

EFFECT OF TEMPERATURE AND PRESSURE ON FORMATION OF  
PRECIPITATES IN AVIATION KEROSESINESV. A. Astaf'ev, S. N. Krylov, V. G. Gorodetskiĭ,  
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When kerosines are heated in the fuel systems of aviation engines, they may form precipitates that interfere with normal operation of the engines, thereby reducing reliability [1]. The effect of a number of operating factors on the process of precipitate formation, in particular temperature, has been studied. It has been determined that under both static and dynamic conditions, the amount of precipitate in the fuel and the corresponding pressure drop across the control filter increases with temperature up to a certain value, then falls with further temperature increases. Thus, the dependence of precipitate formation in fuels on temperatures has a maximum.

The decrease in precipitate formation in fuels with increasing temperature is contrary to the law of Arrhenius. A number of hypotheses concerning this inconsistency have been put forward [2]. Most widely held is the hypothesis that the reduction in precipitate formation in the fuel at temperatures higher than those determined under static test conditions (in two-phase closed systems) reflects the strong oxidation of vapor in the gas phase that has not reached the precipitate-formation stage. The fraction of oxygen consumed in oxidizing the fuel in the liquid phase is reduced; in this phase, precipitate formation occurs at a higher rate than in the gas phase [3].

The maximum rate of precipitate formation is achieved during oxidation of the fuel at the gas-liquid interface, since all other conditions being the same, the concentration of reactants (hydrocarbons and oxygen) is greatest at this surface. Energetic features of this surface probably play a certain role here. It is thought that under dynamic test conditions, for instance in a DTS-1 test unit, a two-phase system also forms due to the high temperature gradients between the heater walls and the flow. As a result, the pressure of the saturated fuel vapor may exceed the pressure in the fuel system of the unit [4]. At the pressures achieved in DTS-1M, DTS-2, and TsITO-MM laboratory test units, among others (0.5-0.8 MPa), however, this is unlikely to occur.

The maximum in the precipitate formation curve under dynamic conditions may be caused by the development of a second phase as a result of the lowering of the solubility of oxygen and nitrogen in a fuel at elevated temperatures [5]. In this case, the pressure drop in the fuel system of the laboratory unit must affect the process of precipitate formation. There is little information available in the literature on the effect of pressure on the thermooxidative stability (TOS) of aviation kerosines. For instance, it has been reported that under static conditions, increasing the overall pressure at a given oxygen concentration has practically no effect on precipitate formation at elevated temperatures [6].

In connection with the significant difference (almost an order of magnitude [7-9]) between pressures in the fuel systems of gas-turbine engines and those in a number of domestically-produced test units for measuring the TOS of aviation kerosines, and also to investigate the reasons for the lowering of the TOS of fuels with increasing temperature under dynamic conditions, we have studied the effect of pressure in a TsITO-MM unit. A feature of this unit is the unpowered thermosiphon injection of fuel through a control filter made of twill-weave nickel mesh having a pore size of 12-16  $\mu\text{m}$  [10].

Unpowered fuel pumping is accomplished by circulating the fuel up a tube with a heater and down a cooling tube. When the control filter becomes clogged with precipitate, the degree of circulation of the fuel in the unit falls, leading to a reduction in its temperature  $t_2$  at the cooling-tube outlet. The temperature of the fuel  $t_1$  at the cooling-tube inlet (where the control filter is located) is held constant. The rate at which the temperature  $t_2$  falls is proportional to the amount of precipitate in the fuel clogging the pores of the control filter of the unit, and is a criterion for evaluating the TOS by the given method.

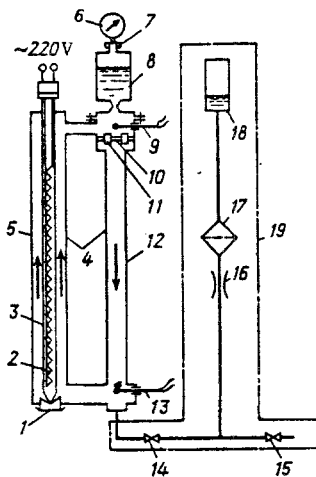


Fig. 1. TsITO-MM test unit for evaluating the thermooxidative stability of circulating aviation kerosines: 1) plug; 2) electrical heating spiral; 3) electrical-heater housing; 4) housing; 5) uptaking tube; 6) manometer; 7) manometer joint; 8) compensation reservoir; 9, 13) thermocouples; 10) control filter; 11) control-filter subassembly; 12) cooling tube; 14) cut-off valve; 15) drain valve; 16) jet; 17) filter; 18) fuel tank; 19) fuel supply and removal system.

