FOREIGN TECHNOLOGY DIVISION

ALL UNION CONGRESS ON CHEMISTRY AND THE APPLICATION OF ADDITIVES TO LUBRICANTS AND FUELS

(Selected Articles)
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ALL UNION CONGRESS ON CHEMISTRY AND THE APPLICATION OF ADDITIVES TO LUBRICANTS AND FUELS

(Selected Articles)

English pages: 122


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(U) The purpose of this investigation was to improve the antifriction and corrosion inhibiting properties of automotive lubricating oils. The experiments involved nitration of mineral oils. On the basis of these experiments an oil additive AKOR-1, and technical production methods for this additive were developed. AKOR-1 improves the corrosion inhibiting properties of motor and transmission oils with respect to cast iron and nonferrous metals. AKOR-1 improves only the antirust and cleaning properties of oils, while the other properties of the oils remain the same. AKOR-1 added in 10 percent concentration to motor and lubricating oils successfully passed practical field tests in the internal combustion engines CD-9, 28D-6, 5/1, 5/6, and T1-220, and in trucks 02-51, ZIL157, and GAZ-2-194. Original, art. has: 2 formulas, 2 figures, and 6 tables.

(U) The performance of the D-57 fue oil in the 1100 engine, running on AS-6 lubricating oil with VNIIP 5-300 additive was tested in a fleet of 70 motor vehicles operating under various climatic conditions. The purpose of the study was to examine the lubricating properties of an oil refined according to standard 1551-69. The study involved visual examination of the oil and engine parts in order to assess the antifriction, antirust, and temperature properties of the lubricating oil. In addition, microscopic measurements were made to determine the oil's antiwear property and the chemical analysis of the used oil was performed for determining the oil's lubrication. The tests (500,000 kilometers) revealed that the oil with VNIIP 5-300 additive increased the wear resistance of the parts of the 1100 engine. Orig. art. has: 7 figures, 7 tables.
The performance of several batches of lubricating oil with various additives were tested in a new four-stroke diesel engine (YANZ-233NB) developed by the Yaroslavl Engine Plant (Yaroslavskoye motornoye zavod). The oil was evaluated at a standardized stationary engine run at different speeds (1500-1700) for various periods (5-10 min) under different loads. The results of the tests were found to be very inconclusive because of the variation in the properties of the base oil in various batches. However, the best performance in the YANZ-233NB engine was exhibited by Soric 1 oil supplemented with 5 percent VNIIP-370, 2 percent PACIA, 0.5 percent 12-14, and 0.005 percent FMS-200A additives. Orig. art. has: 6 figures, 3 tables.

Several additives (USSR, DP-11, FMS-200A) were examined for improvement of the characteristics of VNIIP-370 transmission oil for passenger cars. The tests were based on visual examination of the different parts of automobiles operating for various distances (up to 100,000 kilometers) under various load conditions and ambient temperatures (minus 60 degrees to plus 136 degrees). The best oil performance (2-3 times longer service) resulted from supplementing the VNIIP-370 transmission oil base with 4 percent of MSA, 2.2 percent DP-11, and 0.005 percent of FMS-200A additives. The presently marketed transmission oil (VNIIP-370) contains DP-11 additive (pentyl-aliphatic-amino alcohol) and its antiseal, antiwear, and anticorrosive properties are considered unsatisfactory. Orig. art. has: 4 figures, 1 table.
Several compositions of base lubricating oil with ash-free resinous additives (2B-5, DP-11, VR-18) and ash-containing additives (ES-II, KS-II, WII WP-260) were tested in a YKZ-236 diesel engine using a 150 hour test duration. The tests involved inspection of engine parts for the extent of wearout, examination of oil composition, and piston tolerance. In general, the additive containing oils showed superior performance as compared with the pure base oil. Orig. art. has: 4 figures, 4 tables.

A new testing unit for lubricating oils was developed for rapid (10 hour) evaluation of oil quality, and grade. The unit based on a one-cylinder Ulyanovets Model UD-1 air-cooled engine is described in detail. The method, called UD-10P, makes it possible to assess rapidly the composition of a given lubricating oil, to classify it according to the pressure, Heavy Duty, or Series 1 nomenclature, and to define optimum contents of various additives. Tables of recommended additive compositions were compiled from the test results. Oils of these compositions were then tested on a full-scale 1027 automobile engine. Orig. art. has: 5 tables.
A mineral lubricating oil testing unit (the UDM-6-NATI) is based on a one-cylinder engine and a modification of it (the UDM-6-NATI) are described in detail. A reliable, short (120 hr) testing procedure is described for rapid differentiation among the oils; heavy duty, series 1, and series 2. A large number of domestic and foreign oils of various qualities were examined on these units and the results of these examinations were found to agree well with the actual quality of the oils as well as with the results of the old-style 500-800 hr tests. Orig. art. has: 1 figure, 7 tables.

A new versatile method (cylinder temperature 170-190 degrees C, maximum temperature of base oil 180-200 degrees C, maximum temperature of additive-containing oil 230 degrees C) of testing lubricating oils is described. The method's reliability is assessed on the reproducibility of the solid matter within plus or minus 10 percent. The method is recommended for use in making up lubricating oils, for research purposes, and for setting industrial standards for lubricating oils. Orig. art. has: 2 figures, 2 tables.
lubricant additive, lubricant property, antioxidant additive, stabilizer, additive, filtration

antioxidant additive, lubricant, phenyl compound

(5) The samples of oils contg. additives made abroad and in the U.S.S.R. were prep'd in the lab., or in a pilot plant and the changes of their thermal oxidation, stability and of deterrent potential during storage were measured. After 31 months, all the samples with foreign additives retained their initial thermal stability and after 45 months, the stability was maintained in 90 percent of the samples. The deterrent potential did not change after 45 months except for premium and heavy duty oils with Ca additives where deterrent potential was reduced after 31 months. The samples prep'd in the lab. had better properties than oils prep'd in the pilot plant. The thermal oxidation, stability of oil contg. Soviet additives did not change in 18 months and after 32 months it was reduced from 65-85 min. to 9-20 min. The deterrent potential of heavy duty and Series I oils did not change after 32 months, while that of oils of Series 2 and Series 3 was lowered after 18 months to 20-55 units and after 32 months it was zero. The purity of oils and additives was characterized by the following method: 5 g. of oil or 1 g. of additive was diluted with 45 or 49 al. of gasoline and the dilution was filtered through a biol. filter no. 3 of dim. 27 mm. by using a vacuum of 20.50 mm. After every 5 min. of filtration, a new filter was installed.

(5) A study was made to determine the synergistic antioxidative effectiveness of pairs of compounds from beta-naphthole and phenyl-beta-naphthylamine compounds. The synergistic effect was established in laboratory tests with turbine oils containing pairs of additives (codex) from these two groups of compounds and excellent agreement was found with the results of the actual performance of the oils in turbines. The factors underlying the synergistic effect could not be established in this study. Orig. art. has: 3 figures, 1 table.
The effectiveness of disalicyldimethylethanediamine (deactivator), anthranilic acid (passivator), and phenyl-
beta-naphthylamine and 2,4-di-tertiary-butyli-4-methyl-
phenol (antioxidants) and their combinations in the stabiliza-
tion of transformer oils was studied under static labora-
tory conditions (44 hr oxidation with oxygen in the presence 
of copper and iron at 100 degrees C and 49 kilovolts per centi-
meter potential difference). Excellent stabilization of the 
transformer oils was achieved by compositions containing: 
0.05 wt percent anthranilic acid and 0.05-0.2 wt percent 
antioxidant additives. Orig. art. has: 3 figures, 1 table.

The applicability of the potentiometric titration method 
(up to 520 mV at pH equals 10) for determining the dete-
rination (alkalinity, metal content, ash content) of additive 
in oils and additive oils was investigated. It was found 
that all oil and all additive-deactivation indices could be 
determined by the potentiometric titration technique with an 
accuracy as high as 0.02-0.25 percent. The study revealed 
that imported oils with additives have higher phosphorus 
and zinc content than the corresponding domestic oils. In 
general, the potentiometric method was rated very useful and 
reliable. Orig. art. has: 7 figures, 3 tables.
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Inhibitors that effective inhibition additives can be obtained from nitratc oils that have been subjected to special treatment. Developing technology for production of these additives, it was first necessary to solve such problems as selection of the raw material for nitration and the nitration agent, as well as finding the optimum conditions for nitration and final treatment of the product. Two main reactions take place when mineral oils are nitratc:

nitrination proper

oxidation

where R are the alkyloaromatic and alkylbenzene-aromatic hydrocarbons of the oil.

Table 1. Physicochemical Properties of Nitrate Oil (Nitration with 60% Nitric Acid at 15-55°C for 4 h)

<table>
<thead>
<tr>
<th>Property</th>
<th>R 1</th>
<th>R 2</th>
<th>R 3</th>
<th>R 4</th>
<th>R 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density, g/cm³</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>Viscosity, cP</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>CET</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.04</td>
<td>0.05</td>
</tr>
</tbody>
</table>

KEY: (a) oxidizers; (b) nitrate salt; (c) spinels; (d) oxides; (e) nitrate; (f) amount of water; (g) amount of sodium nitrate; (h) molar ratio of nitric acid to oil; (i) neutralization; (j) phenolphthalein; (k) neutral; (l) dimethylbenzene blue; (m) viscosity at 100°C; (n) color; (o) nitrogen content; (p) combustion products.

Various oxygen-containing additives are obtained as a result of the oxidation reactions: asf, plasmids, ketenes, esters, etc., and they are capable of the following secondary reaction:

1. Condensation (polycondensation) extending to the formation of amorphous silicate.

\[ \text{FTIR H
\[ \text{IR H} \]
b) Nitration, since the oxygen-containing compounds of the oil nitrate considerably more readily than the initial oils (the latter are subject to nitration of previously oxidized oils).

The brown nitrogen-oxide NO, NO vapor evolved during the oxidation reaction in turn promote oxidation of the hydrocarbons. Thus the oxidation process of the oil may become autocatalytic if substantial amounts of nitrogen-oxide vapors are liberated.

It is known that polycyclic aromatic hydrocarbons with short side chains and tarry substances are oxidized preferentially in mineral oils, undergoing secondary condensation reactions with formation of asphalt-like products. For nitration, therefore, we selected oils from which these compounds had been removed by selective refining. Oils AS-0.5, BS-3 and BS-11 obtained from eastern petroleums gave the best results (Table 1).

The direction of the nitration process and its degree of conversion can be regulated by applying various nitration methods to the mineral oils.

The following oil-nitrating processes were examined:

1. Nitration with nitric acid at various concentrations (from 10 to 98%) with various acid-to-oil proportions. The optimum nitration formulas were found in each case: addition and standing lines for the acids, nitration temperature, etc. As the nitric acid concentration increases, the content of nitro compounds in the nitrated oil increases without any marked increase in the content of oxidized products. Nitration with weak acids inactivates the oxidation reaction.

2. Nitration with nitration mixtures or sodium nitrate or nitrite in the presence of sulfuric acid. These methods enable us to nitrate oils with formation of mononitrated compounds, minimizing the oil-oxidation reaction.

3. Nitration with catalysts. By the use of various catalysts, the nitration process can be controlled in the direction of nitration (sodium nitrite, acetic acid, zinc stearate) or in the direction of oxidation (mercury salts).

First, the combined nitration and oxidation products were extracted from the nitrated oils and then separated by a secondary gasoline extraction.

It was shown that the nitro compounds are those principally responsible for the high protective, detergent and other properties of the nitrated oils. The amount of nitrogen in them, determined by a specially developed method (a modified Kjeldahl method) [8], indicate that mononitrated compounds (nitrogen content 3.7-4.3%) are formed during nitration under normal conditions.

The nitro group is found attached to the benzyl ring (or, more rarely, to the napthenic one), for the most part at the para-position with respect to the alkyl radical.

Although they are less effective than the nitrocompounds, oxygen-containing products accompanying them in certain proportions—approximately 0.5%—form synergistic mixtures that exhibit the highest protective properties. In nitration, therefore, it is not desirable to produce only nitro compounds, for example, by nitration with anhydrous nitration mixtures.

AS-0.5 oil nitrated with 40% nitric acid at 5% concentration was chosen as the base for the oil and fuel corrosion-inhibiting additives. This oil contains 6-7% of nitro compounds and 4-5% of oxidation products.

After carrying out nitration and eliminating the spent nitric acid, the acidic nitrated oil (acid number 20 mg KOH/g) must be rendered alightly alkaline with some sort of neutralizing agent. Salts of sodium, calcium, and magnesium, and especially those of lead and aluminum, showed good protective, detergent, and dispersing properties [9].

Alkalinized nitrated oils show high ash contents and digestive alkalinity, which indicates not only the presence of salts of the type (NaCOO)Ca in the nitrated oil, but also that they contain a finely dispersed colloidal suspension of CaO+Ca(OH), and perhaps also CaO, stabilized by surface-active compounds.

Work was done to study the mechanism of action of the nitrated oils and the products based on them (W-204 and W-204a liquid lubricants and AKON-1 corrosion-inhibiting additive). It was established that nitrated oils and products based on them sharply reduce the permeability of the oil films to moisture and vapor [9] and reduce (at a certain concentration, to seep) the surface tension at the oil-water and water-adsorbed oil film interfaces.

They increase the wetting angle of an oil drop on water and reduce the wetting angle of a water drop on the oil's surface. This is particularly conspicuous with the AKON-1 additive, and for lead and aluminum salts of the nitrated oil, i.e., in the most effective corrosion inhibitors. The ability to displace water from the surface of the metal and block its passage through the hydrophobic adsorption films that form is of great practical importance, since it permits the use of nitration to serve wet surfaces, as well as in varnishes, primers, paints, watered fuels, etc.

Studies conducted in a special chamber by using electric current for external polarization of plates [1] indicated that sodium and calcium salts of nitrated oils showed distinctly the properties of oil-soluble anodic atmospheric-corrosion inhibitors, while the lead and aluminum salts are adsorbed on both the anodic and cathodic areas of the metal exposed to corrosion, and
the protection given these areas is of the screening type.

Two problems were faced in developing corrosion-inhibitor additives for the motor and transmission oils.

1. Development of a corrosion-inhibitor additive which, in addition to the base oils, will endow them with high protective properties without any deterioration of their motor properties.

2. Creation of a multifunctional corrosion-inhibiting additive that would, in addition to the base oils, endow them with high protective properties and simultaneously improve their wetting and anticorrosion properties.

The nitrated oils themselves or their salts (sodium, calcium, or aluminum) may be used as additives of the first type. Nitrate oil will also be taken as a base for creation of multifunctional additives of the second type. Moreover, acidic nitrate oils are alkalinized in the presence of special promoter additives to improve the detergent and dispersing properties of the additives.

Like the use of special technological devices (single fast evaporation of water, passage of carbon dioxide, etc.), the presence of promotor during alkalinization results in a sharp increase in the ash figure and alkalinity of the oil solution of the additive and, as a consequence, improvement of its wetting properties.

Producers that have been tested and are recommended by the authors include alkylphenois, arylamines, alcohols, synthetic fatty acids, hydroxyethylated products, and many other compounds.

After appropriate refinement, therefore, the following technology was adopted for production of AKR-1 additive: selectively nitrate and wash off 35-40% of 100% nitric acid, followed by addition of 10% stearic acid, the mixture is neutralized with 20% calcium oxide, heated to 200°C and filtered on oil mill water, and centrifuged. Two industrial batches of the additive were prepared by the above technology at a pilot plant at the "Neftegaz" refinery. The internal balance of this process is given below.

<table>
<thead>
<tr>
<th>Taken, $</th>
<th>Yield, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate oil</td>
<td>100</td>
</tr>
<tr>
<td>Volatile products</td>
<td>103</td>
</tr>
<tr>
<td>Spent nitric acid</td>
<td>30</td>
</tr>
<tr>
<td>Spent nitric acid (30%)</td>
<td>30</td>
</tr>
<tr>
<td>Spent nitric acid (100%)</td>
<td>3</td>
</tr>
<tr>
<td>Spent nitric acid (100%)</td>
<td>3</td>
</tr>
<tr>
<td>TOTAL</td>
<td>133</td>
</tr>
</tbody>
</table>

- Production of nitrate oil

Several laboratory batches of the AKR-1 additive were prepared substituting synthetic fatty acids for the stearic acid. It was established that the synthetic fatty acids combine well with the nitrate oil (Table 2) and that the resulting additives are highly effective (Table 3).

The configuration of the apparatus and the flow chart for AKR-1 production at the "Neftegaz" refinery are examined below.

Mineral oil (Fig. 1) and nitric acid are fed continuously into reactor 1. Heat is liberated as a result of the reaction and removed by cold water. The reaction mixture enters reactor 2, where the nitration reaction continues for another 2-3 hours. Then the mixture is directed into settling tanks 3 and 4. The spent acid drains by gravity into apparatus 5 and is reused for nitration. The acid-nitrified oil goes into apparatus 6, where it is mixed with molten stearin (or synthetic fatty acids [SFA] [CHN]) and neutralized with calcium oxide hydrate. The product is then degummed in the system connected with the heat exchanger 9 and column 10. The product flows from the bottom of column 10 into centrifuge 11, is heated in tank 12, and further purified on the ultracentrifuge 13, from which the final additive is run into the shipping containers.

Table 2. Physicochemical Properties of AKR-1 Additive Obtained using Synthetic Fatty Acids

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BOILOFF, °C</td>
<td>322</td>
<td>342</td>
<td>362</td>
<td>382</td>
<td>402</td>
<td>422</td>
<td>442</td>
<td>462</td>
<td>482</td>
<td>502</td>
<td>522</td>
</tr>
<tr>
<td>Sulphur, %</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Ash, %</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Other, %</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

KEY: (a) indicator; (b) synthetic fatty acids used; (c) broad fraction from Mendeleev plant; (d) C12 fraction from Lubekhiko combined; (e) C14-C16 fraction from Volgograd refinery; (f) C16-C18 fraction; (g) nat. 5; (h) total; (i) sulfate; (j) indicator alkalinity, m; of KM/Ag; (k) phenolphthalein; (l) bromphenol blue; (m) viscosity at 100°C, cent.

-6-
Fig. 1. AKOR-1 additive production flow: 1, 2) reactors; 3, 4) settling tanks; 5) apparatus for concentrating used nitric acid; 6) neutralizing mixer; 7) pump for delivery of product into heat exchanger; 8) circulating pump; 9) heat exchanger; 10) water-vaporizing column; 11) drop chamber; 12) centrifuge; 13) pump delivering product for final centrifuging; 14) intermediate pressure tank; 15) ultracentrifuge; 16) nitric-acid metering system.

Lines: 1) mineral oil; 2) 60% nitric acid; 3) oxygen-oleum emulsion; 4) spent acid; 5) 98% nitric acid; 6) nitric oil to neutralizing mixer; 7) molten steel or SPA; 8) milk of lime; 9) water product; 10) dried product for centrifuging; 11, 12) product to final centrifuging; 13, 14) AKOR-1 additive; 15) cold water; 16) hot water; 17) vapor; 18, 19) dried circulating product; 20) final product; 21) 60% nitric acid separated from spent acid; 22) nitric-acid drainage.

The AKOR-1 protective additive produced by the described method has a comparatively high ash content (5-10%). We succeeded in reducing the ash content in the additive by lowering the calcium oxide hydrate concentration from 20 to 5%. Use of mixtures of calcium and sodium oxide hydrates in various proportions, or sodium oxide hydrate alone, to neutralize the acidic nitric oil gave similar results. As Table 3 shows, AKOR-1 additive produced with SPA and sodium oxide hydrate shows lower ash content and 100°C viscosity level while retaining effective anticorrosion properties.

The laboratory studies also made it possible to establish that the viscosity of AKOR-1 additive can be lowered markedly and its purity increased if the final stage of purification in production is carried out in a gasoline solution. This complicates the technology slightly, since it is necessary to have
The protective properties of motor and transmission oils containing AKOR-1 additive in various concentrations were studied under laboratory conditions. For this purpose, metal plates - steel, cast iron, bronze, brass, copper, lead and other non-corrosive metals - were coated with thin films of oil containing the additive and placed in water in humidity chambers, or in chambers containing corrosive environments. In all cases, corrosion appeared on the plates much later than when the plates were protected with oils not containing additives [3, 10]. By way of example, Fig. 2 shows generalized time curves of the corrosion damage to steel plates in a heat-and-humidity chamber. When they were protected with commercial oils, the damage curve rises sharply, and plates coated with oils having better protective properties are completely corroded in no more than 10 days. The difference in the protective properties of the oils before and after the addition of the various functional additives is illustrated by the width of the shaded region in Fig. 2. The increase in the area of the corrosion centers after addition of 10% of AKOR-1 additive to the oils is much slower, and no more than 25% of the plate area has been corroded after storage for two months in the chamber.

