jobs inside passenger, isothermal, and other railroad cars, electric and diesel locomotives.

Thick milled lead chrome yellow consist of dry chrome yellow — extract without filler and with filler (heavy spar), milled on natural drying oil or on treated vegetable oils.

Chrome yellow is applied as yellow paint for inscription, decorative bands, and stencils similar to them on railroad cars, orange — for high-quality primers.

Thick milled zinc chrome yellow consists of dry zinc chrome yellow and filler (light spar), milled on natural drying oil or treated vegetable oils. Zinc chrome yellow is used for pictorial art, painting inside railroad cars, composition of color paints, and as high-quality protector primer.

Thick milled vermilion is a paste, consisting of dry cinnabar, milled on natural or heat-bodied drying oil.

Cinnabar is used for signal painting of automatic brakes, machinist cranes, for inscriptions, and for addition into compound color paints. As filler in chalky cinnabar there is used chalk, in ordinary and special — heavy spar and limestone.

Thick milled black paint is a paste consisting of a mixture of petroleum or gas black with filler (heavy spar, Ilmenite), milled on natural or heat-bodied drying oil.

Black paint is designed manily for painting locomotives, undercarriages of railroad car , and other similar articles.

Thick milled mineral earth paint. Oil earth include iron-oxide red paint, colcothar, mineral ocher, and umber. These paints are a paste consisting of corresponding pigment, milled on natural or heat-bodied drying oil. Earth colors, furthermore, are produced in ready to use form, not requiring additional dilution.

Mineral earth paints are applied when painting railroad freight and passenger cars, in road economy, construction. Iron-oxide red paint is basically used when painting metal articles and roofs of buildings and railroad cars. For painting wooden articles and bodies of railroad cars we apply colcother and ocher, and for finishing under various types of wood-raw and burnt umber.

Thick milled lead green is a paste consisting of dry lead green as a mixture of lemon or yellow lead chrome yellow, paint azure, and filler (heavy spar), milled on natural or heat-bodied drying oil or on treated vegetable oil.

Besides lead greens, there is produced ocherous green, where lead chrome yellow is replaced by light golden ocher.

For painting vestibules and outer side of bodies of railroad cars there is applied special railroad-car green: for railroad cars of long-range travel — dark, for railroad cars and electrosections of suburban travel — light; for painting panels and walls inside railroad cars it is possible to apply ordinary green, and also green for internal jobs and ocherous green.

Thick milled zinc green is a paste consisting of dry zinc green or a mixture of zinc chrome yellow and filler with paint azure, milled on natural or seminatural drying oil or on treated vegetable oil. As filler there is used heavy or light spar. Green made with light spar is applied espically for painting the inside of railroad cars.

Thick milled colored oil paints for external jobs are paste consisting of a mixture of dry pigments and filler, milled on natural or heat-bodied drying oil. They are designed for external finishing jobs after dilution with natural or glyptal drying oil.

Ready to use oil and alkyd paints (thin milled) are mixtures (suspensions) of pigments in different drying oils with introduction of additives (fillers, desiccant, and others) or without them, produced by dilution of thick milled pastes or by milling in ball mills.

Depending upon assignment, and also upon applied drying oils and pigments, ready to use oil and alkyd paints are produced in different brands (Table 10).

Paints for external jobs are produced on the basis of the following pigments: titanium rutile whites, zinc white, ocher, colcother, iron-oxide red paint for internal jobs on the basis of titanium anatase white, zinc white, lithopone white, and also other pigments of various colors.

Table 10

Brands of oil and alkyd paints for jobs		Applied drying oils
external	internal	
MA-11	MA-21 and MA-22	Natural linseed or hemp seed for whites of crude oils
MA-15	MA-25	Heat-bodied (combined with 30% solvent)
GF-13	GF-23	Glyptal
PF-14	PF-24	Pentaphthalic

§ 4. Enamels

Enamels (varnish paints) are a mixture of pigments or organic dyes, milled with binder (drying oil, varnish, etc). and diluted by varnish to state of delivery with addition of solvent and when necessary desiccant.

Enamels are produced also by direct mixing of pigments or their pastes and binding in ball mills.

Enamels are intended for painting of prepared external and internal surfaces or directly on metal, wood, or other materials.

While drying varnish paints will form a hard brilliant layer, having good luster, similar to luster of silicate enamel, and therefore are called enamels.

Enamels are delivered from the plant-producer ready to use.

With application of varnish paints the periods of painting of articles are reduced considerably, since in this case it is not required to cover with varnish. Depending upon applied binder varnish paints are subdivided into oil, alkyd glyptal, pentaphthalic), phenol, epoxy enamels, etc.

Oil enamels are mixtures of dry pigments, milled on drying oils or oil separation and separated by oil varnish, consisting of processed linseed oil, resins, desiccant, and solvent. Oil enamels are designed for painting by brush, sprayer, or in electrical field of metal, wooden, and other surfaces.

On railway transportation these enamels are used mainly for painting internal surfaces of railroad cars and rooms.

Glyptal enamels are applied on surface as upper layers of coating. Film of enamel protects layer of primer from destruction and simultaneously gives a decorative view to the colored articles.

For painting inside railroad cars we apply mainly enamels of types PF-133 [b. FSKh] (b. ΦCX) and [GF-230, [b. FO(MO)]] (ГΦ-230, [b. ΦO(MO)]). Enamels of type PF-133 are of higher quality than GF-230.

As diluents of enamels PF-133 we apply solvent, xylene, turpentine, or a mixture of one of the shown solvents with white spirit, content of which in mixture should not exceed 50%; for enamels GF-230 we apply white spirit, turpentine.

It is not recommended to paint surfaces requiring high strength of covering (floors, sofas, desks, chairs, benches, etc.) with GF-230 enamel.

Enamels of brand PF-223 of different colors (formerly enamels of brands A and AM-4) for covering of internal (metal) surfaces are paints consisting of a mixture of pigments, milled on glyptal or oil separation or alkyd varnish, and separated by oil or alkyd varnish with addition of desiccant and solvent. They are applied on primered surfaces by sprayer or brush; they are diluted by white spirit, gasoline, xylene, solvent, or their mixtures in a quantity not more than 10%.

Pentaphthalic enamels are mixtures of thinly milled pigments or dyes in pentaphthalic varnish with addition of desiccant and solvents.

Pentaphthalic enamels possess good water-resistance and stability during action of 0.5% solution of hard household soap at 40-50°C. Thickness of single-layer coating of enamel of all colors should be 18-23 μm, and black color — 10-15 μm.

Varnish and paint industry has mastered the production of pentaphthalic enamels of brand PF-115 on titanium whites of rutile modification. These enamels are applied successfully at plants and roads of network.

Enamels are designated for painting metal, wooden, and other surfaces, subjected to atmospheric influences. Enamel is applied with a paint sprayer, brush, or atomization in electrical field.

For dilution to working viscosity coal-tar, white spirit, turpentine oil solvents or their mixtures are suitable. With atomization of enamels in electrical field the enamels are diluted to working viscosity with solvent [RE-4] (РЭ-4), consisting of a mixture of the following composition (with respect to weight in %); solvent — 50, aceton — 30, and ethanol — 20.

During thermoradiation drying of pentaphthalic dark-green enamel PF-65 and PF-115 to pendulum hardness 0.2 the time of drying depends on temperature of painted surface (Table 11).

Table 11

Time of drying in min	5	10	15	20	25	30
Temperature of surface of article in °C	140	125	115	105	95	80

Thixotripic enamels. During application of varnish and paint materials there are encountered difficulties, caused by their runoff from painted surface. This leads to necessity of repeated painting. A large deficiency is also settling of pigments in primers, paints, and enamels during storage and transportation. Settled pigments are difficult to evenly distribute in binder, as a result of which the color of enamels and paints worsens and considerable losses of thickened paints occur.

These difficulties can be considerably reduced and even completely removed by means of application of materials possessing thixotropic properties, which in a state of rest will form a system of reversible gels, destroyed during heating or mixing. Analogous gel will be formed during application of thixotropic varnish and paint materials on surface. Appearance of jellylike structure during storage of pigmented thixotropic materials prevents settling of pigments.

There are 2 methods of obtaining thixotropic varnish and paint materials:

1) introduction into prepared varnishes and enamels of various kinds of additions such as bentonite, salts of complexing metals and others;

2) application of thixotropic film-forming materials.

Thixotropic paints and enamels possess the following advantages:

during storage in container the pigments and fillers contained in paint do not settle;

after application the paint does not run and will not form drips;

it is possible to collect much paint on a brush;

paint is not spattered during application, does not drip from brush, and does not flow on handle;

paint can be applied in a thicker layer than usual;

paints do not require dilution and mixing, are applied easier than usual paints and enamels.

A deficiency of thixotropic alkyd resins, modified by polyamides, is poor stability of luster in atmospheric conditions. Great care should be observed during introduction of desiccants, since an unnecessary amount of desiccant causes formation of film on surface of paint.

Thixotropic enamels are produced in brands GF-220, [TS-3] (TC-3), TS-4 for internal jobs, and PF-143 for external jobs.

Enamels on 100% phenolic resins are produced from a mixture of these resins with linseed and tung oils. Besides a mixture of linseed and tung oils, there can be applied a mixture of tung and processed sunflower oils. There can also be obtained oil varnishes and enamels from 100% phenolic resins, modified with glyptal resins and vegetable oils.

On the basis of these resins there were made long varnishes (ratio of oil to resin 3:1) for weatherproof covering enamels [FL-14] (ФЛ-14) (No. 130/101, 130/108), and also several different types of primers (FL-03k, FL-013, and others) and furniture varnishes.

Enamels on 100% phenolic resins possess a reduced period of interlayer drying – 6-8 h. Thus, they can be applied 2 times during one working shift with subsequent complete drying (under natural conditions).

