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## CHEMICAL SCIENCES



## TECHNICAL SCIENCE

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# ОБҐРУНТУВАННЯ ТЕХНОЛОГІЇ КОНСЕРВАЦІЇ СІЛЬСЬКОГОСПОДАРСЬКОЇ ТЕХНІКИ ПРИ ЗБЕРІГАННІ

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# SUBSTANTIATION OF TECHNOLOGY OF CONSERVATION OF AGRICULTURAL EQUIPMENT DURING STORAGE

***Анотація.***

*Застосування більшої частини машинно-тракторного парку на польових роботах складає 10-15% календарної пори року. Техніка тривалий час зберігається під впливом атмосферних опадів, підвищеної вологості повітря, перепадів температур, сонячної радіації, рослинно-ґрунтових забруднень. Під час зберігання, відкриті металеві поверхні деталей піддаються інтенсивній корозії, а лакофарбові покриття руйнуються і втрачають захисні властивості. Процес корозії в рівній мірі стосується як вітчизняних, так і імпортних машин, так як їх робочі органи виготовлені з низьколегованих і вуглецевих сталей. До 30% відмов багатьох видів техніки викликано корозією і зниженням втомної міцності пошкоджених корозією деталей.*

*На сьогодні не існує ефективних і недорогих консерваційних матеріалів для захисту техніки. Використання відпрацьованих мастил і бензино-бітумних сумішей для консервації машин є досить не ефективне адже вони мають низький термін захисної дії.*

*В даній статті розглянуто питання поліпшення рецептури бітумних складів і вдосконалення конструктивних і технологічних параметрів обладнання, що використовується при їх виробництві і нанесенні. Обґрунтовано поліпшену рецептуру інгібованих бітумних складів на основі доступних компонентів. Проведена оцінка інгібованих бітумних складів та їх технологічні і протикорозійні властивості в умовах зберігання сільськогосподарської техніки. Визначений вплив технологічних чинників на змішування рідких і твердих компонентів при отриманні інгібованих бітумних складів.*

*З врахуванням отриманої інформації, зроблені висновки та проведений аналіз технологій консервації сільськогосподарської техніки з використанням бітумного складу та обладнання для його нанесення.*

***Abstract.***

*The use of most of the machine-tractor fleet in field work is 10-15% of the calendar season. The equipment is stored for a long time under the influence of precipitation, high humidity, temperature changes, solar radiation, plant and soil pollution. During storage, exposed metal surfaces of parts are subject to intense corrosion, and paints are destroyed and lose their protective properties. The corrosion process applies equally to both domestic and imported machines, as their working parts are made of low-alloy and carbon steels. Up to 30% of failures of many types of equipment are caused by corrosion and reduction of fatigue strength of corrosion-damaged parts.*

*To date, there are no effective and inexpensive conservation materials to protect equipment. The use of waste oils and gasoline-bitumen mixtures for the preservation of machines is quite ineffective because they have a low protective life.*

*This article considers the issue of improving the formulation of bituminous compositions and improving the design and technological parameters of the equipment used in their production and application. The improved formulation of inhibited bituminous compositions on the basis of available components is substantiated. The evaluation of inhibited bituminous compositions and their technological and anticorrosive properties in the conditions of storage of agricultural machinery is carried out. The influence of technological factors on the mixing of liquid and solid components in the production of inhibited bituminous compositions is determined.*

*Taking into account the received information, conclusions are made and the analysis of technologies of preservation of agricultural machinery with use of bituminous structure and the equipment for its drawing is carried out.*

***Ключові слова****: корозія, бітум, інгібітор, захист, Сталь 08 КП, захисна суміш.*

***Keywords:*** *corrosion, bitumen, inhibitor, protection, steel 08 kp, protective mix.*

**The state of the issue.** Slow renewal of the composition of the machine-tractor fleet, leads to the fact that a significant proportion of machines continue to be used beyond the depreciation life. This equipment has a low level of residual life and maintainability. The average cost of maintaining equipment in working order is quite high and is 12-15% of the cost of production, while in foreign practice they do not exceed 4-6% [2].

To reduce the cost of depreciation of equipment, helps to protect the working parts of machines from corrosion. Applying preservative coatings in preparation for storage, extends the service life of the units of the machine-tractor fleet. One of the main cost items for the preservation of machinery is the cost of protective materials and equipment. Saving money on corrosion protection of equipment leads to significant costs and greater damage from reduced reliability of units, their premature repair and replacement of parts affected by corrosion [2].

Under the influence of corrosion and mechanical wear there is a change in the efficiency of the surface of components and parts of agricultural machinery. This becomes noticeable when the machines are put into operation after storage. The most prone to this type of wear are sprockets, roller chains, parts of cutting devices, pulleys, plows and plowshares, discs of harrows and plows, auger and reaper bottom, fan and unloading auger casings, middle boards of grain and ear elevators [conveyor surface 1].

The machines do not work during storage and are stationary, at this time the corrosion processes proceed at high speeds, because the condensed moisture films are on the surfaces of the products for a longer time (approximately three times) compared to operation in operating modes. The safety of machines in the period of inactivity is determined by corrosion and aging, which in turn depend on the quality of preservation of machines [3-7].

Safety is also affected by the operational wear of parts and their protective coatings, the complexity of preparation for storage and maintenance during storage.

The safety of $S_{зб}$ machines is determined by the following described by formula [4].

$$S_{зб} = f(O, J, K, T) \qquad (1)$$

where O - maintenance;
J - total wear;
K - corrosion;
T - aging.

During the storage period of equipment, such indicators as: wear, corrosion, aging and complexity of maintenance of machines, depend on how they are protected from the harmful effects of external environmental factors.

Protection of units is provided by means, ways and methods of preservation.

The following formula determines the methods and techniques of conservation – $C_{конс}$ [1, 4].

$$C_{конс} = f(E_{кон}, Z_{кон}, U_{кон}, V_{кон}), \qquad (2)$$

where $E_{кон}$ – preparation for protection (1 component of conservation);

$Z_{кон}$ – protection of machines against corrosion and wear (2 components of conservation);

$U_{кон}$ – reviews and reconservation (3 components of conservation);

$V_{кон}$ – deconservation and commissioning (4 components of conservation).

Such a component as - protection of machines from corrosion, wear and aging (the second component of conservation) - is the main and consists in the correct choice and application of means, methods and techniques of conservation [2, 7].

Unp rotected steel 20 in the open field under atmospheric corrosion reduces its fatigue strength by 41% in 1 year. This is due to the formation of stress concentrators in the form of deep corrosive shells. When applying NG-204U preservative oil in a thin layer (50-100 μm), the fatigue strength of steel 20 under the same storage conditions decreased by only 1.2-1.4% per year [6].

Reduction of corrosion losses of welded joints of steel 08 SP in 5-12 times, is reached by means of temporary anticorrosive protection by the inhibited bituminous structures. The fatigue strength of the protected welded joint with inhibited bituminous compositions is 14-18% higher than that of unprotected steel.

Corrosion of steel 08 KP with a thickness of 0.8-1.0 mm for 12 months reduces the corrosion and fatigue strength by 45% [4].

**The purpose and objectives of the study.** Improving the formulation of bituminous compositions and improving the design and technological parameters of the equipment used in their production and application.

To achieve this goal you need to solve a number of key tasks:

1. Justify the improved formulation of inhibited bituminous compositions on the basis of available components.
2. To evaluate the inhibited bituminous compositions of their technological and anti-corrosion properties in the conditions of storage of agricultural machinery.
3. To determine the influence of technological factors on the mixing of liquid and solid components in obtaining inhibited bituminous compositions.
4. Taking into account the received information, to draw conclusions and to carry out the analysis of technologies of preservation of agricultural machinery with use of bituminous structure and the equipment for its drawing.

**Fundamentals of conservation warehouses for agricultural machinery.** Means for temporary protection of agricultural machinery from corrosion are divided into 2 groups [1].

The first group includes:

❖ preservative materials of industrial production, suitable for protection of agricultural machinery;

❖ conservation (protective) oils;

❖ conservation oils;

❖ film-forming oil compositions;

❖ protective water-wax dispersions;

❖ oil-soluble corrosion inhibitors;

❖ additives.

The second group includes:

❖ by-products of industry and agriculture with anti-corrosion properties;

❖ VAT residues and petrochemical wastes;

❖ waste mineral and synthetic oils;

❖ waste and sludge of vegetable oils;

❖ self-made conservation compositions.

According to their purpose, the means of temporary corrosion protection of machines are divided into 3 levels:

– for protection of external surfaces of cars;

– for protection of internal surfaces of engines, transmissions, transmissions;

– to protect open gears and mechanisms.