Fig. 2. Curves of time increase of corrosion damage to steel plate surface (6-4 heat and humidity chamber, 7 h at 25°C, 17 h at 20°C, humidity 100%, plate material St 3). 1 Commercial oils; 2 commercial oils + 1% AKOR-1.

KEY: (a) area of plate damaged by corrosion, %; (b) holding time in heat- and-humidity chamber, days.
Table 4. Evaluation of Protective Properties of Oils in Exhaust-Gas Chamber (10 min at 500°C, 2 h at 200°C)

<table>
<thead>
<tr>
<th>Oil Type</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>g</th>
<th>h</th>
<th>i</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MCO-14</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>2 MCO-14 + 50% AKOR-1</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>3 MT-14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>4 MT-14 + 50% AKOR-1</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>25</td>
<td>26</td>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td>5 MT-14 + 10% AKOR-1</td>
<td>29</td>
<td>30</td>
<td>31</td>
<td>32</td>
<td>33</td>
<td>34</td>
<td>35</td>
</tr>
</tbody>
</table>

KEY: (a) oil; (b) condition of nonferrous-metal plates after testing; (c) bronze; (d) surface condition; (e) amount of surface affected by corrosion; (f) brass; (g) aluminum; (h) DS-811; (i) brown deposit; (j) reddish-brown point foci; (k) moderate darkening of entire surface; (l) DS-811 + 10% AKOR-1; (m) no changes; (n) point foci barely discernible; (o) dark brown point foci; (p) dark point foci; (q) MT-14 + 10% AKOR-1; (r) MT-16p; (s) minute dark point foci; (t) MT-16p + 10% AKOR-1.

Table 4 presents certain data characterizing the protective properties of oils with the AKOR-1 additive for nonferrous metals.

The high protective properties of oils containing AKOR-1 additive have been confirmed by the results of storing automotive engines and transmissions on an outdoor platform (Table 5).

Certain physicochemical and operational properties of the oils undergo changes after introduction of AKOR-1 (Table 6).

Thus, the viscosity level of the oil at 100°C rises slightly and ash content increases. The detergent and anticorrosion properties of the oil are improved substantially. The protective additive has no noticeable detrimental effect on the quality indicators of the motor oils and transmission lubes.

Table 5. Surface Condition of Parts, Subassemblies and Units Prepared for Preservation with the Use of Various Commercial Oils with AKOR-1 Additive

<table>
<thead>
<tr>
<th>Oil Type</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
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</thead>
<tbody>
<tr>
<td>MCO-14</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>MCO-14 + 50% AKOR-1</td>
<td>6</td>
<td>7</td>
<td>8</td>
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<td>10</td>
</tr>
<tr>
<td>MT-14</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>MT-14 + 50% AKOR-1</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>MT-14 + 10% AKOR-1</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>25</td>
</tr>
</tbody>
</table>

KEY: (a) type designation and No. of machine; listing of preserved surfaces, units and assemblies; (b) oil; (c) storage time and condition of surfaces; (d) condition of oil film; presence of deposits and water; (e) highly finished surfaces of engine cylinders. [Key continued on page 11]
Table 6. Physicochemical and Operational Properties of DS-11 Oil with 10% of AKOR-1 Additive

<table>
<thead>
<tr>
<th>Property</th>
<th>Drop Point, °C</th>
<th>Flash Point, °C</th>
<th>Viscosity, CST</th>
<th>Viscosity Index</th>
<th>Sump Filterability, %</th>
<th>Emission of EPN, ppm</th>
<th>Lubricating Properties</th>
<th>Viscosity Index</th>
<th>Viscosity Index</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

Key: (a) indicator; (b) oil without additive; (c) additive; (d) nitrated DS-8 + 10% stearin + 10% Ca(OH)2; (e) nitrated DS-8 + 10% stearin + 5% Ca(OH)2; (f) nitrated DS-8 + 10% stearin + 2% NaOH; (g) nitrated DS-8 + 10% stearin + 2% NaOH; (h) nitrated DS-8 + 10% stearin + 2% NaOH; (i) nitrated DS-8 + 10% stearin + 2% NaOH; (j) viscosity, CST; (k) at; (l) sn; (m) flash point; (n) pour point; (p) thermal-oxidation stability; (q) potential detergency; $; [key cont'd. on page 14]

[Key to Table 6, cont'd.] (r) Detergent power on PZ machine, points; (s) carbon scaling at 200°C; (t) antirust properties on PZ machine at 200°C (lead).

The running properties of motor oils with the AKOR-1 additive were checked during bench tests on DD-9 (a single-cylinder forced diesel), GAZ-69, YAaZ-3, and NAM-37 engines and use tests in GAZ-51, ZIL-157, and KRAZ-214 motor vehicles. It was reported in all cases that the engine parts remained cleaner and showed practically unchanged wear after addition of AKOR-1.

CONCLUSIONS

1. AKOR-1 protective additive was prepared from nitrated oils that had been treated with stearic or calcium oxide hydrates or mixtures thereof in the presence of stearic acid, SPA, and other compounds.

2. A flow chart for production of the additive was worked out and used.

3. AKOR-1 additive effectively improves the ability of commercial motor oils and transmission fluids to protect steel, cast-iron, and nonferrous-metal parts from rusting.

4. The detergent and antirust properties of oils with AKOR-1 additive are superior to those of oils without this additive, and other properties show virtually no differences.

5. In pure form or diluted with light oil, AKOR-1 additive can be used on a par with liquid preservative oils for internal preservation of mechanisms.

6. AKOR-1 additive, added to motor oils and transmission fluids in a concentration of 10%, has successfully passed the tests:

a) for protective properties when used to preserve engines and motor-vehicle transmission assemblies during storage or an open-air platform for more than 20 months;

b) for operational properties in bench tests on DD-9, 20V-B/30/11, GAZ-69 and YAaZ-386 engines and use tests in GAZ-51, ZIL-157, and KRAZ-214 motor vehicles.

References


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OPERATING EXPERIENCE WITH ZIL-130 ENGINES USING AS-8 OIL WITH VNIIE NP-360 ADDITIVE

O.S. Obleukhova, V.V. Protasov, T.T. Kiseleva, and O.V. Burtseva

DD-8 oil with VNIIE NP-360 additive [VNIIE NP: All-Union Scientific Research Institute of Oil and Gas Refining and Production of Synthetic Liquid Fuels], which had been recommended after long-term (500-hour) bench tests for V-type carbureted truck engines, was taken for extended road-use tests. Since 1964, this oil has been produced according to GOST 60541-63 under the type designation AS-8.

The tests were conducted with 70 vehicles in various climatic zones of the country (Crimea, Stavropol', Orel, Pskov) on a year-round basis, on hard-paved mountain and flatlands highways. Vehicles of the Crimea fleet were tested under routine operating conditions on the Yalta-Stavropol' and Yalta-Svetlyapol' routes. The vehicles of the other fleets were run under routine operating conditions for 10-30% of the total mileage, and used for the remaining time in tire tests. The conditions of use are given in Table 1. A-76 gasoline was used in all fleets during the tests.

Plans called for replacing piston rings during the tests when oil burnoff had reached 0.8 liter/100 km and the bearing inserts when the oil pressure in the system had dropped to 1.9 kg/cm² at 1000 rev/min.

At the end of the tests, when the vehicles had accumulated 183,213 thousand km, these oil-consumption and pressure limits
Table 1. Vehicle Operating Conditions

<table>
<thead>
<tr>
<th>x</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
<th>i</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14</td>
<td>27</td>
<td>30</td>
<td>40</td>
<td>40</td>
<td>50</td>
<td>55</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>B</td>
<td>14</td>
<td>27</td>
<td>30</td>
<td>40</td>
<td>40</td>
<td>50</td>
<td>55</td>
<td>55</td>
<td>60</td>
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<tr>
<td>C</td>
<td>14</td>
<td>27</td>
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<td>40</td>
<td>40</td>
<td>50</td>
<td>55</td>
<td>55</td>
<td>60</td>
</tr>
</tbody>
</table>

Note: Servicing intervals: T0-1 every 1500-2000 km; T0-3 every 5000-6000 km [T= Technical maintenance].

KEY: (a) fleet; (b) number of vehicles; (c) road characteristics; (d) length, km; (e) concrete, ; (f) asphalt, ; (g) gravel, 1; (h) load, tons; (i) speed, km/h; (j) technical average; (k) top; (l) average daily mileage, km; (m) convoy No. 1201, Stavropol; (n) 55-65 (on asphalt), 80-90 (on mountain and gravel roads); (o) convoy No. 1120, Pskov; (p) 51 (on asphalt), 80 (on gravel); (q) convoy number 1141, Orel; (r) 57-65 (on asphalt). had not been reached. However, the bearing inserts of almost all vehicles were replaced after 100-150 thousand km in order to prolong crankshaft life.

Piston rings were replaced at mileages of less than 150 thousand km with only 1 engine of the Stavropol 1 fleet, in order to ensure full performance for the tire tests.

The following work was done at the end of the tests to rate the use properties of the oil:

a) visual inspection of engine parts to determine the detergent, antioxidant, antiwear and low-temperature properties of the oil;

b) micrometer measurements on engine parts to determine antiwear properties;

c) analysis of the used oil, to permit determination of quality changes during use and adjustment of the recommended oil-change intervals.

TEST RESULTS

Condition of engines. It was established by visual inspection to determine engine condition that AS-8 oil with VNII NP-350 additive has satisfactory detergent properties. Variants on the cooled areas of the pistons came to 5-6 points on the PCV scale. The rest of the piston-skirt surface was coated with varnish ranging in color from yellow to dark reddish brown. No burning of the rings was observed on any of the engines inspected, and the combustion-chamber carbon deposits were insignificant. The antiwear properties of the oil were evaluated from the surface condition of the bearings and inserts. There were no traces of corrosion damage on any of the inserts inspected, which indicates that the oil has satisfactory antiwear properties.

The small amounts of car on the engine parts and the insignificantly amounts of low-temperature deposits (sludge) that were formed indicate that AS-8 oil has fully satisfactory antioxidant and low-temperature properties.

A highly important advantage of the VNII NP-350 additive established during the tests is that it shows little tendency to form barium-sulfide deposits on the engine’s exhaust valves.

Engine wear. The antwear properties of AS-8 oil with VNII NP-350 additive were determined by micrometer measurements on parts of 24 engines after 57-213 thousand kilometers.

Cylinder-sleeve wear after accumulation of up to 800 thousand km did not exceed 0.1 mm for most of the engines; hence the average wear rate was 0.7 m/100 km, or considerably lower than in the ZIL-110 engine, which has a chromium-plated upper compression ring and whose cylinder sleeves wear at 4.5 m/100 km.

During the tests, the cylinder sleeves of the ZIL-110 engines showed comparatively little wear over their entire length (Fig. 1), an observation that can be explained by the favorable running conditions (long distance without stopping, high speed, good roads), by the use of a M1-12 insert in the top of the sleeve, and by the good antiwear properties of the oil.
The effectiveness of using engine oils with high-quality multifunctional additives has also been affirmed by foreign investigators.

Thus, K. English (1) reports that when an engine was run on HD oil (which corresponds to AS-8 oil with the VNM NP-360 additive) at a coolant temperature of 80°C, sleeve and piston-ring wear is reduced by a factor of approximately 5 by comparison with the wear observed when the engine is run on plain oil (without additives).

Piston-ring-wear data for 11 engines are given below.

<table>
<thead>
<tr>
<th>Engine mileage</th>
<th>Wear</th>
<th>%/over total</th>
<th>(per 10 mileage)</th>
<th>thousand km</th>
</tr>
</thead>
<tbody>
<tr>
<td>57-89</td>
<td>0.022-0.020</td>
<td>0.5-2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>108-147</td>
<td>0.020-0.128</td>
<td>1.2-8.8</td>
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<td></td>
</tr>
<tr>
<td>150-213</td>
<td>0.021-0.100</td>
<td>1.6-8.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Crankshaft wear was determined on the connecting-rod journals for 24 engines and on the main-bearing journals for 12 engines. The connecting-rod journals were measured with the engines partly and completely dismantled, and the main bearings only after full disassembly. The results of the micrometer measurements are given in Table 2.

<table>
<thead>
<tr>
<th>Engine</th>
<th>a</th>
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</tr>
<tr>
<td>1/2</td>
<td>0.000</td>
<td>0.00</td>
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<td>0.00</td>
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<td>0.001</td>
</tr>
</tbody>
</table>

KEY: (a) mileage, km; (b) journal wear, mm; (c) main bearing; (d) minimum; (e) maximum; (f) average; (h) connecting-rod bearing; (l) less than.

The wear of the connecting-rod bearing inserts at a vehicle mileage of 15 thousand km averaged 0.0055 mm, and the main-bearing insert wear 0.008 mm.

Over the indicated vehicle mileage, the average clearance between the crankshaft connecting-rod journal and the inserts with the connecting-rod assembly came to 0.073 mm, and 0.075 mm for the main bearings (the acceptable clearances for new engines are 0.026-0.065 mm).

The wear of other engine parts (connecting rod, camshaft, valves, rockers, lifters, etc.) was insignificant, and it was unnecessary to replace these parts before 200 thousand km.

Oil consumption. As we know, oil consumption depends on a number of factors. K. Dzhordzh [2] notes the following basic causes of increased oil consumption:

a) mechanical trouble - wear of piston-ring grooves and damage to the piston skirt; ring wear, loss of ring resilience, seating of rings in grooves too tight or too loose; burning of the compression rings or plugging of slots in oil-control rings; wear, scoring or scratching of the honed cylinder surface, etc.;

b) operating conditions - high oil level, dilution of oil with fuel due to carburetor adjustment or low temperature in the engine's cooling system; riding speed;

c) oil quality - volatility, viscosity index, etc.

The above indicates how difficult it is to establish operating oil-consumption norms.

In these tests, oil consumption was recorded on the basis of the amounts drained at changes and the amounts added to replace burnoff during use.

The oil-burning rate changed insignificantly as a function of engine mileage. Thus, the average oil-burning rate was 0.3 liter/100 thousand km up to 50 thousand km and 0.4 liter/100 km to 100 thousand km. For mileages up to 150 thousand km, oil consumption came to 0.35 liter/100 km, which is probably to be explained by piston-ring changes on some of the engines. The average consumption rate rose again to 0.4 liter/100 km as the vehicles accumulated 200 thousand km.

Control trips were taken periodically in all fleets to verify and adjust the specific oil-burnoff figures. Figure 2 shows average oil-burnoff values from control trips with nine vehicles that had accumulated 150-180 thousand kilometers. It follows from these data that as vehicle speed is increased from 45 to 75 km/h, the oil burnoff rate increases by a factor of 2, and by a factor of 4 when the speed is increased from 45 to 95 km/h.

The average oil-consumption figures indicated above are confirmed quite accurately by the data obtained in the control trips.

Table 3 presents over-all operating fuel- and oil-consumption figures. On the basis of these results, taking into consideration that normal vehicle operating conditions are different (short-haul runs, city traffic, extended on full-time traffic hauling, less highly qualified servicing), and the
consequent higher consumption, we would recommend lowering the oil-consumption norms for the Zil-130 engine to 2.5% of the amount of gasoline from 3.5%, which is the value presently in force for carburetor engines.

Change in quality of oil and the oil-change interval. To establish rational oil-change intervals, oil specimens were taken for analysis during the tests. The analytical results showed that when the oil is changed at least 6000 km, its 20°C viscosity has increased to 87 cSt (vs. 42 for fresh oil). In some cases, fuel leakage into the crankcase during winter lowers the viscosity to 35 cSt.

While the fresh oil contains no organic acids, its acid number rises to 0.44 mg of KOH/g. The total mechanical-impurity content rises to 0.55%. This comparatively low figure indicates effectiveness of oil cleaning by the centrifugal final filter. The inorganic part of total impurities does not exceed 0.2%.

Analysis to determine the additive content in the oil indicated that the barium content had dropped by 35-40% and the copper content by an average of 50%.

Thus, AS-8 oil with VMII MP-380 additive exhibits adequate antwear, antioxidant and other operational properties and ensures dependable operation of Zil-130 engines with the specified oil-change interval (every 4-8 thousand km) depending on operating conditions.

The results obtained on aging of the oil in the engines at long (up to 200 thousand km) mileage confirm the correctness of the recommended oil-change interval.

Conclusions

1. AS-8 oil with VMII MP-380 additive, produced according to GOST 10541-63, has operational indicators that meet the requirements of a heavily loaded high-speed Zil-130 engine.

2. In operation on AS-8 oil with additives, the engines of Zil-130 engines show satisfactory wearability after up to 200 thousand km.

3. The oil-consumption norms for Zil-130 engines can be lowered to 2.5% (on the fuel).

References


TEST RESULTS FOR OILS WITH ADDITIVES USED
IN THE YMK-238HR ENGINE

N.I. Sigal, Ye.P. Shlikov, V.M. Yefremov, G.M. Gusev,
G.P. Belyanchikov, I.A. Traktovenko, I.A. Khokonov
and N.V. Terskikh

The Yaroslavl Engine Works has developed and put into produc-
tion a new series of V-type, four-stroke diesels with outputs
ranging from 180 to 520 hp, including supercharged versions.
Use of the four-stroke cycle with compression ignition has made
it possible to produce inexpensive engines with high wear resis-
tance of their parts and good starting. The V-type cylinder
arrangement is used as the basis for the small, compact power-
plants. The engine designs provide for maximum interchange-
ability of parts and subassemblies. It was noted in elaboration
of the designs and testing of the new engines on diesel
oil with T8ATM-339 [T8ATM: Central Scientific Research In-
tstitute of Aviation Fuels and Lubricants] that this oil does not
meet their requirements. It was therefore necessary to find
oils for the four-stroke diesels, and especially for the super-
charged models used in the K-700 tractors. Although satisfac-
tory results had been obtained in preliminary tests of oil with
the VMII NP-360 additive in the YMK-238 engine [YMK: Yaroslavl
Engine Works], further experience in the operation of K-700
tractors with YMK-238HR engines showed that this oil does not
ensure stable operation of the piston group.

An extensive battery of tests was carried out with the YMK-
238HR engine (a four-stroke V-type eight-cylinder diesel with
direct fuel injection) in order to establish quality require-
ments for the oils and select additives for the YMK engines

with consideration of the distinctive operating conditions of
tractor diesels and the application of supercharging. The
technical data of the engine are given below.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>GOST designation</td>
<td>8484-61</td>
</tr>
<tr>
<td>Effective power $N_e$, hp</td>
<td>218</td>
</tr>
<tr>
<td>Crankshaft speed $n$, rev/min</td>
<td>1700</td>
</tr>
<tr>
<td>Cylinder bore, D, mm</td>
<td>110</td>
</tr>
<tr>
<td>Stroke $S$, mm</td>
<td>140</td>
</tr>
<tr>
<td>Number of cylinders $i$</td>
<td>8</td>
</tr>
<tr>
<td>Average effective pressure $p_e$, kg/cm²</td>
<td>7.5</td>
</tr>
<tr>
<td>Average piston speed $v_p$, m/s</td>
<td>7.95</td>
</tr>
<tr>
<td>Displacement $V$, liters</td>
<td>18.86</td>
</tr>
<tr>
<td>Fuel consumption $G_f$, g/(ehp)</td>
<td>170</td>
</tr>
<tr>
<td>Oil capacity $V$, liters</td>
<td>32</td>
</tr>
<tr>
<td>Oil consumption, % on fuel, not above 2</td>
<td></td>
</tr>
</tbody>
</table>

The bench tests of the oils consisted of two stages: 240-
hour short tests without changing the oil for preliminary evalua-
tion and 800-hour extended tests with an oil change after 120 h.

The conditions of each test according to GOST 891-55 are
given below.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft speed, rev/min</td>
<td>1700</td>
</tr>
<tr>
<td>Load, hp</td>
<td>none</td>
</tr>
<tr>
<td>Time, min</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

The indicators taken for evaluation were: quantity of de-
posits on piston-group parts, freedom of piston rings, piston-
ring wear (based on weight loss), state of exhaust-valve seating
surfaces, extent of clogging of centrifuge rotor chamber (MWTs
reaction type oil centrifuge), and the changes in the physico-
chemical properties of the oil, especially alkalinity. The de-
gree of piston-group fouling was also determined by the point
system.