Alkyd-urea and alkyd-melamine enamels. On the basis of urea- and melamine-formaldehyde resins in a mixture with alkyd resins there are produced a number of high-quality synthetic alkyd-urea and alkyd-melamine enamels. These enamels are promising for finishing railroad passenger cars of international service (ML-12). They are used for painting railroad cars of delivery of German Demorcratic Republic plants.

Such enamels are a suspension of pigments in binder, consisting of a mixture of solutions of alkyd and urea-formaldehyde (MCh-13) or melamine-formaldehyde (ML-12) resins.

Before usage the enamels are diluted with solvent No. 651 or coal-tar solvent, and when painting in electrical field by solvent RE-1, RE-2, or RE-3.

Enamels ML-12 are produced in a large assortment of various colors (white, white night, beige, neutral, coral, blue, electric blue, riviera, ritsa, emerald, green, sea wave, etc.).

Two brands of enamel ML-12 are produced:

[V] (B) — high viscosity for application in electrical field or with preliminary preheating;

[N] (H) — low viscosity — for all others jobs.

Enamels have luster according to lusterometer not less than 55; viscosity of brand V — 90; brand N — 50 s with respect to VZ-4. Content of dry residum in enamels of brand V — 50%; N — 45%; covering power of light tones 70-100, others 36-60 g/m^2. At present there are manufactured for railroad cars with drying temperature 80°C.

Urea-formaldehyde enamels MCh-13 and others are intended for painting bicycles, motorcycles, instruments, but are successfully used for painting equipment of railroad cars.

Polyester acrylate enamel. In recent years there has been developed a new type of synthetic film-forming material on the basis of polyhydric alcohols (pentaerythrite, glycerine, diethylene glycol, and others), polybasic acids (phthalic anhydride, adipic acid, and others), and monobasic methacrylic acid, having received the name polyester acrylates. On the basis of polyester acrylates there are developed enamels [PE-126] (ПЭ-126), PE-127, and varnishes PE-214.

Application of enamel PE-126 permits reducing the number of coating layers on railroad cars to two instead of four, since they can be applied on an undried lower layer after waiting 15 min. Coatings possess high weather resistance.

As compared to pentaphthalic enamels PF and alkyd-melamine ML-12, PE-126 enamels have the best spread, high luster, which is well preserved in operation, higher hardness of coating, and the best ability to be polished.

Hammer enamels of brand PE-29 are suspensions of pigments in binding substance, consisting of mixture of solutions of glyptal and melamine-formaldehyde resin with addition of silicone oil. Such enamels are designed for decorative coloring of different instruments and apparatuses.

Hammer enamels are produced in various colors. They are applied on surface by paint sprayer. After drying there will be formed a film with characteristic appearance.

There is recommended the following sequence of application: primer No. 138 or FL-03K; synthetic enamel, hammer enamel.

Duration of drying at temperature 120°C is 1 h, preliminary holding of painted articles in normal conditions is not more than 15 min. Viscosity of working enamels at temperature 18-20°C according to VZ-4 is within limits of 55-65 s.

Alkyd-styrene enamel [MS-17] (MC-17) is suspension of pigments in alkyd-styrene varnish with plasticizer and desiccant, which are added to enamel immediately before application in quantity 2-5% of weight of enamel.

Enamel MS-17 is designed for painting internal metal and wooden surfaces, preliminarily primered or without primer. Two layers of enamel are applied on surface by brush or sprayer. As diluent to working viscosity we apply xylene or solvent.

Duration of drying at temperature 18-20°C "from dust" is not more than [illegible] h, practical drying not more than 3 h. Color of enamel is black and gray; shade is not standardized.

Moire brand enamels — heat resistant. Moire enamels are a mixture of pigments, milled on glyptal separation with addition of heat-bodied turg oil, desiccant No. 7640, and solvent. When heating the coating in a chamber to temperature 85 ± 5°C for 30-45 min there will be formed a characteristic pattern. Final drying of black enamel is produced at temperature 160-165°C for 3 h, and colored enamels at 80-85°C for 12-14 h.

Enamels of moire brand are produced in various colors.

Acrylic enamels. Acrylic enamels and primers are produced on the basis of acrylic resins. These materials possess good water-resistance and color fastness. Therefore, there are used successfully for painting water tanks of railroad passenger cars and bodies of isothermal railroad cars.

Vinyl-perchloride and copolymer enamels. Basic deficiency of oil, alkyd, and other enamels on the basis of condensation resins is the duration of their drying time at normal temperature and therefore the necessity of high-temperature drying for reduction of drying time, which is especially important under conditions of assembly line production at plants of ministry of Railroad [MPS] (МПС).

In this respect the application of vinyl-percholride, copolymer, and several other enamels on the basis of polymerization resins is very effective. Vinyl-perchloride and copolymer enamels dry in 1-3 h at 18-23°C.

Vinyl-perchloride [PKhV] (ПХВ) enamels are a solution of vinyl-perchloride resin in a mixture of volatile organic solvents with addition of other resins, plasticizers, and pigments. Vinyl-perchloride enamels are designed for painting various wooden or preliminarily primered metal articles, operating in atmospheric conditions. Vinyl-perchloride resin possesses poor adhesion; therefore, for increase of adhesion into vinyl-perchloride varnishes, applied for enamels, there are introduced alkyd and other resins.

Vinyl-perchloride enamels have a number of advantages over other materials. They are characterized by resistance of films to abrasion, high tear resistance at considerable elongation, low combustibility of films, good stability in solutions of acids, alkalis, and also water-resistance, oil-resistance, and very prolonged weather resistance.

Enamels are delivered in ready to use form with viscosity according to VZ-4 30 s and with content of dry residum not less than 26%; they are applied by sprayer, application by brush is very difficult and requires specific experience.

With thickening of enamels it is possible to dilute them with solvent R-4, which consists of butylacetate or amylacetate — 12%, acetone — 26, and toluene — 62%. During application of vinyl-perchloride enamels by method of spraying in electrical field, they are diluted by solvent RE-1.

Along with positive qualities the vinyl-perchloride enamels have a number of deficiencies: limited solubility and limited assortment of solvents; poor cohesion (adhesion) of films with metal; inclination to gelatinization, especially in the cold, fire, and explosibility of solutions due to presence of highly volatile solvents in them; toxicity; slow yield of residua of solvents by film and due to this preserving a sharp odor (chlorobenzene) for a long time; ability to dissolve films of oil paints and to curdle oil paints.

Besides vinyl-perchloride enamels of brand PKhV, there is produced a number of other types of vinyl-perchloride enamels of brands [KhV-16] (ХВ-16), [KhVE] (ХВЭ), KhV, [KhSE] (ХСЭ), and [PKhVO] (ПХВО).

Enamels KhV-16 are a solution of dry vinyl-perchloride in organic solvents with addition of glyptal resin and pigments, milled on plasticizer.

Enamels of brand KhVE have composition analogous to enamels of brand KhV-16.

Enamels KhV-124 (various colors) and KhV-125 (aluminum) are weather-resistant enamels and are applied on primered surface by spraying in a layer with thickness 18-23 μm.

Enamels possess good water-resistance, chemical stability, gasoline and oil resistance, and stability in tropical climate.

Chemically stable enamels of brand KhSE differ from other vinyl-perchloride enamels by the fact that they contain corresponding resins, pigments (chromium oxide, titanium dioxide; iron-oxide red paints, etc.), and as plasticizer — chlorinated biphenyl.

While possessing good chemical stability, they are less stable in atmospheric conditions as compared to enamels PKhV, KhV-16, and KhV-124.

Enamels of brand PKhVO are produced as fireproof paints of beige (PKhVO-4) and light-gray (PKhVO-29) color.

Chemically stable enamel of brand KhS-710 is a suspension of pigments in solutions of resin SVKh-40 (copolymer of vinylidene chloride with vinyl chloride) in a mixture of volatile organic solvents. Enamel is resistant to 25% solutions of acids and sodium hydroxide at temperature up to 60°C.

White enamel [VKhE-4001] (ВХЭ-4001) is produced analogous to this enamel.

Enamels are used for painting internal surfaces of railroad cars carrying live fish. A positive factor of these enamels is their harmlessness for food cargoes and absence of odor of coating.

KhS-119 enamels on the basis of copolymer of vinyl chloride with vinyl acetate. Vinyl-perchloride enamels have a number of deficiencies, such as a specific unpleasant odor, insufficient color fastness of coating, complexity of process of their production (additional chlorination of polyvinyl chloride), and also the application of highly volatile solvents. Enamels on the basis of copolymers of vinyl chloride with vinyl acetate of brand KhS-119 do not have these deficiencies.

Enamels of brand KhS-119 possess good elasticity and high adhesion properties, exceeding vinyl-perchloride enamels in this respect. These enamels have advantages over vinyl-perchloride enamels with respect to their color fastness, oil and gasoline resistance, and a number of physical chemistry indices. With respect to their weather resistance and operational stability they are not inferior to vinyl-perchloride enamels.

KhV-113 enamels on low-viscous vinyl-perchloride resin. Improvement of a number of physical, mechanical, and technological indices of vinyl-perchloride enamels is attained with application of vinyl-perchloride enamels on low-viscous resin of brand KhV-113.

KhV-113 enamels are suspension of pigments in solution of low-viscous vinyl-perchloride resin, pentaphthalic resin, and plasticizer.

Advantage of vinyl-perchloride enamels of brand KhV-113 over enamels PKhV, KhV, and KhSE and those analogous to them is the improvement of composition of solvents applied in these enamels, which approaches composition of solvents applied for pentaphthalic and glyptal enamels. Furthermore, color of vinyl-perchloride enamels of brand KhV-113 are richer and brighter than PKhV-14 enamels, approaching color of pentaphthalic enamels. If determine color of green enamel KhV-113 by card file of color standards [GIPI-4] (ГИПИ-4), it will correspond to number 311, i.e., it coincides with number of color of pentaphthalic green enamel PF-65; whereas color of vinyl-perchloride green enamel PKhV-14 (on high-viscous resin) sharply differs from color of pentaphthalic enamel; color of vinyl-perchloride green enamel PKhV-14 on card file corresponds to No. 724 and 728, i.e., is much more darker and duller than No. 311. It is impossible to change the color of vinyl-perchloride enamel PKhV-14 to brighter, since bright pigments and organic dyes all the more so, are not combined with it and darken very rapidly.

