THE RUSSIAN LITERATURE ON ROCKET PROPELLANTS

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P-1954

March 25, 1960

To be presented at the 137th National Meeting of the American Chemical Society in Cleveland, Ohio on April 8, 1960.

PREFACE

This paper was prepared for presentation and discussion on April 8, 1960, at the Symposium on the Literature and Technology of Rocket Propellants held in connection with the 137th National Meeting of the American Chemical Society in Cleveland, Ohio. The Symposium is jointly sponsored by the A.C.S. Division of Chemical Literature and the Division of Industrial and Engineering Chemistry.

INTRODUCTION

Early in its history the Soviet Union set itself the task of overtaking and surpassing the capitalist countries in science, technology, and economics. The first step in fulfilling this task was to master all the knowledge of science and technology to be found in the most advanced countries of Europe and America. The extent to which the Soviets have achieved this mastery is evident today in their avid and thorough assimilation of Western technical publications and the rigor and discipline of their educational program with its emphasis on scientific and technical subjects.

In addition to keeping up with Western technical developments, the Soviets are conducting a broad scientific research and development program of their own by means of which they intend to surpass the West. Rocketry is a field in which the Soviet Union has apparently already surpassed the West. Yet, despite their spectacular successes in space exploration by means of rockets, the Soviets publish only certain scientific aspects of their space research, and maintain rigid security restrictions on the technological aspects.

As a result of this policy, Soviet open literature contains no direct information concerning rocket-propellant developments. Contributions made by Russian rocket pioneers are discussed at length, but detailed discussions of developments since the beginning of World War II are conspicuously avoided, even though Soviet technical journals contain a substantial number of papers that appertain to propellant development. They are generally basic studies applicable to a number of fields of science and technology.

Ostensibly there are in the open Soviet literature only two periodicals directly concerned with rocketry; both, however, comprise articles translated from non-Soviet sources. One, Voprosy Raketnoi Tekhniki (Problems of Rocket Technology), published monthly since 1951, is a collection of abridged translations and abstracts of foreign periodical literature. The other, issued 48 times a year since 1957 by the All-Union Institute of Scientific and Technical Information, is entitled Ekspress Informatsiya: Raketnaya Tekhnika (Express Information: Rocket Technology).* It is published in loose-leaf form and consists of condensed translations of foreign articles that are issued within three months after their original publication.

The Soviets are very discriminating in their selection of materials to be translated into Russian. Their criteria demand that the information be new, authoritative, original, and make a positive contribution to the development of rocket science and technology. It might be said that only the best of the West finds its way into the storehouse of Soviet technical information.

The Soviets pride themselves on the breadth and depth of their published research, which is indeed impressive. But trying to establish any continuity in certain sensitive areas of research, such as propellants, can be a frustrating experience without foreknowledge of the devious methods the Soviets use in publishing the results of their research, or of the variety of publications in which the materials appear. A guide is essential in travelling through the apparent jungle of Soviet technical literature.

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*Since the beginning of 1960 this series has been called Astronavtika i Raketodinamika (Astronautics and Rocket Dynamics).

Most readily available, but generally of secondary importance to the researcher, are the publications of the Soviet popular press. From the Western point of view, newspapers are not generally considered the most reliable and authoritative sources of scientific information. But in the Soviet Union Pravda (The Truth), the official organ of the Central Committee of the Communist Party of the Soviet Union, has no peer and is above criticism. Its primary function is, of course, to sound the Communist Party line in all matters, technological as well as political. Pravda asserts this prerogative by being first to publish TASS announcements and reports on scientific and technological developments and to expatiate on these developments by means of editorials and articles by or interviews with leading Soviet scientists and engineers. Other influential Soviet newspapers, as well as several leading popular-science magazines, that are potential sources of information on rocket-propellant research and development are listed in Table 1. Priroda (Nature), a kind of Russian Scientific American without ads, is published by the USSR Academy of Sciences. Vestnik Vozdushnogo Flota (Herald of the Air Fleet), one of many military journals published monthly by the USSR Ministry of Defense, carried a survey article on rocket propellants in its August, 1958, issue.