The main representatives of conservation materials at each level for two generations are shown in Figure 1.

The first generation materials for the protection of the outer surfaces of machines, included home-made preservatives. These are gasoline-bitumen compositions and waste oils thickened with PVC gun oil.

In the second generation industrial materials appear and are delivered to the agricultural enterprises:

- protective wax (not inhibited);
- IVVS (inhibited);
- bituminous composition of Inhibi-C.

Today, such materials as: PVC, Cormin and others, remain relevant for temporary corrosion protection of equipment. Also, most of the anti-corrosion materials are withdrawn from production (NG-204U, ZVVD-13, etc.) due to their low profitability for refineries compared to the production of fuel and working oils.

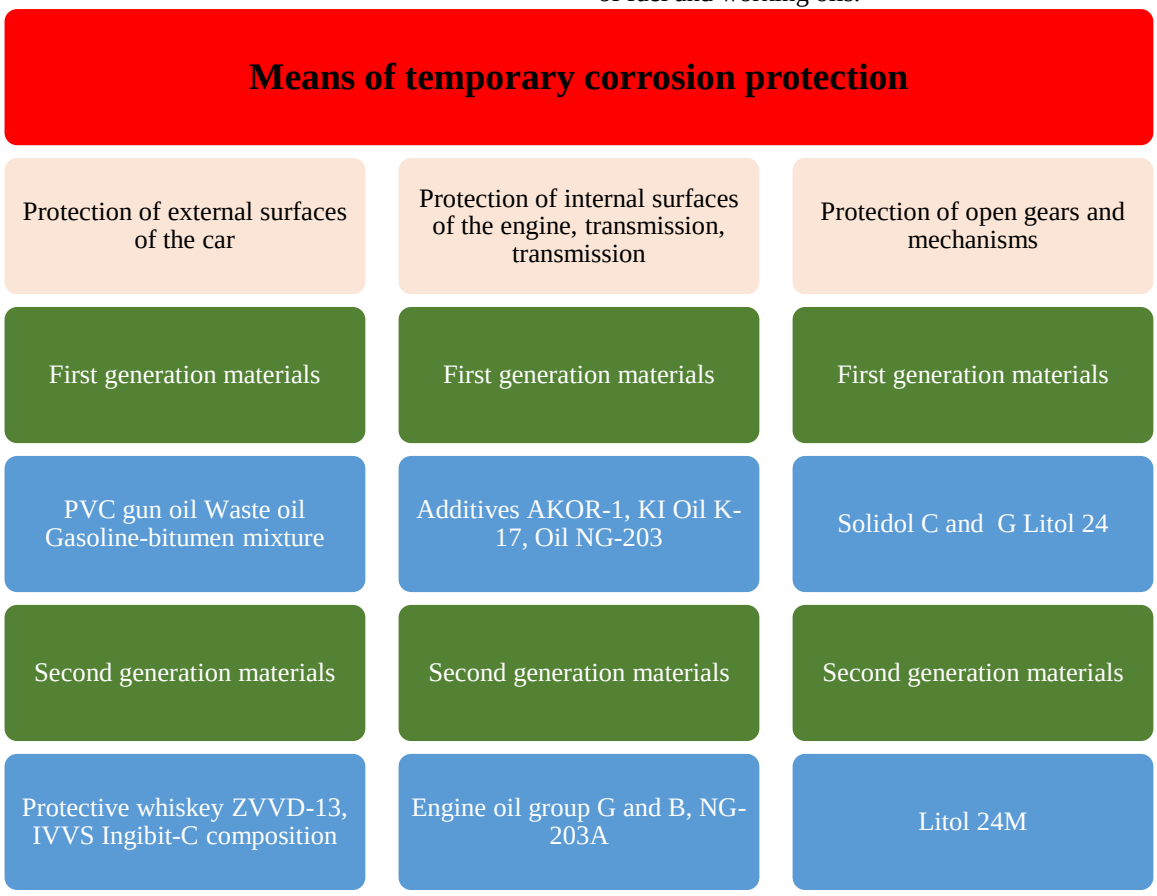



*Figure 1 - Means of temporary corrosion protection of agricultural machinery.*

Domestic manufacturers meet the needs of industrial enterprises in small wholesale supplies of lubricants, corrosion inhibitors, components for paint production and in anti-wear additives to lubricants.

Research is currently being conducted in Europe and around the world on the use of vegetable oil wastes to protect machines and mechanisms from corrosion. This goal serves to expand the raw material base for conservation materials and reduce their cost [7,8].

The use of vegetable oils is possible only in a modified form. By adding additives, oils are modified, but their environmental friendliness is reduced. Sediment of sunflower and rapeseed oils have rather high protective properties. In the conditions of open

sites the term of protection of equipment by sediments of vegetable oils reaches 12 months [8].

The scope of use of vegetable oils and their sludge for the preservation of agricultural machinery is significantly limited, their use can only be local. Wastes of vegetable oils in farms are practically absent, however there is a large amount of the fulfilled autotractor oils. On the basis of used autotractor oils, it is possible to obtain low-component preservative oils and compositions with a varied term of protective action [3-6].

The use of oil-soluble additives, bottoms and petrochemical wastes (emulgin, KO-SZhK) in combination with spent IMO oils (mineral and synthetic), produce thickened lubricants for preservation in open areas: working bodies of tillage equipment and open joints. The use of used tractor oils in combination with additives, partially solves the problem of lack of conservation materials of agricultural enterprises.

Thickened oils have the property of not drying out, which in turn contaminates the crops and clothing of machine operators, so their use in agriculture is limited. On farms, canning equipment is still carried out with traditional gasoline-bitumen compositions, they have much worse protective properties than industrial automation, but they are many times cheaper.

To obtain gasoline-bitumen compositions used petroleum construction bitumen brand BN-IV and BN-V, and as a solvent - unleaded gasoline at a ratio of bitumen and gasoline from 1: 1 to 1: 3 [1]. To improve the physical, mechanical and protective properties of the applied bituminous coatings, waste oil is added to their composition. The duration of preparation of the composition lasts 7 days with twice daily stirring, before use the composition is filtered through a metal mesh № 15. Bituminous compositions protect against corrosion of the outer surfaces of the working bodies of tillage and harvesting machines (dumps, discs, harvesters, etc.).

Protective effect of gasoline-bitumen coatings on open areas - does not exceed 6 months. The effectiveness of protection depends largely on the condition of the surface, if the original surface of the steel is affected by corrosion, the corrosion rate increases by 8-10 times. When applied to a rusty surface there is a decrease in the protective effectiveness of gasoline-bitumen compositions, due to their weak adhesion. When rust is left, as well as moisture and air penetrating through the bituminous coating, cause an increase in corrosion damage to steel, and most - in the first 2 months.

To date, there is no improvement in the provision of agricultural enterprises with quality protective materials. Therefore, the question of finding possible modifications of bituminous compositions is relevant from a scientific and technical point of view.

When modifying bitumens with polymers, their atmosphere increases the stability [4]. The use of isoactic polypropylene (up to 2%) is quite promising. Reducing the temperature of brittleness, increasing frost resistance, as well as weather resistance is achieved through the introduction of resins and oils in bituminous compositions, which enriches the oil phase of bitumen and their ductility.

When increasing the oil content of bitumen provides a more complete and easier combination with modifiers. Depending on the nature of plasticizing additives, their optimal content depends, it ranges from 5 to 10%, with further increase reduces the viscosity of the mixture [4]. To carry out the modification, the bitumen is pre-dissolved in organic liquids. Diesel fuel, gasoline, kerosene, and white spirit are used to dilute bitumen. In the hot method of dissolution, the bitumen is melted to 100-120 ° C and mixed with a solvent. The ratio of bitumen and solvent is about 1: 1 [2].

The most effective way to increase the protective properties and extend the service life of bitumen-based coatings is to add corrosion inhibitors to their composition.

**Corrosion inhibitors** (укр. інгібітори корозії; рос. *ингибиторы коррозии;* англ. *corrosion inhibitors;* нім. *Korrosionsinhibitoren m pl*) are substances whose introduction in relatively small quantities into an aggressive environment causes a marked slowdown in the corrosion of metals [9].

Competitive adsorption with activator particles and the formation of protective adsorption or phase films on the metal surface, sometimes with barrier properties, inhibit the corrosion process. Inhibitors affect the kinetics of electrode processes that take place during corrosion. Inhibitors have the ability to form oxide and hydroxide and other films on the metal and convert it to a passive state.

Inhibitors are divided into:

- hydrogen sulfide corrosion;
- carbon dioxide corrosion;
- wastewater disposal systems.