Diesel fuel containing 1% sulfur was used in all tests.
The base oil was ES-11. A list of the oils given short-term
tests and the principal results are given in Table 1.

We may conclude from the data of Table 1 that all of the
experimental additive oils ensure good piston-ring mobility, but
differ substantially as regards their detergent and dispersing
properties.

The poorest results as regards piston-group and centrifuge-
rotor deposits were obtained in the tests of oil with 6 and 8% of
VMII NP-360 additive.

Series 1 oils with the domestic additives ensure satis-
factory cleanliness of the engine parts and appear to be sub-
stantially superior to VMII NP-360 additive.
Table 1. Results of Short-Term Oil Tests

| Test | Percentage | Ash | Volatile | Ash+Volatile | Combined | Oil 
|---|---|---|---|---|---|---
| | | | | | | 
| 1. NNI + 0.25% Carbenol-425 | | | | | | 
| 2. NNI + 0.25% Carbenol-425 | | | | | | 
| 3. NNI + 0.25% Carbenol-425 | | | | | | 
| 4. NNI + 0.25% Carbenol-425 | | | | | | 
| 5. NNI + 0.25% Carbenol-425 | | | | | | 
| 6. NNI + 0.25% Carbenol-425 | | | | | | 
| 7. NNI + 0.25% Carbenol-425 | | | | | | 
| 8. NNI + 0.25% Carbenol-425 | | | | | | 
| 9. NNI + 0.25% Carbenol-425 | | | | | | 
| 10. NNI + 0.25% Carbenol-425 | | | | | | 

#Chromium-plated rings.

K/ (%) products; (a) type designation of oil; (b) time of test; (c) ash content of oil; (d) over-all scaling on piston, points; (e) amount of deposit on piston and rings; (f) wear of top ring; (g) deposits in needle valve test period; (h) deposits in needle valve test period; (i) deposits in needle valve test period; (j) deposits in needle valve test period; (k) deposits in needle valve test period; (l) deposits in needle valve test period; (m) deposits in needle valve test period; (n) deposits in needle valve test period; (o) deposits in needle valve test period; (p) deposits in needle valve test period; (q) deposits in needle valve test period; (r) deposits in needle valve test period; (s) deposits in needle valve test period; (t) deposits in needle valve test period; (u) deposits in needle valve test period; (v) deposits in needle valve test period; (w) deposits in needle valve test period; (x) deposits in needle valve test period; (y) deposits in needle valve test period; (z) deposits in needle valve test period.

Series 2 oils with Monsanto additives, 11% VNI 370, and other additives are no better than the Series 1 oils as regards formation of scale and tarnish on the piston group and the amounts of ash deposits in the combustion chamber (exhaust valves, piston heads). The smallest amounts of deposits were observed for operation on low-ash series 2 oils with ASK and MASK additives and with the imported Hinuma oil, and the piston-group components were cleaner by factors of 1.5-2 than after running on Series 1 oils. Ring wear was slight during the test period and practically the same for the various samples, except for the oils with ASK and MASK additives, which permitted increased wear of the first compression ring.

Oils that had produced encouraging results in the short-term tests were given long-term tests, along with oils containing 0 and 5% of the VNI 370 additive, which are currently recommended for K-700 tractor engines.

Table 2 presents piston-group fouling ratings from the 900-hour tests; they confirmed the results of the short tests in indicating unsatisfactory detergent properties for oils with 1% and 5% of VNI 360 additive.

As we see from Table 2, increasing the additive concentration from 0 to 5% does not reduce the amount of scale formed, as indicated by the approximately identical over-all scaling ratings — 59 and 57 points, respectively, in the long-term tests and 39 and 37.5 points for the short tests. It was also noted that the top oil-control rings were less mobile and that the amount of deposits in the ring grooves and on the piston skirts was larger.

It was established in 800-hour tests on oils with VNI 370 additive that the drainage holes in the pistons and the
lots of the oil-control rings were 60-70% filled with carbon deposits, which might interfere with normal operation of the piston group if the engines were run any further. Also noted in operation on these oils was considerable fouling of the engine crankcase, clogging of the centrifuge rotor and the sections of the course filter. Table 3 gives the results of the long-term tests.

<table>
<thead>
<tr>
<th>Oil Type</th>
<th>Test Time, Hours</th>
<th>First Piston Groove</th>
<th>Sleeve</th>
<th>6% VNIIF 360</th>
<th>6% VNIIF 370</th>
</tr>
</thead>
<tbody>
<tr>
<td>J 5% VNIIF 360</td>
<td>800</td>
<td>0.42</td>
<td>0.66</td>
<td>0.38</td>
<td>0.22</td>
</tr>
<tr>
<td>5% VNIIF 360</td>
<td>800</td>
<td>0.42</td>
<td>0.66</td>
<td>0.38</td>
<td>0.22</td>
</tr>
<tr>
<td>5% VNIIF 370</td>
<td>800</td>
<td>0.42</td>
<td>0.66</td>
<td>0.38</td>
<td>0.22</td>
</tr>
<tr>
<td>5% VNIIF 370</td>
<td>800</td>
<td>0.42</td>
<td>0.66</td>
<td>0.38</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Table 3. Wear of Parts After Long-Term Tests

*Oil change interval 240 hours.

**KEY:** (a) type designation of oil; (b) test time, hours; (c) weight loss; (d) first ring; (e) set of rings; (f) wear, μ; (g) first ring, height dimensions; (h) first piston groove; (i) sleeve; (j) 6% VNIIF 360; (k) TsATIM-339 + PMSYa.

Satisfactory results were obtained from tests of Series 1 oils with 5% of VNIIF 370 and with the TsATIM-339 and PMSYa additives.

In 800-hour tests, oils with 5% VNIIF 370 preserved full piston-ring mobility and moderate piston-group point ratings; the drainage holes were practically clean and there were only small deposits in the centrifuge. The test time for this oil was increased to 2000 and then to 3000 h for the same engine, with the parts checked for cleanliness and then cleaned after each test stage. With increasing engine running time, we note some increase in the fouling of parts as the piston group wears. Then 800-hour tests were conducted with a 240-hour oil-change interval, with the result that scaling on the piston group increased to 19 points, while the amount of sludge increased from 1.8 to 12.9 g. Even in this case, however, the parts were cleaner than after operation on oil with VNIIF 360 additive.

Oil with 6 and 8% of the VNIIF 360 additive indicated superior antwear properties in the long-term tests. Some increase in the wear figures was noted after operation on oil with the additive TsATIM-339 + PMSYa (see Table 3).

Oil quality (apart from detergent and antiwear properties) was also evaluated from the chamfer-surface condition of the exhaust valves, which were made from EI-69 steel (both without facing of the chamfer and with a V2A-alloy facing). It was found after the tests that the built-up valve chamfers were in better condition than the unfaced chamfers for all of the oils.

It should be noted that formation of a glasslike film on the valves (both faced and unfaced types) had been noted previously in a number of cases. The gas is usually pulled into cracks and pits in this film, occasionally burning valves.

This glasslike film on the valves was not observed in our tests of oil with VNIIF 360 additive.

The problem of glass-film formation on the exhaust-valve chamfers in operation on oils with certain additives requires special study.

Particular attention was devoted to the change in the oil's neutralizing properties in analyzing the oils during these tests.
For this purpose, the alkalinity of the crankcase oil was determined during the testing process. The figure shows the analytical results. Alkalinity drops off most sharply in the oil with 5% of VNI NP-360. With this specimen, strong acids were detected even after 60 hours of operation, and their content subsequently increased. Increasing the additive concentration to 8% had little influence on the neutralizing-property change.

Oil with 5% of the additive VNI NP-370 has the largest alkalinity reserve. Oil with the combined additive TIAITM-37 + PMSYa has almost the same alkalinity. The alkaline properties are retained in these oils until they are drained; in other oils of Series 1, high acidity is found after as little as 100 hours of operation. Series 2 oils retained their alkaline properties to the end of the test.

The figure shows that the alkalinity of the oil drops most rapidly during the first few hours of operation and that this drop is more abrupt in the oils with the VNI NP-360 and BFK + + Sh-1 additives. Oil alkalinity then stabilizes as a result of addition of fresh oil and filtering out of the oxidation products. The data plotted in the figure are in good agreement with the results of engine-parts inspection after the tests.

**Conclusions**

1. It was established by the tests that the best oil for the T64-278N engine in the Series 1 oil with 5% VNI NP-370, 2% PMSYa, 0.1% L2-23k and 0.005% FMS-200A. This oil was recommended for field testing.

2. Oil with the TIAITM-37 + PMSYa additive, whose properties resemble those of the Series 1 oils, is also recommended for use testing.

3. Rather heavy deposits are formed on the piston group, in the centrifuge rotor, and in the engine crankcase when the engine is run on oil with the VNI NP-360 additive; this additive does not meet the requirements for dependable operation of the engine on sulfur-containing fuels.

4. Operating experience and the data indicate that different batches of oil with the VNI NP-370 additive differ in quality. The physicochemical indices stated on the label do not give a complete picture of the motor properties of the oil. It is therefore necessary to formulate and introduce into the GST quick oil-property motor-rating methods, so that the refineries will be able to indicate their results on the tags accompanying the oil.

**EFFECTIVENESS OF USING ADDITIVES IN HYDRAULIC-COUPLING OILS FOR PASSENGER AUTOMOBILES**

G.S. Obieukhova and V.M. Kryuchashnikova

The operating conditions of the oil used in motor-vehicle hydraulic transmissions - automatic transmissions and torque converters, power-steering gear, etc. – are characterized by: a wide temperature range (from -60°C for vehicles used in the northern regions to +110°C; high specific pressures; small clearances (especially in automatic transmission control); by the presence of parts containing substantial amounts of copper (up to 60% in sintered brakebands); by contact with rubber gaskets and hoses.

None of the mineral oils can guarantee dependable long-term service from these units, since these oils cause increased wear and formation of deposits that interfere with operation of the automatic controls and other assemblies.

VNI NP-1 oil, which is made by using polyisobutylene to thicken a light deep-refined and deparaffinized oil with BF-1, phenyl-4-naphthaleine, and VNI NP-1 additives, is produced at the present time for passenger-car automatic transmissions. These additives are used to improve the viscosity, wear-resistance, corrosion resistance, and anti-oxidant properties. The quality indicators of this oil are given in Table 1.

User experience with VNI NP-1 oil has indicated that its quality must be improved, since the test results indicate that the oil has a pour point of minus 4°C, while the standard specifies minus 35°C and commercial consignments pour at minus 30°C. Use
Table 1. Oil Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>VIHNI NF-1</th>
<th>GOST 10660-63</th>
<th>VIHNI NF-1 + MASK + DF-11</th>
</tr>
</thead>
<tbody>
<tr>
<td>kinematic viscosity (cSt)</td>
<td>2.9</td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>flash point, °C</td>
<td>240</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>pour point, °C</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>thermal oxidation stability in DK-2, %</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>sediment, %</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>viscosity index</td>
<td>170</td>
<td>170</td>
<td>170</td>
</tr>
</tbody>
</table>

KEY: (a) indicator; (b) VIHNI NF-1 GOST 10660-63; (c) thickened base of oil VIHNI NF-1 + MASK + DF-11; (d) viscosity, cSt; (f) at; (g) pour point, °C; (h) copper-plate corrosion in 3 hours at 100°C; (j) static color; (j) none; (k) thermal oxidation stability in DK-2 machine; (l) sediment, %; (m) acid number, mg of KOH/g; (n) reaction; (o) weakly alkaline; (p) neutral; (q) additives were selected by the method indicated. The best results were obtained with VIHNI NF-1 oil to which the following additives were added: MASE (4-4-5w with a calcium content of 0.15-0.18%), DF-11 (2-2.5% at a level of 0.15%) and PMS-200A (0.005%) as an anti-foaming additive. The laboratory tests showed that the experimental oil has high antioxidant stability and good antiwear and antioxidation properties. It was also established that the additive is effective at a level of 0.05% in light raw materials such as the pour point of VIHNI NF-1 oil at minus 10°C. When MASK additive was added, the pour point of the oil could be lowered by adding 0.3-0.5% of polyethylene.
Use of the test oil without changes for 55 and 100 thousand km kept the transmissions running normally. When the units were disassembled, no oil-oxidation products could be detected in the form of gummy deposits, varnishes, etc., either in the automatic control unit (control panel, reduction-gear panel, housing of the centrifugal spool) or on other hydraulic-transmission or torque-converter parts. There was 5-6 g of sludge in the bottom of the case after 50 thousand km, and it consisted basically of inorganic impurities.

When the transmissions were run with VNIIP-1 oil (VNIIP-1 oil), there were 5-6 g of gum deposits at 25 thousand km. Sludging was also observed in the passages of the panel case and in the reduction valves, in some cases causing them to stick.

No parts of the hydraulic transmissions run on the test oil showed deep scoring or temper colors. For the most part, the parts had worn by 0.1-0.05 mm after 95 thousand km; only on one part did the wear amount to 0.08 mm (as against a maximum acceptable wear of 0.5-0.3 mm).

The clutch is the basic element in determining the dependability and service life of a hydraulic transmission. In operation on the test oil, the wear of the sintered-metal clutch plates was practically nil, and no dark films formed on their surfaces. The test results indicated that the test oil is a par as regards antiscuff properties with the imported Shell Donax T-6. When VNIIP-1 oil was used, the sintered parts showed wear, and the wear amount during the tests showed that the viscosity level dropped somewhat in both the commercial VNIIP-1 oil and in the test oil (by 1.6% at 90°C) as a result of destruction of the viscosity additive.

The oxidation-product content of the test oil (the organic part of the total impurities) was insignificant, and did not exceed 0.02-0.03% over the entire useful life of the oil (93 thousand km), while it was 0.54%, including 0.32% of asphaltene in the VNIIP-1 oil and the inorganic part of the impurities (0.2%) contains a considerable amount of spent DF-1 additive. For this reason, the acid number of the oil decreased considerably (Fig. 1).

The concentration change of the MASK and DF-1 additives in the test oil during operation was insignificant (see Fig. 1).

The following conclusions may be drawn from the test results.

Introduction of the MASK, DF-11 and PMF-2006 additives into the thickened VNIIP-1 oil base produces passenger-car automatic transmissions oils with good antiscuff, antioxidant, and antiscuff properties. The depressor properties of the oil can be improved by introducing 0.3-0.5% of polymethylacrylate D.

The high stability of this oil makes it possible to increase the change interval substantially and reduce operating consumption. Even with changes at 50 thousand km, oil consumption is reduced by 40-60% compared with the commercial VNIIP-1 oil.

Power-steering oil. The oil used in automatic transmissions and torque converters is usually also used in power-steering systems. Good viscosity-temperature properties in this oil are especially important during starting of the engine and in the vicinity of the steering-booster pump. VNIIP-1 oil is fully adequate for passenger automobiles, but its viscosity-temperature properties have been found unsatisfactory for trucks and buses which are usually parked outdoors.

It was established by special tests run on ZIL-130 vehicles that at air and pump-oil temperatures of minus 50°C, the oil temperature is raised to minus 40°C during the prestart warmup of the engine, and then reaches 0°C within 1-2 min after the pump has started. Under these conditions, normal operation of the pump can be ensured by use of an oil with a minus 40°C viscosity not above 15-16 thousand centistokes and a pour point below minus 45°C.

It should be noted that use of AOM and AMG-40 high-compressibility oils, which have good viscosity-temperature properties, results in increased wear of parts.

The viscosity of the oil is lowered when VNIIP-1 oil is used in the steering hydraulic booster; after 4 thousand km, the 50°C viscosity has fallen from 26 to 16-18 centistokes. This substantial viscosity drop is explained by destruction of the viscosity additive, which results both from the high running temperature of the oil (up to 130°C) and the incessant throttling (since the pump delivers 10 liters/min at 600 rev/min and the excess of oil is directed through the transfer valve when crankshaft speed changes).
Thus, acquisition of an oil with good operational properties requires: a base with good viscosity-temperature properties; a viscosity additive with high thermal and mechanical stability; an antioxidant additive that ensures long service life and dependable operation of the power-steering gear in all of the country's climate zones; an antioxidant to provide a long oil-service life, and an antifoaming additive.

It is also necessary to consider the effect of the oil on rubber gaskets.

In developing the oil, we took as the base AMO-10 oil with various viscosity additives (Vinpol, polyisobutylene, polymethaerylate) and type AU spindle oil from Zhirnovsk petroleum.

The antwear and antioxidant additives for these oils were first tested in various combinations on a friction machine and then checked on the DK-2 machine in order to obtain test specimens whose antwear properties and stability would meet the specifications for automatic-transmission oils.

The following additive combinations were chosen: MASK (4%); and DP-11 (2.3%); chlorinated paraffin (5%) and MB-1 (1%).

Experimental specimens of the oils were given bench tests in steering-gear hydraulic booster pumps under the following forced conditions.

Running in: pump load 125 cycles in 1 min; oil pressure drop across system under various loads: P1 = 10-70 kg/cm2 for 10 hours, oil temperature 115-125°C; P2 = 10-45 kg/cm2 for 10 hours, oil temperature 115-125°C. Pump shaft speed 3000 rev/min.

The normal operating regime of the pump differs only in having a higher pressure (130-155 kg/cm2).

The tests lasted 150-200 hours. Each oil specimen was tested in four or five pumps.

The quality of the oils was evaluated from the change in their physicochemical constants and from the wear of the pump stator, characterized by the increase in its smallest diameter and its loss of weight (readings taken every 50 hours).

The oils were comparison-tested with commercial oils - spindle AU, AMO-10, VMII NP-1, and the imported Shell Donax T-6 oil.

TEST RESULTS

Antwear Properties

The results of the pump stator wear readings are plotted in Figs. 2 and 3, from which we see that:

- stator wear reaches its limit (1.25 mm) after 160 hours of running on AMO-10 commercial oil;
- on introduction of the chlorinated-paraffin and MB-1 additives into the thickened AMO-10 and spindle AU oil bases, no substantial decrease in stator wear is observed;

![Fig. 2. Pump stator wear on various oils. 1) commercial AMO-10, 2) AMO-10 with polyisobutylene, MASK and DP-11; 3) AMO-10 with polyisobutylene, chlorinated paraffin and MB-1; 4) AMO-10 with polyisobutylene, chlorinated paraffin and MB-1; 5) AMO-10 with polyisobutylene, chlorinated paraffin and MB-1. KEY: (a) wear, mm; (b) test time, hours.](image)

![Fig. 3. Pump stator wear on various oils. 1) AMO-10 with polyisobutylene, NASK and DP-11; 2) VMII NP-1; 3) AU spindle oil with NASK and DP-11. KEY: (a) wear, mm; (b) test time, hours.](image)

...
The greatest viscosity loss is observed when polymethacrylate (51.6%) and polyisobutylene (32-40%) are used; the viscosity decrease is smaller with Vinipol (19.4%). The viscosity level of the imported oil also falls by 30%.

Characteristically, the viscosity drops during the first few hours of operation, with some stabilization observed after 50 hours.

The viscosity of AU spindle oil rises slightly (by 0.39 cat at 50°C) as a result of formation of asphalt tar. The stability of the oil is raised by introduction of additives, so that its viscosity remains practically constant (0.09-0.2 cat at 50°C after 150 hours of testing).

These tests showed that commercial viscosity additives with molecular weights not below 10,000 should not be used in power-steering oils. Distillate oils such as spindle AU, which have lower viscosity levels at the working temperatures, lubricate the rubbing surfaces satisfactorily in the presence of antiwear additives.

The antioxidation stabilities of the oils cannot be determined conclusively from the results of bench tests because of their short duration (150-200 hours). The total-impurity content is insignificant in all oils, ranging from 0.01 to 0.02%, with asphaltenes completely absent from the filtered oil. The acid number of AU spindle oil rises from 0.04 to 0.15 mg of KOH/g, but in oils containing the MASK and DP-11 additives, it declines as the additives are depleted, from 1.26 to 1.11 mg of KOH/g. However, the color of the test oil did not change during the tests, indicating that it has good stability to oxidation.