The prime source of direct information on propellant research and development, however, is the plethora of scientific, technical, and industrial journals published in the USSR. A partial list of scientific journals published by the USSR Academy of Sciences, various universities, academies, and research institutes is given in Table 2. Table 3 presents a partial list of pertinent industrial journals published by the various ministries, offices, and committees of the Soviet Government. A list of books pertaining either in whole or in part to rocket propellants is given in the Appendix.

Table 1

PARTIAL LIST OF SOVIET NEWSPAPERS AND POPULAR SCIENCE JOURNALS CARRYING ARTICLES ON OR PERTAINING TO ROCKET PROPELLANTS

Newspapers	Issues Per Week
Pravda	7
Izvestiya	6
Krasnaya Zvezda	6
Sovetskaya Aviatsiya	6
Sovetskii Flot	6
Promyshlenno-Ekonomicheskaya Gaseta	3

Popular Science Journals	Issues Per Year
Nauka i Zhizn'	12
Priroda	12
Tekhnika-Molodezhi	12
Vestnik Vozdushnogo Flota	12
Znanie-Sila	12

Table 2

PARTIAL LIST OF SOVIET SCIENTIFIC AND TECHNICAL JOURNALS CARRYING ARTICLES ON OR PERTAINING TO ROCKET PROPELLANTS

	Issues Per Year
Atomnaya Energiya	12
Doklady Akademii Nauk SSSR	36
Inzhenerno-Fizicheskii Zhurnal	12
Izvestiya Akademii Nauk SSSR, Otdelenie Khimicheskikh Nauk	12
Izvestiya Akademii Nauk SSSR, Otdelenie Tekhnicheskikh Nauk:	
Mekhanika i Mashinostroenie	6
Metallurgiya i Toplivo	6
Izvestiya Akademii Nauk SSSR, Seriya Fizicheskaya	12
Izvestiya Sibirskogo Otdeleniya Akademii Nauk SSSR	12
Izvestiya Vysshikh Uchebnykh Zavedenii:	
Fizika	6
Kolloidnyi Zhurnal	6
Nauchnye Doklady Vysshei Shkoly:	
Khimiya i Khimicheskaya Tekhnologiya	4
Pribory i Tekhnika Eksperimenta	6
Prikladnaya Matematika i Mekhanika	12
Trudy Tsentral'nego Aerogidrodinamicheskogo Instituta	(*)
Trudy Voenno-Vozdushnoi Inzherernoi Akademii	(*)
Ucheniye Zapiski Moskovskogo Gosudarstvennogo Universiteta	(*)
Uspekhi Fizicheskikh Nauk	12
Uspekhi Khimii	12
Vestnik Akademii Nauk SSSR	12
Vestnik Leningradskogo Universiteta:	
Seriya Fiziki i Khimii	4
Vestnik Moskovoskogo Universiteta:	
Seriya Matematiki, Mekhaniki, Astronomii, Fiziki, Khimii	6
Vestnik Vysshei Shkoly	12
Vysokomolekulyarnye Soedineniya	12
Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki	12
Zhurnal Fizicheskoi Khimii	12
Zhurnal Neorganicheskoi Khimii	12
Zhurnal Obshchei Khimii	12
Zhurnal Prikladnoi Khimii	12
Zhurnal Tekhnicheskoi Khimii	12
Zhurnal Tekhnicheskoi Fiziki	12

*Issued irregularly.

Table 3

PARTIAL LIST OF SOVIET INDUSTRIAL JOURNALS CARRYING ARTICLES ON OR PERTAINING TO ROCKET PROPELLANTS

	Issues Per Year
Byulleten' Izobretenii	24
Byulleten' Tekhniko-Ekonomicheskoi Informatsiya	12
Informatsionnyi Ukazatel' Standartov	12
Izmeritel'naya Tekhnika	12
Izvestiya Vysshikh Uchebnykh Zavedenii:	
Aviatsionnaya Tekhnika	4
Khimiya i Khimicheskaya Tekhnologiya	6
Mashinostroenie	12
Neft' i Gaz	12
Priborostroenie	6
Khimicheskaya Nauks i Promyshlennost'	6
Khimicheskaya Promyshlennost'	12
Khimicheskoi Mashinostroenie	6
Khimiya i Tekhnologiya Topliv i Masel	12
Kislorod	6
Neftyanoi Khozyaistvo	12
Plasticheskie Massy	12
Priborostroenie	12
Trudy Leningradskogo Inzhenerno-Ekonomicheskogo Instituta:	
Khimiya	(*)
Vestnik Mashinostroeniya	12
Zavodskaya Laboratoriya	12

*Issued irregularly.

