ON THE HISTORY OF THE STRATOSPHERIC ROCKET SONDE IN THE USSR, 1933-1946+

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We shall call a stratospheric rocket one equipped with instruments and designed to fly into the stratosphere for purposes of scientific research. The idea of using a rocket in this fashion occurred almost simultaneously in 1933 with the launching of the first Soviet liquid-propellant rockets. These initial rockets were designed and built first, to fly, and second, to permit studying the rocket's behavior in flight. Naturally, the possible practical uses were of scant interest to the designer, because engineering goals determined the purpose of these rockets. However, since almost every rocket can be launched vertically and equipped with various instruments, without qualification it is perhaps imprecise to categorize rockets as stratospheric. Therefore, in this essay we shall deal only with those rockets conceived and built for the assignment and technical conditions of stratospheric research. This group of vehicles will also contain meteorological rockets—sometimes referred to as "recording rockets"—that only differed from the stratospheric ones in their altitude ceiling.

The reports and resolutions of the All-Union Conference on the Study of Stratosphere that took place in Leningrad from March 31 to April 6, 1934,+++ spread the ideas for building a stratospheric rocket. Participants at the conference proposed to investigate the upper atmosphere, emphasizing their interest in the study of cosmic rays at great

+Presented at the Third History Symposium of the International Academy of Astronautics, Mar del Plata, Argentina, October 1969. For further details on the development of Soviet rocketry during this period, see I. I. Kulagin, "Development in Rocket Engineering achieved by the Gas Dynamics Laboratory in Leningrad;" A. I. Polyarny, "On Some Work Done in Rocket Techniques, 1931-1938;" and M. K. Tikhonravov, "From the History of Early Soviet Liquid-Propelled Rockets;" in The First Steps Toward Space: Proceedings of the First and Second History Symposia of the International Academy of Astronautics, Smithsonian Annals of Flight, No. 10, 1974 - Ed.

++Tikhonravov, an engineer and specialist in liquid-propellant rocketry, helped build the first Soviet liquid-propellant rocket in the Group for the Study of Jet Propulsion (GIRD) in the early 1930's with Leonid Dushkin and Yuri Pobedonstsev. Zaytsev's professional affiliations are unknown.

+++See Reference 1; the resolutions of this conference were published in a separate pamphlet in 1934 at Leningrad.

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altitude. The resolution of the technical section noted that "the conference believes it is necessary to concentrate the main efforts on developing equipment for taking instruments into the stratosphere, using [these] rockets as a transition stage towards designing rockets for manned flight."

S. P. Korolev, Yu. A. Pobedonostsev, N. A. Rynin, and A. N. Shtern, among others, lectured at the conference. M. K. Tikhonravov devoted his address specifically to "the use of rockets for investigating the stratosphere." The rocket Tikhonravov considered for this application was the 09 rocket of the Moscow Group for the Study of Jet Propulsion (GIRD). But this rocket had not been designed to investigate the stratosphere, and was only cited as one example of producing a flying prototype. Thus, it will not be dealt with here. Although confining our attention to rockets expressly designed for entering the stratosphere, we shall include the vehicles actually constructed as well as those that were not launched or even completed.

V. V. Razumov's Rocket. The engineer V. V. Razumov and the Leningrad Group for the Study of Jet Propulsion designed one of the first meteorological rockets. This Leningrad group, organized by the Leningrad Society for Assistance to the Defense Aviation and Chemical Construction of the USSR (Osoaviakhim), built the rocket in mid-1937.+ Figure 1 shows a schematic drawing and a longitudinal section of this machine. The following numbers indicate its parts: 1 - body, 2 - nose cone, containing a parachute and