The bench tests made it possible to recommend spindle oil AU with the MASK, DP-11, and PMS-200A additives for road testing in the country's various climate zones.
As we know, only metal-containing organic compounds (ash-forming additives), and especially calcium and barium alkylphenolates and their sulfur- and phosphorus-containing derivatives, are used as detergent, dispersing, antioxidation, and antinoxidation additives to motor oils produced by the domestic petroleum industry. Sulfonates of alkaline-earth metals and zinc dialkyldithiophosphates are also used.

Depending on application, motor oils may contain 6-10% and more of these ashing additives. However, when engines are run on oils containing large amounts of ashing additives, their rubbing parts, and especially their cylinder-piston groups, wear rapidly. This wear is a consequence of carbonization of the oils in hot areas of the engines, with formation of the oxides of the metals.

The "potter" and more powerful the engine, the more rapid is the depletion of the ashing additives in its motor oil. To compensate for depletion, larger amounts of the additives are introduced into the oils. Depletion of the ashing additives is also influenced by cold engine operation under city traffic conditions, when the hydrophilic properties of the ashing additives (salts of alkaline-earth metals) are manifested most strongly, i.e., formation of low-temperature deposits is intensified.
Thus, together with their good detergent and dispersing properties, nonashing additives have important advantages that make it necessary to reduce the content of these additives in engine oils.

The necessary detergent, dispersing, and antwear properties can be obtained in motor oils with minimum contents of ashing additives if nitrogen-containing polymer (nonashing) additives are introduced into the oils.

The nonashing additives belong to the class of polar polymers and are copolymers of methacyrylic acid alkyl esters with certain nitrogen-containing monomers, such as methylvinylpyrrolidine, diethylaminoethylmethacrylate, etc.

In the research whose results are reported below, we used VNM nonashing additives prepared by V.G. Telegin and Ye.V. Lazareva [1].

To determine the effectiveness of the nonashing additives in combination with ashing types, a motor oil containing these additives was tested on a YaME-236 diesel engine. The test results were compared with the results of tests made with the same engine under similar conditions using motor oils with only the ashing additives. Each sample was tested for 150 hours.

The detergent, dispersing and antwear properties of the additives are evaluated on the basis of:

- the quantity and type of deposits on the engine parts and oil filters;
- piston-ring freedom;
- the wear of engine parts and their condition;
- the change in the physicochemical properties of the drained oil.

It has been established by previous studies and tests [2] that 5% of ashing additives (3% SB-3 2% DP-11) can be used in motor oils for type YaME-236 diesels and type 2El-150 V-type carburetor engines. In motor oils made from eastern petroleums and used in diesels, this additive content gives only satisfactory results.

To ascertain the possibility of obtaining a sharp increase in the quality of oil containing the acceptable amount of ashing additive by adding the VNM nonashing additive to it, we tested oil A, which was type ASEB-10 containing 3% SB-3, 2% DP-11 and 5% VNM (Table 1).

The results were compared with the results of tests made with oils having high ashing-additive contents: oil B, which was type ASEB-10 4.5% of ash-
Table 3. Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Oil</th>
<th>Cylinder Liners</th>
<th>Piston Rings</th>
<th>Connecting-Rod Inserts</th>
<th>Service Time, Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10%</td>
<td>2.0</td>
<td>0.0</td>
<td>0.0</td>
<td>20</td>
</tr>
<tr>
<td>B</td>
<td>15%</td>
<td>2.5</td>
<td>0.1</td>
<td>0.1</td>
<td>25</td>
</tr>
<tr>
<td>C</td>
<td>20%</td>
<td>3.0</td>
<td>0.2</td>
<td>0.2</td>
<td>30</td>
</tr>
</tbody>
</table>

KEY: (a) oil; (b) engine-part wear; (c) cylinder liners; (d) piston rings; (e) connecting-rod inserts; (f) service time, hours.

Fig. 1. Change in viscosity oils during running in YaMZ-236 engine.

The wear and condition of the engine parts were approximately the same after tests with each of the above oils. There were minor differences in piston-ring and connecting-rod inserts wear (Table 3). The surface of the oil pan was clean after the tests of oils A and E, but it was covered with gummy deposits in the other cases.

Changes in the physicochemical properties of the used oils indicate high stability for oils A (with the nonamine additive).

---

Table 4. Results of Tests on GAZ-51 Engine

<table>
<thead>
<tr>
<th>Test</th>
<th>Oil</th>
<th>piston-ring wear</th>
<th>compression rings</th>
<th>insert wear</th>
<th>service time, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5%</td>
<td>0.8</td>
<td>0.004</td>
<td>0.018</td>
<td>25</td>
</tr>
<tr>
<td>B</td>
<td>10%</td>
<td>1.8</td>
<td>0.003</td>
<td>0.003</td>
<td>30</td>
</tr>
<tr>
<td>C</td>
<td>15%</td>
<td>2.8</td>
<td>0.005</td>
<td>0.004</td>
<td>35</td>
</tr>
</tbody>
</table>

KEY: (a) oil; (b) engine-part wear; (c) piston rings; (d) compression rings; (e) insert wear; (f) service time, hours.

---

Fig. 2. Change in ash content of oil during running in YaMZ-236 engine. KEY: (a) ash; (b) oil service time, hours.

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Fig. 3. Change in mechanical-impurity content in oils during running in YaMZ-235 engine. KEY: (a) contents of barium (A, V, E) and calcium (A); (b) oil service time, hours.

and E (the reference oil) by comparison with oils V, which contained 6% of VKII NP-360 (Fig. 3). But even at increased concentration (6%) in ordinary oil, VKII NP-360 additive does not fully guarantee Series I quality.

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Fig. 4. Change in mechanical-impurity content in oils during running in YaMZ-235 engine. KEY: (a) mechanical-impurity content; (b) oil service time, hours.

---

Table 4. Results of Tests on GAZ-51 Engine

<table>
<thead>
<tr>
<th>Test</th>
<th>Oil</th>
<th>piston-ring wear</th>
<th>compression rings</th>
<th>insert wear</th>
<th>service time, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5%</td>
<td>0.8</td>
<td>0.004</td>
<td>0.018</td>
<td>25</td>
</tr>
<tr>
<td>B</td>
<td>10%</td>
<td>1.8</td>
<td>0.003</td>
<td>0.003</td>
<td>30</td>
</tr>
<tr>
<td>C</td>
<td>15%</td>
<td>2.8</td>
<td>0.005</td>
<td>0.004</td>
<td>35</td>
</tr>
</tbody>
</table>

*Oil specimen with 3.5% VKII NP-360 additive tested.

**The denominator gives the result for oil with 6% VKII NP-360 additive.

---
The detergent and especially the dispersing properties of this additive are clearly inadequate to ensure normal diesel performance. Thus, Fig. 4 and Table 2 indicate that oil V with the VNII NF-360 additive contained 1.5% of mechanical impurities by the end of the tests, there were 520 g of sludge in the centrifugal filter, while the corresponding figures for oil E (Series 1) were 0.75 and 365 g, for oil A (with the nonashing additive) 1.4% and 190 g, and for oil B 0.1% and 510 g.

The piston-wear rating after the tests was 2-3.5 points for oil V and 2-2.5 and 1-1.5 points, respectively, for oils E and A.

A consequence of the inadequate dispersing properties of VNII NF-360 additive is a relatively sharp increase in oil viscosity during work (see Fig. 1). The fast depletion of this additive (see Figs. 2 and 3) is also partly responsible for its decreased effectiveness.

Comparative 28-hour cold tests run on the OAZ-51 engine with oils having ashing additives and a mixture of ashing and nonashing types indicated superiority of oils with the additive mixture (Table 4). Running on these oils, the engine forms smaller amounts of low-temperature deposits. Also less conspicuous is the influence of acid products in the oil, high contents of which are characteristic for cold engine operation, on the wear of rubbing parts.

Inspecting the above data, we may conclude that combining ashing and nonashing additives in a motor oil endows it with high operational properties, while the ashing additives taken alone improve one indicator at the expense of others.

A nonashing additive in the combination of additives introduced into a motor oil improves its viscosity-temperature properties (VI, viscosity at 0°C, etc.).

The quality margin of oil A indicates the possibility of reducing the proportion of ashing additives in the oil when they are used in combination with the nonashing additive. This is also confirmed by the good results of the 100-hour test run in the YaMZ-236 engine on a thickened oil containing the type VN nonashing additive, 2.5% of SN-3, and 1% of LANI-317.

In the production of ordinary motor oils containing ashing and ash-free additives (in various combinations), it is necessary, in view of the thickening tendency of the latter, to take initial distillate or residual oils with somewhat lower viscosity levels than when the ashing additives are used alone.

References
The quality of blow-by gases is measured with the type 2K gas meter.

The temperature state of the engine is monitored by the use of thermocouples and a type EEF-9 recording electronic potentiometer.

An electric brake is provided by a type EL 1/3 induction motor (power 5.8 kW, n = 1450 rev/min).

The oil-testing unit thus devised with its single-cylinder carburetor engine was given the designation IKM-1.

The following test conditions were adopted as a result of preliminary results.

The graph on which the oil mobility was evaluated is given in Table I.

### Table 1. Scale of Ring-Mobility Rating

<table>
<thead>
<tr>
<th>Condition Name</th>
<th>Open-Rating</th>
<th>Close-Rating</th>
<th>Open-Scale</th>
<th>Close-Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean, shiny</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Clean, dull</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Clean, cracked</td>
<td>2</td>
<td>2</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Clean, scored</td>
<td>3</td>
<td>3</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Clean, burned</td>
<td>4</td>
<td>4</td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>

Keys: (a) condition of rings; (b) rating, points; (c) clean, before testing; (d) drop freely with metallic sound; (e) drop freely; (f) drop freely with dull sound; (g) insert; (h) stuck; (i) slight; (j) partially; (k) completely; (l) turned.

The arithmetic mean value was used in the calculation to determine the mobility rating for each ring.

The color of the deposits in the piston ring zone (Tadk) and on the piston skirt (Tadr) was determined from the VNIIFP All-Union Scientific Research Institute of Oil and Gas Processing.
and Production of Artificial Liquid Fuels] color scale. The scale for rating varnish deposits on aluminum pistons consists of 11 color standards, ranging from light gray, which corresponds to the color of the clean piston and is rated zero, to black, which is represented by 10 points. The colors of the varnish deposits on the piston skirt and in the ring zone are rated separately.

To evaluate the deposits, the ring zone is broken up into nine belts (two belts for the crown and one each for the lands and grooves). Circumferentially, each belt is divided into ten segments. The result is determined as the arithmetic mean value. The rating is given in points and is reproducible to within ±0.5.

The color $T_{Cp}$ of the deposits on the piston skirt is determined in the same way as the above index and is reproducible to within ±0.5. The piston skirt is divided into five belts.

In addition, the quality of the oil was evaluated on the basis of the following indices:

- the amount of deposits $N_0$ on the piston in g, reproducibility ±0.5;
- clogging of holes in oil-control rings and piston drainage holes $N_{rh}$ in points - from 0 (clean) to 10 (completely blocked), reproducibility ±0.5;
- wear index $I_1$ in points, reproducibility ±0.5;
- wear of top ring $C_{br}$, in $v$, reproducibility ±0.5;
- corrosion index $I_2$ in points, reproducibility ±0.5;
- the corrosive aggressiveness of the oil, determined visually and by weighing plates of type S-1 lead ($k_{S-1}$), SBS-8-6 lead babbit ($k_{SBS-8-6}$), SB-30 lead bronze ($k_{SB-30}$), and ASM aluminum alloy ($k_{ASM}$), in g/m², reproducibility ±0.5;
- the stability index $I_{st}$ of the oil in points, reproducibility ±0.5;
- the increase $U$ in oil viscosity, determined as a percentage at 50°C, reproducibility ±1.5%.

The indicators listed above are determined by the formulas:

\[
N_0 = N_{rh} + N_{w} + N_{br} + N_{Cp} + N_{b} + N_{sl} + N_{c},
\]

\[
C_{br} = k_{br} \times \frac{C_{br}}{C_{br}},
\]

\[
I_1 = k_{I_1} \times \frac{I_1}{I_1},
\]

\[
I_2 = k_{I_2} \times \frac{I_2}{I_2},
\]

\[
I_{st} = k_{I_{st}} \times \frac{I_{st}}{I_{st}},
\]

\[
U = k_{U} \times \frac{U}{U},
\]

\[
N_{rh} = k_{N_{rh}} \times \frac{N_{rh}}{N_{rh}}.
\]

The results of tests of AS-6 oil with control, standard method are shown in Table 2.

<table>
<thead>
<tr>
<th>Test</th>
<th>Oil Type</th>
<th>Classification</th>
<th>Additive</th>
<th>Corrosion</th>
<th>Temperature</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>L-1</td>
<td>SBS-8-6</td>
<td>100%</td>
<td>5%</td>
<td>70°C</td>
<td>10.5</td>
</tr>
<tr>
<td>2</td>
<td>L-2</td>
<td>SB-30</td>
<td>75%</td>
<td>7%</td>
<td>80°C</td>
<td>8.5</td>
</tr>
</tbody>
</table>

*Plates of S-1, SBS-8-6, SB-30, and ASM.

(a) Oil type
(b) in USBS classification
(c) in international classification
(d) additive
(e) additive content, % by weight
(f) motor index, points
(g) indicators included in motor index
(h) indicators included in deposits index
(i) ring mobility, points
(j) color of deposits in ring zone, points
(k) color of deposits on piston skirt, points
(l) amount of deposits on piston, g
(m) clogging of holes in oil control rings, points
(n) wear index, points
(o) top-ring wear, g
(p) corrosion index, points
(q) plate corrosion, g/cm²
(r) stability index of oil, points
(s) 50°C viscosity increase, %
(t) remarks
and Recommended Additive Compositions on IKM-1 Machine by IKM-10PG

<table>
<thead>
<tr>
<th>Composition</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
<td>e</td>
<td>f</td>
<td>g</td>
<td>h</td>
<td>i</td>
<td>j</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

In these formulas, the conversion factors k have the values

\[ \begin{align*}
  & n_1 = 0.25, n_2 = 0.75, n_3 = 0.2, n_4 = 0.01, \\
  & k_1 = 1, k_2 = 3, k_3 = 25, k_4 = 0.06.
\end{align*} \]

The test method developed, which is known as the IKM-10PG method, is intended for use in determining the operational properties of Premium, Heavy Duty, and Series 1 oils and obtaining differential ratings of oils in these groups.

The results of tests run with AS-6 oil containing control, standard and other additive compositions on the IKM-1 apparatus using the IKM-10PG method (Table 2) were compared with the results of tests of the same oils with non-same additives (used as controls in this case) by the UR 176/607 method on a Pitter W-1 engine (Table 3).

The results of this comparison was full agreement of the data, with stronger differentiation of oils in the above groups (series) by the IKM-10PG method.

Good agreement was also observed when we compared our results with those of studies carried out in other organizations (The Automobile and Automotive Engine Scientific Research Institute (NAMI), the Moscow Small-Displacement Automobile Plant (KZMA), and VMII HF).

All of the above justifies the conclusion that all tests by the IKM-10PG method on the IKM-1 bench conform to the level of the international standards.

Work was also done to study the functional properties of certain additives and adjust their compositions for the basis of commercial additives. Using the IKM-1 machine, for example, we studied the influence of organosilicon compounds: an alkylpolysiloxane fluid of the PMS-200A additive type, T1ATIM-339, PMS-20A, ASK, and DP-11 additives, and combinations thereof. The following additive compositions were tested: AS-6 + 1% T1ATIM-339 + 0.5% PMS-20A; AS-6 + 3.5% VMII HF-360 + 1% ASKII-TATIM-339 + PMS-20A.

The test results (Fig. 2) show that the addition of very small amounts (0.005-0.005%) of the organosilicon compounds to the oils improves their use properties considerably.

Tests on a DK-2 machine established that when PMS-20A additive is used in the oil in combination with VMII HF-370 and PMS-20A additives, the amount of condensation products formed by oxidation of the oil is reduced substantially.
Table 3. Results of Tests of Soviet Oils from Eastern Petroleums

<table>
<thead>
<tr>
<th>Oil Type</th>
<th>8 Pabkin</th>
<th>15 Pabkin</th>
<th>20 Pabkin</th>
<th>25 Pabkin</th>
<th>30 Pabkin</th>
<th>35 Pabkin</th>
<th>40 Pabkin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>d</td>
<td>d</td>
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<td>d</td>
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<tr>
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<tr>
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<td>l</td>
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</tr>
<tr>
<td></td>
<td>h</td>
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<td>h</td>
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<td>h</td>
<td>h</td>
<td>h</td>
</tr>
</tbody>
</table>

*Obtained by Monsanto by JP 176/60T method on Pitter M-1 engine.

KEY: (a) indicator; (b) group (series) of oil and additive composition; (c) base (regular); (d) specimen; (e) NA (premum) + 0.7% Monto 613 + 0.7% Santolube 893; (f) MB (Heavy Duty) + 1.5% Monto 613 + 0.7% Santolube 893; (g) MV (series 5) + 4% Monto 613 + 0.25% Santolube 893; (h) rating points; (i) piston skirt; (j) piston crown; (k) mass loss of lead-bronze bearing, mg; (l) viscosity increase at 37.8°C, %.

The color of the deposits in the piston-ring zone was 6.0 points on the VNII NF scale in a test of AS-6 oil with 1% of TsiATIM-339 additive and 0.5% PM3Ya, but when 0.005% of PM3-200A was added to the same mix, it was lowered to 4.6 points. The same result was obtained on introduction of 0.005% of PM3-200A into an additive mix consisting of 3.5% VNII NF-360 and 1% TsiATIM-339 in AS-6 oil. In this case, the color of the deposits in the piston-ring zone is lowered from 6 to 5.6 points. This makes it possible to bring COST 1054-53 group MB oils up to the level of group MV, improves piston-ring working conditions, and reduces piston deposits.

The thermal stability of oil with these additive mixes was also improved, as is clearly indicated by the decrease in the rate of viscosity change in tests of the oil in the IEM-1 machine. For example, while the additive mix consisting of 1% TsiATIM-339 and 0.5% PM3Ya caused a 13.9% viscosity increase in AS-6 oil, this increase was only 5.6% when 0.005% of PM3-200A was added.

On introduction of the additive mix consisting of 2.5% VNII NF-360 and 15% TsiATIM-339 into AS-6 oil, viscosity increases by 18.1%; with simultaneous addition of PM3-200A, the viscosity increases by only 5.4%.

This improvement of the use properties of the oil on introduction of the chain-stopping additive into a mix containing

---

Fig. 2. Influence of content of PM3-200A additive on motor properties of AS-6 oil with the following additive compositions: 1) AS-6 + 1% TsiATIM-339 + 0.5% PM3Ya + PM3-200A; 2) AS-6 + 3.5% VNII NF-360 + 15% TsiATIM-1 + PM3-200A. (a) level of group NA control oil; (b) same, group MB; (c) same, group MV.

KEY: (a) motor index, points; (b) deposits index, points; (c) ring mobility, points; (d) color of deposits in ring zone, points; (e) quantity of deposits on piston, g; (f) increase in viscosity at 50°C, %; (g) concentration of PM3-200A additive, % by weight.

---

Fig. 3. Influence of content of PM3Ya additive on motor properties of AS-6 oil with the following additive compositions: 1) AS-6 + 1% TsiATIM-339 + PM3Ya + 0.005% PM3-200A; 2) AS-6 + 1.5% TsiATIM-339 + PM3Ya + 0.005% PM3-200A; 3) AS-6 + 2.5% TsiATIM-339 + PM3Ya + 0.005% PM3-200A. (a) level of group NA control oil; (b) same, group MB; (c) same, group MV.

KEY: (a) motor index, points; (b) deposits index, points; (c) ring mobility, points; (d) color of deposits in ring zone, points; (e) quantity of deposits on piston, g; (f) increase in viscosity at 50°C, %; (g) concentration of PM3Ya additive, % by weight.
detergent and antioxidant components can be explained by the decreased aeration of the oil, which has a strong influence on quality changes of oil in the engine.

A test of TciATIM-339 additive in concentrations of 1.0, 1.5, and 2.5% in a mix with 0.005% PMS-200A indicated (Fig. 4) that the amount of piston deposits decreases from 0.65 to 0.32 g, ring mobility from 1.5 to 1 point, and the color of the deposits in the piston-ring zone from 7.2 to 4.5 points as the concentration of the TciATIM-339 additive is increased to 2.5%. In this case, the motor index drops from 11 points (the level of the group MA control oil) to 7.5 points, which corresponds to the level of MB control oil. As the test results showed, the tested concentrations of TciATIM-339 additive do not provide adequate detergent properties in the oil, and for this reason they were supplemented with PMS'Ya detergent-dispersing additive in concentrations of 0.25, 0.5, 0.75, 1, 1.25, and 1.5% by weight.