To facilitate literature research the Soviet Union publishes a variety of bibliographic and abstract journals, some of which are listed in Table 4. The Letopisi (Chronicles) cite only authors and titles of papers, books, and book reviews. Novye Knigi is a bulletin of forthcoming books. The bibliographic classification of subject matter in the Letopisi does not include a heading for rocket propellants, but it does have one entitled "Production of Explosives." Referativnyi Zhurnal: Khimiya is the Russian counterpart of Chemical Abstracts. Its classification scheme includes the headings "Motor and Rocket Fuels," "Explosives," and "Pyrotechnical Compounds." The Letopisi cover only Soviet publications, whereas the Referativnye Zhurnaly abstract the world literature.

For the non-Russian-reading investigator, English abstracts of articles from many of the journals listed above are available from several sources. One of the oldest and best is, of course, Chemical Abstracts. A more recent source is the series of abstracts made available by the Office of Technical Services, U.S. Department of Commerce. Of particular interest is item PB 131891T, Scientific Information Report, which is prepared by the Central Intelligence Agency and includes, among other things, a section of abstracts devoted to fuels and propellants.

Full translations of many Soviet technical articles and books are now available to the public through the Office of Technical Services, the Special Libraries Association Translation Center, and other Government and private organizations. These are listed as soon as they become available in the OTS bibliographic publication Technical Translations, published twice a month since January, 1959, and sold by Superintendent of Documents, U.S. Government Printing Office. Russian scientific journals available in

Table 4

SELECTED LIST OF SOVIET BIBLIOGRAPHIC AND ABSTRACT JOURNALS

	Issues Per Year
Letopis' Gazetnykh Statei	56
Letopis' Zhurnal'nykh Statei	56
Knizhnaya Letopis'	56
Letopis' Retsenzii	4
Novye Knigi	52
Referativnyi Zhurnal:	
Mashinostroenie	24
Metallurgiya	12
Mekhanika	12
Fizika	12
Khimiya	24

English are also listed in a pamphlet entitled Providing U.S. Scientists with Soviet Scientific Information, available from the Office of Scientific Information Service, National Science Foundation.

Even a superficial search through the Russian literature will reveal a preponderance of certain names that are associated with various fields of scientific investigation. In the area of rocket propellants, the proliferation of names is quite pronounced, and it is not difficult to construct a fairly extensive bibliography. Active contributors to the Soviet rocket-propellant program are listed in Table 5.

Table 5

SOVIET SCIENTISTS PROBABLY ASSOCIATED WITH ROCKET PROPELLANT RESEARCH AND DEVELOPMENT

Andreev, K. K.
Apin, A. Ya.
Assonov, V. A.
Avramenko, L. I.
Bel'kevich, P. I.
Belyaev, A. F.
Bobolev, V. K.
Bol'garskii, A. V.
Bolkhovitinov, L. G.
Bratkov, A. A.
Dobrovol'skii, M. V.
Dubovitskii, A. M.
Efremov, N. N.
Erofeev, B. V.
Fradkov, A. B.
Frank-Kamenetskii, D. A.
Gersh, S. Ya.
Glushko, V. P.
Gol'binder, A. I.
Gorst, A. G.
Kapustinskii, A. F.
Kargin, V. A.
Khariton, Yu. B.
Khitrin, L. N.
Kobozev, N. I.
Kondrat'ev, V. N.
Leskovich, I. A.
Mandel'shtam, S. L.
Mikhailov, B. M.
Mikheeva, V. I.
Mitskevich, N. I.
Nekrasov, L. I.
Nesmeyanov, A. N.
Papok, K. K.
Paushkin, Ya. M.
Pereverzev, A. E.
Pokrovskii, G. I.
Pshezhetskii, S. Ya.
Ratner, S. B.
Semenido, E. G.
Semenov, N. N.
Shaulov, Yu. Kh.
Shchukin, V. K.
Shidlovskii, A. A.
Sinyarev, G. B.
Sobolev, N. N.
Titov, A. I.
Topchiev, A. V.
Tsentsiper, A. B.
Vanichev, A. P.
Voevodskii, V. V.
Vol'fkovich, S. I.
Voyutskii, S. S.
Yastrebov, V. V.
Zarudnii, P. P.
Zel'dovich, Ya. B.
Zhigach, A. F.

