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METHODS OF ESTIMATING THE QUALITY OF JET FUELS

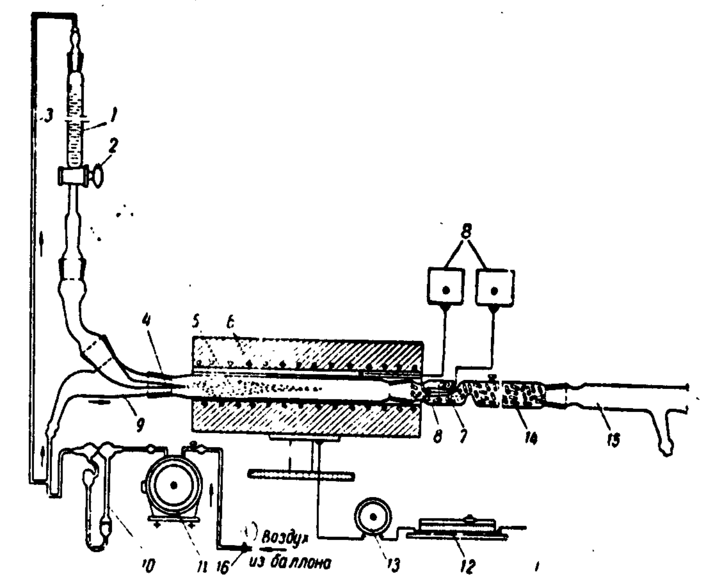
V. N. Zrelov

(Survey)

The development of work on jet fuels is accompanied by the development and use of new methods of estimating their quality. Fundamental attention is given to methods of estimating the quality of high-boiling fuels /1/.

Raising the boiling limits of the fuels causes an increase in their aromatic-hydrocarbon content, the total amount of which can go as high as 28%. Aromatic hydrocarbons cause a considerable increase in the scale-forming capacity of the fuels.

In order to estimate the scale-forming capacity, small laboratory devices have been developed, in which a weighed portion of fuel is burned and the quantity of scale formed is measured. The device proposed by Ya. M. Paushkin et al. /2/ measures the quantity of scale deposited in the upper conical part of a vertically positioned metal tube.



a) air from balloon

Fig. 1. Quartz device for estimating the scale-forming capacity of jet fuels.

1) burette for fuel; 2) stopcock for regulating the fuel intake; 3) pressure compensator; 4) capillary; 5) fire tube; 6) tubular furnace; 7) recess for thermocouple; 8) thermocouple with galvanometer; 9) T-bend; 10) rheometer; 11) gas clock; 12) rheostat; 13) voltmeter; 14) absorbing tube with filling; 15) outlet tube with branch pipe for removing samples of gas; 16) stopcock for regulating the air intake.

The device proposed by Starkman, Cattaneo, and McAllister /3/ operates according to the same principle. Only in this case the combustion tube is horizontally positioned, and the scale is deposited on the walls of the tube.

Common to both these devices is the possibility of estimating not the total scale-forming capacity, but the partial capacity related to the determination of the scale deposited on the walls of the device. These methods do not take into account the scale which is not deposited on the walls and is carried out of the tubes. The total quantity of scale forming during the burning of the fuel is estimated by a tubular-type quartz device, in which the scale is trapped in special absorbers containing porcelain filling and is then weighed (Fig. 1) /4/. In comparison with other methods the quartz device gives a true estimate of the scale-forming capacity of jet fuels.

A tube formerly used for estimating the qualities of lamp kerosenes is used at the present time in the USA for estimating the scale-forming capacity of jet fuels /5/. According to this method, the scale-forming capacity of the fuels is estimated in millimeters over the height of the sootless flame (fuming point), which in the case of jet fuels must be no less than 20mm /6/. With an increase in the quantity of aromatic hydrocarbons the height of the sootless flame decreases /7/. However, the scale-formation in a jet engine depends not only on the height of the sootless flame determined in the tube, but also on the vaporizability of the fuel. Therefore the index of scale-formation is also used for estimating the scale-forming capacity of jet fuels. The index of scale-formation is equal to the fuming point multiplied by 0.42% of the distillate up to 204° during fractionization of the fuel. A direct relationship between this index and the scale-forming capacity has been established, and the index has been introduced into the specifications for JP-5 fuel. The index of scale-formation should be no less than 54. Recently it was found advisable /8/ to use the index of scale-formation for estimating the scale-forming capacity of fuels of wide fractional composition and to use the fuming point for high-boiling fuels of kerosene and gas-oil type.

