N77-33052

ON THE HISTORY OF THE DEVELOPMENT OF SOLID-PROPELLANT ROCKETS IN THE SOVIET UNION+

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Toward the end of the 19th century, solid-propellant rockets were eclipsed by rifled artillery in military applications, lost there former significance, and became used only for secondary purposes such as illumination, signaling, and fireworks, etc. This occurred because of the lack of a scientific theory explaining rocket propulsion, the low effectiveness of the only propellant then used in rockets—gunpowder—and the lack of advance in the design of existing rockets that had hardly changed in the course of centuries. But the principal advantages inherent in the rocket remained: simplicity of design and especially the simplicity and ease of mounting for launching. These considerations constantly attracted the attention of inventors throughout the world. In Russia, work directed toward improving powder rockets never ceased for even a year.

After K.E. Tsiolkovsky created the foundations of rocket-dynamics, the intuitive attempts of inventors to use a propellant with a higher heat energy than gunpowder received a scientific grounding. N.I. Tikhomirov and I.P. Grave independently proposed to use smokeless powder in rockets before World War I. V.A. Artem'ev, I.V. Volovsky, N.V. Gerasimov and others were responsible for a series of interesting proposals to improve the designs of rockets and their launching mounts. But not one of these proposals received official support in Russia.

After 1917 the attitude toward inventors in our country changed sharply. Even during the Civil War, engineers N.I. Tikhomirov and V.A. Artem'ev started work on the design of a smokeless powder rocket and in 1921 a special laboratory was set up for these studies in Moscow. First they tried to work out a rocket engine design that would function according to existing ideas of smokeless powder artillery, but soon they became convinced of the necessity of creating a special, slow-burning rocket powder, realized in the form of a solid composite charge.

+Presented at the Fifth History Symposium of the International Academy of Astronautics, Brussels, Belgium, September 1971.

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In 1924, O.G. Filippov and S.A. Serikov, pyrotechnic specialists working at the Artillery Academy then located in Leningrad, developed a formula for a new type of powder based on a non-volatile solvent 76.5% by weight of nitrocellulose, 23% TNT, and 0.5% centralite to retard burning. It was called "PTP", i.e. pyroxyline TNT powder. By 1928-1929, the work conducted in the Artillery Academy on the new rocket fuel formula and its technology permitted development of a semi-production technique for preparing the solid composition PTP by pressing the prepared powder mass into hollow, preheated female dies.

Preparation of long rods of the solid composite charges of PTP, each with a diameter of 24 mm, for Tikhomirov's Moscow laboratory, was organized in the powder workshops of the Port of Leningrad using the very same presses on which many years before the great Russian chemist D.I. Mendelyev had prepared samples of smokeless powder for the first time. In the mid-1920s Tikhomirov's laboratory was transferred to Leningrad where, during the course of several years, static tests were conducted on composite propellants of various sizes. V.A. Artem'ev obtained positive results in static tests of larger propellant charges made up of five rods compressed together with a combined diameter of 76 mm, with "even" burning over the entire surface. A rocket was soon designed using these solid composite charges and it was successfully tested on March 3, 1928. An ordinary mortar was used to launch the rocket and establish its trajectory in the first 300 meters. This rocket traveled 1,300 meters overall, using half the rocket charge. This was the first Soviet smokeless powder rocket. V.A. Ventsel' and M.B. Serebrjakov also supplied valuable help, working out theoretical questions and solving practical problems of internal and external ballistics.

Having achieved the first promising results, N.I. Tikhomirov and V.A. Artem'ev determined to apply this knowledge toward broadening the scope of their work. A few months later, in June 1928, Tikhomirov's laboratory was reorganized as the Leningrad Gas Dynamics Laboratory (GDL). G.E. Langemak began work at GDL in 1928. He was placed in charge of one of the first priority tasks at the laboratory—the study of the characteristics of burning of powder composite charges in rocket chambers with nozzles. Thereafter he contributed a great deal to the design theories of powder rockets and the methods of calculating rocket loading with charges of smokeless powder. The basic principles such as the burning of rocket charges were first advocated and confirmed in experiments he conducted.

In 1929 B.S. Petropavlovsky was appointed director of experiments at GDL. He soon became the main scientific director of the laboratory. His name is connected with the rejection of the "active-jet propulsion principle" and the switch that led to actually broadening the application of powder rockets designed in GDL. Under Petropavlosky, the basic 24 mm solid composite charges made from PTP, which were prepared in the laboratory shops in great quantities, were selected as the standard in GDL. Therefore, on this standard engineers developed three basic sizes of scaled-up rocket chambers of 68, 82, and 132 mm calibers. The latter two subsequently became the basic calibers of Soviet rocket missiles for decades: the RS-82 and the RS-132, later named "Katyusha."

Various types of solid rocket projectiles were developed on the basis of the experiments and theoretical research conducted in GDL. The main consideration was stability in flight, and the rockets were designed to revolve around their longitudinal axi , maintained by an outflow of gases through a tangential nozzle. However, with such an arrangement for stabilization, about 25% of the rocket charge was lost in imparting the necessary rotation to the projectile. Thus, in developing the rocket projectiles, the collective of GDL had tried first of all to solve the problem of flight stability in order to achieve the highest accuracy. Launch of these rockets was accomplished from a tube. The first missiles were designed in GDL with calibers of 82 and 132 mm, and designated for aircraft. But the missile with the smaller caliber was also designated for firing as a hand-operated anti-tank weapon. However, at this time the turbo-rocket missiles could not be applied as weapons because they were still under development.