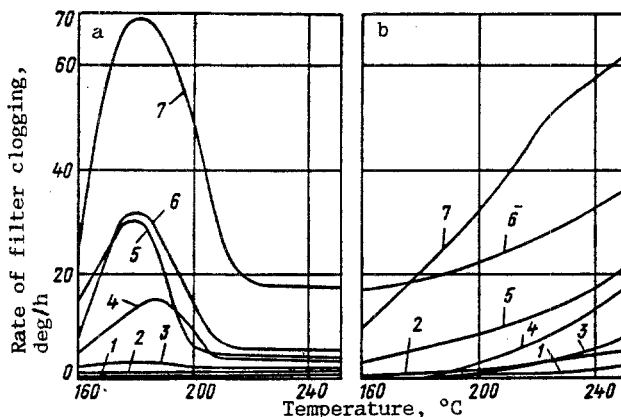


Fig. 2. Effect of temperature on the rate of clogging of the TsITO-MM test unit control filter in tests of aviation kerosines: a) at 0.8 MPa; b) at 2 MPa; 1) T-8V (I); 2) RT; 3) T-8V (II); 4) T-6; 5) TS-1 (I); 6) TS-1 (II); 7) TS-1 (III).

In connection with the important influence of dissolved oxygen on the TOS of the fuel, conditions should be arranged so that it is constant in each experiment. The TsITO-M unit was modernized to allow for this: the pressure in its fuel system was not produced using compressed air, as in the standard version, but by autoinflation. Essentially, the modernization consists of filling the compensation chamber (separated by a capillary from the circulation loop) with fuel while increasing its volume by heating (Fig. 1). The ratio of the volume of the gas phase in the compensation chamber and the volume of the fuel in the test unit ensured the required pressure in the circulation loop.

The effect of pressure in the fuel system on TOS was studied for TS-1, T-6, RT, and T-8V aviation kerosines, which satisfy the requirements for standards, at pressures of 0.8-2.5

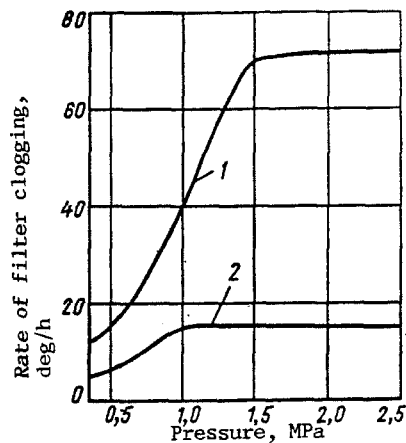


Fig. 3. The effect of pressure on the rate of clogging of the TsITO-MM unit control filter (250°C) in testing the following fuels: 1) TS-1; 2) T-6.

MPa and temperatures of 150-250°C. For a pressure in the circulation loop of 0.8 MPa, the dependence of precipitate-formation on temperature exhibited a maximum for all of the fuels studied (Fig. 2). For a pressure of 2 MPa, the curve for precipitate-formation vs. temperature increases monotonically, i.e., the maximum disappears.

The data in Fig. 3 confirm the importance of the pressure effect in the fuel system of the dynamic TOS test unit for aviation kerosines. At a pressure above a certain value that depends on the fractional composition of the fuel, however, this effect disappears. The appreciable influence of pressure on the rate of control-filter clogging in the TsITO-MM unit and the disappearance of the maximum on the precipitate-temperature curve (as in the static system) can be accounted for by the formation of a two-phase flow at elevated temperatures due to the decrease in the solubility of oxygen and nitrogen [5]. The dissolved gases may exist in a supersaturated state, leading to the formation of gas bubbles, into which the fuel vapor diffuses.

