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 usually is 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 cracked 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 mercaptan sulfur in jet fuels is determined abroad quantitatively by potentiometric or conductometric titration.[46]

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

References

[1] Conn, M. E. and Dukek, W. G., Soc. Automotive Engrs. 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, Moscow, 1956), p. 76.

[3] Starkman, E. C., Cattaneo, A. G., and McAllister, S. H., Ind. Eng. Chem. **43**, 2822 (1951).

[4] Chertkov, Ya. B. and Zrelov, V. N., Nov. Neft. Tekh., Neftepererabotka (Adv. Petrol. Eng., Petrol. Process.) **2**, 15 (1956).

[5] Worall, G., Ind. Eng. Chem. **46**, 2178 (1954).

[6] Kuhbach, C. M., Ritcheske, W. F., and Strauss, K. H., Soc. Automotive Engrs. J. **63**, 64 (1955).

[7] Shalla, R., Clark, T., and MacDonald, J., Vopr. Raket. Tekh. (Prob. Rocket Tech.), no. 5, 69 (1956).

[8] Droegemueller, E. A. and Nelson, R. K., Soc. Automotive Engrs. Preprint N47A (1958).

[9] Tereshchenko, Ye. R., Zaloga, B. D., and Maksimov, S. M., Khim. i Tekhnol. Topliv i Masel (Chem. Technol. Fuels Lubricants), no. 11, 65 (1960).

[10] Williams, C. G., Engineering **176**, 4563 (1953).

[11] Tentative method of test for hydrocarbon types in liquid petroleum products (fluorescent indicator adsorption method)," Am. Soc. Testing Mater. ND 1319 (1956).

[12] Barringer, C. M., Corsilius, M. U., and Rodgers, J. D., Petrol. Process. **10**, 1909 (1955).

[13] Johnson, C. R., Fink, D. F., and Nixon, A. C., Ind. Eng. Chem. **46**, 2170 (1954).

[14] Crampton, A. B., Gleason, W. W., and Wireland, E. R., Aircraft Eng. **27**, 320, 346 (1953).

[15] Chertkov, Ya. B. and Zrelov, V. N. *The Operational Properties of Jet Fuels at Elevated Temperatures* (GOSINTI, State Institute of Technical Information, 1959), p. 57.

[16] Sablina, Z. A. and Gureyev, A. N., Khim. i Tekhnol. Topliv i Masel (Chem. Technol. Fuels Lubricants), no. 9, 63 (1957).

[17] Tereshchenko, Ye. R. and Tararyshkin, M. Ye., Khim. i
Tekhnol. Topliv i Masel (Chem. Technol. Fuels Lubricants), no. 2, 25 (1959).

[18] Shimonayev, G. S., Churshukov, Ye. S., and Rozhkov, I. V., Khim. i Tekhnol. Topliv i Masel (Chem. Technol. Fuels Lubricants), no. 4, 46 (1958).

[19] Chertkov, Ya. B. and Zrelov, V. N., *Chemistry of Sulfo-Organic Compounds Contained in Petroleums and Petroleum Products* (Bashkir Branch of the Academy of Sciences of the USSR, 1958), p. 69.

[20] Chertkov, Ya. B. and Melekhin, V. M., *Operational Properties of Jet Fuels at Elevated Temperatures* (GOSINTI, State Institute of Technical Information, 1959), p. 4, 1959.

[21] Chertkov, Ya. B. and Shagin, V. M., Khim. i Tekhnol. Topliv i Masel (Chem. Technol. Fuels Lubricants), 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, 1959), p. 65.

[23] Gureyev, A. A. and Sablina, Z. A., Nov. Neft. Tekh., Neftepererabotka (Adv. Petrol. Eng., Petrol. Process.) **2**, 21, 1959.

[24] Rozhkov, I. V. and Sablina, Z. A., Vestn. Vozdushn. Flota (Bull. Air Force), no. 2, 69, 1959.

[25] Korobov, B. F. and Komarov, B. I., Khim. i Tekhnol. Topliv i Masel (Chem. Technol. Fuels Lubricants), 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, 1959), p. 61.

[27] Oil Gas J. **55**, 116 (1957).

[28] Budarov, I. P., Nov. Neft. Tekhn., Neftepererabotka (Adv. Petrol. Eng., Petrol. Process.) **10**, 27 (1958).

[29] Bukler, V. O. Khim. i Tekhnol. Topliv i Masel (Chem. Technol. Fuels Lubricants), no. 10, 51 (1959).

[30] Zizin, V. G. Azerb. Neft. Khoz. (Azerbaidan Petrol. Ind.), no. 5, 19 (1954).

[31] Chertkov, Ya. B. and Zrelov, V. N., Zavod. Lab. (Factory Lab.) **8**, 951 (1954).

[32] Chertkov, Ya. B. and Zrelov, V. N., Nov. Neft. Tekh. Neftepererabotka (Adv. Petrol. Eng., Petrol. Process.) **2**, 21, 1956.

[33] Thompson, J. W., Oil Gas J. **53**, 123, 175, 125, 154 (1954).

[34] Sablina, Z. A. and Gureyev, A. A., Nov. Neft. Tekhn., Neftepererabotka (Adv. Petrol. Eng., Petrol. Process.) **2**, 21 (1958).

[35] Sablina, Z. A. and Gureyev, A. A., Azerb. Neft. Khoz. (Azerbaidan. Petrol. Ind.), no. 12, 31 (1957).

[36] Skyways **14**, no. 12, 28 (1955).

[37] Giuliani, R., Rev. Inst. Frans. de Petrol. **8**, 282 (1953).

[38] Blade, O. C., Oil Gas J. **54**, 251 (1955).