SOLID PROPELLANTS

Russian literature on combustion, detonation, and explosion is very extensive, and the fundamental investigations in these areas of such men as K. K. Andreev, A. F. Belyaev, D. A. Frank-Kamenetskii, Yu. B. Khariton, L. N. Khitrin, L. D. Landau, N. N. Semenov, K. I. Shchelkin, and Ya. B. Zel'dovich are well known. Russian literature on explosives is also extensive and dates back to 1854, when N. N. Zinin and V. F. Petrushevskii developed a method for using nitroglycerin in projectiles and mines during the Crimean War. D. I. Mendeleev developed a smokeless powder on the basis of pyrocollodion, a variety of nitrocellulose containing 12.5% nitrogen, which he first prepared in 1892.

Russian literature on rocket propellants, however, has been deliberately amorphous ever since the Soviet Government, in the early 1930's, realized the enormous military potential of the rocket and organized a Government-sponsored rocket-research program. Russia, like Germany, but unlike the United States, Great Britain, and France, entered World War II with vigorous projects on rocket weapons, being more or less prepared for their immediate military use. According to Red Air Force Major General N. Dolginov,(1) prototypes of 82 and 132 millimeter rocket missiles were built in 1935. Following successful tests, the weapons were commissioned for the armament of the Red Air Force in 1937. At the beginning of World War II, all basic types of Soviet fighters and attack planes were equipped with rocket missiles. The technical achievements of the Soviet ammunition industry during the war years 1939-1945 were reviewed by A. E. Pereverzev(2) in a paper published in 1946.

During World War II the United States supplied the Soviet Union with a double-base smokeless powder (Russian cordite) manufactured according to Soviet specifications. The composition and properties of this slow-burning propellant are discussed by R. N. Wimpress,[3] whose book, incidently, has been translated into Russian. A. G. Gorst,[4] in his book on powders and explosives, gives the compositions of three colloidal propellants, which he designates as flameless, diglycol, and nitroguanidine powders, presumably used by the Soviets during World War II.

An indication of Soviet interest in improving colloidal propellants is the study by V. I. Alekseenko and associates on the compatibility of nitrocellulose with other polymers, such as butadiene-acrylonitrile copolymers with varying nitrile content.[5]

The Soviet literature is singularly lacking in information on composite propellants as such. There is, however, considerable information on certain possible components for oxidizers and binders. Thus, ammonium nitrate is the subject of much study in the Soviet Union. Its technology is discussed in a monograph by A. M. Dubovitskii and Ya. I. Kil'man.[6] The conversion kinetics and properties of its polymorphic modifications are described in several papers by various authors, including B. V. Erofeev and M. I. Mitskevich,[7-10] I. A. Leskovich,[11-15] and M. P. Mokhnatkin.[16]

Certain ammonium-chromium salts are being studied as potential oxidizers. P. I. Bel'kevich and B. V. Erofeev[17] have investigated the mechanism of the thermal decomposition of ammonium chromate and dichromate. The combustion of ammonium dichromate and trichromate has been studied, and their heats of formation determined by A. A. Shidlovskii and associates.[18-19]

Much work is being done on the chemistry and technology of polymers. A detailed analytical and comparative study of published material, however, is required to determine its applicability to rocket propellants.

That the Soviets are well aware of the limitations of the C-H-O-N system of compounds is evident from their efforts in developing what they call "elemento-organic chemistry." For propellants this means the introduction of such elements as Li, Be, B, F, Mg, Al, and Si into organic nuclei. Soviet activity in boron research increased markedly after the publication of the review papers on boron hydrides by Ya. M. Paushkin(20) in 1953 and by V. I. Mikheeva(21) in 1954. Of particular interest is the more recent paper by A. F. Zhigach and coworkers(22) on the reactions of amines with pentaborane. In 1953, A. I. Titov, who has worked extensively on the nitration of various organic compounds, published a paper on a method for introducing fluorine into an aromatic nucleus.(23) Significantly, no further papers on this subject have appeared in the Russian literature.