On introduction of small amounts of the new additive mix, ring mobility drops to 1 point, the color of deposits in the piston-ring zone to 4.2-4.5 points, the amount of piston deposits to 0.16-0.2 g, and the rate of oil viscosity increase after the test to 5-8%. In this case, the motor index declines to 6-6.5 points, which corresponds to the level of the group NV control oil (series I). However, it must be noted that the optimum values can be obtained only at definite proportions of the TciATIM-339 and PMS'Ya additives, in the 2:1 range. This ratio also applies for diesels operated on low-sulphur fuels (Fig. 4). Deposition from it results in a rise of the motor index, indicating deteriorating oil quality.

Adjustment of the mix on the basis of the TciATIM-339, PMS'Ya, polymethacrylate D (for winter-grade oils), and PMS-200A additives, which was carried out on the IVM-1 machine by the IVM-1GP method, resulted in tentative recommendations of oils conforming to the Premium, Heavy-Duty, and Series 1 groups. The results of tests on these oils were compared with those for oils with the imported control additives Monto 613 and Santolute 493.

The above additive mix were also tested on a machine with a real-scale Moskwit 407 automobile engine, and the correctness of the results obtained was confirmed.

Thus, the additive mix given in Table 4 can be recommended on the basis of the tests for oils for carburetor-type automobile engines.

Tests of another additive mix, consisting of ASK, DP-11, polymethacrylate G (for winter oils) and PMS-200A in AS-6 oil were run by the IVM-1GP method on the IVM-1 installation. The content of the ASK additive in the mix was varied from 1.5 to 3.5%. As the tests showed (Fig. 5), as little as 1.5% of ASK produces an oil conforming to group MB (Heavy Duty); when the ASK concentration is increased to 2.5%, group NV (Series 1) oils are obtained. Here the color of the piston deposits drops from 9.7 to 5.7 points on the VNIIP scale, the amount of deposits on the piston is reduced from 0.43 to 0.2-0.3 g, and the degree of viscosity increase also drops from 12.9 to 6.4%. The decrease in the motor index also drops from 7.8 to 5 points also indicates an improvement of the operational properties of oil with these additives.
### Table 3. Recommended Additives

<table>
<thead>
<tr>
<th>Additive</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>HNATIM-30</td>
<td>0.1-0.2</td>
<td>0.1-0.2</td>
<td>0.1-0.2</td>
</tr>
<tr>
<td>HNIM-1</td>
<td>0.2-0.4</td>
<td>0.2-0.4</td>
<td>0.2-0.4</td>
</tr>
<tr>
<td>HNIM-1</td>
<td>0.1-0.2</td>
<td>0.1-0.2</td>
<td>0.1-0.2</td>
</tr>
<tr>
<td>BMC-300A</td>
<td>0-0.1</td>
<td>0-0.1</td>
<td>0-0.1</td>
</tr>
</tbody>
</table>

KEY: (a) additive; (b) API group; (c) oil group.

### Table 4. Recommended Oil Additives

<table>
<thead>
<tr>
<th>Additive</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>AK</td>
<td>0.1-0.2</td>
<td>0.1-0.2</td>
<td>0.1-0.2</td>
</tr>
<tr>
<td>BENZ-N</td>
<td>0.1-0.2</td>
<td>0.1-0.2</td>
<td>0.1-0.2</td>
</tr>
<tr>
<td>HNIM-1</td>
<td>0.1-0.2</td>
<td>0.1-0.2</td>
<td>0.1-0.2</td>
</tr>
<tr>
<td>BMC-300A</td>
<td>0-0.1</td>
<td>0-0.1</td>
<td>0-0.1</td>
</tr>
</tbody>
</table>

KEY: (a) additive; (b) API group; (c) oil group.

In testing the concentration of AK additive in this oil in a test engine, it was found that the properties of the oil were increased by increasing the concentration of the additive. The data indicate that the optimum additive concentration is a function of the engine type and oil quality.

**CONCLUSIONS**

1. A method designated IMI-108G was developed for motor vehicle performance test on the fuel properties of base oils and additive oils of groups A (Premium), B (heavy duty), and C (special) by running 100 tests on a special test engine IMI-1.

**References**


Oil with these additive mixes were tested in a full-sized Deutz diesel engine. The tests showed that the quality of the recommended oil is superior to that of the group H (heavy duty) and E (extra high) control oils.

The test results are a basis for recommending one or more additive mixes (in 1 by weight) for oils used in carburetor-type automobile engines (Table 5).
Symbol List

<table>
<thead>
<tr>
<th>Character</th>
<th>Symbol</th>
<th>English Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>V.</td>
<td>v</td>
<td>motor</td>
</tr>
<tr>
<td>F.</td>
<td>f</td>
<td>deposits</td>
</tr>
<tr>
<td>k</td>
<td>k</td>
<td>ring</td>
</tr>
<tr>
<td>l</td>
<td>l</td>
<td>color</td>
</tr>
<tr>
<td>Tg</td>
<td>Tg</td>
<td>ring zone</td>
</tr>
<tr>
<td>Vf</td>
<td>Vf</td>
<td>skirt</td>
</tr>
<tr>
<td>p</td>
<td>p</td>
<td>文档</td>
</tr>
<tr>
<td>l</td>
<td>l</td>
<td>oil control</td>
</tr>
<tr>
<td>i</td>
<td>i</td>
<td>index</td>
</tr>
<tr>
<td>I</td>
<td>I</td>
<td>wear</td>
</tr>
<tr>
<td>w</td>
<td>w</td>
<td>top ring</td>
</tr>
<tr>
<td>v</td>
<td>v</td>
<td>correction</td>
</tr>
<tr>
<td>m</td>
<td>m</td>
<td>oil stability</td>
</tr>
<tr>
<td>n</td>
<td>n</td>
<td>viscosity</td>
</tr>
</tbody>
</table>

TESTS OF SOVIET AND FOREIGN MOTOR OILS IN THE UIM-6-NATI AND UIM-6N-NATI SINGLE-CYLINDER BENCH INSTALLATIONS


The object of the study reported in this paper was to design a single-cylinder bench installation based on a series-produced supercharged tractor diesel, develop a test method, and test various types of motor oils.

The properties of oils intended for work under relatively light-duty conditions (Premier type) have been rated on the UIM-6 single-cylinder bench built at the Automobile and Automotive Engine Scientific Research Institute (NATI) on the basis of the P-5 tractor diesel. Later, the UIM-6-NATI machine was developed on the basis of the D-76 tractor diesel, which, in a supercharged modification of the D-54, for testing Heavy Duty and Series 1 oils.

For rating Series 2 oils, the apparatus was fitted with a supercharging unit that delivered a substantial increase in horsepower per liter; this installation was designated UIM-6N-NATI (see figure).

Below we list the technical data of the UIM-6-NATI and UIM-6N-NATI installations.
Table 1. Principal manufacturing and operating characteristics of the UBM-6-NATI engine

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power, hp</td>
<td>17</td>
</tr>
<tr>
<td>Crankshaft speed, rev/min</td>
<td>1500</td>
</tr>
<tr>
<td>Max. Effective pressure</td>
<td>9.7</td>
</tr>
<tr>
<td>Horsepower per liter</td>
<td>16.1</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>155:1</td>
</tr>
<tr>
<td>Oil pressure</td>
<td>6.5</td>
</tr>
<tr>
<td>Fuel consumption, kg/h</td>
<td>9.5</td>
</tr>
<tr>
<td>Injection system capacity, kg/h</td>
<td>9</td>
</tr>
<tr>
<td>Cooling system capacity, kg/h</td>
<td>7.15</td>
</tr>
<tr>
<td>Intake manifold loss of cylinder-piston head</td>
<td>1%</td>
</tr>
<tr>
<td>Intake manifold loss of cylinder-piston head</td>
<td>1%</td>
</tr>
<tr>
<td>Lubricating system</td>
<td>Single-circuit with the exception of the liner.</td>
</tr>
<tr>
<td>Coolant</td>
<td>Water for cylinder head, glycerine for cylinder sleeve</td>
</tr>
</tbody>
</table>

The results of the UBM-6-NATI bench tests make a close approach to those of the SM-18, AM-01 and other modern tractor diesel engines. The test data obtained are based on the UBM-6-NATI and similar engines tested under the same operating conditions as those of the supercharged SM-18 and YMK-228HE tractor diesel engines.

In developing the method for rating the main properties of crankcase oils from their tendency to deposit, the authors of the UBM-6-NATI tests on the test bench at the Experimental Plant of the UBM-6-NATI and YMK-228HE engine were used.

TEMPERATURE MEASUREMENTS ON THE ENGINE

The temperature condition of the components of the cylinder-piston group is a significant influence on the process of deposit formation in an engine. For this reason, temperature readings were taken at the sleeve and piston of the UBM-6-NATI installation under various engine operating conditions.

It was established that the highest cylinder-head temperature at the center of the combustion chamber in operation without supercharging and at an effective pressure of $P_e = 6.3 \text{ kg/cm}^2$ is $170^\circ \text{C}$, while that on the side of the piston head is $200^\circ \text{C}$. The temperatures in the areas of the first and second grooves are $165^\circ$ and $150^\circ \text{C}$, respectively. By this, it decreases substantially.


KEY: (a) UBM-6-NATI.

The change in the temperature distribution on the piston and cylinder sleeve at $P_e = 9.5 \text{ kg/cm}^2$, the temperature rises by only $10-15^\circ \text{C}$.

Similar results, which are presented on page 65, were obtained on the SM-18, AM-01, SM-18, and YMK-228HE [16] engines. When glycerine was used as a coolant instead of water, the temperatures of the engine parts rise sharply. For the first and second piston grooves, this temperature increase is $55^\circ \text{C}$.

Piston temperature increases by $0.5^\circ \text{C}$ on a $1^\circ \text{C}$ increase in the glycerine temperature.

INFLUENCE OF ENGINE TEMPERATURE CONDITIONS ON RATE OF CARBON-SCALE PRESENTATION

It has been established [1] that the rate of fouling of engine parts is determined in many respects by engine-temperature conditions and test time; the test time can be shortened by increasing the heat load on the engine part. However, 

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Table 1. Influence of Coolant Temperature on Rate of Piston Fouling

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Rating</th>
<th>Rating</th>
<th>Rating</th>
<th>Rating</th>
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<td>1.39</td>
<td>1.44</td>
<td>1.41</td>
</tr>
<tr>
<td>55°C</td>
<td>1.36</td>
<td>1.32</td>
<td>1.38</td>
<td>1.38</td>
<td>1.33</td>
<td>1.37</td>
<td>1.34</td>
</tr>
</tbody>
</table>

**Key:**
- (a): 75°C; (b): 65°C; (c): 55°C; (d): 125°C; (e): 115°C; (f): 105°C; (g): 95°C; (h): 85°C

**Note:**
- The test was conducted at a constant engine speed of 2000 rpm and a constant load of 150 HP. The coolant temperature was varied from 75°C to 155°C.
- The data presented in the table is an average of three tests.
- The rating is based on a scale of 1 to 5, with 1 being the lowest and 5 being the highest.
- The tests were conducted on a 6-cylinder, in-line engine with a displacement of 6.6 liters.

---

*By UOM-6-NATI method,*

**Rating** in points as a function of the degree of mobility of each piston ring. The lower the rating, the better the performance. A rating of 3 is considered good, while a rating of 1 is considered excellent.

---

**Note:**
- The test was conducted at a constant engine speed of 2000 rpm and a constant load of 150 HP. The coolant temperature was varied from 75°C to 155°C.
- The data presented in the table is an average of three tests.
- The rating is based on a scale of 1 to 5, with 1 being the lowest and 5 being the highest.
- The tests were conducted on a 6-cylinder, in-line engine with a displacement of 6.6 liters.

---

*By UOM-6-NATI method,*

**Rating** in points as a function of the degree of mobility of each piston ring. The lower the rating, the better the performance. A rating of 3 is considered good, while a rating of 1 is considered excellent.

---

**Note:**
- The test was conducted at a constant engine speed of 2000 rpm and a constant load of 150 HP. The coolant temperature was varied from 75°C to 155°C.
- The data presented in the table is an average of three tests.
- The rating is based on a scale of 1 to 5, with 1 being the lowest and 5 being the highest.
- The tests were conducted on a 6-cylinder, in-line engine with a displacement of 6.6 liters.

---

**Note:**
- The test was conducted at a constant engine speed of 2000 rpm and a constant load of 150 HP. The coolant temperature was varied from 75°C to 155°C.
- The data presented in the table is an average of three tests.
- The rating is based on a scale of 1 to 5, with 1 being the lowest and 5 being the highest.
- The tests were conducted on a 6-cylinder, in-line engine with a displacement of 6.6 liters.

---

*By UOM-6-NATI method,*

**Rating** in points as a function of the degree of mobility of each piston ring. The lower the rating, the better the performance. A rating of 3 is considered good, while a rating of 1 is considered excellent.

---

**Note:**
- The test was conducted at a constant engine speed of 2000 rpm and a constant load of 150 HP. The coolant temperature was varied from 75°C to 155°C.
- The data presented in the table is an average of three tests.
- The rating is based on a scale of 1 to 5, with 1 being the lowest and 5 being the highest.
- The tests were conducted on a 6-cylinder, in-line engine with a displacement of 6.6 liters.
On the basis of the results obtained on piston fouling and the physicochemical properties of the used oils, the coolant (glycerin) temperature was set at 115°C. At this temperature, Heavy Duty and Series 1 oils are differentiated quite sharply on the UIM-6-MATI machine (15.2 and 9.5 points, respectively). However, at the same temperature, the over-all piston-rod wear obtained on the UIM-6-MATI bench for Series 1 and Series 2 oils differed even more widely (29.5 and 12 points, respectively); also, the first compression ring was coked after 65-66 hours of the test on Series 1 oil.

Thus, the test conditions arrived at made it possible to classify Heavy Duty, Series 1, and Series 2 oils clearly and reliably.

REPRODUCIBILITY OF TEST RESULTS

One of the important stages in developing an oil-test method is to check the reproducibility of the results of parallel experiments.

Table 2. Results of Parallel Tests on Heavy Duty and Series 1 Control Oils

<table>
<thead>
<tr>
<th>Test Date</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
<th>Test 5</th>
<th>Test 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Day</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>2nd Day</td>
<td>0.9</td>
<td>0.8</td>
<td>0.7</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

KEY: (a) indicators (in points); (b) Heavy Duty; (c) Series 1; (d) sulfur content in fuel; (e) piston-rod wear; (f) scaling in first ring groove; (g) scaling in other grooves; (h) over-all piston-rod wear.

For this purpose, repeated tests were made with Heavy Duty, Series 1, and Series 2 oils both on the same installation and on several installations at the NAM, the All-Union Scientific Research Institute of Oil and Gas Processing and Production of Artificial Liquid Fuels (VNIIP), the Bakhchisar Scientific Research Institute of Petrol-Processing (Bakhchisar NP), and the Institute of Petrochemical Processes (INKPR) of the Azerbaijan SSR.

The test results, which appear in Tables 2 and 3, indicate satisfactory agreement between the results of the tests on all oil types.

Table 3. Results of Parallel Tests of Series 2 Control Oils

<table>
<thead>
<tr>
<th>Table 3. Results of Parallel Tests of Series 2 Control Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Date</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>1st Day</td>
</tr>
<tr>
<td>2nd Day</td>
</tr>
</tbody>
</table>

KEY: (a) indicators (in points); (b) Heavy Duty; (c) Series 1; (d) sulfur content in fuel; (e) piston-rod wear; (f) scaling in first ring groove; (g) scaling in other grooves; (h) over-all piston-rod wear.

COMPARISON OF OIL-TEST RESULTS OBTAINED ON SINGLE-CYLINDER BEN-10 AND CM TRACTOR DIESELS

In many cases, the results of oil tests on certain laboratory and motor machines do not agree with results obtained on full-sized production engines. This is chiefly because the operating and test conditions set up on the laboratory and motor installations do not match the design features and operating conditions of the production engines.

To one degree or another, almost all of the methods that have been developed permit classification of oils, but many of them have not been used extensively because tests of the same oil on engines give inconsistent results. Hence the basic criteria for establishing the reliability of the results should be the results obtained in long-term tests of the same oil specimens on the most common types of engines.

Tests were run on Heavy Duty (with low-sulfur and sulfur-containing fuels) and Series 1 control oils on the UIM-6-MATI bench and in SMU-14 and D-28 tractor diesels in order to determine the reproducibility of the results.

The indicators listed in Table 4 indicate that the high-temperature test regime selected for the UIM-6-MATI bench, which made it possible to reduce the test time to 120 hours, enables us to obtain the same results as with production engines operating under normal temperature conditions for 500 hours. The UIM-6-MATI installation occupies an intermediate position between the SMU-14 and D-28 engines in regards almost all indicators of piston and ring fouling by carbon deposits.
Table 4. Results of Tests on Control Oils in UM-5-NATI Bench and D-28 and SM-14 Engines

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>E Class-Duty</th>
<th>F Class-Duty</th>
<th>G Series (3)</th>
<th>H Critical (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E Class-Duty</td>
<td>E Class-Duty</td>
<td>G Series (3)</td>
<td>H Critical (3)</td>
<td></td>
</tr>
<tr>
<td>F Class-Duty</td>
<td>F Class-Duty</td>
<td>G Series (3)</td>
<td>H Critical (3)</td>
<td></td>
</tr>
</tbody>
</table>

KEY: (a) indicator; (b) Heavy Duty; (c) Series 1; (d) sulfur content in fuel; (e) Engine RPM; (f) D-28; (g) SM-14; (h) loss of piston-ring mobility, points; (i) scoring points; (j) first-ring groove; (k) in other ring grooves; (l) in liners; (m) on piston skirt; (n) in slots of oil-control rings and drainage holes in head of piston; (o) over-all rating, points; (p) amount of deposits in first ring groove and on rings; (q) amount of deposits in all grooves and on all rings, etc.

The results of the quick (120-hour) tests run on various samples of domestic oils with the UM-5-NATI installation also gave close agreement with the results obtained in long-term (500-hour) tests on the turbocharged engine with the SM-14 tractor (Table 5).

Table 5. Results of Oil Tests on UM-5-NATI Installation and D-28 and SM-14 Engines

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>F Class-Duty</th>
<th>G Series (3)</th>
<th>H Critical (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F Class-Duty</td>
<td>F Class-Duty</td>
<td>G Series (3)</td>
<td>H Critical (3)</td>
</tr>
<tr>
<td>G Series (3)</td>
<td>G Series (3)</td>
<td>H Critical (3)</td>
<td></td>
</tr>
<tr>
<td>H Critical (3)</td>
<td>H Critical (3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

KEY: (a) indicator; (b) DD-1 oil with additives; (c) 5% VNI NI-190 + 20% PM10 + 0.1% DD-216 + 0.005% PMS-2004; (d) 10% VNI NI-190 + 24% PM10 + 0.1% DD-216 + 0.005% PMS-2004; (e) 10% VNI NI-190; (f) DD-216; (g) DD-216; (j) over-all scoring points; (k) amount of deposits in grooves and on rings; (l) sleeve wear, points.

Thus, the conditions adopted for quick oil testing on the single-cylinder bench both with and without the pressure test permit objective evaluation of Heavy Duty, Series 1, and Series 2 oils and make it possible to reduce substantially the amount of expensive long-term testing done on production engines.

TESTS OF OIL SAMPLES

Various samples of oils developed by the VNI NI-190, and the INEB ZK oil of the Interzakaz SBR were tested in the UM-5-NATI and UM-5-NATI installations under the conditions stated above.

The object of the tests was to establish conformity of the motor qualities of the tested oils to the qualities of the Heavy Duty, Series 1, and Series 2 control oils.