For scientific-research purposes the estimation of the scale-forming capacity of jet fuels is done on installations with small TRD combustion chambers. For this purpose the fire tube of the combustion chamber is weighed before and after the tests. From the difference in weight we determine the quantity of scale formed on the walls of the fire tube, from which we can estimate the scale-forming capacity of the fuel.

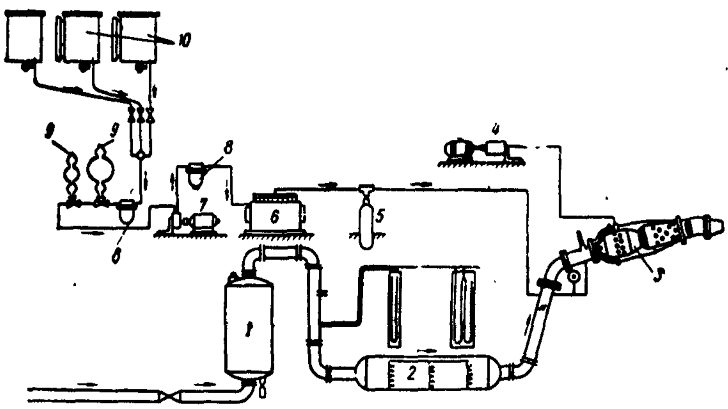


Fig. 2. Design of single-chamber installation for estimating the scale-forming capacity and the completeness of combustion of jet fuels.

1) receiver; 2) electrical air heater; 3) miniature combustion chamber; 4) starting magneto; 5) fuel receiver; 5) fuel receiver; 6) fuel pump; 7) fuel pump; 8) fuel filters; 9) samplers; 10) fuel tanks.

Installations of this type, developed by Ye. R. Tereshchenko /9/ and Williams /10/, have many structural features in common. In addition to estimating the scale-forming capacity, these installations are also used for estimating the completeness of combustion of jet fuels. Ye. R. Tereshchenko's installation (Fig. 2) is widely used for estimating other characteristics of the combustion of jet fuels.

When high-boiling fuels were used abroad in jet engines, special cases of burnout of the combustion chamber were noted. A study of this problem showed that the cause of burnout of the combustion chamber is the great increase in the brightness of the flame during the burning of high-boiling fuels. The bright flame, as a result of an increase in radiation, increases the flow of thermal energy to the walls of the fire tubes, increases their temperature, and causes burnout. Therefore, in order to estimate the ability of the fuels to cause burnout of the fire tubes of the combustion chamber, a laboratory device was developed for estimating this from the brightness of the flame /8/. It was established from studies that the brightness of the flame depends on the amount of bicyclic aromatic hydrocarbons of the naphthalene series in the fuel. Proceeding from this fact, the Pratt & Whitney Co. limited the amount of bicyclic aromatic hydrocarbons in the promising high-boiling fuel PWA-522 (not more than 3%) /8/.

The determination of the total quantity of aromatic hydrocarbons in jet fuels and the separate determination of the amount of bicyclic aromatic and unsaturated hydrocarbons are accomplished by the chromatographic method. Thus, in 1956 a fluorescent indicator, Sudan III, was standardized in the USA for determining the aromatic hydrocarbons in jet fuels /11/. This method enables us to determine rapidly on small laboratory chromatographic columns the amount of aromatic and unsaturated hydrocarbons, using a 1 ml sample for analysis.

Of great importance in evaluating modern fuels for supersonic planes is their sediment-forming capacity. Under conditions of supersonic flight the fuel is heated to above 100^0; this process is accompanied by formation of solid precipitates and clogging of the fuel filters /12, 13, 14, 15/.

The sediment-forming capacity of jet fuels is determined under static and dynamic conditions. Thus, under static conditions the estimate is made with the aid of two devices: a bomb, which was formerly used for determining the induction periods of gasolines, and the ISA apparatus, which is also used for determining the stability of ethylated aviation gasolines.

The determinations of the sediment-forming capacity in these devices differ essentially, both with respect to the amount of the sample being tested and with respect to the ratio between the liquid and vapor phases /16, 17, 18/. Therefore the quantity of sediment obtained in the determination in the bomb is greater than that obtained in the determination in the LSA apparatus. The maximum sediment formation occurs at 200^0 in the LSA apparatus and at 150-180° in the bombs. The introduction of these two methods into the GOST (All-Union State Standard) for fuel T-5 results from the necessity of accumulating experimental data, which will give us the possibility of singling out one method.