LIQUID PROPELLANTS

A great deal of work on the study of liquid rocket-propellants was done by K. E. Tsiolkovskii, F. A. Tsander, Yu. V. Kondratyuk, N. G. Chernyshev, V. P. Glushko, G. E. Langemak, and other rocket pioneers prior to 1936, when the Soviet Union restricted the publication of the results of such studies. These scientists made significant contributions to the field of rocketry: Tsiolkovskii, as early as 1903, proposed the use of liquid propellants; Tsander suggested the incorporation of metals, such as aluminum, into liquid fuels; Kondratyuk suggested the use of ozone as an oxidant; Glushko, who is now a Corresponding Member of the USSR Academy of Sciences, was the first to propose the use of hydrogen peroxide, nitric acid, nitrogen tetroxide, perchloric acid, and tetranitromethane as oxidizers, as well as the use of hypergolic rocket propellants.

There are several authoritative discussions of liquid rocket propellants in the recent Russian literature. These include a review paper by P. P. Zarudnii and A. A. Bratkov[24] in the Vestnik Vozdushnogo Flota; Chapter 5 ("Liquid Rocket Propellants") in the book on liquid rocket engines by G. B. Sinyarev and M. V. Dobrovol'skii;[25] Chapter 15 ("Propellants for Liquid Rocket Engines") in the treatise on motor fuels edited by K. K. Papok and E. G. Semenido;[26] and the monograph by Ya. M. Paushkin[27] on the chemical composition and properties of jet propellants. These works have the common Soviet characteristic of vagueness regarding Soviet applications and of lack of reference to pertinent Soviet research in this area.

The influence of the German school is seen in two recent papers by N. N. Sobolev and coworkers[28-29] on methods for determining, spectroscopically, the flame temperature of a liquid rocket engine. The experiments, initiated in 1949 but not published until 1959, were carried out with a 400-kg thrust engine using kerosene and HNO_3, Tonka 250 (50% xylidene, 50% triethylamine) and HNO_3, and kerosene and liquid oxygen.

Evidence that the Soviets are devoting attention to propellants hypergolic with 98% nitric acid is apparent from a 1956 report by Ya. M. Paushkin[30] showing the variation of ignition delay with temperature for a number of substances.

Soviet literature on fluorine as a rocket propellant seems to be limited to a theoretical paper published in 1950 by K. V. Butkov and R. B. Rozenbaum[31] on the thermodynamic functions of fluorine in the temperature interval from 298.1 to 5000°K. Discussion of the practical application of fluorine as a rocket propellant is apparently based on material from Western sources.

In passing, mention should be made of the theoretical studies conducted at Moscow University in 1953 by A. M. Gurvich and A. V. Frost[32] on the structure, normal vibration frequencies, and thermodynamic functions of the methyl, methylene, methyne, and dicarbon free radicals to 5000°K.

Ozone is the subject of much study by a number of investigators, including N. I. Kobozev, L. I. Nekrasov, V. V. Yastrebov, and others.[33-39] These scientists are contributing papers to a series generally entitled "Physical Chemistry of Concentrated Ozone." The first two papers in this series are concerned with the synthesis of hydrogen superoxide, H_2O_4, which itself is the object of considerable investigation and synthesis by other

methods.[40-44] A new series by L. A. Reznitskii and his collaborators[41] bears the general title of "Concerning the Problem of the Higher Peroxide of Hydrogen and Frozen Radicals." It will be interesting to see what additional material Soviet scientists will publish, not only on H_2O_4, but also on frozen radicals in general.

The above survey, admittedly superficial and incomplete, is indicative of the type and variety of subject matter to be found in the Russian technical literature. Although a large part of this material is being abstracted, and some of it is being translated into English, a substantial portion of it escapes processing. A reading acquaintance with Russian can be an invaluable asset in extracting, absorbing, and more fully appreciating the technical information that the Soviets choose to publish in their ever-expanding literature.

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APPENDIX

ADDITIONAL RUSSIAN BOOKS ON OR PERTAINING TO ROCKET PROPELLANTS

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THE RUSSIAN LITERATURE ON ROCKET PROPELLANTS

F. J. Krieger
Physics Division
The RAND Corporation

P-1954

March 25, 1960 Copy #1

To be presented at the 137th National Meeting of the American Chemical Society in Cleveland, Ohio on April 8, 1960.