Gloss of coloring film of vinyl-perchloride KhV-113 considerably exceeds gloss of vinyl-perchloride enamel PKhV-14, but is inferior to pentaphthalic enamel.

In the process of usage the loss of gloss by enamel KhV-113 occurs slower than for PF-65 enamel; therefore their gloss is compared in 1-1.5 years.

Vinyl-perchloride on low-viscous resin of brand KhV-113 have raised content of dry residum as compared to enamel PKhV-14, namely up to 40% instead of 26. This circumstance permitted reducing the quantity of layers of multilayer covering from three-four to two layers while preserving the same weather resistance and life in operational conditions.

Increased content of dry residium in KhV-113 enamel in turn led to improvement of covering power of this enamel.

Alkali-resistant epoxy enamels [OEP-4171-1] (ОЭП-4171-1)(green) and OEP-4173-1 (cream) are solutions of epoxy resin [E-41] (Э-41) in a mixture of organic solvents with addition of pigments, fillers, and solidifier No. 1.

Enamels are delivered in the form of two semifinished products, to be mixed before application not earlier than 24 hours. They are designed for painting by method of spraying of metal surfaces, subjected to action of cold and hot solutions of concentrated (up to 40%) alkalis. Enamel OEP-4171-1 is more alkali-resistant than enamel OEP-4173-1.

Nitroenamels are produced in various colors depending upon color of pigments added (combined) to ester cellulose base of nitrolacquer for giving it covering power. In the presence of a large amount of pigment the nitroenamel film does not have the proper luster. Therefore, the last layer of nitroenamel should contain a smaller quantity of pigment or the colored surface should be covered by a layer of high-boiling solvent.

In the latter case solvent divides the upper part of film into phases and extracts nitrocellulose and resin on surface of pigmented film due to which the film obtains a uniform silky luster.

Pigments applied for manufacture of nitroenamels are preliminarily milled with application of plasticizers. For triburation of pigments it is recommended to apply a mixture of dehydrated castor oil and dibutyl phthalate with 1:1 ratio.

For manufacture of colored nitroenamels there should not be used pigments having a basic character and assisting gelatinization of varnish base. Phenomenon of gelatinization is removed by addition of 0.01% glacial acetic acid.

Nitroenamel films age strongly, gradually join oxygen, and are destroyed.

In atmospheric conditions aging of nitroenamel films occurs under the influence of temperature, humid air, and ultraviolet sunlight rays. Pigments that do not omit ultraviolet rays, for example, aluminum powder, protect nitrate film from aging best of all. Quality of varnish and paint materials, including nitrocellulose, considerably depends on fine dispersion (fineness of grind) of pigments.

For fine dispersion of pigments there is used method of rolling of high-viscous mass, consisting of binder, solvent, plasticizer, and pigment, on frictional rollers. With this are obtained enamels, forming films with good luster and depth of color tone. Such enamels received the name of enamels on dry rolled pastes [SVP] (СВП).

Paint the basis of bakelite varnish. Formula of steam and water-resistant paint, giving coverings that are stable at temperature up to 200°C, has 3:1 ratio between dry bakelite resin and pigment. Pigment is a mixture of zinc chrome yellow with aluminum powder in ratio 2:3.

Coverings on the basis of bakelite varnish, pigmented with zinc chrome yellow and aluminum powder, are also resistant to turbine oil, distilled water, and a mixture of turbine oil with 3% solution of table salt at temperature 80°C. Relationship 1.86:1 between resin and pigment with the same composition of pigment part gives the best results.

The shown steam-water resistant and oil-resistant paints can be applied by brush or paint sprayer. Painted surface should be cleaned of rust and degreased by white spirit. Paints are diluted with ethyl alcohol to working viscosity 60-70 s according to viscosimeter VZ-4 at temperature 18-23°C. It is recommended to apply a three-layered coating with thickness 60-80 μm. Depending upon temperature of location in which the painting is done, drying of each layer varies from 2 to 24 h.

Water-emulsion and water-soluble paints and enamels. Large deficiency of varnish and paint material is the content of a considerable quantity (from 50 to 80%) of volatile organic solvents in them. The latter create considerable harm for workers because of their toxicity, serious fire — and explosivity, especially in process of volatilization from films during painting operations, and require creation of expensive ventilation and painting devices. Water-soluble and water-emulsion paints and enamel do not have this deficiency.

Water-emulsion enamels are produced on the basis of oil [SEM] (СЭМ) and alkyd [STEM] (СТЭМ) binders with content of water up to 20% and up to 50% oil or alkyd base. They dry at 80-85°C.

Water-emulsion paints of natural drying, which are produced on the basis of various types of synthetic latexes — polyvinyl acetate, divinyl styrene, acrylic, and copolymer, are of considerable interest.

At present the varnish and paint industry produces 6 brands of such paints:

VA-17 — polyvinyl acetate [PVA] (ПВА) water-emulsion paint for external jobs (on rutile);

VA-27A — PVA paint for internal jobs (on anatase);

VA-27 — PVA paint for internal jobs (on lithopane);

[VA-27ng] (ВА-27нг) — incombustible paint (for internal jobs);

[KCh-26A] (КЧ-26А) — styrene-butadiene paint for internal jobs (on anatase);

KCh-26 — styrene-butadiene paint for internal jobs (on lithopane).

Water-emulsion paints of the shown brands, with the exception of VA-27ng paint, are resistant to freezing to -40°C and thawing. Paints are applied on the surface with the aid of a brush, paint sprayer, painting gun, or roller. When necessary the paint is diluted with water.

Paints VA and KCh possess high adhesion (Fig. 50).

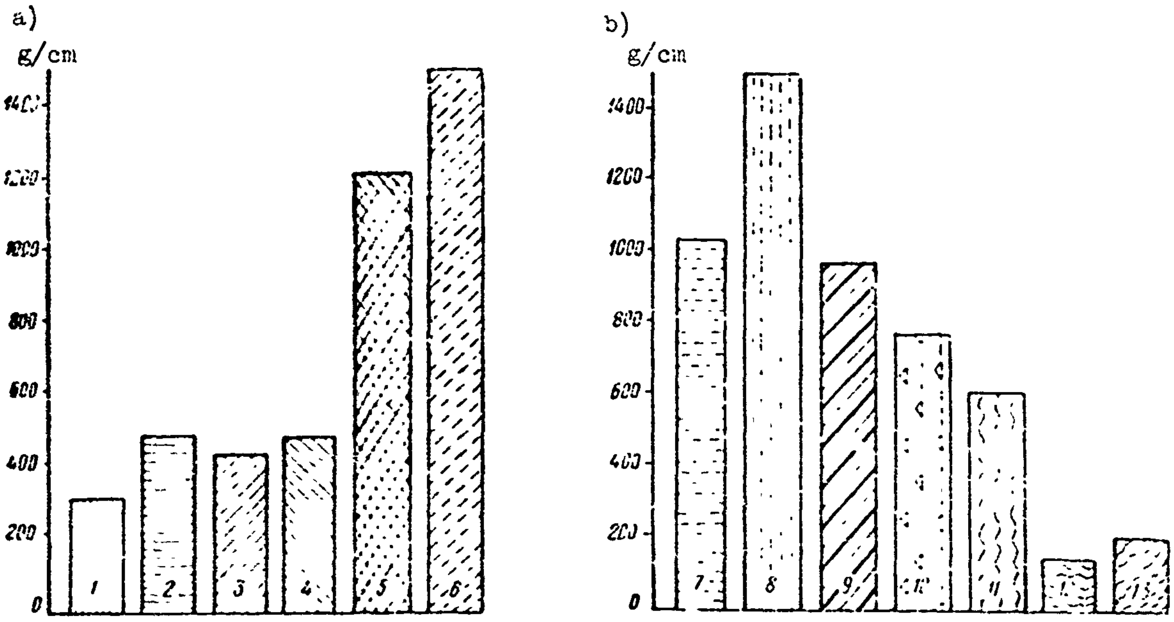


Fig. 50. Diagram of comparative adhesion of paints of VA and KCh: a) — adhesion of 10-day films of various paints to steel; b) — adhesion of polyvinyl acetate water-emulsion paint to various surfaces; 1 — zinc white on natural linseed drying oil; 2 — zinc white on oksol drying oil; 3 — phenol primer FL-013; 4 — pentaphthalic enamel PF-65; 5 — butadiene styrene water-emulsion paint; 6 — polyvinyl acetate water-emulsion paint; 7 — on steel; 8 — on oak veneer; 9 — on aluminum; 10 — on old oil paint; 11 — on copper; 12 — on linoleum; 13 — on lincrust.

Water-emulsion paints will form nonoxidizing and unyellowing films, possess good spreadability, resistance to abrasion, washing with warm water and soda solutions. Coverings possess high alkali-resistance. Polyvinyl acetate paints as compared to butadiene styrene are weather resistant, but are less water-resistant and require the addition of plasticizer. Adhesion of water-emulsion paints to any base layers (steel, copper, aluminum, galvanized iron, wood, veneer oak, lincrust, etc.) is several times higher than adhesion of oil paints to these base layers. Water-emulsion paints are combined well with oil, alkyd primers, and putties, and with old oil enamel coverings. They are not combined with surfaces having greasy spots, mud, dust, etc.; they can be applied on a well cleaned and degreased surface, which can be relatively moist. With application on metal they cause corrosion of the latter; therefore, there is required thorough priming of metal, preferably with two layers of primer.

With application of water-emulsion paints on old coatings it is necessary to preliminarily wash the latter with warm 3% solution of calcinated soda.