In addition to these methods, the complex "KOS" method is also known; it enables us to simultaneously determine the sediment-forming capacity and the corrosive power of fuels /19, 20/.

The "KOS" method (Fig. 3) is superior to the other laboratory methods for estimating the sediment-forming capacity, since it enables us to determine the sediment-forming capacity and the corrosive power of jet fuels. This fact is of particularly great importance when analyzing fuels at 200-250° , when the quantity of sediment is small and corrosion of bronze increases significantly.

In order to estimate the coarseness of the sediments forming in the fuel, Ya. B. Chertkov and V. M. Shagin /21/ developed a screening analysis which makes it possible to classify sediments from 5 to 120 μ. The structure and the coarseness of the sediments are also controlled with the aid of ordinary and electronic microscopy /21, 22/. The chemical composition of the sediments is determined on the bases of an elementary analysis of the organic part and a spectral analysis of the ash components.

Laboratory pumping apparatuses are of great significance in estimating the sediment-forming capacity of jet fuels. On these apparatuses the sediment-forming capacity of the fuels is determined under dynamic conditions directly from the intensity with which the fuel filter is clogged with sediments: for one test from 20 to 300 liters of fuel are consumed; the measurements are made in the temperature range from 150 to 250° ; in the majority of apparatuses the fuel is heated by means of an external source; a screen with openings of 15-20 μ is used as the filter. Figure 4 shows a laboratory apparatus developed by A. A. Gureyev and Z. A. Sablina /23/ for estimating the sediment-forming capacity. A comparison of the results of pumping fuels T-1 and TS-1 on this apparatus with the data obtained on the LSA apparatus proposed by G. S. Shimonayev, Ye. S. Churshukov, and I. B. Rozhkov showed a good agreement between the results /24/. The same picture is observed, when we compare the results of pumping the fuels on Ye. R. Tereshchenko and M. Ye. Tararyshkin's apparatus with the data obtained from the "KOS" method and in the bomb.

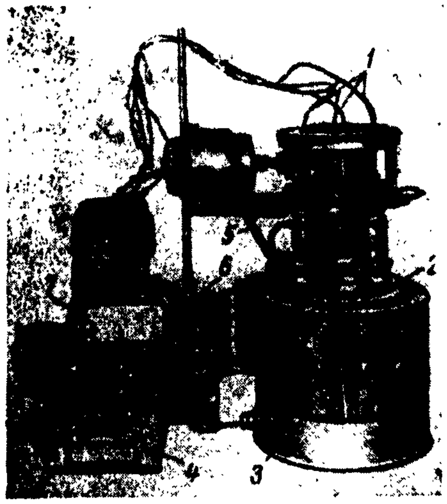


Fig. 3. "KOS" device for combined determination of the sediment-forming capacity and the corrosive power of jet fuels.

1) thermocouples;
2) aluminum heat-control unit; 3) heating casing;
4) resistance bridge;
5) contact thermometer;
6) relay; 7) galvanometer;
8) thermocouple switch.

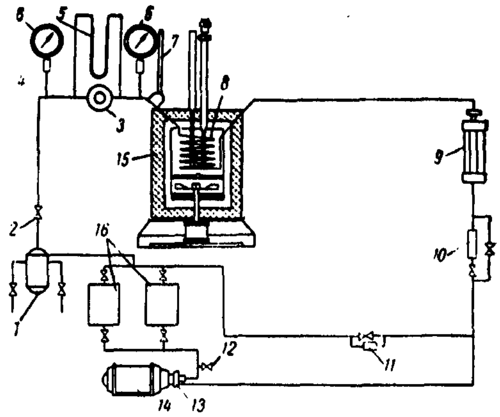


Fig. 4. Design of the apparatus for estimating the sediment-forming capacity of jet fuels.

1) radiator, 2) buttress stopcock; 3) filter;
4) manometer damper;
5) differential manometer;
6) manometers;
7) thermometer for measuring the fuel temperature;
8) heater coil; 9) rotameter;
10) preliminary purification filter; 11) reduction valve;
12) starting valve; 13) gear pump; 14) electric motor;
15) air thermostat for heater;
16) fuel tanks.