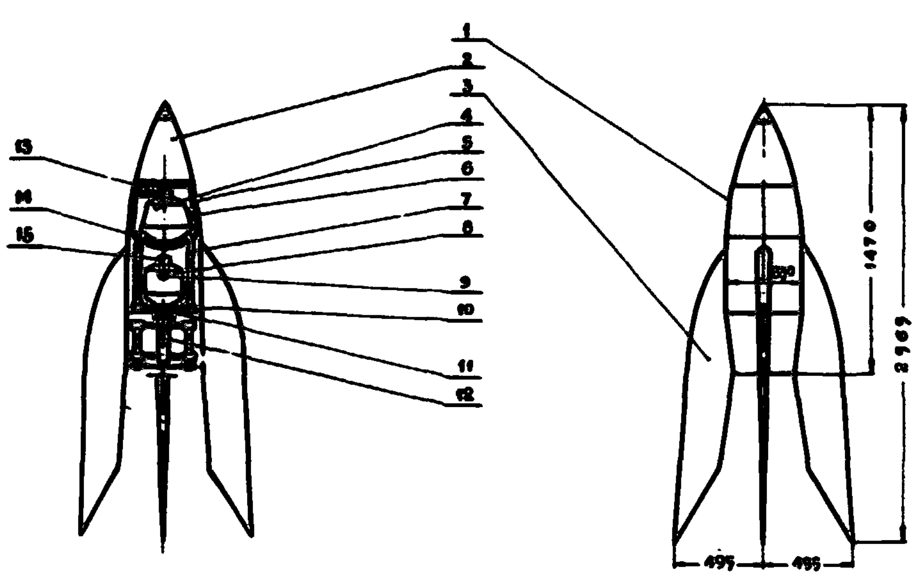

Fig. 1

+A short description of this rocket is contained in an article by N. Rynin [Reference 2], in an article by M. K. Tikhonravov [Reference 3], and also in the newspaper Leningradskaya Pravda [Reference 4].

instruments, 3 - stabilizers, 4 - liquid oxygen tank, 5 - insulation, 6 - liquid oxygen fueling valve, 10 - liquid oxygen shutoff cock, 11 - gasoline tank pre-valve.

The rocket featured an engine designed by A. N. Shtern. One of the rotary-reaction variety, Shtern's choice for an engine design was one attempt to solve the problem of efficiently supplying propellant to the combustion chamber. It consisted of pipes fixed along brackets, through which propellants passed, with the rocket engines attached at the pipe ends. The engine nozzles were cut obliquely so that the reactive force had a component in the horizontal plane, directed perpendicularly to the bracket. With the brackets and engine attached to a bearing on the vertical axis, a rotary system was developed in which centrifugal force supplied propellants to the engine. Figure 2 shows the schematic diagram of this system. Apart from solving the propellant supply problem, it was possible to rely on the gyroscopic effect of the gyrating mass, useful from the standpoint of maintaining stability.

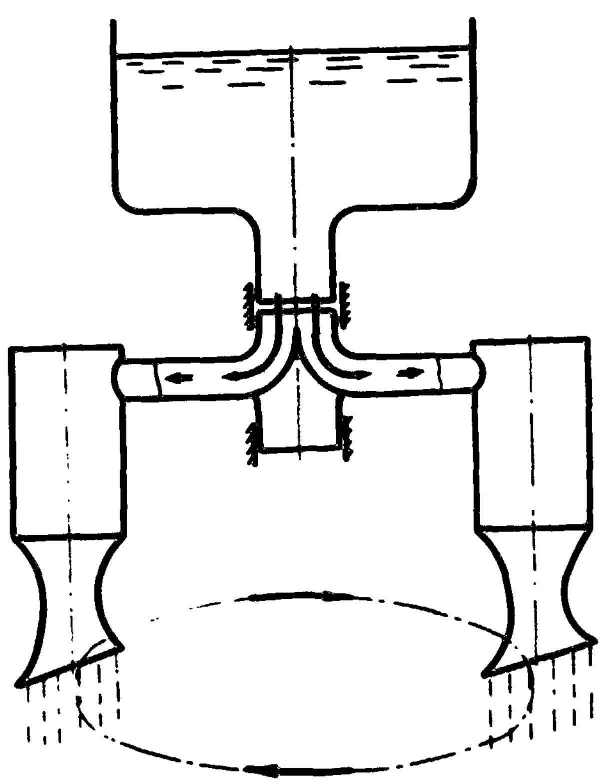

Fig. 2

Shtern designed this engine at the Air Equipment Design Bureau in the Leningrad Society for Assistance to the Defense, Aviation and Chemical Construction of the U.S.S.R. Calculations indicated that the engine could deliver a thrust of 200 kg with an exhaust gas velocity of 2000 m/sec. The maximum estimated speed of the rocket was 100 m/sec; the estimated altitude attainable, 5 km.

The Razumov rocket weighed 90 kg: the construction, 36.2 kg (structure 20.2 kg, engine 16 kg); propellants 22.39 kg (gasoline 4.89 kg, oxygen 17.5 kg); and a payload of 31.41 kg. In this way, the propellant weight amounted only to 25 percent of the rocket's gross weight, or 38 percent, not including the payload. In 1934 the rocket (Figure 3), its drawings and the individual engine components produced by Shtern (a combustion chamber and nozzle), were exhibited during the All-Union Conference on the Study of the Stratosphere. But the building of a complete engine for the rocket dragged on until March 1935, when serious complications caused this effort to be abandoned. However, Razumov's rocket was eventually launched successfully with a solid-propellant powder engine at the Aerolitic Institute station in Slutsk.