When using corrosion inhibitors, take into account the corrosive activity of the environment and application conditions. The specific consumption of inhibitors ranges from 10 to 50 kg per 1 million m3 of gas or (for liquid media) from 100 to 500 mg / l [9].

The use of most inhibitors (oxidized petroleum products, petroleum sulfates, amines and their salts with synthetic synthetic acids, nitrated oils) in bituminous mastic is 3 -5%. As the amount of inhibitor increases, the course of corrosion decreases, the resistance of the coating increases, but this leads to more expensive and loss of adhesive properties of the composition. When corrosion inhibitors (which are surfactants) are used, the pores in the film are closed and the coating is sealed, which reduces the water absorption and water permeability of the films.

As corrosion inhibitors in polymer bituminous compositions, the most widely used compounds containing amino groups and their derivatives. The composition with the addition of amines, can even be applied to a rusty surface. Anti-corrosion, weather-resistant coatings of a wide range of actions are formed on the surface [9-10].

**Characteristics of equipment for the preparation of conservation compositions.** The following components are used for the production of preservatives: bitumen, bitumen-rubber and bitumen-atactic mixtures, they can be solid or plastic. The

components are transported packed in bays and boxes, and the additives are packaged in cardboard winding drums.

To dilute the components of the bituminous composition, it is necessary to heat and mix thoroughly to obtain a homogeneous product. In industrial production, mechanical mixing is carried out using stirrers that receive rotational motion either directly from the motor or through a gearbox or V-belt transmission.

At the agricultural enterprises for preparation of conservation structures the installations equipped with manual stirrers are applied: paddle or sheet. These units are designed for the preparation of thickened preservative oils. They heat and mix used oils with anti-corrosion additives [1,3-6].

Figure 2 shows the installation for the preparation of bituminous mixtures. The solvent in it is diesel fuel.

Installation design:

- cylindrical tank 1 with a capacity of 50 liters;
- stirrer 2;
- protective net 3;
- heating element 4 with a capacity of 2 kW;
- loading window with lid 5;
- drain cock 6;
- support 7;
- temperature regulator 8;
- manometric thermometer 9.

The composition temperature is 110-115 $^0$C.

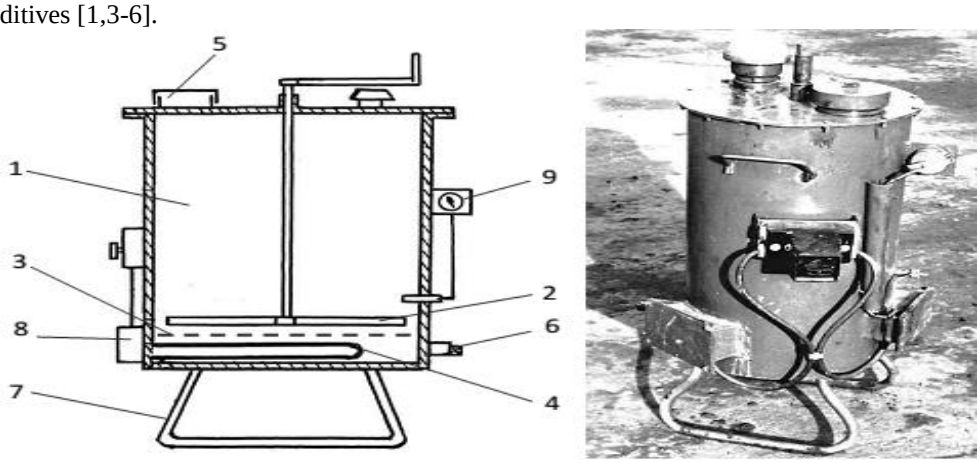



*Figure 2 - Installation for the preparation of bituminous compositions [6].*

The finished mixture is sprayed on the working bodies of agricultural machinery at a temperature of 40 ° C. The applied film of bituminous composition 0.12-0.15 mm thick protects the equipment for 8-9 months of storage. The composition prepared on diesel fuel is stored for a long time, diluted with gasoline or kerosene.

The main disadvantages of this installation include: increased fire resistance due to direct contact of the shell of the heating element with diesel fuel; burning of bitumen on the shell of the heating element, its coking, overheating and destruction of the shell or spiral.

Consider the installation of OPU-80 for the preparation of thickened oils (Figure 3). This installation consists of a heat-insulated tank 1 with a capacity of 80 l, which contains three heaters TEN 14 with a total capacity of 3 kW (220 V), mixing device, drain valve 11, control panel 2. The mixer includes a fixed auger 10 on the tank wall 1 and a screw mixer 8. The rotation of the stirrer 8 is carried out manually using the handle 5 [4, 11].

Heaters-TEN 14 do not come into contact with thickened oil, because they are fixed under the bottom 12 of the tank. These heaters are designed to work in the air. At the same time there is no coking and service conditions improve. With the help of a meter-regulator with an input sensor 1, the heating is controlled in automatic mode.

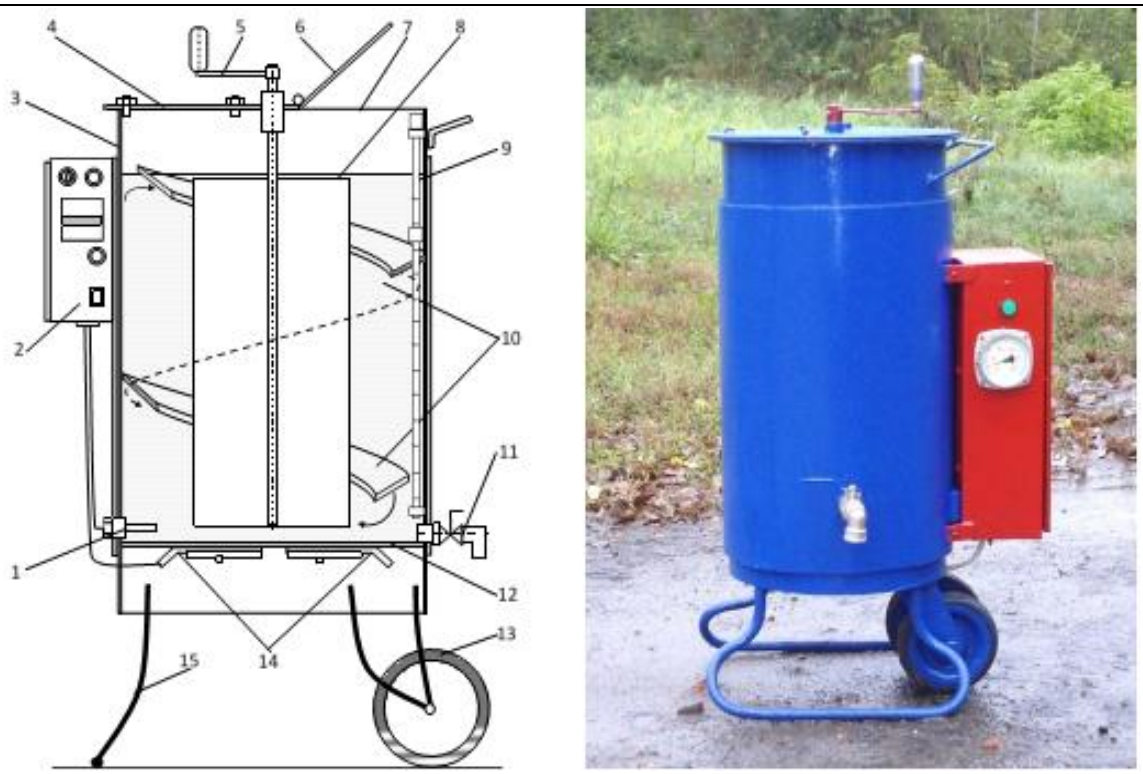



*Figure 3 - Installation for the preparation of thickened oils.*

The annual volume of production of thickened oil by this installation, insignificant - 220-300 l; rather low energy consumption of oil preparation - 0,04-0,06 kWh / l; productivity - 50 l / h.

Installation OPU-80, due to the presence of a manual mixer and the predominant mixing of components in the liquid state can not be effectively used in low-tonnage production of bituminous compositions with an annual volume of 1000-2000 liters.

By means of mixers of various constructive forms, it is possible to carry out mixing of viscous components of bituminous structures. At the bottom stage it is necessary to consider that viscous components practically cannot move without motivation. When mixing them, some layers of the contents of the device must be forcibly pushed into others; considerable effort is expended on this. [11].

**Inspection of equipment for application of conservation compositions.** During the conservation process of agricultural machinery, various means are used to apply protective materials to exposed metal surfaces. To perform a small amount of work, materials are applied with hand brushes, if the amount of work is large enough, the process of applying materials is mechanized and pay attention to increasing productivity, reducing losses of conservation compounds, reducing energy consumption, improving coating quality [1, 4].