62/17

Methods have also been developed for estimating the sediment-forming capacity and the corrosive power of fuels by circulation pumping through the fuel apparatus of a turbojet engine /25, 26/. These methods enable us to obtain results comparable to the results of testing the engine under stand conditions and to the laboratory determinations of the sediment-forming capacity of the fuels.

The sediment-forming capacity of jet fuels is measured abroad at the present time on a standard Erdko pumping apparatus from the intensity with which the fuel filter is clogged /25/.

On this apparatus at a heater temperature of 149^0 and a fuel-filter temperature of 204^0 the pressure drop on the filter after 5 hours of operation should not exceed 300 mm Hg in the case of fuel PWA-522 /8/. In the case of fuel JP-6 according to specification Mil-F-25656 the pressure drop should not be more than 250 mm Hg at a heater temperature of 204^0 and a filter temperature of 260^o /27/. In evaluating the thermal stability on the Erdko apparatus the formation of a small quantity of sediment in the heater is allowed.

The stability of jet fuels under storage conditions is estimated from the change in the amounts of actual resins and the change in the acidity.

In order to determine the actual resins in jet fuels, a new, widely recognized method proposed by I. P. Budarov is used at the present time. The determination of the resins is done in a standard POS-01 device by steaming the fuel with water vapor /28, 29/. Vacuum distillation in combination with molecular distillation can also be used to determine the resins in jet fuels /30/.

It has been suggested that the stability of jet fuels containing cracking components be determined under laboratory conditions in a "PK" device based on the measurement of the absorption of oxygen by the fuel in a thin layer at 120° /31, 32/. On the basis of the values obtained the admissible storage time of the fuel is determined from a nomogram /32/.

The stability of jet fuels is determined abroad from the value of the potential resins /33/. Z. A. Sablina and A. A. Gureyev /34/ suggested estimating the stability of fuels from the rate of formation of potential fuels determined in an LSA device at 110°. In this case it was also suggested that the amounts of soluble and insoluble resins be evaluated /35/. The potential resins are determined from the increase in the actual resins after 16 hours of oxidation of the fuel in a bomb at 100° in an oxygen medium. In order to ensure long-term storage of jet fuels, the potential resins according to the specifications Mil-F-5616 C (USA), D. Eng. R. D.-2482 (England) and Air 3405 (France) should not exceed 8 mg/100 ml and should not exceed 14 mg/100 ml according to the specifications Mil-F-5624 C (USA) and D. Eng. R. D.-2488 (England) /36, 37, 38, 39/.

The foaming capacity of jet fuels is of great importance in evaluating their operational properties under conditions of high-altitude flight and can be determined by means of a laboratory device proposed by Poulston and Thomas /40/. This device consists of a cylindrical chamber with a stirrer. The fuel is poured into the chamber, the necessary vacuum is created, and the fuel is stirred intensely. The foaming capacity of the fuel is determined from the height of the column of foam that forms.

Water contained in dissolved form in jet fuels facilitates corrosion of the parts of the fuel apparatus and is the cause of the formation of ice crystals in the fuel at negative temperatures.

In order to determine the amount of dissolved moisture in fuel T-1, a calcium-hydride method was developed; it is based on the change in the volume of the hydrogen liberated during the interaction between calcium hydride and water /41/. A comparison of this method with methods based on measuring the change in pressure in a vessel, when calcium hydride is introduced into it, showed that the volume method proposed by VNII NP (All-Union Scientific Research Institute for the Processing of Petroleum and Gas and for the Production of Synthetic Liquid Fuel) and TsIAM (Central Scientific Research Institute of Aircraft Engines) gives more reliable results.

An index characterizing the ability of a fuel to dissolve moisture was introduced into the specifications for jet fuels in the USA and England. No more than 2 ml/liter of water should be dissolved in jet fuels. This index is determined from the increase in the volume of the fuel after it is shaken with water.

The calorific value of jet fuels is usually determined by the calorimetric method - by burning a weighed portion of fuel in a bomb. However, this analysis is complicated and time-consuming and can be carried out only by qualified laboratory workers; therefore a calculational method of determining the calorific value of jet fuels JP-3, JP-4 and JP-5 has been standardized in the USA /42/. The calculations are made on the basis of the values for the density, the aniline point, and the total sulfur according to empirical tables. The discrepancies between parallel determinations of the calorific value by the calculational method in one laboratory do not exceed 1 kcal and do not exceed 4 kcal in different laboratories.