Fig. 3

At the beginning of March 1935, in Moscow, a conference on jet propulsion was held on the initiative of the All-Union Aviation, Scientific, Engineering and Technical Society. There, V. N. Vetchinkin, S. P. Korolev, V. P. Glushko, Yu. A. Pobedonostsev,

M. S. Kisenko, and A. V. Zagulin gave lectures. During the conference on March 2, M. K. Tikhonravov also presented another lecture on "the use of rockets for investigating the stratosphere,"[+] in which he showed the possibility of using existing rocket technology to attain altitudes of up to 60 km.

Let us note that the following organizations were interested in or actually developing stratospheric rockets:

1) The U.S.S.R. Academy of Sciences;

2) The Jet Propulsion Research Institute (RNII) of the People's Commissariat of Heavy Machinery Manufacture (NKTP), founded in 1933 on the base of the Moscow GIRD and the Leningrad Gas Dynamics Laboratory (GDL);

3) The Society for Assistance to the Defense, Aviation and Chemical Construction of the U.S.S.R. (Osoaviakhim);

4) The All-Union Aviation, Scientific, Engineering and Technical Society (1932-1941).

To be sure, most of the rockets were built to advance space technology in one way or another, and were not specially designed for investigating the stratosphere. But all of them remain of great interest for the history of the development of jet propulsion in the Soviet Union.

The RNII Rocket. Of the rockets produced by the RNII, the one designed by engineer V. S. Zuyev between 1933-1934 is perhaps the most interesting from the standpoint of studying the stratosphere. The Zuyev rocket was specifically designed for a vertical climb up to 50 km. Shaped like a cigar with four fixed stabilizers on the tail, it had tanks, a body, and tail unit. But it possessed no engine or propulsion unit; eventually the rocket's components were used in another high-altitude rocket. Later on, a rocket of the Zuyev design was built incorporating an 02 engine, and it made flights.

A. I Polyarny's Rocket. A group of public-spirited persons interested in rocket technology formed a special group within the Society for Assistance to the Defense, Aviation and Chemical Construction of the U.S.S.R. in Moscow, and joined in building a rocket engine designed by engineer A. I. Polyarny, who began working with this group in the autumn of 1934. With limited resources, Polyarny designed a relatively simple meteorological rocket (Figure 4). By the spring of 1935 the rocket and its engine had been constructed, and a test firing made at Nakhabino, near Moscow; the flight test, however, proved unsuccessful. The rocket, with its engine ignited, became wedged in the launcher and operated until the propellant was consumed. This occurred because a special key that opened the tank valves was not removed quickly enough.

The Polyarny rocket engine utilized alcohol and liquid oxygen, and developed a thrust of approximately 100 kg. Liquid oxygen was supplied by pressure from its own vapors, in the same manner as the 09 motor, with alcohol fed under pressure previously created in the fuel tank. In time, this rocket was given to Design Office No. 7 where

[+]Published in the Collection of articles in Reference 5.

Polyarny went to work. In Design Office No. 7, created in the second half of 1935, it became known as the R-06, was modernized, and made many flights. However, by then it had a different role to play.

Fig. 4

The All-Union Aviation, Scientific, Engineering and Technical Society Rocket. In 1935, unused components of some oxygen rockets remained at the RNII. Therefore, institute personnel decided to build a stratospheric rocket using this material. The All-Union Aviation, Scientific, Engineering and Technical Society supported this initiative and granted 5000 rubles, allowing the work to proceed.

For this rocket the following components were available: a) a 12k ceramic-lined engine designed by L. S. Dushkin, which delivered a thrust of 300 kg for 60 seconds, and operated on liquid oxygen and 95 percent alcohol; b) an ORM-50 Gas Dynamics Laboratory engine that was to have been used in the 05 GIRD rocket designed by M. K. Tikhonravov in the autumn of 1933. It weighed 15 kg and produced a specific thrust of 205-207 kg. For a variety of reasons, however, this latter unit was not used.

Figure 5 shows a section of this rocket. Stabilizers from the 05 rocket were discarded in favor of stabilizers from the RNII rocket, designed by engineer V. S. Zuyev, that had not been completed. These stabilizer wings were contoured and hollow. In this way, the All-Union rocket assumed a launch weight of 100 kg, of which 32 kg consisted of propellants. Engineers estimated that the rocket would reach an altitude of 3800 meters. The nose cone contained a parachute weighing 8 kg, and was equipped with a simplified barograph designed by S. A. Pivovarov for measuring the altitude.