Devices for applying preservative coatings are divided into: pneumatic spraying, airless spraying and electrostatic. If we compare these devices, for the application of preservatives on agricultural machinery, the most suitable spray of a pneumatic nature. Pneumatic spraying is quite versatile, has a simple design, has a good coating quality and is quite reliable [1, 4].

The design parameters of the spray gun and technological factors (length of the spray torch, flow rate and viscosity of the composition, air pressure of the spray), affect the quality of pneumatic spraying. The efficiency of pneumatic spraying is evaluated by fog formation [12].

Technological means for painting and for application of conservative materials.

When performing small volumes of work using the gun shown in Figure 4, it has a fairly simple system, which includes only a few elements [13]: a gun with a lower tank for spraying materials, a pneumatic hose and a compressor.

The working fluid is sprayed by supplying compressed air from the compressor under a working pressure of 0.6-0.8 MPa. One of the inconveniences is that the gun requires constant topping up of the tank. For operation of the device the compressor with a pneumatic reducer, the electrodistributing device for connection of the compressor, an air hose are necessary.

*Figure 4 - SATA HRS anti-corrosion gun.*

Consider a cheaper compact device PRK-4, which can be used for canning machines on farms with a small fleet of machines [4]. The main elements of this device are (Figure 5): spray gun, nozzle, air hose and removable plastic cylinders from carbonated beverages, which are resistant to oils and gasoline, can withstand an internal compressed air pressure of 0.75 MPa.

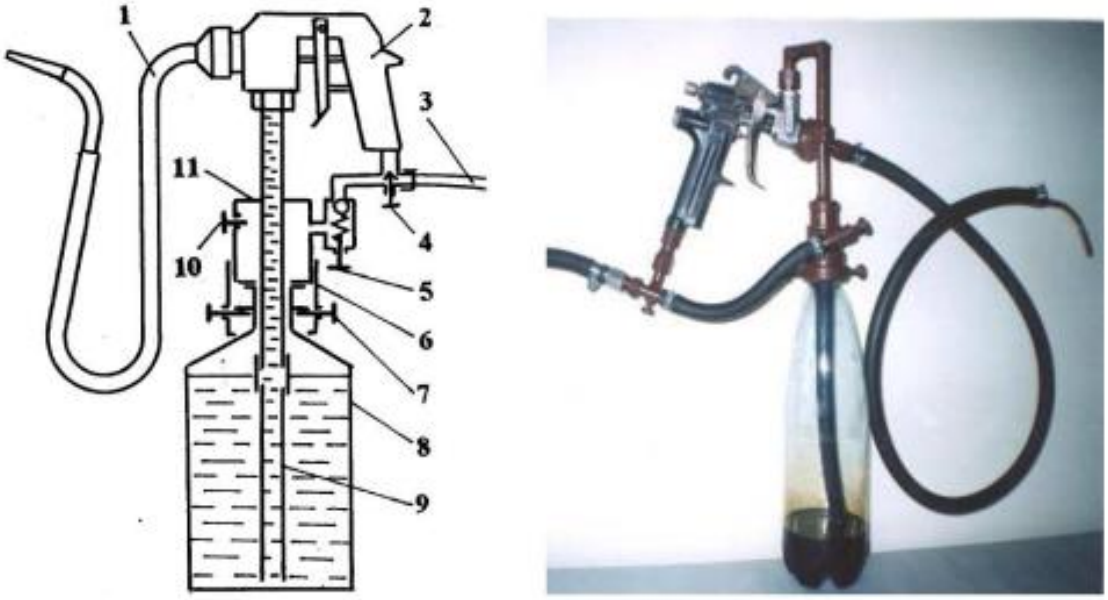



*Figure 5 - Compact device PRK-4:*
*1 - nozzle; 2 - spray gun; 3 - hose; 4 - screw; 5 - pressure regulator; 6 - clip;*
*7 - clamp; 8 - balloon; 9 - tube; 10 - traffic jam; 11 - distributor.*

Paint injection tanks (Figure 6) are used for painting large surfaces and hard-to-reach places [14]. When using injectors, the productivity increases due to the reduction of technological breaks associated with the replacement of the cylinder or pouring paint into the spray tank.

*Figure 6 - Paint injection tank with spray gun and compressor.*

The tank works from the compressor, under pressure of compressed air the structure from a tank on hoses is forced in the paint sprayer equipped with the lower union of paint supply. The paint injection tank has a bucket-liner with a capacity of 20 l and an automatic stirrer with a pneumatic drive.

Thus, the technical means used in the car service for painting cars are quite expensive and do not fully meet the conditions of conservation of agricultural machinery. Therefore, the need to create a portable spray with a pressure tank for the application of preservative materials, which will be convenient to use in open areas of storage of equipment is quite relevant.

**Evaluation of the efficiency of technological processes of machine preservation.** The property of the used conservation materials, their availability, manufacturability at drawing and technical and economic indicators of the applied technical means influence quality and efficiency of preservation of agricultural machines for storage [1, 4].

Industrial anti-corrosion mastics have a fairly high cost, so the surfaces of agricultural machinery are still protected by used motor oils and gasoline-bitumen mixtures. These mixtures do not provide full corrosion protection for long-term storage of equipment [1, 4, 10]. A preferred option may be thickened mixtures containing waste oils with inhibited corrosion-resistant additives, but they are mainly suitable for the protection of tillage equipment.

Preservative materials forming hard-film coverings are suitable for protection against corrosion of surfaces of harvesting machines. The use of hard-film coatings allows in the future not to deconserve the units after the end of storage of machines, and some units - to protect in the process of their further operation. In these materials, the production technology is more complex than the technology of preparation of thickened lubricants. Such materials include inhibited bituminous compositions [1, 4, 10].

The complex technology of manufacturing inhibited bituminous compositions requires a high level of technical equipment in specialized areas, while increasing the price of the finished product.

Production of inhibited bituminous compositions is profitable to create not in small farms, but on the basis of agricultural holdings and technical service enterprises with an annual production of 1-5 tons. Components for low-tonnage production of inhibited bituminous compositions should be available and inexpensive.

Figure 7 shows a diagram that analyzes the rational use of resources in the technology of production and application of inhibited bituminous compositions [1, 4, 10].