Application of water-emulsion paints by paints of [MPS] (МПС) permitted removing harmful paints from use, saving edible vegetable oils entering the composition of oil and other paints and enamels, improving labor conditions of workers, reducing technological cycle of painting, and transfering it on to continous-assembly line conditions.

§ 5. Special Varnish and Paint Compositions

Primers. Layer of coloring material, applied directly on cleaned metal or wooden surface, is called primer. Layer of primer and the priming operation have a number of important specific features, which distinguish them from other operations of the technological process of painting.

Primer layer is that part of the entire protective covering, which should ensure: first of all durable cohesion (adhesion) of entire covering with painted surface of metal or wood or with a layer of old paint, and to preserve this adhesion during entire service life of covering and, secondly, to localize and to passivate all areas of corrosion, which can appear primarily on surface of painted metal article.

Good adhesion of primer can be ensured if the primer layer applied directly on metal moistens it well, possesses sufficiently strong adsorptive properties with respect to metal, and in turn is joined well with subsequent layers of paint. Such requirements are satisfied by high polar or surface active substances.

The following substances, possessing surface activity, include: fatty and resin acids, polymers with carboxyl group, hydroxyacids, and others.

For obtaining a highly durable primer layer the latter should contain optimum quantity of rich binding material and mainly an anticorrosive (passivating) pigment part.

Excess quantity of binder while drying creates greasy and elastic films, which require a long time for drying and may cause undesirable phenomena during subsequent operations of application of paint or putty and mainly during grinding.

With application of a layer of paint or putty on such a priming layer, especially unsanded, good wettability and adhesion to primer layer are not ensured. With grinding of greasy layer of primer or subsequent layer of putty (or paint), in polished places the primer layer can seize abrasive paper and leave burrs, requiring subsequent unproductive expenditure of considerable time for correcting the disturbing integrity of structure of priming layer.

Insufficient quantity of binder in priming material leads to formation of a lean (weak) priming layer, not ensuring sufficient adhesion, both with painted surface and subsequent layers of coating. Such a priming layer during subsequent service ages rapidly due to exhaustion of binder and loses initial elasticity, leading to premature destruction of entire protective coating.

Along with good cohesion priming materials should possess anticorrosion properties, and reduce restability of iron to a minimum. The majority of film-forming substances by themselves do not ensure anticorrosiveness, but in a number of cases assist corrosion. By addition of corresponding pigments into film-forming material it is possible to attain considerable anticorrosion effect.

Priming layer should be sufficiently water and gastight in order to ensure protection of metal from the direct influence of moisture, gases, or air, containing water vapor.

No less important is the corresponding coefficient of linear expansion of priming materials, which at sharp changes of temperature should ensure uniform elongation and compression of film of primer with metal surface.

Combination of primer with subsequent layers of coating with putty, paint, and enamel is also very significant.

During selection of system of coatings the necessity of full coincidence is considered. Never apply lean layers of paint, enamel on greasier primers, and also oil paints or other materials, containing low active solvents, on polymer (vinylperchloride and others) primers. Optimum combination of primers with upper layers of coating also depends on conditions of operation.

Primers are applied with the help of a paint sprayer or brush in a layer 15-20 μm thick under coatings by different enamels.

Oil primers are solutions of thick milled paint pastes in drying oil with addition of desiccant.

For metals we apply primers on lead-oxide red paint with natural linseed drying oil, on iron-oxide red paint, zinc chrome yellow, and also on three-component primer from iron-oxide red paint, zinc whites, and lead (or zinc) chrome yellow in relationship 70:10:20 in a mixture with various drying oils. For wooden surfaces we apply primers containing lithopone, ocher, colcothar, and other pigments.

Varnish primers [KF-030] (КФ-030) (b. [ALG-1] (АЛГ-1), ALG-5), KF-032, ALG-14 are paints consisting of pigments – zinc chrome yellow (ALG-1) with zinc whites and carbon black for coloring (ALG-5) and oil varnish. Varnish primers are used for painting with a brush, spraying, or dipping of steel, aluminum, and other surfaces from light metals.

Glyptal primers No. 138 and GF-020 are suspensions of pigments and fillers in glyptal varnish and are designed for painting metal surfaces.

Primer No. 138 contains iron-oxide red paint and lead yellow chrome yellow as pigment part. In primer GF-020 lead chrome yellow is replaced by a mixture of zinc chrome yellow with iron-oxide red paint, and tung oil – with linseed with simultaneous replacement of glycerine by a mixture of 15% pentaerythrite and 85% glycerine.

Vinyl-perchloride and copolymer primers KhS-010, [KhSG-26] (ХСГ-26), KhS-025 are suspensions of pigments in solution of dry vinyl-perchloride resin (KhSG-26) or resin SVKh-40 on copolymer vinyl chloride with vinylidene chloride (KhS-010) or resin on copolymer vinyl chloride with vinyl acetate (KhS-025) in a mixture of volatile organic solvents.

Such primers are intended for painting metal surfaces in a multilayer overall coating under conditions of atmospheric influence and also with influence of aggressive gases (H_2S, SO_2, CO_2), acids (sulfuric, phosphoric, and hydrochloric), and weak alkalis at temperatures from -40 to +60°C.

Dilution of primers to working viscosity is produced by solvent R-4. Primers are applied on surface by spraying with a layer 20-30 μm.

Acrylic primers Ak-01, [AG-3a] (АГ-3а), [AG-10s] (АГ-10с) are solutions of polybutyl methacrylate and alkyd (FV-2, FPV-2) or 100% phenol (No. 101, 108) resins in a mixture of organic solvents with addition of pigments.

Phenol-formaldehyde primers (FL) are suspensions of pigments and fillers in varnishes on the basis of synthetic phenol-formaldehyde resins with addition of vegetable oils and solvents.

Primer FL-03K of brown color (b. V-329) is a suspension of pigments in solution of 100% phenol-formaldehyde resin No. 101 and phenol-formaldehyde rosin resin.

Primer FL-013 (b. [Ye-329] (Е-329) is a suspension of pigments in 100% resin No. 108 with addition of solvent.

Primer [D-329] (Д-329) is a suspension of pigments in 100% phenol-formaldehyde resin.

As pgiments for primers FL-03K, FL-013 and D-329 there is applied a mixture of iron-oxide red paint, zinc chrome yellow, and zinc whites.

Primers FL-03K, FL-03KK, [FL-03Zh] (ФЛ-03Ж), and FL-013 are designed for metal surfaces and wood. Primers are applied with the aid of a paint sprayer or brush in a layer 12-20 μm thick.

Films of primers are resistant to change of temperature from -50 to +60°C.

For production of working viscosity primers are diluted with xylene or solvent with white spirit in 1:1 ratio.

Parkerizing primers and pastes. One of the most widespread methods of strengthening the protection of steel and other ferrous alloys from corrosion is parkerizing. On large sized articles, such as railroad cars, it is never applied. Instead of this it is possible to apply parkerizing primers, combining phosphate treatment and primer painting of surface of metals into one operation, but not replacing the basic layer of primer, only supplementing it. At present three brands of parkerizing primers are produced: [VL-02] (ВЛ-02), VL-08, and VL-023.

Puttys are paste-like masses, consisting of pigments, fillers, and varnishes with or without the addition of plasticizers.

Industry produces the following puttys:

PF-00-2 — reddish-brown (b. [LSh-1] (ЛШ-1));

KF-00-3 — red (b. AM);

KhV-00-4 — green (b. [KhVSh-4] (ХВШ-4));

KhV-00-5 — gray (b. [PKhVSh-23] (ПХВШ-23));

MS-00-6 — rose (b. [AS-395-1] (АС-395-1));

[NTs-00-7] (НЦ-00-7) — reddish-brown (b. [ASh-24] (АШ-24));

NTs-00-8 — protective (b. ASh-30);

NTs-00-9 — yellow (b. ASh-32);

[EP-00-10] (ЭП-00-10) — reddish-brown (b. E-4021).

Puttys, except MS-00-6 and EP-00-10, are designed for evening and correction of primered metal and wooden surfaces, and also for smoothing the exposed layer of enamel. Putty MS-00-6 is designed for correction of fine defects on primered surface, and also on a surface that is primered and covered with enamel. Putty EP-00-10 is designed for evening primered and unprimered surfaces.

Putty EP-00-10 is produced in the form of two semifinished products:

putty mass;

solidifier No. 1 (50% solution of hexamethylenediamine in ethyl alcohol).

Mixing of putty mass with solidifier is produced at place of application. Solidifier is introduced in a quantity of 8.5 parts by weight to 100 parts by weight of putty mass.

Putty EP-00-10 preserves its painting properties not less than 1.5 h.

Thickness of each layer of putty should be not more than 0.5 mm, and overall thickness on body of railroad car — not more than 2 mm.

Puttys are sanded easily and well by waterproof sandpaper No. 150-280, and puttys PF-00-2 and KF-00-3 — by a piece of natural pumice. With wet sanding in 15 min the putty forms an even, dull, smooth to the touch surface, without edges in places polished before priming, and does not soften.

Anticorrosion mastics. For protection of highly corroding internal metal surfaces of railroad cars anticorrosion bituminous mastics, applied with a sufficiently thick layer (2-3 mm) on phenol primers, and in a number of cases directly on metal, prove themselves well. As such materials we apply: anticorrosion (antinoise) mastic No. 579, mastic No. 213, and also an alloy of rubrax (75%) with petrolatum (25%), developed by [TsNII] (ЦНИИ) MPS.

Mastics No. 579 and 213 are supplied in ready to use form and represent an alloy of refractory natural bitumens, plasticized with heat-bodied vegetable oil (No. 579) or ceresin (No. 213). Alloy of rubrax and petrolatum is prepared immediately before start of operations, by loading rebrax in boiler, and after melting it at a temperature around 160°C we carefully add petrolatum while thoroughly mixing. Alloy is considered ready after dimunation of forming foam and production of homogeneous mass.