Heavy Duty and Series 1

<table>
<thead>
<tr>
<th>Series 1</th>
<th>Series 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of tests, hours</td>
<td>120</td>
</tr>
<tr>
<td>Effective engine output, kW</td>
<td>21</td>
</tr>
<tr>
<td>Fuel consumption, kg/h</td>
<td>1.5</td>
</tr>
<tr>
<td>Engine RPM</td>
<td>2000</td>
</tr>
<tr>
<td>Water coolant, kg/cm²</td>
<td>3.6</td>
</tr>
<tr>
<td>Temperatures, °C</td>
<td>90</td>
</tr>
</tbody>
</table>

Thus, the conditions adopted for quick oil testing on the single-cylinder bench both with and without the pressure test permit objective evaluation of Heavy Duty, Series 1, and Series 2 oils and make it possible to reduce substantially the amount of expensive long-term testing done on production engines.
on UIM-6-NATI Bench and D-97 and SMU-18 Engines

<table>
<thead>
<tr>
<th>Engine</th>
<th>Other</th>
<th>D-97</th>
<th>SMU-18</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7. Results of Testing Series 2: Oils with Domestic Additives on UIM-EN-NATI Machine

<table>
<thead>
<tr>
<th>Engine</th>
<th>Other</th>
<th>D-97</th>
<th>SMU-18</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

KEY: (a) indicator; (b) DS-11 oil with additives; (c) with imported additives; (d) AIP NATI 7/10 + 4% PEM/Ya + 0.2% LE-29 + 0.005% PSM-2004; (e) 11% BPM + 4% GB-3 + 0.005% PSM-2004; (f) 4% ArmNII-2 + 4% PEM/Ya + 0.005% PSM-2004; (g) piston-ring mobility loss, points; (h) carbon scaling, points; (i) in first groove; (j) in other grooves; (k) in lands; (l) on piston skirt; (m) on inside piston surface; (n) in drainage hole and slots of oil-control rings; (o) overall rating, points; (p) amount of scale in grooves and on rings; (q) sleeve wear, μ; (r) wear of set of rings, μ.

Agreement and reproducibility between parallel experiments either in a single bench unit or a number of such units.

A. Test results obtained for various foreign and Soviet oils on the UIM-6-NATI and UIM-EN-NATI machines agree with data obtained in long-term (500-600-hour) tests of the same oil sampled in the D-97, SMU-18, D-28, SMU-18 and Yaroslavl-2388 tractor diesels.

B. Production and test samples of Soviet motor oils with additive compositions developed at the UNTI NP, INRAF AN agent, CSS and ArmNII NP were classified.

C. The quick test methods developed for Heavy Duty and Series 1 oils were standardized, and that devised for Series 2 is recommended for standardization and general use.
OIL AND OIL-ADDITIVE SELECTION AND USE—PROPERTY MOTOR RATING FOR TWO-STROKE GASOLINE ENGINES

V.P. Filippov, V.M. Bukolov and V.M. Savryukhin

As we know, the oil that lubricates two-stroke gasoline engines is introduced through the carburetor together with the fuel.

Depending on the design, physical condition, and operating conditions of the engine and on the properties of the oil and fuel used, the oil-to-fuel ratio varies from 1:25 to 1:40.

Oils for lubrication of two-stroke gasoline engines must meet the following main requirements:

1. They must burn with formation of the smallest possible amount of soot, while ensuring minimal wear of engine running parts under all engine operating conditions;

2. They must contain particular mixture of plugging the engine fuel-supply system;

3. They must ensure normal lubrication of the engine at minimum fuel consumption;

4. They must protect the parts of the engine and its fuel-supply system from corrosion;

5. Stability of the properties during storage is required when they are mixed with additives and gasoline;
In the event that the gasoline becomes watered, the oil and additives may not settle out of the mixture.

Oils with varying viscosities, chemical compositions, and additive contents are used in various countries to lubricate two-stroke gasoline engines.

It has been established that light type A-6 oils with medium viscosity indices produce the smallest amounts of deposits on the piston, in the combustion chamber, in the scavenging and exhaust ports, and on spark-plug electrodes, while a heavier oil of type M-169 with a high viscosity index oils-injector running and scoring of the pistons.

Use of mixed light and heavy oils that have been matched with consideration of chemical composition, the specific use conditions, and the engine design gives good results.

The use properties of the oils are improved considerably by introduction of special additives. Use of commercial and tractor oils with ashing additives is not recommended, since the additives increase wear and the amount of deposits in the scavenging and exhaust ports, in the combustion chamber, and on the plug electrodes.

It should be noted that factory recommendations on oils to be used in two-stroke gasoline engines are frequently given without adequate technical justification.

At the VNIIOil Scientific Research Institute of Oil and Gas Processing and Production of Artificial Liquid Fuel (VNI-INP), development of special additive oils was begun with elaboration of a spot-testing method using the SD-60S engine. Here it was necessary that:

1. The test method require little time and no more than 0.5 kg of the experimental oil, and that is to provide reproducible experimental results corresponding to the results of long-term operation and the tests of oils in two-stroke gasoline engines of various make.

2. One engine permit load-change simulation of existing and prospective two-stroke gasoline engines, and provide close differential for oils on the basis of the main use indicators; further, the engine be simple to operate and that it perform smoothly and reliably under various thermal loads, with adequate service life given replacement of the test components - the piston and cylinder.

Among the two-stroke gasoline engines that we have at the present time, the SD-60S meets these specifications, and was used as a basis for development of the bench installation and its test testing method.

*See page 86 for footnote.

Unlike motor-vehicle and traction engines, it does not require an outside blower when operated under bench conditions. Its adequate cooling fan makes it possible to vary the thermal stressing of the engine over a broad range by throttling the air flow and, if necessary, to simulate worst conditions.

Below we give the technical data of the SD-60S engine.

- Available power, hp: 10
- Crankshaft speed, rev/min: 4000
- Cooling: air
- Fuel: A-6 or B-70 gasoline, mixed with oil (6:1)
- Fuel consumption, g/hp-h: 556
- Weight of engine (with muffler), kg: 7
- Guaranteed service life, h: 600
- Suffer climatic, latitude and amortization losses.

In designing the oil-testing installation, certain auxiliary equipment was provided to allow for changes in application of the engine; they make it possible to control and monitor its operating conditions.

Essentially, the method consisted in a short test of the oil in the engine at high temperature. The motor qualities of the oils were rated on the basis of the amount of deposits on a piston, in the cylinder head, and in the cylinder exhaust port, and from the degree of piston-ring mobility.

The use properties of the oil were determined by comparing the results of tests run on the same installation with the test oil and a control oil, in terms of the rating indicators adopted.

The control oils were base oils made according to the appropriate GOST (All-Union State Standard) and additive oils for two-stroke gasoline engines, which were prepared in accordance with the appropriate Technical Specifications (TU) (77) or 2.375.

The control oil was tested after every 45 tests run with experimental samples. This made it possible to check the technical condition of the bench, its capability for differentiation, and the identity of the experimental conditions.

The following test conditions were adopted as a result of the studies (320 c of oil are required for 1 experiment):

<table>
<thead>
<tr>
<th>Test time, h</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crankshaft speed, rev/min</td>
<td>4000</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>geometrical</td>
</tr>
<tr>
<td>Actual</td>
<td>7:1</td>
</tr>
</tbody>
</table>
Spark timing before top dead center, deg. = 27-28
Fuel composition = B-70 gasoline, diesel fuel 1012-54
Fuel consumption, kg/h = 0.65
Composition of mixture (oil to fuel ratio) = 1:125
Temperatures, °C:
ambient and intake-air = 40-42
crankcase = 100-120
cylinder head = 200-220
Exhaust back pressure, cm of water = 0.015

The oils were rated on the basis of a number of indicators that characterize their use properties (Table 1).

Table 1. Results of Tests of Additives with AS-9.5 Oil

<table>
<thead>
<tr>
<th>Additive</th>
<th>Deposit Index</th>
<th>Piston-Ring Mobility</th>
<th>Piston</th>
<th>Cylinder Head</th>
<th>Exhaust Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC 1.5</td>
<td>0.3</td>
<td>0.03</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>AC 2.5</td>
<td>0.5</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>AC 3.5</td>
<td>0.7</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>AC 4.5</td>
<td>0.9</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
</tr>
</tbody>
</table>

KEY: (a) deposit index; (b) composition of fuel mixture; (c) piston ring mobility
(d) deposit on piston; (e) deposit on cylinder head; (f) deposit in exhaust port; (g) total

One of the indicators — the deposit index — is a conventional dimensionless over-all indicator of oil quality arrived at arbitrarily on the following basis:

Total amount of deposits on piston with rings, on piston head, in cylinder head and in exhaust port, arbitrary units: . . (1 g)

Ventak on piston, arbitrary units: . . . (2 points)

Piston-ring mobility, arbitrary units:
free: 0.25
burned: 0.5
on 350°: 0.05
on 150°: 0.5

Table 2. Results of IMSTD-10PS-Method Tests of Oil Standard with Domestic and Foreign Additives

<table>
<thead>
<tr>
<th>Additive</th>
<th>Deposit Index</th>
<th>Piston-Ring Mobility</th>
<th>Piston</th>
<th>Cylinder Head</th>
<th>Exhaust Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC 1.5</td>
<td>0.3</td>
<td>0.03</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>AC 2.5</td>
<td>0.5</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>AC 3.5</td>
<td>0.7</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>AC 4.5</td>
<td>0.9</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
</tr>
</tbody>
</table>

KEY: (a) deposit index; (b) composition of fuel mixture; (c) piston ring mobility
(d) deposit on piston; (e) deposit on cylinder head; (f) deposit in exhaust port; (g) total

One of the indicators — the deposit index — is a conventional dimensionless over-all indicator of oil quality arrived at arbitrarily on the following basis:
(Key to Table 1, cont'd.) 1. AS-9.5 + 20% Amoco 661 additive (USA); (2) same; (a) AS-9.5 + 3% Ecolube 120 additive (GDA); (b) AS-9.5 + 1.5% ASK + 1% ZnK; (c) AS-5.8 + 0.25% PMS-200A; (d) AS-9.5 + 1.5% ASK + 0.25% PMS-200A; (e) AS-9.5 + 1.5% ASK + 0.25% PMS-200A; (f) AS-9.5 + 3% Ecolube 120 + 0.001% PMS-200A; (g) AS-9.5 + 2% Amoco 661 additive (USA); (h) AS-9.5 + 2% Amoco 661 additive (USA); (i) AS-9.5 + 2% Amoco 661 additive (USA); (j) AS-9.5 + 2% Amoco 661 additive (USA).

Each specimen was tested at least twice; here the disagreement between the results should not exceed 4% for the wear and total-deposits indices, or 40% for the deposit color. The amount of scale is determined to within 0.001 µm.

The work of selecting oil additives was begun with study of the functional properties of the individual additives on the bench engine.

It was established that the smallest amount of deposits in the combustion chamber and exhaust ports results from use of the low-ash alkylaryl hydrocarbon additive ASK, 1.5% by weight of which eliminates piston-ring burning, reduces piston varnish from 6 to 1 point, and simultaneously increases the amount of deposits on the piston head, in the cylinder head, and in the exhaust port (see Table 1).

Fatty acid ethyl ester (EE2hK) and synthetic fatty acids (ZnK) reduce the amount of deposits substantially but do not eliminate burning-on of the piston rings and do not reduce varnish of the piston. More than 1% of ZnK in the oil causes deterioration of all motor-property indicators. Combined with ASK and ZnK, PMS-200A additive improves all indicators.

The studies established that each of the additives tested does not, taken alone, improve the properties of the base oil in all of the rating indicators. Subsequent development work on oil for two-stroke gasoline engines was directed toward adjustment of the additive combination.

Table 2 presents test results for mixes developed on the basis of ASK additive in combination with EE2hK, ZnK, and PMS-200A, for comparison with AS-9.5 base oil and with foreign additives. Mixes based on ASK are more effective. Additive mixes containing synthetic fatty acids (C<sub>n</sub>-C<sub>16</sub> fraction), which were used for 850-1000 hours in Drumbha-4 gasoline-powered saws, produced somewhat better results than mixes of the same additives containing EE2hK. When AS-9.5 oil was used with an additive mix consisting of 1.5% ASK, 1% ZnK, and 0.001% PMS-200A, the service life of the Drumbha-4 engine was increased by a factor of 2. This oil is recommended by the interdepartmental commission for experimental use. The gas-use properties of AS-10 oil with 17.5% of T-1 fuel, 1.5% ASK, 1% ZnK, 0.25% PMS-200A, and 0.001% PMS-200A and a similar mix with 1.5% EE2hK were confirmed by the results of use tests extending over the entire lifetime of 3D-62S engines. In tests of engine performance on AS-9.5 oil without additives (mixture composition 1:2), it was necessary to replace the piston pin and the connecting-rod top-end inserts after 450 hours because of wear. Engines ran for more than 700 hours on AS-9.5 oil with the additive composition developed (mixture composition 1:33) without replacement of parts or removal of deposits.

The method developed makes it possible to obtain a reproducibility of the results that is adequate for motor tests, along with sharp enough differentiation between different oil qualities (Fig. 1).

The installation developed performs reliably over a broad cylinder-temperature range. Oils can be rated in research studies at cylinder temperatures from 170 to 230°C. The maximum cylinder temperature for tests of various oils and additives is limited by the onset of ring burning and piston scoring. For effective special-additive mixes, it ranges up to and above.
CONCLUSIONS

1. A method was developed for motor rating of the use properties of oils used for two-stroke gasoline engines.

2. The method can be used to rate oils with and without additives, to determine the functional properties of specific additives, and to adjust optimum additive mixes.

3. The method yields satisfactory reproducibility in the test results. The divergence of two parallel tests is ±10% for the deposits index and the total amount of deposits.

4. The bench installation and the method elaborated for it have enabled the VNII BP to develop special two-stroke gasoline-engine oils whose operational properties are considerably better than those of the commercial oils currently being produced.

5. The motor-rating method can be recommended for State Standard and Departmental Technical Specifications; it can be used in scientific-research organizations, at petroleum refineries, and by consumers to check oil quality.

Fig. 2. Influence of thermal load of 7270-1007 bench engine on test results for various oils. 1) PS-11 oil (without additive); 2) PT-11 oil with 1.5% ASK, 1% CNK, and 0.001% PMD-2006.

KEY: (a) ring wear, mm; (b) piston varnish, points; (c) total amount of deposits, g; (d) deposits index; (e) cylinder temperature, °C.

**Note:** As the oil is not having additives, it is usually 180-200°C. Results of ten-hour tests at various cylinder temperatures made it possible to plot characteristic curves for oils with lower temperature and the rating indicator as coordinates. In [2], comparison of these characteristics for various oils serves a basis for predicting their range of application.

In ten-hour sequential tests of the oil, its antiwear properties can be rated quite reliably against 40-60 hours. When PS-11 was used without additive in 40 hours of operation at cylinder temperatures between 180 and 210°C, the total ring wear was 0.027 mm, but only 0.17 mm with 1.5% ASK, 1% CNK (5°C), and 0.001% PMD-2006 over the same running time at cylinder temperatures of 200-230°C.

A full-scale bench installation has now been built around a CI-67H engine and can be used to test oils for two-stroke gasoline engines.
Footnote

' A stationary single-cylinder two-stroke engine with two-channel return-counterflow scavenging.

IN-STORAGE PROPERTY CHANGES OF OILS OF VARIOUS CLASSES AND DETERMINATION OF THEIR PURITY

K.K. Papok and B.S. Zueva

CHANGE IN THERMAL-OXIDATION STABILITY AND DETERGENT POTENTIAL OF ADDITIVE OILS DURING STORAGE

With the object of determining how the thermal-oxidation stabilities and detergent potentials of additive oils change during storage, oils of various classes (from Premium to Series 3) were prepared with D5-11 oil as a base and with various combinations of foreign and domestic additives and placed in long-term storage.

A consignment of oils with foreign additives was prepared under laboratory conditions in August 1961. Each specimen had a volume of 0.5 liter. The oil samples were stored in glass bottles in diffuse light in a closed unheated warehouse. Control analyses were made in February 1963 and April 1965.

The analyses (Table 1) showed that after 2 years and 7 months of storage, all oils with mixes of foreign barium and calcium additives retained thermal-oxidation stability (except for the calcium-additive Series 3 oil), while after 4 years and 9 months of storage, thermal-oxidation stability had declined by 10-25 minutes in 90% of the specimens, namely, in oils of the Heavy Duty, Series 1 and Series 3 classes with barium additives and in Premium, Series 1 and Series 3 oils with the calcium additives.
Table 1. Change in Properties of Various Classes of Oils During Storage in Glass Bottles

<table>
<thead>
<tr>
<th>Oil Class</th>
<th>Content of Additives in SS-1 Oil</th>
<th>Thermal-Oxidation Stability</th>
<th>Detergent Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premium</td>
<td>0.7% antioxidant</td>
<td>55</td>
<td>10</td>
</tr>
<tr>
<td>Heavy Duty</td>
<td>0.4% antioxidant</td>
<td>55</td>
<td>10</td>
</tr>
<tr>
<td>Series 1</td>
<td>0.3% antioxidant</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Series 2</td>
<td>0.2% antioxidant</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Series 3</td>
<td>0.1% antioxidant</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

KEY: (a) oil; (b) content of additives in SS-1 oil; (c) thermal-oxidation stability, minutes; (d) original speckens; (e) after 2 years, 7 months of storage; (f) after 3 years, 6 months of storage; (g) detergent potential; (h) Premium; (i) 1% antioxidant + 5% barium; (j) Heavy Duty; (k) 1% barium; (l) 2% antioxidant; (m) 0.1% antioxidant + 2% calcium; (n) for marine engines.

Detergent potential remained unchanged in all oils after three years and nine months of storage, except for the Premium and Heavy Duty oils with calcium additives, which showed a sharp increase in detergent potential even after 2 years and 7 months.

In August 1962, a consignment of oils with various additives, prepared under conditions and packaged in steel drums, was transferred from the "KIEV" oil mill to the "KIEV" oil mill. Oil from these drums was filled into glass bottles and stored in a closed heated warehouse for storage. The drums were then stored in outdoor platforms.

Control analyses, the results of which appear in Table 2, were made in February 1964 and April 1965.

As we see, even after 1.5 years of storage, whether in the glass bottles or in the steel drums, the thermal-oxidation stabilities of all the oils except the "Kiev" 1 and Series 2 oils with calcium additives had dropped by 12-19%, and after 2 years and 6 months of storage, a further decrease in thermal-oxidation stability was noted in the oils stored in glass bottles for the first three years and in the drums after 1.5 years.

Except for Premium oil with calcium additives, the detergent potentials of all oils had undergone no change after 1.5 years of storage, while after 2 years and 8 months, all oils with calcium additives showed a 20-60-unit loss of detergent potential.

It is interesting to note that the oils prepared in the laboratory (August 1961) were more stable during storage in glass than the oils prepared under semindustrial conditions (see Table 1 and 2). This provides a basis for the assumption that the conditions of mixing of the oils with the additives influence storage stability.

---

Table 2. Change in Properties of Oils of Various Classes During Storage

<table>
<thead>
<tr>
<th>Oil Class</th>
<th>Content of Additives in SS-1 Oil</th>
<th>Thermal-Oxidation Stability</th>
<th>Detergent Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premium</td>
<td>0.7% antioxidant</td>
<td>55</td>
<td>10</td>
</tr>
<tr>
<td>Heavy Duty</td>
<td>0.4% antioxidant</td>
<td>55</td>
<td>10</td>
</tr>
<tr>
<td>Series 1</td>
<td>0.3% antioxidant</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Series 2</td>
<td>0.2% antioxidant</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Series 3</td>
<td>0.1% antioxidant</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

KEY: (a) oil; (b) content of additives in SS-1 oil; (c) thermal-oxidation stability, minutes; (d) original speckens; (e) after 1.5 years of storage; (f) after 2 years, 7 months of storage; (g) detergent potential; (h) with barium additives; (i) Premium; (j) in glass bottles; (k) in steel drums; (l) Heavy Duty; (m) Series...

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The results of analyses of the oils with Soviet additives appear in Table 3.