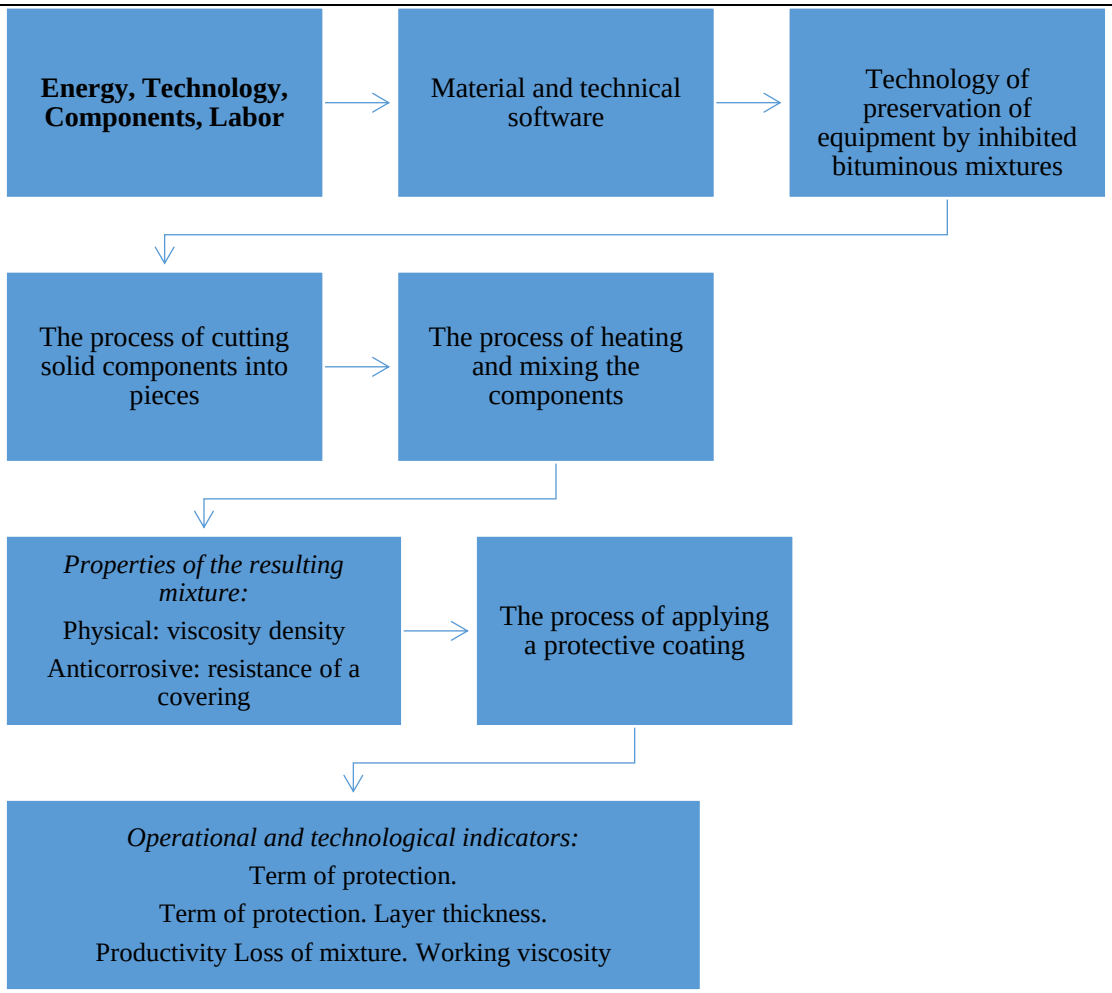



*Figure 7 - Scheme of development of technology of preservation of equipment by inhibited bituminous compositions.*

This scheme allows you to get a rational relationship between the resources required for the production and use of inhibited bituminous composition, and its properties, which determine the operational and technological performance of the conservation process. The problem of rational resource use is also solved, the cost of funds for the production and application of bituminous composition is minimized, but the level of corrosion protection of agricultural machinery is not reduced.

With the help of target functions, the technology of preservation of equipment by inhibited bituminous compositions is evaluated, taking into account the volumes of their production and consumption.

The objective function $\Phi_п$ of estimating the technology of low-tonnage production of inhibited bitumen composition is determined by the following formula [1-10].

$$\Phi_п = Z_{пр}/V_{пр} \rightarrow min \qquad (3)$$

where $Z_{пр}$ – total costs for the production of bituminous composition, UAH;

$V_{пр}$ – annual production of bituminous composition, l.

For the annual production of bituminous composition, the total cost of resources in general includes the following indicators (UAH) [1-10].

$$Z_{пр} = \sum v_i Ц_i + Т_{Рп} \cdot С_Т + ЕЦ_е + К_а \qquad (4)$$

where $v_i$ – is the annual demand for the i-component, l / year;

$Ц_i$ – the price of the i-component, UAH / l;

$Т_{Рп}$ – annual labor costs for the production of the warehouse, people · h / year;

$С_Т$ – average hourly wage with accruals, UAH / person hour;

E – annual electricity costs for warehouse production, kWh / year;

$Ц_е$ – the price of electricity, UAH / (kW year);

$К_а$ – depreciation of technical means for the production of the warehouse, UAH / year.

According to formula 5, the target function for evaluating the technology of conservation of equipment is determined [1-10].

$$\Phi_к = \frac{Ц_н \cdot V_н}{R_з} \rightarrow min, \qquad (5)$$

Цн – cost of application of conservation structure, UAH / l;

$V_н$ – annual need of the farm in the conservation composition, l.

$R_з$ – coefficient of protective ability of the conservation composition.

The objective function $Ф_к$ corresponds to the annual need $V_п$ of the farm.

Taking into account the operating costs (UAH / l) for the purchase and application of 1 liter of composition, the cost of $Ц_н$ in general includes [1-10].

$$Ц_н = Ц_{бс} + Т_{Р_н} \cdot C_Т + Е_н Ц_{ер} + К_н \quad (6)$$

where $Ц_{бс}$ – the price of the conservation composition, UAH / l;

$Т_{Рн}$ – complexity of application technology, people h / l;

$Е_н$ – energy consumption of application technology, kWh / l (l / l);

$Ц_{ер}$ – the price of energy resource, rub / kWh (UAH / l);

$К_н$ – d epreciation of technical means for applying the composition, UAH / l.

The price of the composition roughly corresponds to the value of the objective function $Ф_п = Ц_{бс}$, and the other components are the operating costs E_вна application of 1 liter of the composition.

Taking into account expression (3), we write formula (6) in the form [1-10].

$$Ц_н = Ф_п + Е_в = Z_{пр}/V_{пр} + Е_в \quad (7)$$

The annual need $V_н$ farm in the composition is determined depending on the structure of the machine-tractor fleet [1-10].

$$V_н = А_к S_{сум} \quad (8)$$

where $S_{сум}$ is the total surface area of the machines covered with the preservative mixture.

$А_к$ – standard costs of the warehouse per 1 m2:

Substitute expressions (7), (8) into (5) and obtain [1-10].

$$Ф_к = \left(Z_{пр}/V_{пр} + Е_в\right)\frac{А_к S_{сум}}{R_з} \rightarrow min \quad (9)$$

The total surface area of machines canned in a particular farm is almost unchanged, then expression (9) is permissible to reduce to 1 m2 of area, divided by $S_{сум}$

Therefore, the expression of the objective function $Ф_к$ (UAH / m2) for the evaluation of conservation technology will have the following form [1-10].

$$Ф_к = \left(Z_{пр}/V_{пр} + Е_в\right)\frac{А_к}{R_з} \rightarrow min, \quad (10)$$

The coefficient $R_з$ is defined as the ratio of the term t_c protective action to the term $t_к$ storage of equipment [1-10].

$$R_з = \frac{t_з}{t_к} \quad (11)$$

From expressions 10 and 11 follows the objective function of evaluation of conservation technology [1-10].

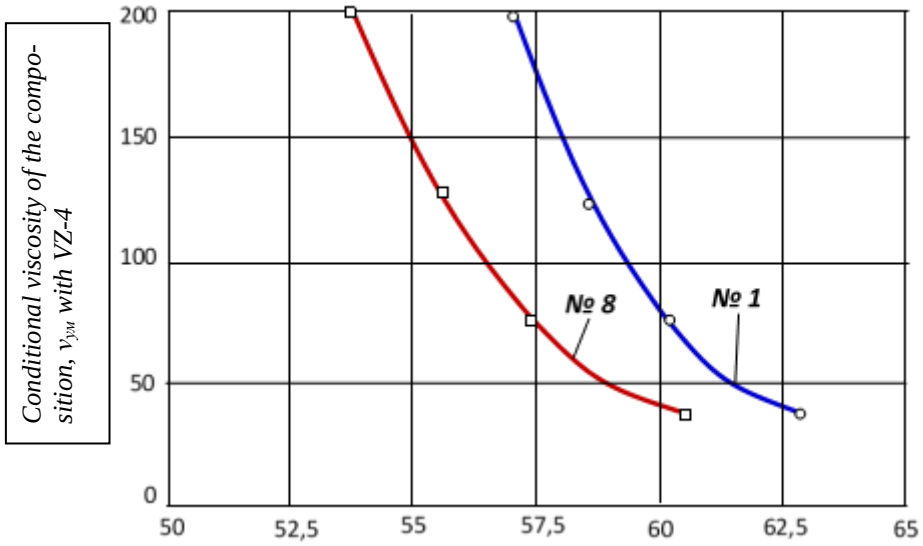
$$Ф_к = \left(Z_{пр}/V_{пр} + Е_в\right)\frac{А_к}{t_з/t_к} \rightarrow min, \quad (12)$$

The application of formula 12 gives a comparative assessment of technologies for the conservation of agricultural machinery. With its help the advantages of application of inexpensive and technological structures with long term of protective action are defined.

**The results of experimental studies**. The upper viscosity limit of protective lubricants is 150 of VZ-4, these parameters satisfy the application by pneumatic method [15]. When using air sprays should focus on good spraying and the viscosity level of the inhibited bituminous composition - 100 with VZ-4 [1]. The viscosity of bituminous compositions depends on the solvent introduced into the mixture and the heating temperature.

The effect of white spirit on the conditional viscosity of bituminous compositions № 1 and № 8 was studied, the study was carried out at a temperature of 20-22 ° C.

From Figure 1, the dependences of the viscosity ν_um of bituminous compositions on the content of white spirit in them are determined by the technological concentrations of the solvent.




*Graph 1-Influence of white spirit content on conditional viscosity v_um of bituminous compositions №1 and №8.*

Considering the bituminous composition № 1, the technological concentration of white spirit in it is 59%, and for the composition № 8 it is approximately 57%. The conditional viscosity of the compositions at technological concentrations of white spirit is slightly below 100 of VZ-4. This mixture provides high-quality spraying when applied with a pneumatic spray CO-71. The thickness of the protective film can reach 60 μm.