Stains or mordants consist of solutions of organic dyes in water or water-alcohol mixture, applied on simple varieties of wood (plywood) for coloring them to simulate valuable varieties of wood, (mahogany, walnut, oak, and others). After drying the mordants shade the texture of wood in relief, giving it the necessary shading.

Pore fillers (mastics) serve for filling the pores of wood and evening the surface before varnishing, ensuring preservation of texture of wood. Pore fillers are produced by mixing of finely dispersed fillers with oil or oil-resinous bases. Pore filler should easily penetrate the pored of wood, while cementing it.

Sealers are prepared by direct mixing of chalk and natural drying oil into thick plastic mass not sticking to the hands. For window frame putty in certain types of railroad cars we apply sealer of the following composition: chalk — 83-85%, natural linseed or hempseed drying oils 17-15%.

§ 6. Auxiliary Materials

Abrasive materials. During application of varnish and paint materials on surface there is required a number of auxiliary materials.

For sanding metal, paint, enamel, varnish, and putty we apply lump and ground pumice, polishing sandpaper on cloth or paper base, joined with a layer of abrasive grain with the aid of glue, and also water-resistant sandpaper, where abrasive is durably connected with paper by amber varnish YaK-1.

For manufacture of polishing sandpaper there are applied materials of natural or artificial origin, possessing high hardness, — so-called abrasive materials. The following abrasives have the greatest application for grinding, and also polishing: corundum, carborundum, emery, silica, tripoli, pumice, crocus, lime, ferric oxide, aluminum oxide, and chromium oxide.

Artificial abrasive materials — electrocorundum, carborundum, and boron carbide — are used for thin grinding. Natural corundum powders and emery are applied mainly for decorative sanding. For water resistant sandpaper we use green silicon carbide.

Abrasive materials are classified in accordance with GOST 3647-59 according to the metric system by granularity numbers, siminishing with decrease of grain sizes.

Chemical components. For etching of ferrous metals before painting we apply a number of acid compositions, containing from 10 to 25% sulfuric or hydrochloric acid or 6-10% phosphoric acid with addition of corrosion inhibitor and emulsifier. For removal of old paint we apply solutions of alkalis, alkali pastes, and organic paint removers.

In railroad car repair plants paste of the following composition (in parts by weight) proves itself well: unslaked lime — 45, ground chalk — 28, black oil — 18, caustic soda — 9, water — for bringing to soured cream state.

Paint removers are produced by industry in ready for use brands [SD] (СД) [ob] (об), SD [sp] (сп), and [AFT] (АФТ). Into their composition enter organic solvents with addition of paraffin. Paint removers are inflammable and during their application one should observe caution.

§ 7. Cleansing Agents. Preventive and Polishing Compositions

Railroad passenger cars and locomotives in operation are rapidly covered with dust, mud, soot, scale, and oil contaminations. For cleaning and treatment of railroad cars there are applied cleansing agents, preventive compositions, and polishing pastes.

Soap solutions are recommended for regular application for washing moderatly contaminated railroad cars.

Solutions are produced from solid household or liquid salvelike (green) soap. The latter is dissolved in warm water (40-60°C) to a concentration not more than 5% and is applied in warm state.

Time of action of solution on painted surface should not exceed 15 min. With solution of high concentration, and also with more prolonged action on painted surface, a dull deposit remains and brightening of color occurs.

Surface treated with soap solution is washed with warm water.

Emulsions. Emulsion has the simplest composition. It is prepared from a soap solution of 0.2-0.3% concentration with addition of 1% kerosene. Kerosene accelerates and improves the process of cleansing. For washing of contaminated surfaces in winter (to -25°C) to these compositions it is possible to add up to 5-10% ethyl alcohol-raw material, isopropyl alcohol, or ehtyleneglycol.

Instead of emulsions containing scarce soaps, it is expedient to apply water — oil emulsions, which are harmless in use, do not damage coloring layer, and maintain its brightness and color. It is possible to apply them by method of wet washing with subsequent rinsing by warm water with addition of 1% emulsifier moistener [OP-10] (ОП-10) or OP-7 or by means of dry wiping.

Cleansing agents. Highly contaminated surfaces are washed with more effective synthetic cleansing agents.

Preparation of synthetic cleansing agents is produced according to formulas recommended by Central Scientific Research Institute of MPS and All-Union Fats Scientific Research Institute (VNIIZh).

For this 2-4% Petroff kerosene contact [KPK] (КПК), sulfonol, sulfonate, azolyat, or other cleansing substance and 2-4% technical oxalic acid are dissolved in warm water (92-96%). These agents are used for external cleansing of railroad cars. For washing of railroad cars inside we apply 0.5-1% solutions of cleansing substances in water without oxalic acid.

Preventive and polishing compositions are mixtures of binding and polishing materials (paraffin, ceresin, wax, varnish, rosin, or other resin or solution of rubber) with solvents (white spirit, turpentine, kerosene, water) without or with addition of finely dispersed hard or soft abrasive (crocus, emery, powdered silica gel, carborundum, aluminum powder), and sometimes desiccant.

Depending upon composition and character of action on film these materials are designed for grinding and treatment after grinding of nitrocellulose coatings (grinding paste No. 4, grinding polishing paste No. 5, 289), for polishing of nitrocoverings (polishing paste No. 290, polishing paste wax No. 2, polishing wax composition No. 3, polishing water), for polishing of varnish-oil, alkyd, alkyd-melamine coatings (paste wax No. 2-35-61), and also preventive protection of alkyd and other coatings in operation (preventive compositions [PS-3] (ПС-3), PS-4, and PS-5, composition of Moscow Aviation Technology Institute).

Compositions are in the form of hard paste (polishing paste wax No. 2), in salvelike state, and some in viscous (preventive compositions) or in liquid (polishing water) state. They should be homogeneous, stable, and should not have mechanical impurities.

Most compositions are not mixed with water; compositions No. 4 and 5 are mixed with 8% water, and polishing paste No. 290 and polishing water – in any relationship.

Questions for Self-Check.

1. How are natural drying oils produced?

2. What are the merits of oksol and glyptal drying oils?

3. What is the difference between oil, alcohol, and nitrolacquers and where are they applied?

4. What processes occur in drying oils and oil varnishes during their drying?

5. What varnishes are produced on synthetic resins?

6. What are glyptal, pentaphthalic, and other enamel paints?

7. What enamel paints are applied for painting railroad rolling stock?

8. What materials are applied for painting freight and isothermal railroad cars?

9. What is the difference between oil and enamel paints?

10. What advantages do vinyl-perchloride enamels and their copolymers possess?

11. What properties do nitroenamels possess and where are they applied?

12. What distinguishes acrylic enamels from oil enamels?

13. Is it possible to use alkyd-melamine enamels for painting railroad passenger cars and under what conditions?

14. What are water-emulsion paints, what are their properties and assignment?

15. What paints are stable under the influence of hot water, gasoline, and acids?

16. What materials serve for corrosion protection of internal surfaces of metal bodies of all metal railroad cars?

17. For what is putty intended and how is it prepared?

18. For what are primers intended?

19. What are the known primer compositions and their properties?

20. Which cleansing and preventive agents are applied for cleaning and treatment of surfaces of railroad cars?

CHAPTER VIII

TESTING OF VARNISH AND PAINT MATERIALS

Varnish and paint materials applied in railway economy should be checked in a laboratory for conformity of their properties and qualities to state standards and technical conditions by basic indices, shown in § 4 Chapter V.

For tests (GOST 9980-62) from three barrels, cans, flasks, large bottles, or jars of each batch there is removed a small amount of material and it is mixed into one average sample weighing not less than 0.5 kilograms. From drying oils, varnishes, solvents, enamels, paints, puttys, primers, and other materials the samples are removed with the aid of a glass tube, special sampler, or wooden trowel.

Before taking a sample the products are thoroughly mixed (except oil varnishes); with the presence of film on the surface, it is removed. Samples of dry pigments and fillers are removed with the aid of a metal probe from the top, from the middle, and from the bottom of drum, barrel, or bag, each time from the probe taking lower layer with height 10-15 cm. Selected samples are connected together, thoroughly mixed, weight of average sample is brought to 0.5 kg and placed in a clean dry tightly closed jar. On the jar we glue a label with indication of type of material, plant-supplier, number of batch, date of sampling, then the sample is transmitted for tests.

§ 1. Determination of Conditional Viscosity

Conditional viscosity of varnish and paint materials is determined by [VZ-4] (B3-4) viscosimeter (Fig. 51) in accordance with GOST 8420-57. For this the opening of nozzle 2 is closed and viscosimeter is completely filled with tested material, temperature of which should be exactly 20°C. Then we open the nozzle opening and simultaneously with appearance of liquid from nozzle we start a stop watch, which is stopped at the moment of appearance of interrupted stream of varnish and paint material.

Time in seconds of outflow of varnish and paint material from viscosimeter is the conditional viscosity of this material.

§ 2. Determination of Drying Time

For determination of drying time (GOST 10086-39) on a glass or metal plate with approximately 9 x 12 cm dimension we pour the varnish and paint material to be tested. Period of drying "from dust" is determined by sprinkling of lycopodium or talc powder on painted surface; if while blowing away the powder is not held on film, we record time of drying "from dust".

In a defined time, shown in technical conditions, on the tested material on

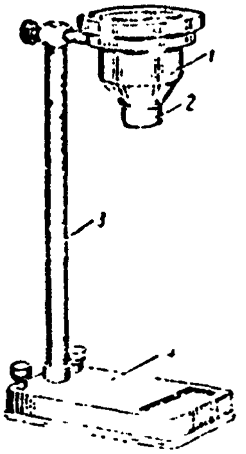


Fig. 51. VZ-4 viscosimeter: 1 — funnel; 2 — nozzle; 3 — support; 4 — base.

the plate we place a small cotton wad, which we cover with a dry clean metal or wooden plate with dimension 1 cm^2. On the plate we place a weight 200 g and hold for 0.5 min, then the weight, wad, and plate is removed. If on the surface there are no adhering cotton fibers or traces of them, then this characterizes moment of total practical drying of coating.

