

## METHODS OF ANALYSIS

## EVALUATING THE CORROSIVENESS OF JET FUELS

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There is a very large number of causes of corrosion of parts and units in operation of aircraft. The main cause is the aggressive components of the fuel. The corrosiveness of domestic jet fuels are assessed by the effect on a copper plate (GOST-6231) or on electrolytic copper and VB-23NTs bronze (GOST-18598) and in isolated cases, with the methods of the All-Russian Institute of Aviation Materials and All-Russian Scientific-Research Institute of the Petroleum Industry [1].

The essence of almost all of these methods consists of thermostating a sample of fuel and a metal plate at 100 – 150°C and determining the change in the weight of the plate after contact with the fuel. Their drawbacks

TABLE 1

Indexes	TS-1 fuel	
	according to GOST 10227-86	tested
Density at 20°C, kg/m <sup>3</sup>	Minimum of 775	784
Distillation, °C		
IBP	Maximum of 150	140
10%	Maximum of 165	147
50%	Maximum of 195	163
90%	Maximum of 230	206
98%	Maximum of 250	245
Viscosity, mm <sup>2</sup> /sec		
at 20°C	Minimum of 1.3	1.28
at -40°C	Maximum of 8	4.4
Acidity, mg KOH/100 cm <sup>3</sup>	Maximum of 0.7	1.3
Initial crystallization point, °C	Maximum of -50	-64
Iodine number, g I <sub>2</sub> /100 g	Maximum of 3.5	0.45
Thermal stability (150°C, 5 h): sediment content, mg/100 cm <sup>3</sup>	Maximum of 18	18
Existent gum content, mg/100 cm <sup>3</sup>	Maximum of 5	2.8
Sulfur content, wt. %		
total	Maximum of 0.25	0.07
mercaptan	Maximum of 0.005	0.003
Copper plate test	Passed	

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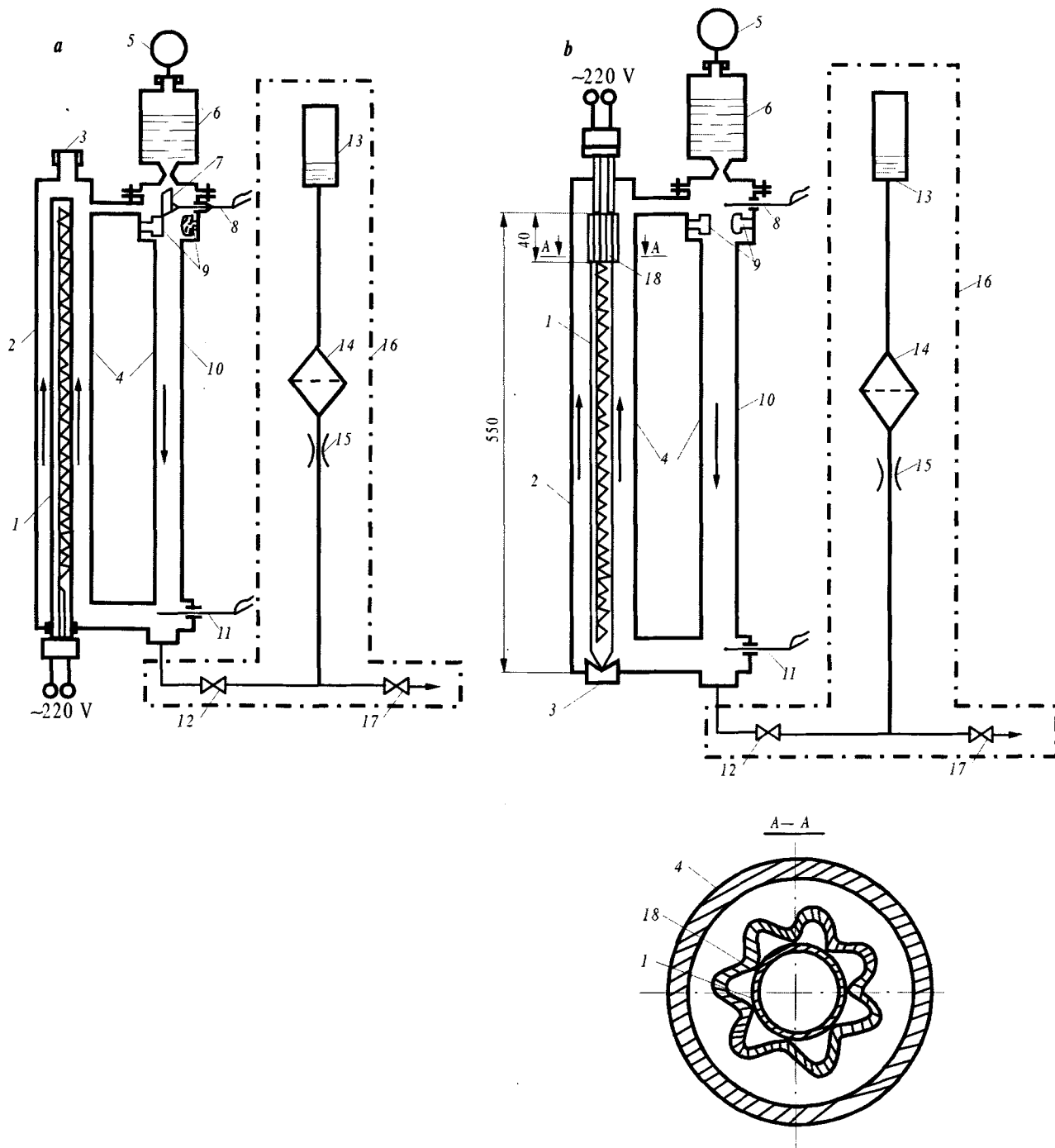