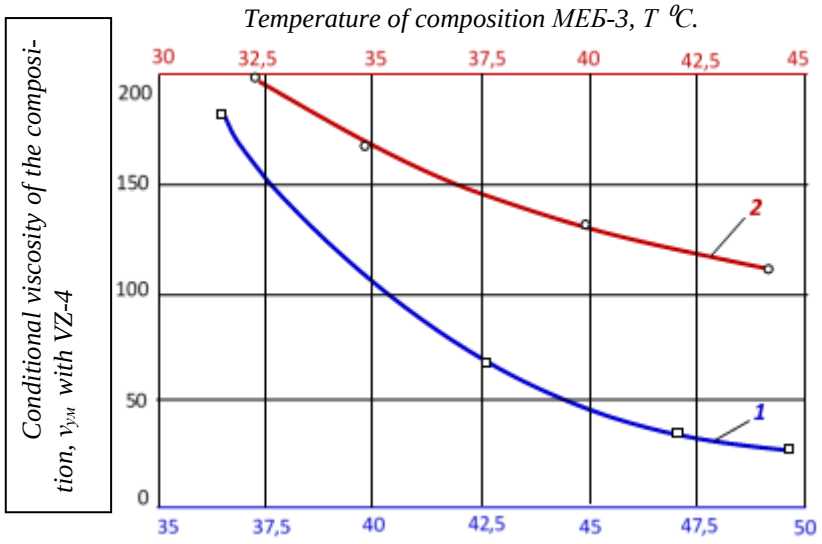
In compositions № 1 and № 8 slate mastic is used, which is quite expensive, so the bituminous composition introduced a more affordable and cheaper plasticizer - fuel oil M100. Inhibited bituminous compositions such as: OIE-3 and OIE-4 contain M100 fuel oil.

The components of the finished inhibited bituminous compositions of OIE-3 include (in% by weight):

- bitumen - 31%;
- fuel oil - 31%;
- white spirit - 31%;
- Emulgin additive - 7%.

The inhibited bituminous composition of OIE-3 dries in the open air for 2 months, and retains its elasticity.

Figure 2 shows the dependence of the viscosity on the heating temperature and the content of white spirit.




*Graph 2 – Influence of the content of white spirit (1) and the temperature T of heating (2) on the conditional viscosity v_um of the bituminous composition of OIE-3.*

The composition of MEB-3 at a temperature of 30° C has a viscosity above 250 with VZ-4. If the composition is heated to 40-45 ° C, the viscosity is reduced to 100-130 with VZ-4, and it is quite well sprayed with a pneumatic spray. Better spraying with a pneumatic spray can be achieved by adding to the

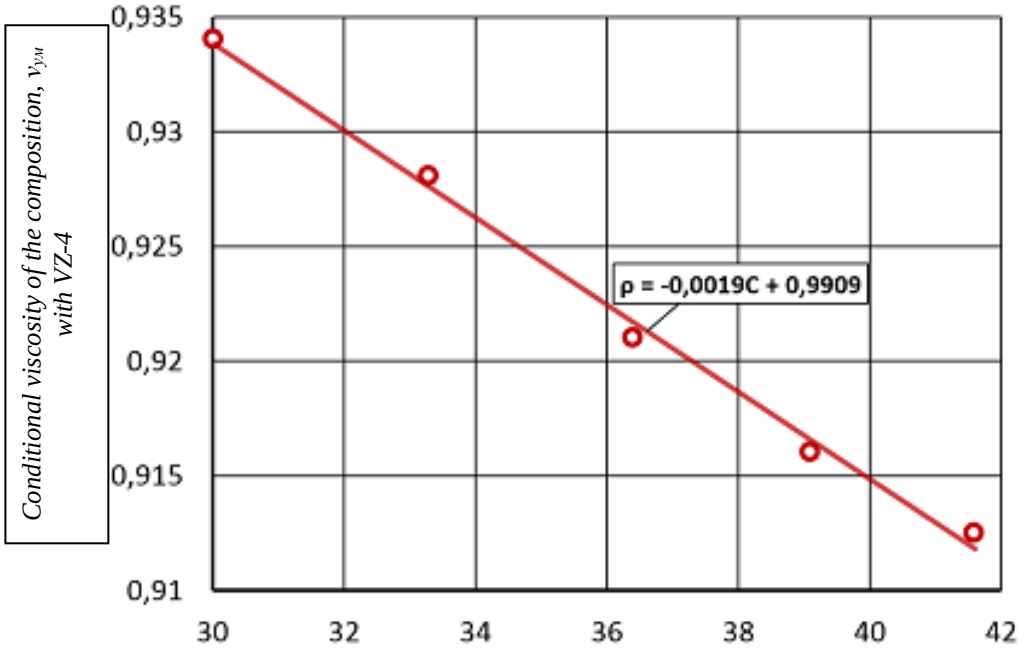
finished form of the composition of MEB-3 - white spirit in the amount of 10% while its viscosity will be reduced to 100 with VZ-4. The total content of white spirit in the composition of OIE-3 will increase from 31 to 41%. Although OIE-3 and № 8 formulations have the same viscosity, OIE-3 formulations contain 16% less white spirit, which costs the highest of all components.

To reduce the cost of production of inhibited bitumen compositions, the issue of replacing white spirit with a cheaper solvent - diesel fuel. In the new composition of OIE-4 it is possible to replace white spirit with diesel fuel and restore the ratio of components.

The inhibited bituminous composition of OIE-4 includes the following components (in% by weight):

- bitumen - 25%;
- fuel oil M100 - 40%;
- emulgin additive - 5%;
- diesel fuel - 30%.

When increasing the content of diesel fuel from 30 to 42%, the density of the composition of the OIE-4 decreases linearly, as shown in Figure 3.




*Graph 3 - Influence of the content of diesel fuel (C) on the density (ρ) of the composition of OIE-4.*

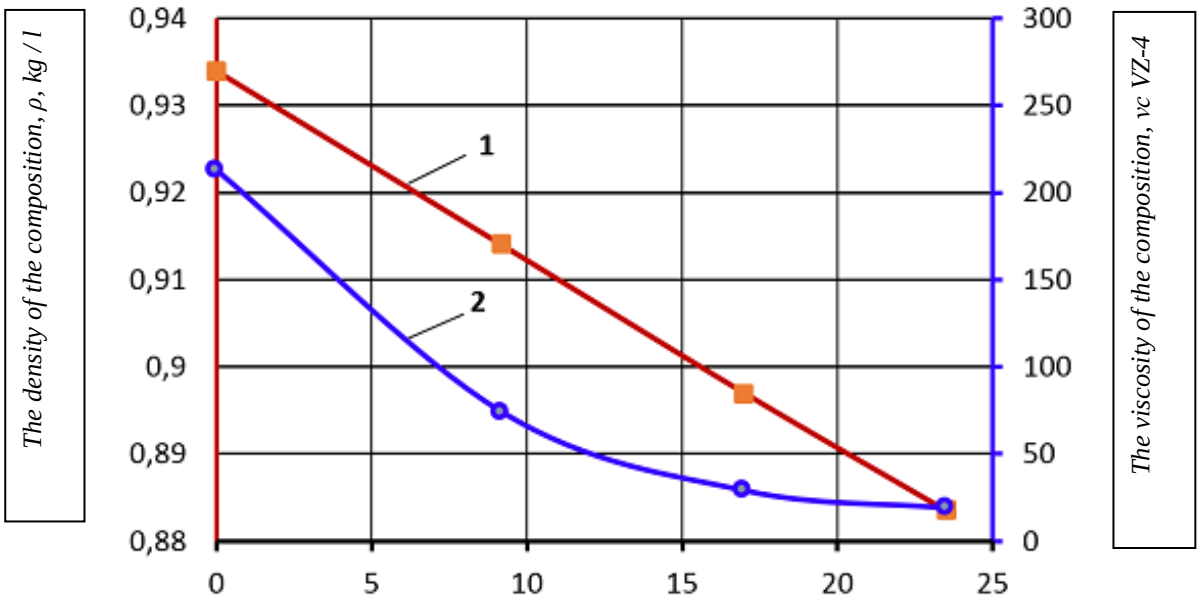
Express assessments of the quality of mixing of components are determined depending on the density of the composition of the OIE-4 and the content of diesel fuel ρ (C).

Ready inhibited bituminous composition MEB-4, has a viscosity greater than 200 of VZ-4. Unleaded motor gasoline can be used for dilution.

At a temperature of 20 ° C determined the effect of gasoline on the viscosity and density of the composition of the OIE-4 (Figure 4).