§ 3. Determination of Oil-Absorption Power of Pigments

For determination of oil-absorption power of pigments it is necessary to have a porcelain cup, buret with linseed oil, and scales.

Oil-absorption power is determined in the following way (GOST 10086-39). We take a sample of dry pigment weighing 5 g, suspended with an accuracy of 0.01 g, and place it in a porcelain cup. After that we pour raw linseed oil from buret into cup by drops (oil should be without mucin and with acidity not higher than 6 milligrams [KON](KOH)), while mixing it with pigment by a small glass stick, without application of pressure. While mixing there will be formed separate small clumps which are gradually connected into one solid lump. This quantity of oil (in ml) we record as oil-absorption power of pigment.

Quantity of oil (in g) necessary for saturation of 100 g pigments is determined by the following formula:

$$M=ad\cdot 20,$$

where M — oil-absorption power of pigment; a — quantity of oil in ml, expended for saturation of 5 g pigment; d — specific gravity of oil at 15°C.

§ 4. Determination of Degree of Paint Milling by "Wedge" Method

Degree of paint milling is determined by "wedge" method (Fig. 52) in accordance with GOST 6589-57. Method involves determination of the smallest thickness of layer of paint, distributed in wedge-shaped micrometric groove, with which separate unmilled granules (aggregates) from pigment particles cease to be visible.

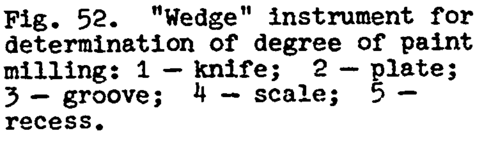


Fig. 52. "Wedge" instrument for determination of degree of paint milling: 1 — knife; 2 — plate; 3 — groove; 4 — scale; 5 — recess.

For this the paint to be tested is mixed thoroughly and placed in recess of plate in a quantity that is sufficient for filling the wedge-shaped groove. On edge of the plate at an angle of approximately 45° in direction of groove there is placed a knife and with its rapid shifting the paint is distributed along the entire groove in direction of decrease of depth of wedge.

With such distribution of paint the particles of pigment with dimensions larger than depth of groove in given place protrude above the surface of paint and are seen with the naked eye. With a large number of such particles the surface becomes granular and dull. The place on the scale where particles of pigment do not protrude from groove is recorded as degree of milling with respect to "wedge".

§ 5. Determination of Covering Power

For determination of covering power of varnish and paint materials (GOST 8784-58) we use a glass plate, on one side of which there are applied 3 colored bands (one white and two black). On the reverse side of plate we apply a thin layer of tested material. By the difference of results of weighing of glass plate before painting and with the applied layer we determine weight of tested paint expended on covering the plate. This weight is scaled 1 m^2 and recorded as covering power of paint.

§ 6. Determination of Dyeing Ability of Pigments

Determination of dyeing ability (intensity) of pigments (GOST 10086-39) is based on qualitative and quantitative comparison of tested paint with a standard sample. With this comparison we change the shades of tested paints by adding unbleaching paint to them, and by its quantity we indicate the intensity of tested pigments.

Selection of unbleaching paint depends on color of tested pigments. For example, when determining the intensity of white paints the unbleaching paint is carbon black, ultramarine, or iron azure; for black paints we apply whites, and for yellow - iron azure.

For white and yellow paints bringing the shade of tested paint to a standard sample is produced by gradual addition of it to corresponding quantity of unbleaching paint.

§ 7. Determination of Color

Color of varnish and paint coverings can be determined by three methods:

1) visual comparison of color of tested sample with standard;

2) with the aid of card file of color standards [GIPI-4](ГИПИ-4) (Fig. 53a);

3) photoelectric colorimeter [KNO-2](КНО-2) (Fig. 53b), KNO-3, or KON-4.

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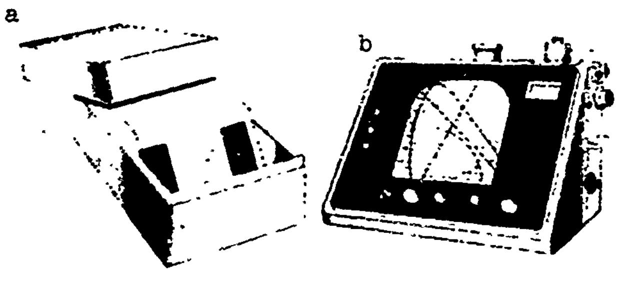

Fig. 53. Card file and colorimeter for determination of color of paints: a) card file of color standards; b) colorimeter KNO-2.

§ 8. Determination of Gloss of Coverings

Gloss (luster) is the property of surface to reflect light rays falling on it in one direction. Determination of gloss by photoelectric method (GOST 896-41) by instrument [FB-2](ФБ-2) (Fig. 54) or [FB-1A](ФБ-1А) involves measurement of value of photocurrent, excited with beam of light reflected by varnish and paint film, hitting light-sensitive layer of photocell.

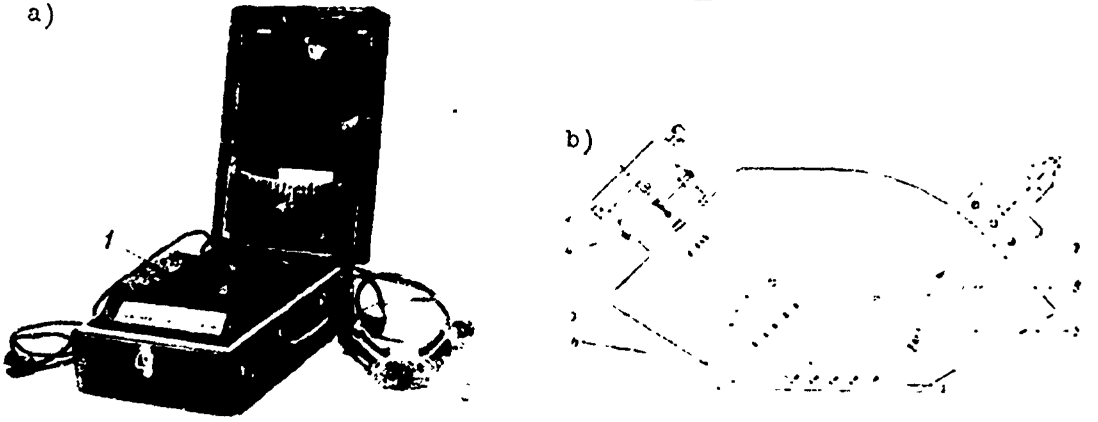

Fig. 54. FB-2 lusterometer: a) overall view of instrument; b) diagram of determination of luster; 1 — galvanometer; 2 — photoelectric head of instrument; 3 — photocell tube; 4 — diaphragm; 5 — condensing lenses; 6 — tested covering; 7 — illuminator tube; 8 — electric lamp.

By this method we determine degree of intensity of gloss of varnish and paint coatings as compared to gloss of a glass, accepted for standard. Readings of instrument are expressed in relative units — percents for characteristics of basic standard sample, accepted arbitrarily for 100%.

§ 9. Determination of Bending Strength of Films

Strength of films is determined according to minimum diameter of rod (GOST 6806-53), bending of painted metal plate on which does not cause mechanical destruction of varnish and paint coating.

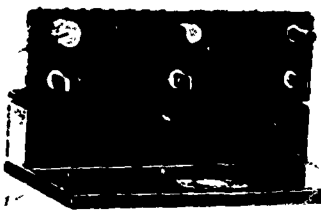

Fig. 55. ShG-1 flexibility scale.

Scale of flexibility (Fig. 55) for determinaion of strength of films is a set of six steel ods 2 of various diameter or cross-section, astened on base 1. Base itself is fastened to dge of table.

Rods have the following diameters 20, 15, 10, 2.5, 1.5, 0.5 mm.

§ 10. Determination of Hardness of Film on Pendulum Instrument

Hardness of film (coating) is determined by relationship of time of damping of oscillations of pendulum 5 (Fig. 56), located on surface of painted glass plate, to time of damping of oscillations of pendulum of instrument on clean glass (GOST 5233-50).

For this after drying of coating the painted glass plate is placed on block of pendulum instrument film upwards under steel balls of pendulum. The latter are installed on surface of film in such a manner that the pendulum would be near zero of scale 7.

Then we raise the frame, press the connecting strip to it, and set the pendulum on zero. While holding the connecting strip, with the aid of starting attachment the pendulum is carefully moved to the left to scale division 5°; with this we watch so that balls do not shift from place.

After that the frame of instrument is lowered, pendulum is freed, forcing it to rock freely, and simultaneously with this we start the stop watch.

When amplitude of oscillations of pendulum reaches 2°, we stop the stop watch and record the number of oscillations.

Hardness of film is calculated with respect to number of oscillations of pendulum on clean glass (440 ± 6).

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Fig. 56. M-3 pendulum instrument for determination of conditional hardness of films: 1 — clamping strip; 2 — tested plate; 3 — block; 4 — frame; 5 — pendulum; 6 — weights; 7 — scale; 8 — base(block); 9 — starting attachment; 10 — support; 11 — plumb line; 12 — cabinet.

Fig. 57. U-1A instrument for determination of impact strength of films: 1 — scale; 2 — support; 3 — stop; 4 — weight; 5 — striker; 6 — anvil.

§ 11. Determination of Impact Strength of Coating

Impact strength of coating is determined by deformation of film during instantaneous application of load-impact (GOST 4765-59). For this we use instrument [U-1A](У-1А) (pile driver), presented on Fig. 57. The painted plate is placed paint upwards on an anvil under striker. Plate should be adjacent to anvil along the entire surface.

Impact strength of film is recorded in centimeters of maximum height of fall of weight, weighing 1 kg, at which mechanical destruction is not yet observed (cracking, peeling), and is expressed in kgf·cm.