Fig. 1. Diagram of the TsITO-M(M) unit with a 150 cm<sup>3</sup> (a) and 650 cm<sup>3</sup> (b) volume of fuel tested: 1) body of estimating electric heater; 2) riser; 3) plug; 4) body of unit; 5) pressure gauge; 6) compensation tank; 7) bronze plate; 8, 11) thermocouples; 9) control filter unit; 10) tube condenser; 12) stopcock; 13) fuel tank; 14) filter; 15) jet; 16) fuel filling and removal system; 17) drain cock; 18) corrugated bronze cylinder.

are: unsatisfactory metrological characteristics; noncorrespondence of testing conditions to conditions of use (the tests are performed in static conditions, while the fuel is at relative rest only in the tanks).

We selected a TsITO-M(M) unit [2], which allows placing fuel in contact with a sample of construction material in a stream, for studying the corrosiveness of jet fuels. Two schemes which differ by the volume of fuel

TABLE 2

Chemical element	Content (g/ton) in products of corrosion of plates tested in 150 cm <sup>3</sup> TS-1 fuel at, °C			
	130	150	180	200
<i>In storage of plates before test</i>				
<i>in air</i>				
Iron	0.38	0.38	1.6	—
Copper	4	2.8	12.3	—
Zinc	0.14	0.07	1.63	—
Lead	3.7	0.67	10.52	—
<i>in fuel tested</i>				
Iron	2.1	1.25	0.74	2.1
Copper	11.5	12	19	32
Zinc	1.13	1.25	1.97	4
Lead	8	6.2	8	4.8

tested and the method of mounting the metal samples of different shapes are shown in Fig. 1.

The parts of the fuel pumps most frequently exposed to corrosion are usually made from KhVG, Kh12M, 50KhFA steels and VB-23NTs bronze. We selected VB-23NTs bronze to investigate since highly alloyed steels are almost not subject to chemical corrosion at temperatures below 200°C; they are affected by electrochemical corrosion due to the formation of a film of water in dead zones, for example, in the cavities of fuel pump pistons [3].

The method of determining the corrosiveness of jet fuels for VB-23NTs bronze at high temperatures in a stream consisted of the following stages:

- preparation of the samples, additional reagents, and equipment for the tests;
- placing the jet fuel in contact with the VB-23NTs bronze in the TsITO-M(M) unit;
- removing products of corrosion from the metal samples by ultrasound treatment in a UZDN-2T unit;
- obtaining samples of the products of corrosion by filtering the fuel through a membrane filter;
- determining the concentration of chemical elements in the construction material on a BARS-3 analyzer (the principle of action of this instrument is based on excitation and recording of the characteristic fluorescent radiation of the chemical elements constituting the substance analyzed);
- processing of the results obtained.

The physicochemical properties of the high-acidity TS-1 fuel tested produced at Krasnodar Refinery are reported in Table 1. The degree of corrosion of the samples was determined as a function of the method of their storage after preparation for the tests, the temperature, and the volume of fuel tested.

The fuel was filtered through a Vladipor membrane filter (filtration fineness: 1.2 μm) before the tests. Two 40 × 10 × 2.5 mm bronze plates with a hole 2 mm in diameter 4 mm from the center of one of the 10-mm-long faces was marked and cleaned with GOI paste. They were then polished, washed with alcohol—toluene mixture, dried between sheets of filter paper, and held in air for 24 h.

The prepared plates were mounted in the TsITO-M(M) unit with 150 cm<sup>3</sup> of fuel at the site where the control filter was positioned (see Fig. 1a) and then held for 3 h in accordance with the method in [2]. After the tests were completed, the fuel was poured into a beaker and the plate was carefully transferred into it. Each side was treated with a UZDN-2T ultrasonic vibrator with 50 mA power for 2 min.

The fuel was then filtered through the Vladipor membrane filter (type MFAS-A2) in a vacuum to obtain samples of the products of corrosion. The arithmetic mean (for four measurements\*) of the set of pulse counting rates determined on the BARS-3 instrument was calculated for each sample. The concentration of elements — iron, copper, lead, zinc — were subsequently found with calibration curves.

\* The measurements were performed by O. A. Starodubtseva.