Among the operational characteristics of jet fuels the corrosive power is of great significance. Several methods have been developed for estimating the corrosive power of jet fuels differing from each other with respect to temperature regime, test length, metal assortment, etc.

In practice the corrosive power of jet fuels is usually estimated from the amount of hydrogen sulfide, mercaptan sulfur and elementary sulfur contained in them.

For determining the hydrogen sulfide a method previously used in determining the hydrogen sulfide in diesel fuels was used. For determining the mercaptan sulfur in straight-run jet fuels the Adams method /43/ was used. It is based on the ability of the mercaptans to form copper mercaptides when interacting with an ammonia solution of copper sulfate. Z. N. Moguchaya /44/ suggested that fuels containing cracking components be treated before determining the amount of mercaptan sulfur in them.

The presence of elementary sulfur is determined from the change in color of a copper plate. In fuels not containing or possessing traces of elementary sulfur the copper plate should not change its original color. However, at the present time a method of determining the elementary sulfur in type-T fuels has been developed by A. Ya. Ryasnyanskaya and V. P. Muzychenko /45/. It is based on the ability of the elementary sulfur to react with caustic soda, when a weighed portion of fuel is heated in isopropyl alcohol to form the end products sodium sulfide and sodium hyposulfide, which do not hydrolyze in the given medium. This method enables us to determine elementary sulfur to an accuracy of 0.0002%.

Only the mercaptan sulfur in jet fuels is determined quantitatively abroad by means of potentiometric or conductometric titration /46/.

The fractional composition, the viscosity, and other indices are determined by the usual methods.

REFERENCES

1. CONN, M. E., DUKEK, W. G. SAE Annual Meet, Preprint N55B, 1959.
2. PAUSHKIN, Ya. M., SYCHEV, R. V., VISHNYAKOVA, T. P., and ZHOMOV, A. K. Inter-VUZ Conference on Petroleum Chemistry, Moscow State University, p. 76, 1956.
3. STARKMAN, E. C., CATTANEO, A. G., McALLISTER, S. H. Ind. Eng. Chem., 43, 12, 2822, 1951.
4. CHERTKOV, Ya. B. and ZRELOV, V. N. Novosti neftyanoy tekhniki. Neftepererabotka, 2, 15, 1956.
5. WORALL, G. Ind. Eng. Chem., 46, 2178, 1954.
6. KUHBACH, C. M., RITCHESKE, W. F., STRAUSS, K. H. SAE J., 63, 8, 64, 1955.
7. SHALLA, R., CLARK, T. and MacDONALD, J. Voprosy raketnoy tekhniki, No. 5, 69, 1956.
8. DROEGEMUELLER, E. A., NELSON, R. K. SAE National Aeronautic Meet, Preprint N47A, 1958.
9. TERESHCHENKO, Ye. R., ZALOGA, B. D. and MAKSIMOV, S. M. Khimiya i tekhnologiya topliv i masel, No. 11, 65, 1960.

10. WILLIAMS, C. G. Engineering, 176, 4563, 37, 1953.

11. Tentative method of test for hydrocarbon types in liquid petroleum products (fluorescent indicator adsorption method). ASTM ND, 1319, 1956

12. BARRINGER, C. M., CORSILIUS, M. U., RODGERS, J. D. Petrol, Proces., 10, 12, 1909, 1955.

13. JOHNSON, C. R., FINK, D. F., NIXON, A. C. Ind. Eng. Chem., 46, 10, 2170, 1954.

14. CRAMPTON, A. B., GLEASON, W. W., WIRELAND, E. R., Aircraft Eng., 27, 320, 346, 1953.

15. CHERTKOV, Ya. B. and ZRELOV, V. N. Collection "The Operational Properties of Jet Fuels at Elevated Temperatures". GOSINTI, p. 57, 1959.

16. SABLINA, Z. A. and GUREYEV, A. N. Khimiya i tekhnologiya topliv i masel, No. 9, 63, 1957.

17. TERESHCHENKO, Ye. R. and TARARYSHKIN, M. Ye. Khimiya i tekhnologiya topliv i masel, No. 2, 25, 1959.

18. SHIMONAYEV, G. S., CHURSHUKOV, Ye. S., and ROZHKOV, I. V. Khimiya i tekhnologiya topliv i masel, No. 4, 46, 1958.

19. CHERTKOV, Ya. B. and ZRELOV, V. N. Collection "Chemistry of Sulfo-organic Compounds Contained in Petroleums and Petroleum Products". Bashkir Branch of the Academy of Sciences of the USSR, p. 69, 1958.