§ 12. Determination of Tensile Strength of Films

Tensile strength of films is determined in millimeters of depth of sag of metal plate at the moment of destruction of film of varnish and paint coating applied on it (GOST 5628-51). Tests were conducted on a brand [E](Э) instrument-press for stamping of sheet metal (Figs. 58 and 59a).

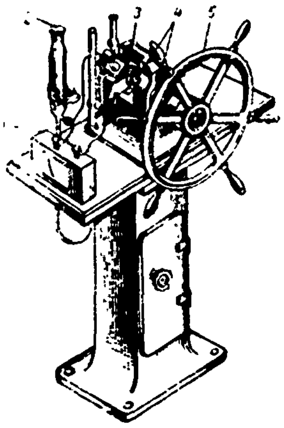

Fig. 58. Brand E instrument for Erichsen test of sheet metal: 1 — galvanometer; 2 — tube with electrolyte; 3 — painted plate to be tested; 4 — screw; 5 — wheel.

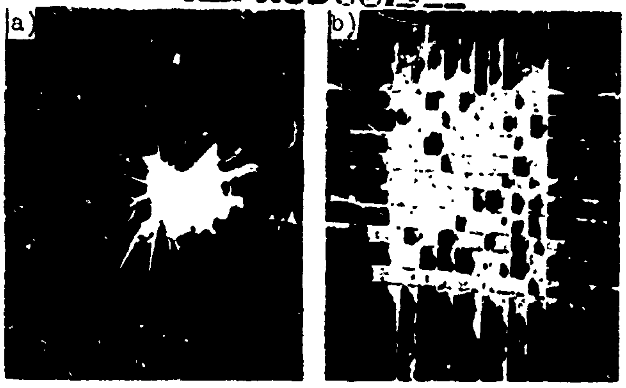

Fig. 59. Form of unsatisfactory coating: a) after testing on brand E instrument; b) after lattice notching.

Tensile strength of coating, equal to depth of penetration of punch into plate until the beginning of destruction of coating, is expressed in millimeters with accuracy up to 0.1.

§ 13. Determination of Adhesion by Method of Lattice Notch

Determination of adhesion by method of lattice notch consists in the fact that with the end of a blade or highly sharpened penknife we make 4-5 parallel notches of coating with 1 mm intervals and as many notches, perpendicular to the first, at the same distance from each other. Notches must penetrate the base layer. Then with light pressure we criss-cross the squares 3 times with a bristle brush. If all the squares are preserved, adhesion is good, if 5-7 squares are painted, — satisfactory, and if more — adhesion is poor (Fig. 59b). When testing multilayer coatings the intervals between notches are increased to 2 mm.

§ 14. Determination of Water Resistance of Films

Two sheet metal plates, painted with tested material, are dried according to technical specifications, and then held at 20°C (before tests) 120 h. After that the plates are suspended vertically at 2/3 height in a glass bath with distilled water, heated to 20°C, for the time shown in technical specifications on material to be tested, but not less than 1 h. Film is inspected 2 h after removal of plates from bath and drying in air; during this we note dulling, whitening, and the beginning of destruction of film (formation of loose material, blisters, wrinkles, peeling, etc.). State of surface is compared with requirements of standard on given material.

In a similar way there are conducted tests on anticorrosion resistance in 3% solution of table salt, and also the resistance to aggressive media in weak solutions of acids, alkalis, salts, or oil-gasoline resistance in gasoline, kerosene, mineral oil, etc.

Questions For Self-Check.

1. How is the color of paint or enamel determined?

2. How is the viscosity of drying oil, varnishes, and enamel paints determined and by what instruments?

3. What do methods of determination of hardness and elasticity of films of enamels and varnishes consist of?

4. What is covering power of paints?

5. What value does degree of paint milling have?

6. How is oil capacity of pigments determined?

7. How is intensity of pigments determined?

8. What attachments are used for sampling of varnish and paint materials?

9. How is water resistance of coatings determined?

10. How is adhesion of paints determined?

11. How is impact and tensile strength of films determined?

CHAPTER IX

OTHER METHODS OF CORROSION PROTECTION OF SURFACES

§ 1. Methods of Lowering Corrosion-Fatigue Damages

As was noted, many parts of railroad cars are subject to corrosion-fatigue damages. Methods of lowering these damages can be divided into constructive, metallurgical, and technological measures.

Constructive measures are reduced to giving to parts such shapes, with which concentration of stresses will be minimum. These measures can include — increase of radius of fillets, replacement of key joints by slotted, reduction of difference in hardness of separate sections, removal of flats of holes, and others.

Metallurgical measures can include correct selection of material for each element of structure, optimum conditions of heat treatment, removal of shrinkage cavities, cracks, blowholes, nonmetallic inclusions, etc.

In spite of the wide application of shown constructive and metallurgical measures corrosion-fatigue damages are still very widespread and their further reduction is attained by a number of technological measures.

Machining — grinding, polishing — increase strength of parts 10-20%, surface hardening by methods of shot-peening, shot-blasting treatment, and also rolling by rolls increases life of parts by 60%. Surface thermochemical (case hardening, nitration, etc.) and especially heat treatment (with high frequency currents) sharply increase the life of articles and their components.

Application of surface metal, plastic, and varnish and paint coatings is an effective means of lowering corrosion-fatigue damages.

§ 2. Corrosional Resistance of Different Metals and Alloys to the Influence of Aggressive Media

It is possible to considerably increase corrosion resistance of structural elements of railroad cars and, in particular, highly corroding tanks and isothermal railroad cars by application of corrosion-resistant metals and alloys. Use, for example, of naturally alloyed steels of Khalilov deposit permits extending the service life of gondola cars, frames of railroad cars of all types, and a number of other structural units and parts of railroad cars 1.5-2 times.

Under conditions of influence of such aggressive media as acids, alkalis, organic substances, the application of stainless steels and, in particular, clad steels is effective, where basic supporting structures are manufactured from carbon steel [St. 3](Ст. 3), and a thin (thickness 1.5-4 mm) layer of clad stainless steel serves as anticorrosion protective layer of construction.

Basic elements, which increases acid resistance of steels, are: chromium, nickel, molybdenum, titanium, silicon, vanadium, manganese, tungsten, and others.

From steels with such additives we manufacture both monolithic and two-layered tanks and cisterns for various types of concentrated and diluted acids and their mixtures (melange). Many of these steels ensure absolute anticorrosion protection of constructions of railroad cars from the influence of various aggressive media.

Sharp growth of production of aluminum and aluminum alloys creates favorable conditions for their application in railroad-car construction. Many years of experiment of application of aluminum during manufacture of boilers of cisterns for nitric acid and other liquids completely justified themselves. Aluminum alloys, thanks to their light weight, permit lowering the packing of railroad cars and increasing their load capacity 10-25% while preserving mechanical strength of railroad cars.

By investigations it is established that for railroad cars and their parts it is most expedient to apply the following brands of aluminum alloys, ensuring raised anticorrosion resistance: [AMg6](АМг6), [AMg5m](АМг5м), AMg3.

Aluminum is corrosion resistant in media of acetic and other organic acids, and compounds, concentrated nitric acid, hydrogen peroxide, petroleum fuels, water; however, alkalis and alkali media, and also the presence of chlorions in water may cause considerable localized damage of aluminum, right up to through damage of thin sheets.

For casting of parts of pumps, compressors, and other machines and pipelines, which operate under conditions of influence of mineral and organic acids, and alkalis, there are applied corrosion-resistant cast irons — nickel-copper-chromium, high-silicon, high-chromium, and austenitic.

As corrosion-resistant metals and alloys there are also applied:

copper (mainly pure), which is stable under conditions of the influence of hydrochloric and acetic acids and relatively stable in sulfuric (concentration 10-55%) and phosphoric acids, but is destroyed under the influence of nitric acid;

brass and bronze for manufacture of steam boiler fittings, boilers, capacitors, kitchen equipment, etc.;

nickel, nickel bronzes and brasses, Nichrome, and acid-resistant alloys of nickel with molybdenum and iron.

As protective metal coverings for steel articles there are applied: zinc, lead, tin, chromium.

§ 3. Metal Coverings

One of the most radical methods of corrosion protection is application of more corrosion-resistant metal surface coverings on steel and other articles. The following are methods of application of metal coverings: hot, electrolytic, chemical, diffusion, cladding, and metallizing by spraying.

Hot method involves application of covering by submersion into molten metal; for this purpose we use fusible metals: zinc, lead, tin, aluminum.

We degrease the article, produce chemical or electrochemical etching, and wash with water; then we subject it to fluxing for final purification from contaminations of metal surface, protection of it from oxidation, and improvement of wettability of article by melt, after which the article is immersed in melt.

During zinc plating there is applied flux from a mixture of ammonium chloride, zinc oxide, and zinc chloride; during tin plating — solution of zinc chloride with hydrochloric acid; during lead plating the flux is zinc chloride, and into melt there is introduced tin, interacting with iron and ensuring its cohesion with lead;

when covering with aluminum the flux is a mixture of sodium and ammonium chloride or a solution of boric acid.

Galvanized iron is widely used for roof of isothermal railroad cars, internal facing, overhead tanks, etc. Boilers, boilers for cooking food in railroad dining cars, dairy cans and others for storage of food and products are subjected to tin plating; lead coverings are necessary in accumulators, and aluminum covers in heaters and capacitors.

Cladding involves mechanical covering of one metal by another and thus obtaining, for example, clad steel, where the cladding layer is more corrosion-resistant. Clad steel is produced by rolling of steel billet with a sheet of cladding metal.

From clad steels we manufacture boilers of tanks for transporting acids. As cladding metals there are applied stainless steels, aluminum, nickel, copper, brass.

Diffusion (thermal diffusion) coverings are used for increase of corrosion resistance of parts in frictional units, for protection from gas corrosion, and in a number of other cases.