TABLE 3

Chemical element	Content (g/ton) in products of corrosion of cylinders tested at 180°C in 650 cm <sup>3</sup> of TS-1 fuel after storage	
	in air	in fuel
Iron	2.48	3.32 (1.22/2.1)
Copper	15.6	13.4 (5.4/8)
Zinc	0.99	1.92 (0.92/1)
Lead	10.8	28.7 (14.8/13.9)
<b>Notes.</b> 1. In testing cylinders stored in air, the products of corrosion migrating into the fuel were not taken into consideration. 2. In parentheses; in the numerator: in products of corrosion migrating into the fuel; in the denominator: in products of corrosion on the cylinder.		

The study of the effect of the temperature on the degree of corrosion of VB-23NTs bronze revealed an extremum at 150°C (Table 2). At this temperature, corrosion of the individual elements of the bronze is minimal. The degree of corrosion of lead increased with an increase in the temperature to 180°C: its concentration attained more than 10 g/ton, i.e. it became higher than the calibration value of the BARS-3. In addition, iron from the unit's construction materials began to enter the fuel.

A blank experiment (180°C, 3 h) was simultaneously conducted, where the fuel in the unit's system was only in contact with its construction materials. The studies of a sample of the products of corrosion obtained by filtering the fuel after the blank experiment on the BARS-3 analyzer showed that the content of iron, copper, lead, and zinc in it did not exceed the background values for the given instrument.

In the next series of experiments, the prepared bronze plates were lowered into TS-1 fuel prepared for the tests, not previously held in air, and were stored under a layer of the fuel. The results of these experiments (see Table 2) showed the undesirability of storing the prepared plates in air due to the formation of a protective oxide film on their surface. The overall level of corrosiveness of TS-1 fuel in this series of experiments was much higher than in the first series.

For example, there was 54% more copper found in the products of corrosion at a temperature of 180°C. At 150°C, as in the first series of experiments, the degree of corrosion of the bronze was minimal. When the temperature was increased from 180 to 200°C, the copper content primarily increased in the products of corrosion, while the lead content decreased to the background value.

The effect of the amount of fuel and dynamic factors on its corrosiveness was investigated in the TsITO-M(M) unit with a 650 cm<sup>3</sup> volume of fuel (see Fig. 1b). The dimensions and configuration of the bronze sample — a corrugated cylinder — were selected in the condition of ensuring maximum contact surface area and constant temperature of the entire surface.

The corrugated cylinder (height: 40 mm, diameter: 33 mm) with internal grooves similar to the outer grooves for maintaining the temperature regime in the unit's system during the tests was rigidly installed in the estimating preheater. Before the test, its surface was treated with fine emery paper, polished with diamond paste, and then washed with isooctane. The TS-1 fuel (see Table 1) was filtered through a membrane filter (filtration fineness: 1.2 μm) before being poured in the unit.

A blank experiment (180°C, 3 h) without a corrugated cylinder was conducted first to determine the effect of the unit's construction materials on the content of different chemical elements in the fuel after its contact with the system. It was found that the content of copper, zinc, and lead in the products of corrosion were not above the background values of the set of pulse counting rates and the iron content was less than 0.38 g/ton.

The experiments with the bronze cylinder were conducted in the same conditions as the blank experiment. The cylinder was carefully removed after the tests and placed in the initial filtered fuel (50 cm<sup>3</sup>) and then treated with ultrasound on the UZDN-2T in the same way as the flat plates; the treatment time for each side was 2 min and the vibrator power was 50 mA. The samples of products of corrosion were obtained with the method described above.

An experiment was also conducted in which samples of the products of corrosion obtained by filtration of the entire volume of the fuel (650 cm<sup>3</sup>) and samples of products of corrosion removed from the cylinder by ultrasound treatment in the initial fuel were analyzed separately. The results of the different series of experiments in the unit with a tested fuel volume of 650 cm<sup>3</sup> are reported in Table 3.

A comparison of the data in Tables 2 and 3 shows that the products of corrosion of the cylinder stored in air contained more iron and copper than the products of corrosion of the plates stored in the same conditions. This is probably due to an increase in the contact area of the bronze with the fuel. In addition, according to the data in these tables, the rate of corrosion of the bronze increased due to contact with the heater material (see Fig. 1b).

The iron and lead content in the products of corrosion increased by 2 and 3 times, respectively, while the copper content decreased by ~30%. Increasing the linear flow rate of the fuel in this unit washed the corrosion products off into its volume (see Table 3), which must be taken into consideration in conducting the experiments.

Corrosion of bronze thus takes place at a different rate with respect to the individual elements; the temperature affects the degree of corrosion (at 150°C, it is minimal); contact of the bronze with steel alters the direction of its corrosion by elements; in dynamic conditions, up to 50% of the products of corrosion pass into the bulk of the fuel.

## REFERENCES

1. N. N. Grishin, B. S. Gutenev, V. L. Lashkhi, et al., *Order of Clearance for Production and Use of Fuels, Oils, Lubricants, and Special Fluids in RF* [in Russian], GosNII 25 MO RF, Moscow (1998).
2. A. A. Gureev, E. P. Seregin, and V. S. Azev, *Classification Methods for Testing Petroleum Fuels* [in Russian], Khimiya, Moscow (1984).
3. A. A. Bratkov (ed.), *Chemmotology of Rocket and Jet Fuels* [in Russian], Khimiya, Moscow (1987).