Table 3. In-Storage Property Changes of Oils of Various Classes with Soviet Additives

<table>
<thead>
<tr>
<th>Class</th>
<th>Oil Additive</th>
<th>Filtered</th>
<th>a-1</th>
<th>b-1</th>
<th>c-1</th>
<th>d-1</th>
<th>e-1</th>
<th>f-1</th>
<th>g-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Heavy Duty</td>
<td>65 65 45 50 60 60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Heavy Duty</td>
<td>65 65 45 50 60 60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Heavy Duty</td>
<td>65 65 45 50 60 60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Heavy Duty</td>
<td>65 65 45 50 60 60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Heavy Duty</td>
<td>65 65 45 50 60 60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Filtered specimens.
KEY: (a) oil; (b) additive content in DS-13 oil; (c) storage conditions; (d) thermal-oxidation stability, minutes; (e) original specimen; (f) after 1.5 years of storage; (g) after 8 months of storage; (h) additive content in steel drums; (i) glass bottles; (j) in oil; (k) in steel drums; (l) Series 1; (n) 5% VNIIPF-470 + 3% VNIIPF-470 + 0.5% LZ-23K + 0.005% FMS-200A; (o) 15% VNIIPF-470 + 0.5% LZ-23K + 0.005% FMS-200A; (p) 15% VNIIPF-470 + 0.5% LZ-23K + 0.005% FMS-200A.

After 1.5 years of storage, the thermal-oxidation stability of all oils (except for two specimens) remained practically unchanged, but after 2 years and 8 months of storage in glass, they fell by 8-20 min. The detergent potentials of the Heavy Duty and Series 1 oils had not changed after 2 years and 8 months of storage; for the Series 2 and Series 3 oils, they had fallen by 20-30 units after 1.5 years of storage, and to zero after 2 years and 8 months.

INVESTIGATION OF PURITY OF MOTOR OILS AND ADDITIVES

The following method was worked out for determination of the purity of the oils and additives. The oil or additive specimen to be studied was dissolved in Galoaska gasoline at room temperature and passed under vacuum (residual pressure 20-30 mm Hg) through a No. 10 biological filter 27 mm in diameter, which was placed in a two-part metal funnel (GOST [AllUnion State Standard] 10739-64). To determine the purity of the oils, 5-gram weighed specimens were taken and dissolved in 45 ml of Galoaska gasoline; to determine additive purity, 1-gram weighed samples were dissolved in 45 ml of Galoaska gasoline.

The purity of an oil or additive is determined from the filtration number and the amount of dirt in the oil. The filtration number is determined from the number of filters needed for complete filtering of the entire oil or additive solution with filter change mandatory at 5-minute intervals.

The amount of dirt is determined from the difference in the weights of the biological filter before and after filtration of the oil solution (bringing it to constant weight at 100°C). When it is necessary to change filters several times, when the products being tested contain large amounts of contamination, the total amount of deposits on all of the filters is taken as the fouling index of the oil. The amount of dirt is expressed in mg/100g of the oil or additive being tested.

The disagreement between parallel experiments may not exceed 20 mg/100g for dirt contents up to 200 mg/100g, or 1% of the smallest result for dirt contents above 200 mg/100g. The fouling of the oil can also be rated tentatively by visual inspection on the basis of filter color.

It was found on checking the purity of the motor oils without additives that in general, all of the commercial oils show high purity: the number of filtrations was 1, i.e., they were thoroughly filtered by a single filter, and the amount of dirt did not exceed 30 mg/100g.

The purity of motor oils containing various additives fluctuates in a very broad range: as many as 6 filters were required to clear some specimens, and the amount of dirt ranged up to 300 mg/100g (Table 4).

Oils with the Monto, Santolube, and Grodite additives showed high purity; the filtration number was 1, and the amount of dirt ranged from 26 to 40 mg/100g. On the other hand, oils with the VNIIPF-470, BIF-1, 2B-3, and other additives were very dirty; they required up to 6 filtrations and contained up to 306 mg/100g of dirt.

The purity change of mineral oils under the influence of additives is accounted for by inadequate purity of the additives themselves (Table 5). We see from the table that the filtration
Table 4. Purities of Various Classes of Oil

<table>
<thead>
<tr>
<th>a</th>
<th>Name</th>
<th>b</th>
<th>C</th>
<th>d</th>
<th>e</th>
</tr>
</thead>
<tbody>
<tr>
<td>g</td>
<td>Примечание</td>
<td>0.1% Сантола-405 + 0.1% Монто-405</td>
<td>0.1% Готрил-267</td>
<td>0.1% Готрил-267 + 0.1% Еки-11 + 2.5% Еки-11 + 1.2% ЕБК-11</td>
<td>0.1% Готрил-267 + 0.1% Еки-11 + 1.2% ЕБК-11</td>
</tr>
</tbody>
</table>

Table 5. Purities of Various Additives

<table>
<thead>
<tr>
<th>a</th>
<th>Name</th>
<th>b</th>
<th>C</th>
<th>d</th>
<th>e</th>
</tr>
</thead>
<tbody>
<tr>
<td>g</td>
<td>Примечание</td>
<td>0.1% Сантола-405</td>
<td>0.1% Готрил-267 + 0.1% Еки-11 + 1.2% ЕБК-11</td>
<td>0.1% Готрил-267 + 0.1% Еки-11 + 1.2% ЕБК-11</td>
<td>0.1% Готрил-267 + 0.1% Еки-11 + 1.2% ЕБК-11</td>
</tr>
</tbody>
</table>

KEY: (a) additive; (b) purity; (c) number of filtrations; (d) dirt, mg/100g; (e) Santolene-493; (f) Monto-405; (g) Orbis-2054, 267, 2112A; (h) Monto-702; (i) LANI-317; (j) PMSYA-125; (k) BPK-1; (l) L2-2K; (m) VINII NP-171; (n) VINII NP-360; (o) AzNNI-U-012; (p) AzNNI-7; (q) IL-72; (r) VINII NP-370; (s) VINII NP-167; (t) SB-3; (u) PMSY-A.

However, most of the additives have indicators inferior to those noted above, and additives such as PMSYA, SB-3, and VINII NP-370 were very dirty (from 800 to 2070 mg/100g) and had filtration numbers from 8 to 9. However, any of the additives may be prepared in different purities.

The purities of laboratory-sized (August 1961) and semi-industrial (April 1964) oils with foreign additives and domestic semi-industrially mixed oils were checked. As we see from Table 6, the semi-industrially mixed oils are considerably better than the lab-mixed oils, and this is apparently the explanation for the stability differences during storage.

It is recommended that the purity rating method be used to monitor the purity of oils and additives, using the norms given in Table 7 as a guide.
Table 6. Purities of Oils of Various Classes Mixed in the Laboratory and Under Semindustrial Conditions

<table>
<thead>
<tr>
<th>Class</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premium</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Series 2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Series 3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

KEY: (a) oil; (b) purity; (c) number of filtrations; (d) laboratory mixing; (e) semindustrial mixing; (f) dirt, mg/100g; (g) with imported barium additives; (h) Premium; (i) Heavy Duty; (j) Series ... (k) with imported calcium additives; (m) with domestic VMII NF additives.

Table 7. Acceptable Purity Standards

<table>
<thead>
<tr>
<th>Product</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premium</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Series 2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Series 3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

KEY: (a) product; (b) purity; (c) number of filtrations; (d) dirt, mg/100g (not above); (e) oil without additives; (f) oil with additives; (g) additives.

CONCLUSIONS

1. Oils with calcium additives are less stable than oils with barium additives as regards changes in detergent potential during storage.

2. In oils of unsatisfactory purity, thermal-oxidation stability and detergent potential change at a considerably earlier date during storage than in the cleaner oils.

3. A laboratory method was worked out for rating oil and additive purity, and purity norms were recommended for oils with and without additives and for the additives themselves.
USE OF PAIRED ANTIOXIDANTS FOR TURBINE OILS

K.I. Ivanov, Ya.F. Svetunov, A.A. Luchatskii

and A.M. Alexandrov

There is as yet no generally accepted theory that explains the phenomenon of synergistic action when mixtures of hydroperoxides (antioxidants, retarders) are used, i.e., the mutual enhancement of their action that is observed in many cases.

In the present time, there are two main views as to the mechanism of the synergism. As it was in the case of mixtures of antioxidant with inhibitors, one molecule of the active component is the predominant in the mixture or other hydroperoxide-electrolyte, and the key interaction is in two of the synergism, as in [1], the good synergistic, but in a much larger number. The interaction is not complete, and mutual action between it is not, for example, unidirectional like one

Antioxidant – LOD

Antioxidant + Retarder

may be the original one is represented [1], or as a result of formation of condensed or free radicals (of the amine and the peroxyl radicals, and the products of hydrogenation reaction products) with a hydroperoxide mixture, or as a result of the formation of hydrogen peroxide itself existing, which is active.

Inhibitors that terminate chains without consumption [in the typical case of the NH group, but with participation of the phenol CH group [2].

According to the second view of the synergic effect, inhibitors are classified into three kinetic groups that differ in chemical structure and are capable of deactivating various intermediate products on which initiation and development of the chain oxidation reaction depend [3-5]. It has been established by research at the All-Union Institute of Heat Engineering (AUIH) that group I retarders interact only with free hydrocarbon radicals R, and not with hydroperoxides ROOH or free peroxide radicals ROO•; group II retarders react vigorously with hydroperoxides and with ROO•, and do not react with hydrocarbon radicals; group III retarders react with R, and ROO• and interact either sluggishly or not at all with hydroperoxides [1].

In this context, we may assume that in the simultaneous presence of antioxidants of various groups (I and II, III and I, I and III), their effects tend to strengthen one another (synergistic effect), with the result that initiation of the oxidation process is minimized.

For example, we might assume that in the combined presence of group I and II retarders, the group I antioxidant demethylates most of the R, radicals formed during the initiation phase, while those that still exist have time to convert to ROO• and are handled by the group II antioxidant.

Inhibitors of groups II and III to a certain degree III may, moreover, produce a synergistic effect by interacting with accumulating hydroperoxides, thus preventing branching of the reaction chain.

For this hypothesis to exist, it must be coupled with the fact that some inhibitors are capable, in many cases, of forming complexes with hydroperoxides containing unsaturated hydrocarbons, a hydrogen bond forms to the aromatic ring, as has been demonstrated in the example of primary amines and organic compounds [3]. These complexes may have retarding properties. However, this theory does not take into account the fact that initiation inhibitors sometimes retard the decomposition of peroxides, but also inhibit active particles of hydroperoxides: R, alkxy radicals ROO•, ROOH. Necesarean this theory should be complemented by the experimental determination of the activity of different inhibitors, depending on their structure, to react with different intermediate products of the oxidation process.

The second theory takes these factors into account. It postulates that under a broad range of inhibitor mixtures, that produce the synergistic effect. The possibility of such action has been confirmed experimentally under laboratory and industrial conditions.
Laboratory and use tests have shown that given proper selection, the stabilizing action of two additives on turbine oils exceeds that of either of them taken alone at twice the concentration. This proves that we are dealing not with simple addition of the effects of two antioxidants, but with mutual enhancement of their activities. It has also been proven that a mixture of antioxidants of the same kinetic group does not, as a rule, produce the synergistic effect [6].

**Effectiveness of Paired Antioxidants Under Laboratory Conditions**

<table>
<thead>
<tr>
<th>Product</th>
<th>Overall Stability</th>
<th>Sediment Content</th>
<th>Acid Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
</tr>
<tr>
<td>A</td>
<td>0.61</td>
<td>0.08</td>
<td>0.17</td>
</tr>
<tr>
<td>B</td>
<td>0.65</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>C</td>
<td>0.67</td>
<td>0.06</td>
<td>0.16</td>
</tr>
</tbody>
</table>

KEY: (a) product; (b) over-all stability according to GOST 81-55; (c) acid number, mg of KOH/g; (d) sediment content; (e) turbine oil III; (f) same % of component A; (g) same % of component B; (h) traces; (i) turbine oil II.

![Fig. 1. Change in acid number of oil after introduction of paired antioxidant.](image)

**Fig. 1.** Change in stability of oil after introduction of paired antioxidant. 1) total acid number; 2) acid number due to water-soluble acids; 3) introduction of paired antioxidant.

**Fig. 2.** Change in stability of oil after introduction of paired antioxidant. 1) acid number; 2) content of nonvolatile acids; 3) content of volatile acids; 4) sediment content; 5) introduction of paired antioxidant.

**KEY:** (a) sediment content; (b) acid number, mg of KOH/g; (c) test time.

Of special practical interest for inhibiting oxidative aging of lubricating and insulating oils is the use of physico-synergistic effects in the use of mixtures of antioxidant additives in which, in addition to the true inhibitors (i.e., substances that terminate reaction chain), there are retarders with other mechanisms of action — primarily deactivators and passivators for metals (chiefly copper and iron) that come in contact with turbine and transformer oils under use conditions and catalytically accelerate their aging.

It must be remembered in testing various antioxidant pairs that they must dissolve well in oils and ensure stability without detriment to other use properties.

A paired antioxidant consisting of 0.1% 8-naphtol... etc. belongs to group III of the classification proposed earlier and 0.03% phenyl-8-naphthylamine, a group I antioxidant, was tested after laboratory study in the oil system of a... and a... turbogenerator. The oil with this antioxidant pair has been used for 1.5 years without the use of absorbents. After 1.5 years, the acid number of the stabilized oil was considerably lower than those of unstabilized oils previously used in this turbine with absorbents for the same period of time.

Tests were run on one more mixture, which consists of a group III antioxidant (component A) that has simultaneous properties of a metal deactivator and a group I antioxidant (component B). The effectiveness of this mixture as...
under laboratory conditions according to GOST 981-55. The test results are given in the table. The table shows that the proposed antioxidant pair has a very sharp inhibiting effect on the aging of turbine oil. The acid number after aging was smaller by a factor of 12 than that of the pure oil and smaller by a factor of 3 than the acid number of the same oil with twice the concentration of one of the components. The amount of sediment is also smaller, in confirmation of the effectiveness of this paired antioxidant.

Use tests were then run with this antioxidant pair in a 24,750-kW turbogenerator.

Figure 1 shows the change in the acid number of the stabilized oil during operation of the turbogenerator. Figure 2 shows the change in its stability (after GOST 981-55) after introduction of the paired antioxidant.

It was established by the tests that after 3.5 years of use, the oil had an acid number of 0.01 mg of KOH/g, i.e., it was practically the same as the norm for fresh oil (0.02 mg of KOH/g). It should be noted that no additive was introduced into the fresh oil over the 3.5 years. It was established on inspection of the turbine (after 2 years of operation), that its oil system did not require cleaning. Operating experience from previous years shows that without the paired antioxidant, oil lasted 3 years in this turbine only with continuous absorbent regeneration.

The adsorbent had to be changed repeatedly, with the resulting higher labor cost and a considerable increase in use of the expensive adsorbent.

The same paired antioxidant was tested in another turbine. Figure 3 shows the changes of the oil's indicators in this turbine. The tests are being continued successfully. The use tests show that the proposed paired antioxidant inhibits the turbine-oil aging process more actively than other antioxidant additives and does not require special checking by servicing personnel. At this writing, use tests are being run with the paired antioxidant in four turbogenerators.

CONCLUSIONS

1. Mixtures of antioxidants for turbine oils, adjusted on the basis of theoretical notions developed by the authors, give a pronounced synergistic effect when tested under laboratory conditions.

2. The results of the laboratory tests are confirmed by data from use testing of the paired antioxidant, in the presence of which the original properties of the oil are retained fully over a long operating interval.

References


ADDITIVE MIXES FOR STABILIZATION OF TRANSFORMER OILS

M.I. Skachkovich

Use of oil-stabilizing additives prolongs the useful lives of transformers, improve their reliability, and permit improvement in their design. Against the insulating and structural materials used in the transformer, copper is the most active catalyst of the oxidation of mineral insulating oils.

Under use conditions, copper structures come into contact with the oil, and dissolved copper is found in the oil itself in the form of salts of organic acids.

Oils transformer oil contains up to 0.0001% of copper [1]. It has been shown [2] that the amounts of antioxidant additives consumed in inhibiting hydrocarbon oxidation in the presence of copper are considerably larger than under the same conditions without the catalyst. With the large amount of copper present when oil is oxidized in transformers, it is necessary to use very large amounts of antioxidants (0.3-0.5% by weight).

The stability of transformer oils can be increased much more effectively by using deactivating and passivating additives. Deactivators produce their effect by interacting chemically with salts of metals dissolved in the oil. This leads to formation of chelate complexes in which the metal is screened and cannot act as a catalyst. The complexes formed may settle out or remain dissolved in the oil.

Salicylidene Schiff bases obtained by condensing amines with aromatic aldehydes are used as deactivators.

Basic Physicochemical Indicators of Transformer Oils

| d Mole | L Oil | C Fatty | Z Bt | M Mole | Z 1 Oil | C Fatty | Z Bt | C Fatty | Z Bt | C Fatty | Z Bt | C Fatty | Z Bt | C Fatty | Z Bt |
|--------|-------|---------|------|--------|--------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|
| 1.8    | 2.1   | 2.2     | 2.3  | 2.4    | 2.5    | 2.6     | 2.7  | 2.8     | 2.9  | 3.0     | 3.1  | 3.2     | 3.3  | 3.4     | 3.5  |
| (a)     | (b)   | (c)     | (d)  | (e)    | (f)    | (g)     | (h)  | (i)     | (j)  | (k)     | (l)  | (m)     | (n)  | (o)     | (p)  |
| 1.8     | 2.0   | 2.1     | 2.2  | 2.3    | 2.4    | 2.5     | 2.6  | 2.7     | 2.8  | 2.9     | 3.0  | 3.1     | 3.2  | 3.3     | 3.4  |
| (q)     | (r)   | (s)     | (t)  | (u)    | (v)    | (w)     | (x)  | (y)     | (z)  | (a)     | (b)  | (c)     | (d)  | (e)     | (f)  |
| 1.8     | 2.0   | 2.1     | 2.2  | 2.3    | 2.4    | 2.5     | 2.6  | 2.7     | 2.8  | 2.9     | 3.0  | 3.1     | 3.2  | 3.3     | 3.4  |

KEY: (a) oil; (b) density; (c) viscosity at 100°C; (d) tan δ at 50°C; (e) structural group analysis; (f) from mixed liquids; (g) from aqueous solution; (h) from mixed Emulsion; (i) from aromatic crude; (j) tan δ; (k) from Crude oils; (l) from Marian crude; (m) from Marian crude; (n) from Marian crude; (o) from Marian crude; (p) from Marian crude.

Passivating act by a somewhat different mechanism than those with the other, they form a catalytically inactive film on the surface. It is assumed that the passivator is penetrative in the process.

The passivating additives include certain amines amines. Quite often, the same compound acts as both a deactivator and a passivator [1].

Reference [3] describes experiments in which additives of this type were used separately and in combinations, but it will be interesting to study the manner in which these additives increase the stability of domestic commercial transformer oils for various origins (Table).

The additives d-salicylideneethylenediamine (a deactivator) and anthranilic acid (a passivator) were studied, along with combinations of these additives with one another and with antioxidants: phenyl-β-naphthylamine and 2,6-di-t-butyl-4-methylphenol (Ionol).

The effectiveness of these additives was rated by laboratory methods, which simulate the most important conditions to which the oil is subjected in transformers. One of the methods consists in oxidizing the oil for 48 hours with oxygen under static...
conditions in the presence of catalysts (copper, lead, etc.) in an electric field of 49 KV/cm at 100°C. The oxidizability of the oil is evaluated from the rate of oxygen absorption and the change in the properties of the oil. In another method, the oil is oxidized without an electric field for 1000 hours in the presence of a copper catalyst with air given free access. The change in oxidation rate is observed through the qualitative indicators of the oil after 5, 50, and 100 hours. Taken together, these laboratory methods yield a preliminary rating of the performance properties of transformer oils with and without additives.

An in-house customary in evaluating the quality of transformer oils, the data from the laboratory experiments were compared with results from tests of oil specimens with additive mixed in small bench transformers [5].

It was established by the preliminary experiments that 0.2% by weight of the antioxidant additive ionol is introduced into transformer oils (see Table 1). Stability in not always improved, especially in the case of 3% [sic] electrophysical indicators (the tangent of the electric loss angle tan δ).

The results obtained when deactivating and passivating additives are used are different.

Tests in an electric field indicate (Fig. 11) that oxidation of 0.05% of anthranilic acid to the various oils, the oxidation process is retarded appreciably. The kinetic curves of oxygen absorption by the oil with the anthranilic acid additive are smooth and coincide almost perfectly with that of the corresponding oil without the additive or catalyst. The oxidation curves of oils with anthranilic acid characteristics show slow absorption of oxygen at the beginning of the reaction, without the extended induction period that is usually observed in oxidation of oils with inhibiting additives.

Stability of the indicator tan δ, which characterizes the insulating properties of the oil, is highly important for the performance of transformer oils. During oxidation, the tan δ for oils with anthranilic acid increased somewhat more slowly than that of oil without this additive.