Diffusion covering is made by submersion of heated parts in powdered alloy, atoms of which penetrate into basic metal as a result of diffusion, forming a protective layer on its surface. For diffusion coverings we apply silicon, chromium, aluminum, chromium alloys with silicon or with aluminum.

Metallizing by spraying involves application of molten metal on article. For spraying we apply metallizing guns, in which metal wire or powder is melted by voltaic arc and is aprayed on surface with air.

By metallizing it is possible to cover the body of a railroad car, and also any materials (metal, paper, wood, etc.). Metallizing can be accomplished by zinc, aluminum, copper, lead, iron, stainless steel, etc. Usually we apply two-layered coverings.

Deficiency of metallization coverings is their porosity and insufficient cohesion with surface.

Electrolytic-galvanic method of application of coverings is the most economical of all the different described methods.

Galvanic method consists in the fact that if a constant electrical current from an external source is passed through a solution of metal salt, then on the surface of articles, serving as cathodes, there occurs discharge of cations of solution and deposition of metal (salt of which is in solution).

By the galvanic method there can be applied: zinc, cadmium, tin, lead, nickel, copper, chromium, silver, and various alloys. Usually there are applied one, two, and three-layered coverings.

As anticorrosion galvanic coverings for steels there are recommended the following coverings and their thicknesses (in μ);

1) three-layered coverings (protective-decorative):

a) copper — 36; nickel — 15; chromium — 0.5;

b) copper — 6; nickel — 9; chromium — 3;

2) two-layered coverings (protective-decorative):

copper — 36; tin and nickel — 15;

3) single-layer coverings:

a) zinc — 12 or 18;

b) chrome — 36.

Galvanic coverings are distinguished by high purity, durable cohesion with basic metal, greater chemical stability than other coverings, and therefore great service life of pro ective anticorrosion covering.

Chemical method of producing metal coverings involves reduction of ions located in solution to metal by special reducers (hyposulfite, formaldehyde, and others).

Besides metal, as protective coverings there are applied various oxide films by "oxidizing" method; some of these processes have special names. By this method it is possible to apply iron and its alloys (oxidizing, parkerizing, sulfiding), zinc, aluminum, copper and its alloys, ferrous nickel, nickel, and others.

§ 4. Plastics as Anticorrosion Materials

In recent years plastic anticorrosion coverings have been widely applied.

Plastic masses are high-molecular substances — polymers in pure form or in composition with fillers and other substances, possessing plastic properties at a specific stage.

Plastics can be applied in the form of structural parts and articles in exchange for corroding, film sheet, materials for facing (lining) of metal surfaces, packing of viscous masses (hermetics), or spraying (flame dusting or vortex method) of plastic materials on surface.

Certain areas of application of different types of polymer coverings and materials are shown in Table 12.

Table 12

Designation and brand of plastics	Basic assignment	Method of application
Polyvinyl chloride insulating plastic (formulas 230,224) and strips from it	For insulation of pipes, cables, etc.	Winding, gluing
Polyvinyl chloride hose plastic (formulas 239 and 640)	For manufacture of protective hose shells and tubes (in exchange for lead, copper)	—
Polyvinyl chloride insulating adhesive tape PIL	For insulation of pipes	Gluing
Glass plastics	For manufacture of roofs, of railroad cars, water tanks, bodies, etc.	—
Polyethylene (PE-500; PE-450; PE-300; PE-150)	For insulation of cables, pipes, wires. For manufacture of water tanks and others	—
Polychlorotrifluorothylene	For anticorrosion and chemically stable coverings	Application of suspensions
Polytetrafluoroethylene	The same	Lining or facing
Epoxy resins ED-5, ED-6	For filling compositions	—

Table 12 (Continued)

Designations and brand of plastics	Basic assignment	Method of application
Compounds on the basis of epoxy resin 153, 168, 293, 115	For covering, filling, hermetic sealing of units and parts, floors in railroad cars	—
Polyvinyl acetate latex with filler	For hermetic sealing and sealing of floors in railroad cars	—

For protection of metal articles from corrosion during storage and transportation various lubricants are also applied, basic types of which are described earlier.

§ 5. Inhibitors of Corrosion

In a number of cases of atmospheric and liquid corrosion, especially with influence of aggressive liquids on metal, corrosion protection can be carried out by application of inhibitors — retarders of corrosion.

Inhibitors are chemical compounds or their mixtures of both inorganic and organic type, introduced into aggressive medium. Of the inorganic inhibitors there are applied to hydroxides of alkali and alkali-earth metals, phosphorous, chrome, and nitrous salts, nitric acids, silicates, sodium carbonate, strong oxidizers such as sodium sulfite, hydrazine, and others, and from organic — amines and their salts, aldehydes, mercaptans, heterogeneous ring compounds, salts of high-molecular aliphatic or aromatic carbonyl acids, urea, thiourea, and others.

Method of protection with the aid of inhibitors is economically effective in closed systems with a limited volume, such as cisterns, heating system of railroad passenger cars, cooling system of trains with machine cooling, baths for etching, where it is possible to avoid unproductive expenditure of additive.

For achievement of the necessary effect of anticorrosion protection a small amount of inhibitor is usually sufficient — from several grams to several kilograms in 1 m^3 of liquid medium.

Principle of action of inhibitors involves the ability to form protective films or other compounds on metal surface that are not soluble or scarcely soluble in given aggressive medium. These compounds can appear on anode sections of corroded metal, hampering the transition of metal into solution (anode inhibitors), on cathode sections, hampering discharge of hydrogen ions or ionization of oxygen (cathode inhibitors), or can completely insulate the surface of metal (shielding inhibitors).

Depending upon aggressive medium and areas of application, the inhibitors are subdivided into the following group:

for neutral and weak-alkali media;

atmospheric corrosion;

acid corrosion;

for strong-alkali media;

for anhydrous media.

Inhibitors for neutral and weak-alkali media possess oxidizing properties; they include the following inorganic inhibitors:

chromates of sodium Na_2CrO_4, potassium K_2CrO_4, and zinc $ZnCrO_4$, and also bichromates of sodium $Na_2Cr_2O_7$ and potassium $K_2Cr_2O_7$. Chromates will form a protective film on surface of metal in neutral and weak-alkaline medium;

nitrites ($NaNO_2$, KNO_2) and nitrates ($NaNO_3$, KNO_3). They possess oxidizing properties and will not form soluble oxide compounds on surface of iron;

hydroxides of alkali metals (NaOH, KOH), action of which consists of neutralization of hydrogen ions and formation of protective film on metal;

phosphates $\left[Na_3PO_4 \cdot 12H_2O;\ Na_2HPO_4 \cdot 12H_2O;\ (NaPO_3)_6\right]$ are more effective than alkalis.

The most widespread organic inhibitors are:

sodium benzoate and benzoate buffer (mixture of sodium benzoate with benzoic acid), protective action of which is reduced to formation of insoluble iron benzoate;

monoethanolamine ($NH_2C_2H_4OH$) and other amines, and also inhibitor [PB8/2] (ПБ8/2).

In a number of cases mixtures are more effective instead of individual inhibitors, for example, mixture of sodium nitrite with potassium bichromate, mixture of phosphates with chromates, etc.

In heating system of all-metal railroad passenger cars a mixture of bichromate (1 g/l) with sodium nitrite (2 g/l) is effective. In cold water supply system (water lines) calcined soda (20-30 mg/l) is useful. In brine system of trains with machine refrigeration organic inhibitor PB8/2 in a concentration of 10 g/l proved itself well.

Certain inhibitors are introduced directly into paints: sodium nitrite — in water-emulsion, guanidine chromate — in oil, chromates — in primers, etc.

Inhibitors of atmospheric corrosion are applied basically as additives for strengthening the action of protective film of paint, lubricant, etc. Chromates, mixture of chromates with sodium nitrite, and others are the most effective.

For preservation of internal equipment of railroad cars during the winter we use volatile inhibitors, in particular, cyclohexylamine carbonate, deficiency of which is its toxicity.

Cheap inhibitors are applied in storehouses of packed parts for preservation:

a) mixture of urotropine and sodium nitrite (1:1) in the form of 30-50% solutions or powder;

b) mixture of diammonium phosphate (50%), sodium nitrite (45%), and calcined soda (5%) in the form of 15% solution or powder;

c) mixture of sodium nitrite and ammonium carbonate (1:1), and also sodium benzoate or a mixture of urea and sodium nitrite (1:3).

Inhibitors of acid corrosion. In railway transportation there are used steel cisterns for transporting inhibited hydrochloric acid. Inhibitors in this case are additives PB-5 and others on the basis of urotropine. The most effective inhibitors in hydrochloric acid are recently developed additives [BA-12](БА-12) and BA-6 on the basis of benzylamine.

Inhibitors for anhydrous media (lubricants, mineral oils, fuels, etc.) are applied in the form of additives on the basis of sodium benzoate, ammonium benzoate,

benzoate buffer, monoethanolamine, dicyclohexylamine, and also multifunctional additives of type [VNII NP-111](ВНИИ НП-111), "Neftegaz-203," and others.

Questions For Self-Check.

1. How is it possible to reduce corrosion-fatigue damages?
2. Which metals are more stable against corrosion?
3. What are the methods of corrosion protection by metal coverings?
4. What are the methods of corrosion protection of metal by plastics?
5. What are inhibitors and where are they applied as retarders of corrosion?
6. Into what groups are inhibitors subdivided?
7. Which inhibitors protect from atmospheric and acid corrosion and in hydrous medium?

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

FOLLOWING ARE THE CORRESPONDING RUSSIAN AND ENGLISH DESIGNATIONS OF THE TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	sin^{-1}
arc cos	cos^{-1}
arc tg	tan^{-1}
arc ctg	cot^{-1}
arc sec	sec^{-1}
arc cosec	csc^{-1}
arc sh	sinh^{-1}
arc ch	cosh^{-1}
arc th	tanh^{-1}
arc cth	coth^{-1}
arc sch	sech^{-1}
arc csch	csch^{-1}

rot	curl
lg	log