20. CHERTKOV, Ya. B. and MELEKHIN, V. M. Collection "Operational Properties of Jet Fuels at Elevated Temperatures". GOSINTI, p. 4, 1959.

21. CHERTKOV, Ya. B. and SHAGIN, V. A. Khimiya i tekhnologiya topliv i masel, No. 11, 23, 1959.

22. CHERTKOV, Ya. B., ZRELOV, V. N., and MARINCHENKO, N. I. Fifth Scientific Session on the Chemistry of Sulfo- and Nitro-organic Compounds Contained in Petroleums and Petroleum Products. Bashkir Branch of the Academy of Sciences of the USSR, p. 65, 1959.

23. GUREYEV, A. A. and SABLINA, Z. A. Novosti neftyanoy tekhniki. Neftepererabotka, 2, 21, 1959.

24. ROZHKOV, I. V. and SABLINA, Z. A. Vestnik vozdushnogo flota, No. 2, 69, 1959.

25. KOROBOV, B. F. and KOMAROV, B. I. Khimiya i tekhnologiya topliv i masel, No. 4, 51, 1958.

26. TERESHCHENKO, Ye. R., TARARYSHKIN, M. Ye., ZRELOV, V. N., TUROV, A. I., and BARANOV, B. N. Fifth Scientific Session on the Chemistry of Sulfo- and Nitro-organic Compounds Contained in Petroleums and Petroleum Products. Bashkir Branch of the Academy of Sciences of the USSR, p. 61, 1959.

27. OIL and GAS, J., 55, 28, 116, 1957.

28. BUDAROV, I. P. Novosti neftyanoy tekhniki. Neftepererabotka, 10, 27, 1958.

29. BUKLER, V. O. Khimiya i tekhnologiya topliv i masel, No. 10, 51, 1959.

30. ZIZIN, V. G. Az. neft. khoz., No. 5, 19, 1954.

31. CHERTKOV, Ya. B. and ZRELOV, V. N. Zavodskaya laboratoriya, 8, 951, 1954.

32. CHERTKOV, Ya. B. and ZRELOV, V. N. Novosti meftyanoy tekhniki. Neftepererabotka, 2, 21, 1956.

33. THOMPSON, J. W., OIL and GAS, J., 53, 6, 123; 7, 175, 8, 125; 9, 154, 1954.

34. SABLINA, Z. A. and GUREYEV, A. A. Novosti neftyanoy tekhniki. Neftepererabotka, 2, 21, 1958.

35. SABLINA, Z. A. and GUREYEV, A. A. Az. neft. khoz., No. 12, 31, 1957.

36. SKYWAYS, J. 14, 12, 28, 1955.

37. GIULIANI, R. Rev. Inst. Frans. de Petrol., 8, 6, 282, 1953.

38. BLADE, O. C., OIL and GAS, J., 54, 6, 251, 1955.

39. GUTHRIE, V. B. Petro. Proces., 7, 10, 1425, 1959.

40. POULSTON, B. V., THOMAS, A. K., J. Roy. Aeronaut. Soc. 63, 586, 581, 1959.

41. LYSENKO, T. D., MALANICHEVA, V. G., OGAREVA, N. V., TARARYSHKINA, M. Ye., TUGOLUKOV, V. M., and SHCHETSKO, M. I. Khimiya i tekhnologiya topliv i masel, No. 8, 53, 1958.

42. Tentative method of test for estimation of heat of combustion of liquid petroleum products. ASTM ND 1405, 1956.

43. ADAMS, B. G. Refiner and natural gasoline manufactures, 1941.

44. MOGUCHAYA, Z. N. Collection "Chemistry of Sulfo-organic Compounds Contained in Petroleums and Petroleum Products". Bashkir Branch of the Academy of Sciences of the USSR, p. 30, 1958.

45. RYASNYANSKAYA, A. Ya. and MUZYCHENKO, V. P. Standartizatsiya, 6, 53, 1959.

46. Standard methods for testing petroleum and its products. Publ. Inst. of Petrol., London, 1956.

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