As the pressure in the fuel system of the laboratory unit increases, the volume of the gas bubbles and the interfacial surface area decrease, changing the rate of precipitate-formation. Pressure effects at different temperatures are different. For example, up to 140-160°C the solubility of the gases is practically the same as at 20°C, so that the pressure has no important effect on precipitation. In the temperature range 150-180°C, the solubility of the gases in the aviation kerosines decreases, i.e., a two-phase system may form. The amount of oxygen consumed in oxidizing the vapor in the bubbles is still insignificant, however. Thus, at a pressure of 0.5-0.8 MPa, oxygen is consumed in oxidizing the bulk fuel and the fuel at the interfacial surface.

At pressures above 2 MPa, the volume of the vapor-filled gas bubbles and the interfacial surface area decrease, as does the effect of the latter on oxidation. As a consequence, the rate of precipitate-formation is somewhat reduced (cf. Fig. 2). At a temperature above 190°C, the solubility is reduced to a greater degree, furthermore, the fuel vapor in the gas bubbles is oxidized. At low pressure, the volume of the vapor-filled gas-bubble phase increases, the oxygen in the bubbles goes to oxidize the vapor, and the role of oxidation in the liquid phase and at the interfacial boundary is reduced. As a consequence, the rate of precipitate formation at elevated temperatures is also reduced. As the pressure increases, the volume of the vapor-gas bubbles decreases and oxidation occurs primarily in the liquid phase, so that the rate of precipitate formation at elevated temperatures rises.

Thus, when the pressure in the fuel systems of laboratory test units used for evaluating the TOS of aviation kerosines is low, different oxidation conditions may prevail that do not completely correspond to the oxidation conditions in engines. It is therefore advisable to evaluate the TOS index when the pressure in the fuel system of the laboratory unit is at least 1.5 MPa. On the basis of this study, the method for evaluating the TOS of aviation kerosines at 250°C and a pressure of  $2.0 \pm 0.5$  MPa using a TsITO-MM test unit has been included in the procedure for rating fuels for aviation gas-turbine engines.

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## VARIATION IN PROPERTIES OF A HYDRAULIC OIL IN OPERATION OF TRACTORS

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The rational use of lubricants is a problem of particular interest in the operation of agricultural equipment. Although about 30 grades of different oils are used in this field, this number can be substantially cut down by using all-weather (common) types suitable for various subassemblies of tractors and other agricultural machinery.

In our opinion, one of the prospective oils of this type is the hydraulic fluid MGE-68V. It is a mineral-base oil with multifunctional (antioxidant and antiwear), anticorrosive, pour-point depressant, and antifoam additives [1]. The oil is used as the working fluid in hydraulic systems of tractors at  $-25^{\circ}$  to  $90^{\circ}\text{C}$  temperatures.

The aim of this article is to study the dynamics of variation in the physical and chemical properties of this oil over a period of 2000 motor-h service in T-150 and T-150K tractors as well as to determine the possibility of using it as a common oil for oiling hydraulic systems and transmissions. The study was carried out in collective farms of the Odessa region on four each T-150 and T-150K tractors. Samples were taken for analysis after every 250 hours of service from the gear box (GB), hydraulic suspension system (HSS), final reduction gear (FRG), and rear axle (RA).

Oils M-8V<sub>2</sub> (GOST 8581-78) and TAp-15V (GOST 23652-79) used in serially manufactured tractors were taken for evaluation of the results and for comparison. The oils were analyzed by standard methods. The silicon content and that of the elements of wear (iron, copper, aluminum, chromium, etc.) were determined by emission spectrum analysis in the MFS-5 apparatus which records the intensity of the spectral lines.

The results of investigation of the properties of MGE-68V oil show that there is insignificant variation during the process of operation and this is confined within the limits specified in the norms. The viscosity of the oil in the GB and HSS of the experimental tractors increased by 5-8% after 2000 h service, total content of mechanical impurities increased to 0.05-0.06%, and quantity of combustible impurities (which characterize the aging process of the oil) increased by only up to 0.02% (Fig. 1). This testifies to the high chemical stability of the oil during service in hydraulic systems of the T-150 and T-150K tractors.

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