[39] Guthrie, V. B., Petrol. Process. **7**, 1425 (1959).

[40] Poulston, B. V. and Thomas, A. K., J. Roy. Aeronaut. Soc. **63**, 581–586 (1959).

[41] Lysenko, T. D., Malanicheva, V. G., Ogareva, N. V., Tararyshkina, M. Ye., Tugolukov, V. M., and Shchetsko, M. I., Khim. i Tekhnol. Topliv i Masel (Chem. Technol. Fuels Lubricants), no. 8, 53 (1958).

[42] "Tentative method of test for estimation of heat of combustion of liquid petroleum products," Am. Soc. Testing Mater. ND 1405 (1956).

[43] Adams, B. G., Refiner and natural gasoline manufactures (1941).

[44] Moguchaya, Z. N., *Chemistry of Sulfo-Organic Compounds Contained in Petroleums and Petroleum Products* (Bashkir Branch of the Academy of Sciences of the USSR, 1958), p. 30.

[45] Ryasnyanskaya, A. Ya. and Muzychenko, V. P., Standartizatsiia (Standardization) **6**, 53 (1959).

[46] *Standard Methods for Testing Petroleum and Its Products* (Publications Institute of Petroleum, London, 1956).

Reviewer's Comment

The article is basically a review of methods used to study the quality of jet fuels. Approximately 80% of the article is concerned with methods developed in the United States for determining fuel thermal stability and deposit-forming tendencies.

The author's interpretation of significance of results is questionable with regard to smoke point, which is actually an empirical test of burning quality and could be considered only as related to deposit-forming tendency in combination with other factors. The index of deposit-formation referred to when discussing smoke point and volatility corresponds precisely to the smoke volatility index developed in the United States by the Coordinating Research Council and incorporated in specifications of the American Society for Testing and Materials (ASTM), although the author makes no reference to either organization in this connection.

Another notable omission in the discussion of burning quality and radiation is the development by the Coordinating Research Council of the luminometer method to determine flame temperature. Results by this method are now incorporated in ASTM specifications for commercial aviation turbine fuels.

There is an ambiguity in the statement that bicyclic aromatics are determined by the chromatographic method. Although chromatographic methods for the determination have been reported, the referenced method does not provide for such determination, and preferred spectroscopic methods usually are used.

—C. M. McKINNEY
U. S. Department of the Interior

Transition of Burning into Detonation in Gases

R. I. SOLOUKHIN

Transition of burning into detonation may take place in a number of different ways,[1] depending on the particular condition of gas flow. The initiation of detonation is associated with the acceleration of the burning region, which gradually changes the shape of the convex laminar flame. The increase of the surface area of the flame leads to the progressive increase in burning rate of the gas, which in turn causes an increase in pressure, flow speed, and temperature of the unburned mixture in a compression wave in front of the flame. The detonation wave is generated as a result of an explosive auto-ignition by adiabatic heating of the mixture in the burning region or ahead of it.

The burning region, as it accelerates, may overtake the compression wave-front without forming a detonation. In such case, after a little while, the flame and the compression wave may be propagated in the form of a single complex.[2] Thereafter, the process culminates also in an explosion in the body of the gas. If the compression wave is reflected from the closed end of the tube, explosive ignition may take place in the compressed gas behind the reflected wave. If the temperature of the gas behind the reflected wave is below the auto-ignition temperature of the mixture, the reflected wave induces some additional deformation of the flame, increasing the burning rate.

Currently known methods of predicting the formation of the detonation wave (see, for example, Refs. 1, 2, and 3) are based on consideration of the condition for simultaneous existence of two discontinuities, the shock wave and the flame front, which are in the process of interaction and coalescence. It can be seen from experiments described in this paper that the pressure change in the shock front of the compression wave that propagates ahead of the flame is much smaller than the pressure increase in the region where the compression is continuous and adiabatic. Under such circumstances, it is convenient to limit the analysis to the approximate model involving an adiabatic wave and a flame, quite different from actual observations but permitting an easy evaluation of the thermodynamic state of the compressed gas.

1. Computation of the State of the Gas

WE consider the flow generated in a long tube of constant cross section on ignition of the mixture at the closed end. A compression wave is propagated ahead of the flame front, bounded in the general case by a shock wave of small amplitude at its forward end. We will assume as an approximation that, in this wave, the two families of characteristics are subject to the condition of conservation of the Riemann invariant

$$u_2 - \frac{2}{\gamma - 1} c_2 = -\frac{2}{\gamma - 1} c_1$$

The speed with which the burning region is translated relative to the walls of the tube is found as the sum of the speed of the gas flowing ahead of the flame and the burning speed.

For a laminar flame, the relative translation speed is therefore

$$U = u_2 + S = u_2 + S_n \frac{\Sigma}{\sigma}$$

Here Σ is the surface area of the flame, σ the area of the tube cross section, and S_n the normal burning speed of the mixture. If we assume that the burned gas is at rest with respect to the tube wall, it is possible to describe the motion of the flame by the following relations:

$$\rho_2 S = \rho_3 (S - u_3) \qquad S^2 = \frac{\rho_3}{\rho_2} \left(\frac{p_3 - p_2}{\rho_3 - \rho_2} \right)$$

$$u_3 + u_2 = 0 \qquad \frac{p_3}{\rho_3} \frac{\rho_2}{p_2} = a \frac{T_1}{T_2}$$

The latter expression is a close approximation to the experimental data presented in Ref. 3.

For the mixture $C_2H_2 + O_2$ the value of a may be taken equal to 24.3. The degree of approximation in this relation, and also the absence of any consideration of the dependence of specific heat on temperature, limits the accuracy of the computation of the state of the gas to about 10%.