When adding 8-10% (by volume) of gasoline to the composition of the OIE-4 is a decrease in its viscosity to 70-100 with VZ-4, and the composition of the technological properties is suitable for pneumatic uncoupling.

Table 1 shows the minimum standard costs of bituminous compositions and the thickness of their coatings formed on the vertical surfaces of steel plates.




*Graph 4 - The effect of gasoline content on the density (1) and viscosity (2) of the bituminous composition of MEB-4.*

Table 1.

**Parameters of bituminous coatings on a vertical surface**

| Name of composition | Minimum standard consumption of mix, g / m$^2$ | | Average thickness of a covering, microns | |
|---|---|---|---|---|
| | After 4 hours | After 14 days | After 4 hours | After 14 days |
| МЕБ-4 | 50 | 39 | 53 | 40 |
| МЕБ-4+16% gasoline | 44 | 35 | 49 | 37 |
| МЕБ-4+24% gasoline | 42 | 33 | 47 | 35 |
| МЕБ-4+9% diesel fuel | 38 | 30 | 41 | 32 |
| МЕБ-4+17% diesel fuel | 28 | 21 | 31 | 22 |
| Gasoline and bitumen | 74 | 72 | 89 | 76 |

Diagram 1 shows that: the protective properties of the coating of gasoline-bitumen composition (with a significant thickness) were worse than other compositions, as well as corrosion losses are much higher. Metal losses in the protection of BBC are taken equal to 100%. When adding 16% gasoline to the composition of the OIE-4 is a slight decrease in its protective properties, as metal losses increase from 9.9% to 22.8%. The properties of the composition of MEB-4 are equivalent when adding diesel fuel to 4% or diluting this composition with 16% gasoline. If you increase the percentage of dilution with diesel fuel to 17%, then there is a decrease in the protective properties and metal losses from corrosion increase to 73.4%.

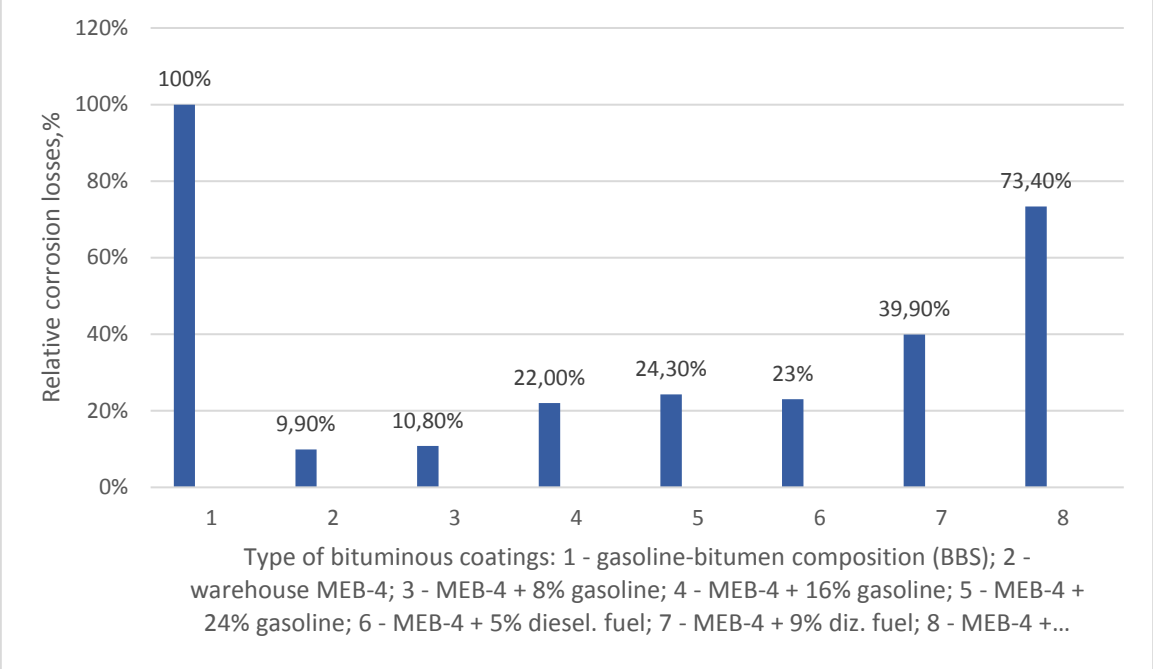



*Diagram 1*

*Relative corrosion losses of steel 08 KP in 3% NaCl solution under protection with bituminous coatings.*

The composition of MEB-4 in comparison with the composition of BBS provides better protection of steel from corrosion under coatings, having a coating 2-3 times thinner. With the introduction of the additive emulgin containing aliphatic amines, there is an increase in inhibitory properties in bituminous compositions [11].

Atmospheric resistance of inhibited bituminous coatings. Preservatives based on inhibited bituminous compositions covering machines and equipment located in open areas are exposed to moisture, oxygen, solar radiation, temperature changes and much more. Under the influence of these factors, there is a change in the structure of the coating and its protective properties deteriorate [11,15].

To assess the degree of protection of the coating, it is also important to assess the level of reduction of the corrosion rate of the protected metal.

Therefore, the degree of protection $Z_1$ is determined by the formula [1,15].

$$Z_1 = \left(1 - \frac{K_1}{K_0}\right) \cdot 100\% \qquad (13)$$

where $K_0$ – is the corrosion rate of the control batch of plates, g / (m2 · months).

$K_1$ – corrosion rate of the metal.

The ratio of corrosion rates on the protected and control plates is found by formula 14 [1,15].

$$\frac{K_1}{K_0} = 1 - \frac{Z_1}{100} \qquad (14)$$

When the content of components in the bituminous composition changes, the corrosion rate of the metal under the new coating will change.

Then the ratio of corrosion rates on the protected and control plates will be [1,15].

$$\frac{K_2}{K_0} = 1 - \frac{Z_2}{100} \qquad (15)$$

where $K_2$ – is the corrosion rate of the metal under the new coating.

$Z_2$ – the degree of protection of the coating.

Using expressions 14 and 15, we determine how the corrosion rate of the protected metal will change when the degree of protection of the coating changes [1,15].

$$\frac{K_1}{K_2} = \frac{100 - Z_1}{100 - Z_2} \qquad (16)$$

Using formula 16, it is possible to evaluate the dynamics of inhibition of the corrosion process on protected plates using an improved formulation of bituminous compositions.

With an increase in the content of shale mastic and a decrease in bitumen increases the weather resistance of the coating in the comparative compositions № 1 and № 8. Also decreases the loss of protected metal - from 3.9 to 2.6 g / m2.

The effect of ultraviolet rays on bituminous coatings, causes a decrease in the average thickness of all compositions, due to the destruction of the structure of the bituminous mixture, while there is an activation under the influence of moisture and sharp temperature fluctuations [16].

Thus, for protection in atmospheric conditions, the degree of protection of steel parts by inhibited bituminous compositions increases with increasing content of fuel oil M100. In a NaCl-like environment, the degree of protection of steel parts by inhibited bituminous compositions increases with increasing bitumen content.

*Analysis of the solubility of bitumen in obtaining bituminous mixtures.* Bituminous mixtures are prepared depending on the time spent on melting and dissolving pieces of bitumen. The traditional technology involves grinding bitumen and filling it with gasoline, holding it for several days and mixing it thoroughly. It takes 3-3.1 hours to prepare BBC. or 182 minutes Heat is required to dissolve bitumen in white spirit or diesel fuel. The rate of dissolution of bitumen in white spirit is influenced by its size. Indicators of bitumen dissolution in white spirit are given in table 2.

Table 2.

**Parameters of dissolution of bitumen in white spirit.**

| № | Indicator | indicator value | | |
|---|---|---|---|---|
| 1 | Weight of a piece of bitumen, gr. | 90-95 | 35-40 | 15-20 |
| 2 | Mass of white spirit per 1 piece of bitumen, gr. | 180-190 | 70-80 | 30-40 |
| 3 | White spirit temperature, $^0$C | 98 | 98 | 98 |
| 4 | Dissolution time of the piece in white spirit, min. | 92 | 65 | 54 |

The duration of dissolution of bitumen in heated white spirit is significantly reduced from 92 to 65 minutes (by 27 minutes), if the mass of pieces of bitumen is reduced from 90-95 grams. up to 35-40 gr. When reducing the weight of pieces of bitumen from 35-40 gr. to 15 20 gr., the time of dissolution of bitumen in heated white spirit decreased from 65 to 54 minutes. (11 minutes.). Thus, the optimal weight of the crushed pieces of bitumen is approximately 40-60 grams.