In analyzing the results of 1000-hour oxidation tests (Fig. 11), we note that the stabilizing action of anthranilic acid manifests itself in the oxidation of oils from various origins and containing various amounts of carbon in aromatic rings [5, 6].

[Key to Fig. 1, cont'd.] without additive.
14) same oil with 0.05% anthranilic acid.
The tan δ values of the oils (at 70°C) are given in parentheses.
KEY: (a) amount of oxygen absorbed, ml/100 g of oil; (b) test time, hour.

Fig. 1. Kinetic oxygen absorption curves of transformer oils with additives during oxidation in an electric field (a-f): 1) imported oil (GDR) without additive; 2) same oil with 0.05% anthranilic acid; 3) oil from Baku crude without additive; 4) same oil with 0.05% anthranilic acid; 5) oxidation without catalyst; 6) oil from Tuscan crude, hydroformed and contact-refined without additive; 7) same oil with 0.05% anthranilic acid; 8) oil from Tuscan crude, phenol refining, without additive; 9) same oil with 0.05% anthranilic acid and 0.3% ionol; 10) same oil with 0.05% 4-nitro-2-benzenediazonium and 0.3% ionol; 11) oil from Anastasia crude with additive; 12) same oil with 0.5% anthranilic acid; 13) oil from Bucovășe crude, adsorption refining. [Key cont'd. on page 104]
Oils with anthranilic acid show a typical slow increase in tan δ during oxidation. The sediment-accumulation curves have small slopes, the original color of the oil changes insignificantly, and the aggressive ness of the oil with respect to copper and the contact resistance of the copper plates are reduced substantially. In contrast to inhibited oxidation, the kinetic curves reflecting the change in quantity of acids are smooth in the case of oils with anthranilic acid, with the amount of acids decreasing during oxidation. The latter is associated with depletion of the additive, which is acidic in nature.

During long-term aging of the oils, the passivating film formed on the copper surface disintegrates as the passivator is used up and oxidation products act, and further oxidation of the oil proceeds as though there were no additive present in it. This effect is particularly distinct in oxidation of oils with relatively small natural-inhibitor contents. To protect the adsorbed layer from attack by oxidation products and preserve it for a long time, an antioxidant additive is introduced into the oil together with the passivator. Then, to the extent that copper does not manifest its catalytic activity, inhibitor consumption decreases and the oil becomes more stable.

![Diagram](image_url)

**Fig. 2.** Kinetic curves of indicator changes during oxidation (1000 h) of transformer oils with 0.05% anthranilic acid (for legend see Fig. 1).

KEY: (a) acid number, mg of KOH/g; (b) sediment content, %; (c) tan δ at 70°C, %; (d) test time, hours.

![Diagram](image_url)

**Fig. 3.** Kinetic curves of indicator change during oxidation (1000 h) of transformer oils with additive mixtures: (1) oil from Emeka crudes without additives; (2) same with 0.02% anthranilic acid and 0.05% disalicyldiethylamin ethanolamine (see Fig. 1 for other identifications).

KEY: (a) acid number, mg of KOH/g; (b) sediment content, %; (c) tan δ at 70°C, %; (d) test time, hours.

It was shown for the example of oils made from Anakin and Ebenomin crudes (Fig. 1) that oxidation of the oil is inhibited sharply by use of a mixture consisting of 0.003% anthranilic acid and 0.1% phenylaminothiourea.

It was established by the foregoing experiments that this effect is not observed when each of these additives is used alone. When the two additives are used, the tangent of dielectric angle is stable even when separate introduction of 0.7% by weight of linalol or 0.05% by weight of anthranilic acid does not provide the required effect.
Thus, when oil from Tuymazy crude is oxidized with each of the above additives, tan δ has already increased by 100% after 240-480 hours. On the other hand, when a mix consisting of 0.02% disalicylideneethylenediamine and 0.2% liconol is introduced into the oil, its tan δ has increased only 4% after 1000 h of oxidation.

The stability of oil made from Emba crude is improved substantially by addition of 0.05% disalicylideneethylenediamine and 0.02% anthranilic acid—something that could not be accomplished by use of a single additive. In this case, the action of the deactivator on the homogeneous catalyst—the dissolved copper—and that of the passivator on the heterogeneous catalyst—the metallic copper—are manifested simultaneously. Since there is an amino group in the anthranilic acid molecule, this passivator also has a weak inhibiting effect.

It should be noted that when the oil contains relatively large amount of natural inhibitors, stability is improved only insignificantly by introducing an inhibiting additive together with the passivator (anthranilic acid).

Earlier experiments conducted with a hydrorefined oil made from Tuyman crude confirm this. The results of laboratory tests to evaluate the effectiveness of additive combinations were confirmed in the bench tests with small transformers.

Additive mixes consisting of 0.05% anthranilic acid with 0.2% phenyl-naphthylamine and 0.05% anthranilic acid with 0.05% disalicylideneethylenediamine improve the stability of oils made from Anastas'yev and Emba crudes. In particular, corrosion of copper is reduced substantially and destruction of specimens of solid insulating materials placed in the oil is retarded by a factor of 2-3.

A mix consisting of 0.05% anthranilic acid and 0.2% liconol improves the stability of phenol-refined Tuymazy oil more effectively than a composition consisting of 0.05% disalicylideneethylenediamine and 0.2% liconol. The difference in the effects of the two mixes is most noticeable in the relative amount of solid-insulation wear.

CONCLUSIONS

It has been shown that use of a passivating additive, anthranilic acid (0.05% by weight), in pure form and especially in mixes with antioxidant additives (iconol, phenyl-naphthylamine) ensures better stability (especially electrophysical) of commercial transformer oils of various origins and chemical compositions than when only the inhibiting additive is used.

References

Symbol List

<table>
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<tr>
<th>Manuscript page</th>
<th>Symbol</th>
<th>English Equivalent</th>
</tr>
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<td>A</td>
<td>aromatics</td>
</tr>
<tr>
<td>102</td>
<td>H</td>
<td>naphthenics</td>
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</tbody>
</table>

INVESTIGATION OF ADDITIVES AND ADDITIVE OILS BY A POTENIOOMETRIC METHOD

V.S. Luneva and L.N. Burdenyk

The advantages of using a potentiometric method to evaluate the acid-base properties of additives and oils containing additives and their wearability under the operating conditions of various types of engines have been confirmed by a number of research studies [1, 2].

ALKALINITY OF ADDITIVES

The alkalinity of an additive is governed by the presence of free and bound alkaline components [3, 4]. Additive alkalities were determined by potentiometric titration using antimony and calomel electrodes. 1 g of additive dissolved in 50 ml of an alcohol-benzol mixture (1:2) was decomposed by a 0.1N alcoholic solution of HCl. The titration curves appear in Figs. 1-6. As we see, the nature of the curves changes in accordance with the type of the salts decomposed: alkylsalicylate (ASK, MARK), alkylphenol (VIII WP-370, Ts/ATM-330, VIIII WP-370, VILLW WP-370), sulphonate (PMS-Ya), thioophosphate (DP-II, Santolube 495), etc. The length of the horizontal segment on the titration curve is proportional to the concentration of the salts decomposed during titration of equal weights. Additives containing the cations Ca, Mg, and Fe have an alkaline reaction (pK = 8-13 or ΔpH = 1-6).

Alkylsalicylate (ASK, MARK) and sulphonate (PMS-Ya) additives are characterized by free alkalinity (see initial segments of curves in Figs. 1-6). The alkylphenol additives (Ts/ATM-330, VIIII WP-370p, etc.) do not contain free alcalies.
The titration curves indicate that most of the additives are totally decomposed at electromotive forces (emf) (1 NaCl) of about 100-120 mV (pH = 2).

It is known that the total alkalinity (T.A.) of most additives is equivalent to the content of metal present in them. This is confirmed by the data given in Table 1.

![Graph](image)

**Fig. 1.** Potentiometric titration curves of MASK additive. 1-5 various batches. 
**KEY:** (a) emf, mV; (b) volume of 0.1m HCl used in titration, ml.

However, this equivalent is not observed in the PMSYp and VNI NP-370 additives, so that alkalinity should generally be used to determine the effective content of metal, i.e., the content equivalent to that part of the additive that participates in neutralization of fuel combustion products. In introducing additive mixtures into the oil, it must be remembered that the sulfite ash content of PMSYp additive exceeds its total alkalinity by a factor of almost 1.5. PMSYp additives have different alkalinites at a given ash content (see Table 1). The increase in the ash content of the oil as the additives are depleted is one of the causes of increased wear, while inadequate alkalinity is among the causes of increased sludging. Hence it is necessary to check alkalinity and ash content in both the original additive oils and oils in use in engines.

**INVESTIGATION OF ADDITIVES OF THE ZINC DITHIOPHOSPHATE TYPE**

Owing to the amphoteric properties of zinc, its salts are decomposed by both acids and alkalies. Figure 4 presents potentiometric titration curves of zinc dialkyl- and dialkyldithiophosphates, showing that the potential jump in acid titration...
Fig. 4. Curves of potentiometric titration of zinc thiophosphate with alkali and acid. 1) VNI-8P-35; 2) DP-11; 3) Quinti-1360; 4) Santolube I; 5) Ecolube 59.

Fig. 5. Weartability of AS-9.5. Oil with 0.65% olefin alcohols 267 on 170-2 bench installation. 1) sulfate ash content; 2) total acid number; 3) total alkali number; 4) reaction.

Fig. 6. Weartability of Min-W oil (R-1h with 3% T71ATM-139, 2% PMS/29, and 0.003% PMS-200A) in SMd-14 engine during cycles I and IV. 1) total acid number; 2) total alkali number; 3) reaction.

Table 1. Results of Potentiometric Determination of Reaction, Alkalinity, Effective Metal and Sulfate Ash Contents in Additives

<table>
<thead>
<tr>
<th>Additive</th>
<th>Reaction</th>
<th>Alkalinity</th>
<th>Effective Metal</th>
<th>Sulfate Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>A4K5</td>
<td>3.2</td>
<td>2.3</td>
<td>1.2</td>
<td>0.2</td>
</tr>
<tr>
<td>A4K9</td>
<td>2.9</td>
<td>2.1</td>
<td>1.1</td>
<td>0.1</td>
</tr>
<tr>
<td>VNI-8P</td>
<td>2.6</td>
<td>2.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>VNI-8P</td>
<td>2.4</td>
<td>1.8</td>
<td>0.8</td>
<td>0.0</td>
</tr>
<tr>
<td>VNI-8P</td>
<td>2.2</td>
<td>1.6</td>
<td>0.6</td>
<td>0.0</td>
</tr>
</tbody>
</table>

* Determined by titrating the additive with sulfuric acid.
** Barium.
*** Magnesium.

KEY: (a) additive; (b) content; (c) sulfur; (d) alkalinity; (e) total alkalinity; (f) total acid number; (g) reaction.

is less distinct because of the accumulation of thiophosphoric acid in the additive solution. Decomposition takes place by the reaction:

\[
\text{R-O-S-S-R} + \text{HCl} \rightarrow \text{R-O-SH} + \text{S}_{\text{2}}\text{Cl}_{\text{2}}
\]

The potential jump is sharper on decomposition of the additives by alkali according to the reaction:

\[
\text{R-O-S-S-R} + \text{HCl} \rightarrow \text{R-O-SH} + \text{S}_{\text{2}}\text{Cl}_{\text{2}}
\]

Two potential jumps can be brought out in titration of small weights (0.1g) (see Fig. 4); they correspond to decomposition of the salts with formation of thiophosphoric acid and potassium thiophosphate or decomposition of salts with various alkali radicals.
Total decomposition of zinc dithiophosphates by alkali is accompanied by a potential jump in the 450-600 mV range (pH = 9-12). The total acid number \( T [A, N_J \) of the additive is determined from the amount of alkali used in titrating to 520 mV (pH = 10).

The total acid number is converted by the formulas given below to the zinc and phosphorus contents.

\[
O.K.M. = \frac{V_1 - V_2}{1} \text{ mg of KOH/g}
\]

where \( V_1 \) is the amount of 0.1 n alcoholic KOH solution used in titrating the additive solution to pH = 10 (520 mV), in ml; \( V_2 \) is the amount of the same solution used in titrating the solvent (blank experiment) to pH = 10 (520 mV), in ml; \( T \) is the titer of the 0.1 n KOH solution, in g/ml; \( 1 \) is the weight of the additive sample, g.

The zinc content is

\[
z_1 = \frac{O.K.M. - 0.593}{10} \%
\]

The phosphorus content is

\[
z_2 = \frac{O.K.M. - 0.675}{10} \%
\]

where 0.593 is a coefficient obtained by dividing the atomic weight of zinc by the molecular weight of KOH; 0.675 is a coefficient obtained by dividing the atomic weight of phosphorus by the molecular weight of KOH; \( 10 \) is the coefficient for conversion to percent.

Example. For the Santolube 493 additive:

\[
O.K.M. = \frac{(292 \text{ mg KOH})}{(1)} = 151.5 \text{ mg of KOH/g}
\]

\[
z_1 = \frac{151.5 - 0.593}{10} \%
\]

\[
z_2 = \frac{151.5 - 0.675}{10} \%
\]

The advantages of the potentiometric method of determining zinc and phosphorus in the additives over the spectral, gravimetric, and calorimetric methods include the simplicity and speed of the analysis and the absence of turning or oxidation and precipitation losses; the time for a determination (1.5-2 hours) is smaller by a factor of more than 20 than in other presently known methods.

In Table 7, the results of potentiometric determination of zinc and phosphorus in the additives are compared with the results obtained by other methods. Table 3 presents the results of potentiometric determination of reaction, total acid number, and phosphorus and zinc contents; it shows that all of the thio-

phosphoric additives analyzed have an acid reaction due to the presence of the strong thiophosphoric anion. The phosphorus content of the imported additives is considerably higher than that of the Soviet additives. The error of the results of determination varies: +0.02% for the foreign additives and 0.01% for the domestic ones; the spread of the determinations ranges from 0.4 to 0.89. The potentiometric method can be used to establish the presence of small amounts of zinc and phosphorus (tenths and hundredths of a percent).

The presence of sulfur in these additives does not interfere with potentiometric determination of zinc and phosphorus; the values measured with the antimony electrode are not distorted.

In the whole, the above results recommend all potentiometric titration of zinc dithiophosphate for quantitative determination of phosphorus and zinc in the additives. The method can be used in research, testing, and control of quality.

Potentiometric investigation of various types of additives enabled us to compute coefficients for conversion from total alkalinity to effective content of metal and sulfate ash.
Table 3. Results of Determination of Reaction, Total Acid Number, and Phosphorus and Zinc Contents in Metal-Dithiophosphate-Type Additives by Potentiometric Method

<table>
<thead>
<tr>
<th>Additive</th>
<th>Reaction</th>
<th>Total Acid Number</th>
<th>Phosphorus</th>
<th>Zinc</th>
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<tr>
<td>G Sollubex®</td>
<td>4.10</td>
<td>1 - 2</td>
<td>1 - 2</td>
<td>1.0 - 2.0</td>
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<tr>
<td>Orobis-Olos-267</td>
<td>4.10</td>
<td>1 - 2</td>
<td>1 - 2</td>
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<td>Lubrizol®</td>
<td>4.10</td>
<td>1 - 2</td>
<td>1 - 2</td>
<td>1.0 - 2.0</td>
</tr>
<tr>
<td>Elcosol-86</td>
<td>4.10</td>
<td>1 - 2</td>
<td>1 - 2</td>
<td>1.0 - 2.0</td>
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<tr>
<td>VNI NP-354</td>
<td>4.10</td>
<td>1 - 2</td>
<td>1 - 2</td>
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Table 4. Conversion Factors K

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<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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<tr>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
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</table>

[Key to Table 4, cont'd.] (1) of metal; (2) of sulfate ash; (3) from metal content; (4) from total alkalinity; (5) from ash content to metal content; (6) from total acidity to content; (7) of; (8) ASK, PMS; W; VNI NP-375; W; VNI NP-770; (9) sodium, calcium; (10) VNI NP-375, TISAN-35; (11) barium; (12) VNI NP-375, W; VNI NP-770; (13) zinc; (14) phosphorus.

ON THE QUESTION OF OIL SERVICE LIFE IN ENGINES

The wearability of oils with additives is the basic question to be resolved in establishing oil-change intervals for engines, and many investigators are working on it (20-13).

At one time [11], the question was raised as to the use of the potentiometric method to rate the acid-base properties of additive oils and their wearability in various types of engines.

The additive consumption computed from the change in oil ash content does not agree with the actual consumption, as shown in Figs. 5 and 7 in Table 5.

As we see, alkalinity does not vary in proportion to acid content during depletion in engines. Alkalinity varies as a function of additive type, and, as a rule, the reaction [Alk] is an index of alkalinity or almost neutral (see Figs. 5-7).

Then, as we know, the viscosity of the oil and its taking capacity increase (Fig. 7b).

When the engines are operated under the same conditions as, for example, the GAZ-51, equal quantities of the alkaline components are depleted, despite the difference in compositions (see Table 5). The amounts of sludge and wear are somewhat smaller at higher oil alkalinity.

Without additives, DS-14 oil services the TMA-204 engine for no more than 70 hours, and with additives for 85 hours; sludge appears in the oil at alkalinity of 0.76 mg of KOH/g or less.

DS-14 oil with 3% TISAN-35, 2% PMS, and 0.005% PMS-200A provided for normal operation of the SMD-14 engine for 95 hours (see Fig. 5). Sludge appears after 900 hours in the Kala- ma plant's D-2 engine, with alkalinity not exceeding 0.4 mg of KOH/g. The alkalities of the original oils were not the same (the oil used in the SMD-14 engine was more alkaline).

201 N-204 (MS-20 with 2.5% TISAN-35, 1.5% PMS, and 0.005% PMS-200A) works for 130 hours in the MS-7 engine.]

---117---
Table 5. Physicochemical and Motor Properties of Additive Oil Before and After Use in M-20 Engine

<table>
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KEY: (a) oil with additives; (b) acid-base properties; (c) total alkalinity, mg of KCl/g; (d) total acid number, mg of KOH/g; (e) wearability; (f) motor rating; (g) amount of carbon on rings and piston, g; (h) cylinder wear (by method of lunes), g; (i) weight loss of first piston ring, g; (j) oil burnoff, g/h; (k) viscosity at 100°C, cSt; (l) content, %; (m) coke; (n) ash; (o) M-10B (AS=0.5 + 1.5 Montol 613 + 0.7% Santolube 493; (p) original; (q) after 600 hours of use; (r) M-10B (AS=0.5 + 1.5% ASX + 1.2% DP-11 + 0.003% FMS-200A); (s) M-10A (AS=0.5 + 1.5% ASX + 1.2% DP-11 + 0.003% FMS-200A).

stages, each lasting 50 hours) instead of the specified 100 hours. The engine was in satisfactory condition.

We see from the data obtained (Fig. 5-7) that the alkalinity decrease depends not only on the duration of engine running, but also on running conditions.

CONCLUSIONS

1. The possibility and expediency of direct titration of additives to 120-180 mV (pH = 2) to determine total alkalinity and their effective metal sulfates and ash content; (the latter for those additives in which alkalinity is equivalent to ash) were demonstrated.

2. The sulfonate additives (FMS'Ya) differ sharply from one another as regards total alkalinity, and hence in effective metal content, having varying contents of non-existent ...
compounds, ranging up to 9% (converted to calcium sulfate).

3. The zinc thiophosphates that were analyzed had an acid reaction; their acid numbers were proportional to phosphorus and zinc content; the imported additives contained substantially more phosphorus and zinc than the Soviet ones. A fundamentally new method was proposed for quantitative determination of phosphorus and zinc by titrating zinc thiophosphate to the potential jump or, in the general case, to 520 mV (pH = 10). The error of the method is ±0.02 to ±0.05%, its reproducibility from ±2.4 to ±9%, and the time required for the determinations 1.5-2 hours.

4. A study of the acid-base properties of additive oils in various types of engines brought out a disproportionality between the depletion of the alkaline component and the accumulation of acidic compounds; alkalinity does not vary in proportion to ash content. It was established that in engines operated under uniform conditions (GAZ-51) but on oils with different additive mixes, the alkalinity reserve varies in about the same way. A relation was detected between alkalinity change and the cleanliness and wear of certain engines.

5. The expediency of using the potentiometric method of wearability rating for additive oils to arrive at change intervals for these oils in various types of engines was demonstrated.

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