In 1929, at the suggestion of V.I. Dudakov, work began at GDL on developing solid-propellant rocket engines for accelerating the lift-off of aircraft. After N.I. Tikhomirov's death on March 38, 1930, B.S. Petropavlosky was named head of GDL, and, after December 1932, I.T. Kleimenov. During this period test pilot S.I. Mukhin played a significant role in the test work of GDL; he fired the 82 mm rotating rockets from a Y-1 aircraft and for the first time accomplished the first practical jet-assisted takeoff of the Y-1 and TB-1 aircraft.

But by 1933, tests of these same rockets with various shapes and with a number of different tail assemblies which did not exceed the caliber size showed that it was impossible to maintain a steady flight and obtain satisfactory accuracy. Therefore, in mid-1933, a project involving rockets with tail sections exceeding the size of the caliber of the projectile was undertaken. In order to launch these rockets, special aircraft firing stands had to be created with longitudinal plates strengthened by curved cross-members. Soon, rockets with the new stabilizer design were created. The dimensions of the tail assembly were 200 mm for the 82 mm rocket, and 300 mm for the 132 mm rocket. The first experimental launchings brought completely satisfactory results in accuracy. The RS-82 flew five km, the RS-132 flew six km.

This was as outstanding achievement of the Leningrad Gas Dynamics Laboratory, and determined the direction of future scientific research and experimental design work in the field of solid-propellant rockets in the USSR. Thus, GDL played a significant role in the creation of the basic theories, planning design methods, and testing of rocket engines with the new, more powerful smokeless powder.

In the interest of developing, strengthening, and broadening the work in rocket technology in the future, a move from a small organization to a large scientific research institute with a well-equipped laboratory and experimental base now appeared urgent. Utilizing the two most productive functioning organizations—Leningrad's GDL and Moscow's GIRD—in October 1933 a single Jet Propulsion Research Institute (RNII) was created, and GDL's work in powder rockets and on a series of other problems were transferred to RNII. At this time a final design of the 82 mm and 132 mm rockets was almost completed and brought to the stage of being put into production. Soon, serial production of 100-200 units of each type began. In the years to come, G.E. Langemak, L.E. Shvarts, Yu. A. Pobedonostsev, M.K. Tikhonravov, F.N. Poida, M.S. Kesenko, V.A. Andreev and others worked on powder rockets in RNII.

Aerodynamic testing of rockets was also conducted by the Zhukovsky Central Institute of Aerohydrodynamics (TsAGI), where their stability in flight was tested using various shapes and sizes of tail sections. Launches at the testing grounds were conducted using launch stands of various lengths. Geometrical eccentricity was measured individually for each rocket. The character of the rocket flight was checked by the smoke path and rapid filming. Beginning in 1935, systematic testing of solid-propellant rocket launched from I-15, I-16, and SB aircraft was carried out and returned positive results as to the accuracy of the rocket flight. The organization of work for the first extensive flight tests of the 82 mm rocket on the I-15 fighter was accomplished under the direction of G.E. Langemak. Test pilot G. Ja. Bakhchivandzhi, who later tested the first Soviet aircraft with a liquid-rocket engine, also took part.

In 1937 a new design for launching rockets from aircraft was developed that in the future was even utilized in ground launching stands. Instead of a pair of longitudinal directing plates for each missile, engineers suggested installing a single directing plate for each missile in the shape of a T-slotted trough. The T-shape proposed by Engineer I. Belov, was approved. The T, affixed to the missile, was inserted into the slot on the aircraft wing which served as the guiding rail. The 82 mm rockets (RS-82) were ready for practical use in December 1937, and the 132 mm aviation rockets, in July 1938. The RS-132 was fired from SB aircraft which carried four rockets under each wing, from the I-16 aircraft with two rockets under each wing, and later from the IL-2 aircraft. In August 1939 these aviation rockets were successfully used in a tactical situation on the Khalin-Gol River in Mongolia.

At the beginning of 1937, RNII was given the task of designing a multi-round ground launching and using the T-slotted trough guiding rails adapted from aviation. Toward the end of 1938 the first models of the self-propelled stands for volley firing of powder rockets were finished. I.I. Gvai directed their development. From December 8, 1938, until February 4, 1939, the first tests of 132 mm powder rockets, fired from a multi-round base, were conducted. These tests showed that the stands were not yet ready as they afforded insufficient range and a low level of accuracy. But at the same time the tests demonstrated the great possibilities of these rockets and their launching stands.

Later in 1939, A.S. Popov, V.N. Galkovsky, and A. Pavlenko submitted a new design for the self-propelled 16-round launching stand. It was called MY-2, and, after serial production began, the BM-13. It consisted of 16 V-shaped trough-type guide rails, placed along the axis of the vehicle and rising over the driver's cab. In its construction, every two guide rails were united at a common base. The launching stand was mounted on the body of a powerful, tri-axle automobile--the ZIS-6. The stand allowed firing of all its missiles in 7-10 seconds. This firing stand was constructed in August 1939, and in September-November factory testing was carried out that showed a high utility factor. The main rocket model fired from the BM-13 stand was called M-13. Its characteristics actually exceeded the performance of earlier rocket designs. The rocket M-13 reached 8,470 meters with a payload of 4.9 kg, a propellant supply of 7.1 kg and an engine thrust of 2,000 kg. The rocket had improved aerodynamic characteristics which guaranteed sufficiently high accuracy.

In late 1940 and at the beginning 1941, the M-13 rockets and the BM-13 launching stands underwent final testing and development, and were then turned over for mass production for the Army. The successive accomplishment of the application of these rockets contributed to a considerable extent to rocket technology developed in the USSR in the post-war period. The outstanding results later achieved in our country in the development of rocket technology and in the conquest of space were to a significant extent brought about because of the early success of these rockets.