The rational sequence of heating and mixing of components in the preparation of the inhibited bituminous composition of MEB-4, is implemented by two technologies for the preparation of this composition:

The first technology.

The following components are placed in a container with a capacity of 1 liter: bitumen 125 gr. + fuel oil 200 gr. + Emulgin 25 gr. + diesel fuel 150 gr. The container with these components is heated by an electric stove, while periodically stirring the components every 0.5 hours. until complete dissolution of bitumen. The heating temperature was 105 □C. The composition of MEB-4 on the first technology, becomes fully prepared in 215 minutes (3.6 hours).

The second technology.

Diesel fuel (150 gr.) And bitumen (125 gr.) Are placed in the tank. These components were kept for 2 hours, then heated on an electric stove, stirring every 0.25 hours. The heating temperature is 103 ° C. Within 1.0 hour bitumen is dissolved in diesel fuel, then to the hot bituminous solution was added emulgin (25 gr.) and fuel oil (200 gr.). After that, the mixture was heated and stirred for 0.6 h to obtain a homogeneous mass of the composition of OIE-4. To prepare the composition of the second technology must spend 96 minutes (1.6 hours).

Figure 2 shows the results of the dissolution of bitumen in the preparation of different variants of bituminous compositions.

Rational order of realization of two-stage technological process of preparation of the inhibited bituminous structures containing fuel oil:

Stage 1 - heating bitumen in diesel fuel for dissolution;

Stage 2 - the use of additives emulgin and fuel oil M100 and subsequent heating and mixing with the resulting bituminous solution.

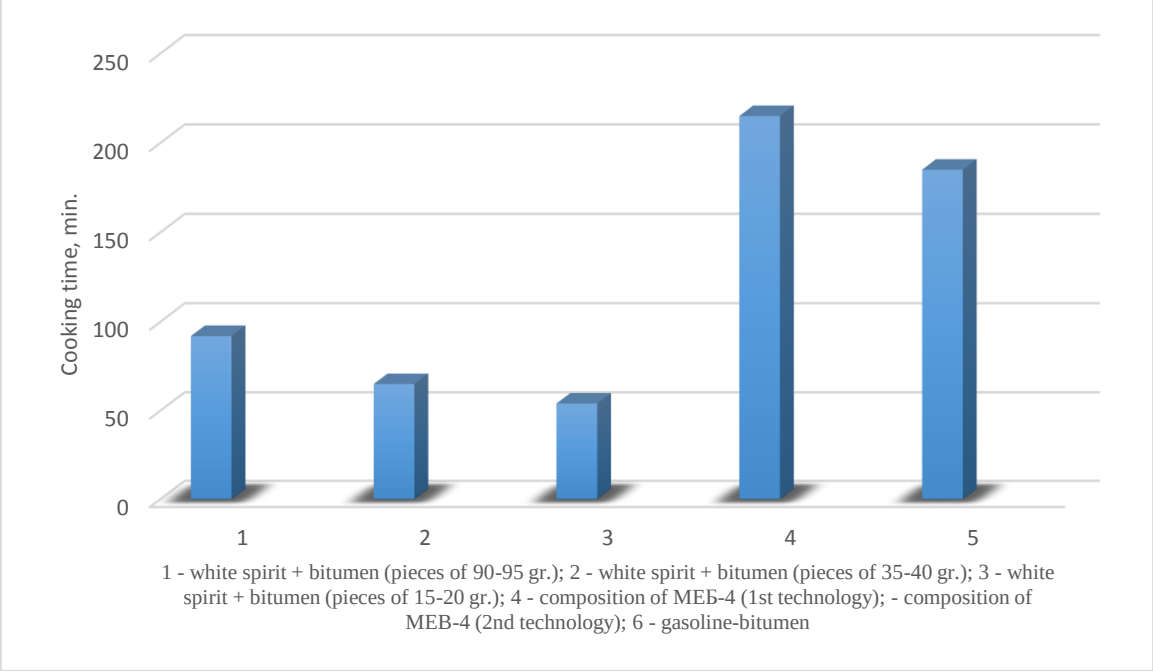



*Diagram 2 - Diagram of time spent on dissolving bitumen or preparation of bituminous mixture МЕБ-4.*

*Pneumatic spraying of the inhibited bituminous mix, change of density and viscosity.* In the inhibited bituminous mixture of МЕБ-4, 17% of the volume is gasoline. The mixture is diluted with gasoline to a viscosity of 32 with VZ-4 and has a density of 0.897 g / cm3 (kg / l) at a temperature of 18 ° C. The tank of the air spray gun was filled with this mixture and at a compressed air pressure of 0.4 MPa is sprayed into the aerosol. The bituminous composition was sprayed on the screen, where it settled in the liquid and flowed into the tray. After spraying, the temperature of the mixture in the tray was 15 $^0$C. After equalizing the temperature of the sprayed mixture to 18 $^0$C, its density was measured - 0.905 g / cm3 and the relative viscosity - 48 with VZ-4.

By means of pneumatic spraying of the inhibited bituminous mix its density increases by 0,9%, and conditional viscosity increases by 50%.

When spraying, the most volatile solvent evaporates - gasoline. Figure 4 shows the residual content of gasoline, according to the density of the mixture after spraying. This density is 0.905 g / cm3, the mixture has a content of 13.5 vol. % gasoline.

During the pneumatic spraying process, approximately 1/5 of the gasoline, the initial content of the МЕБ-4 mixture, evaporated.

**Conclusions**. Thus, with high-quality protection of agricultural machinery and its working bodies, from corrosion by applying preservative coatings, you can maintain their strength and reduce the cost of restoring serviceability to 8%. It was found that in order to achieve more effective preservation of agricultural machinery it is necessary to improve the formulations of bituminous mixtures based on available components, improve technologies and means of their production and application, reducing the cost of work up to 30%.

The main reason for poor protection of equipment is the lack of effective and inexpensive conservation materials. Used oils and gasoline-bitumen mixtures used for machine preservation have a low protective life.

They do not have inhibitors that inhibit the electrochemical corrosion of the metal, and components that increase the weather resistance of preservative coatings. Known technical means for the preparation of conservation compositions and for their application, do not meet the technology of preparation of agricultural machinery for storage and are not in demand. Therefore, the study of technological processes for the preparation of inhibited bituminous compositions and obtaining coatings with the best protective properties in the conditions of storage of machines in open areas, is relevant.

Resistance to atmospheric influences of bituminous compositions increases when they are suppressed by the additive emulgin (5-7%) containing aliphatic amines, and the introduction as a plasticizer of fuel oil M-100 (31-40%).

An improved formulation of the inhibited bituminous mixture МЕБ-4 containing bitumen (25%), M100 fuel oil (40%), emulgin additive (5%) and diesel fuel (30%) was analyzed.

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## ИСПОЛЬЗОВАНИЕ ЛАЗЕРНОГО СКАНЕРА ДЛЯ УПРОЩЕНИЯ В СОЗДАНИИ BIM МОДЕЛИ ОБЪЕКТА

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## USING A LASER SCANNER TO SIMPLIFY OBJECT BIM CREATION

***Аннотация:***
*В статье рассматривается необходимость использования лазерного сканера в строительной отрасли для упрощения построения BIM модели объекта, а также принцип их совместной работы для минимизации погрешностей и увеличения точности.*

***Abstract.***
*The article discusses the need to use a laser scanner in the construction industry to simplify the construction of a BIM model of an object, as well as the principle of their joint work to minimize errors and increase accuracy.*

***Ключевые слова:*** *лазерное сканирование, информационное моделирование и проектирование зданий, BIM-технологии, цифровизация, облако точек.*

***Keywords:*** *laser scanning, information modeling and building design, BIM technologies, digitalization, point cloud.*

В последние годы в России широко используется информационное моделирование в строительстве (BIM), представляющее процесс общего построения и использования информации о здании и сооружении [1]. Свою популярность BIM получил за счет удобства, а также возможности связать воедино все разделы проекта и исходя из данных, уже на этапе проектирования здания, выявлять какие-либо нестыковки между разделами. Благодаря чему, качество проекта улучшается, а само строительство становится экономичнее. Современные задачи, возникающие при проектировании, строительстве, эксплуатации зданий и сооружений требуют представления данных с максимальной точностью и минимизации погрешностей, возникающих при использовании традиционных методов и инструментов. С появлением и развитием технологии лазерного сканирования задача построения 3D цифровых моделей значительно упростилась [2].

Суть технологий трехмерного лазерного сканирования заключается в определении пространственных координат объекта X, Y, Z при помощи лазерного сканера, который в дальнейшем после обработки полученной информации формирует

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