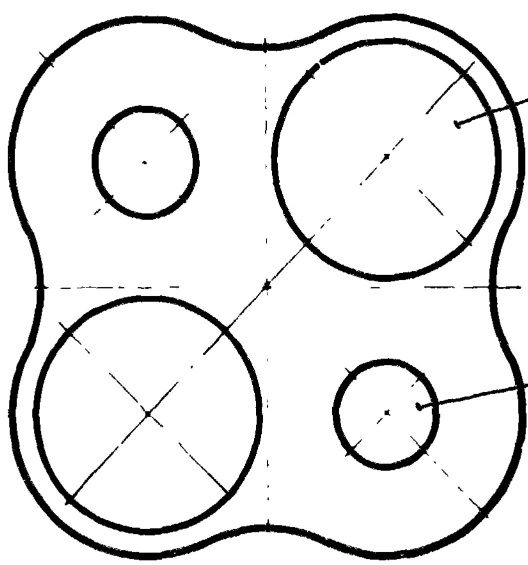

Fig. 5

The first launch of the All-Union Aviation, Scientific, Engineering and Technical Society rocket took place in April 1936 from a Tikhonravov-designed launcher made for the GIRD 07 rocket. However, the rails of this launcher had been lengthened. Pravda featured a report of the launch under the title "A Rocket Goes Into The Air," and carried a photograph of the rocket in the launcher. This is how L. Brontman, the Pravda correspondent, described the rocket's flight: "The mechanic switched on the electrical primer. There was a gray cloud of evaporating oxidizer. A spark. Suddenly, a blinding yellow tongue of flame appeared at the bottom of the rocket. The rocket slowly moved upwards along the launcher guide rails, slipped from their steel clutches and hurtled swiftly upwards. The flight was an unusually effective and beautiful sight. A flame flew from the motor's nozzle, and the gas efflux was accompanied by a deep hollow roar. After reaching a certain altitude, the white parachute in the rocket opened automatically and the machine descended slowly to the snow-covered field."

For further flights, technicians erected a wooden mast similar to 48-meter radio masts, but with a guiding strip made from a rail of a narrow-gauge railway, which held the brackets—the rocket's eccentric clamps (Figure 6). This mast was used as a launcher on August 2, 1937; however, during the launch, the maximum pressure gauge in the tanks failed, forcing a postponement. A few days later, on August 15, a successful launch took place and the rocket rose vertically and almost disappeared from view. When it fell back to Earth, the parachute opened, but became detached and the rocket disintegrated on impact. The instrument for recording the altitude was recovered; it read 2400 meters. Since the instrument was installed inside the rocket, participants assumed that it recorded the altitude at which the parachute opened. The rocket was seen to rise higher after the parachute opened; therefore, there is reason to believe that the rocket reached an altitude greater than 3000 meters.

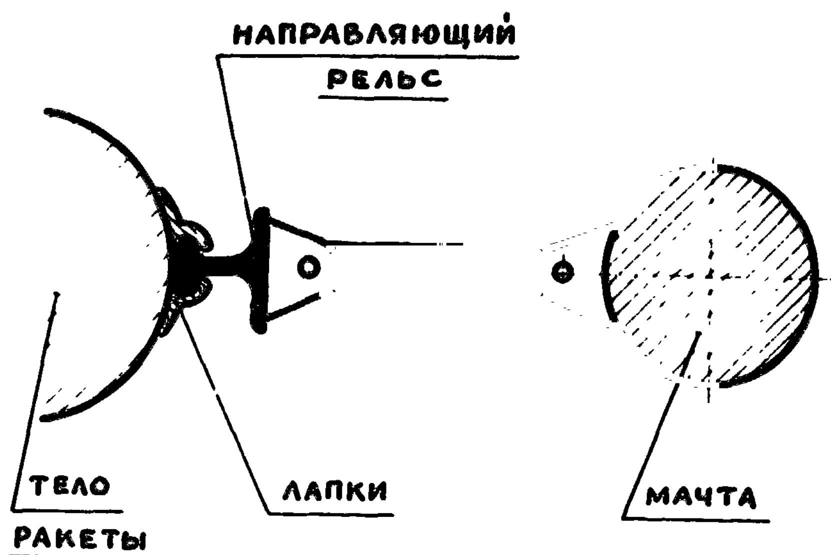

Fig. 6

The A. F. Nistratov Meteorological Rocket. This rocket was built in the workshops of the Scientific Research Institute of the Civil Air Fleet of the U.S.S.R., on funds of 5000 rubles, during 1936 and 1937. Although completed, it was not tested (Figure 7). The engine, made of duraluminum, was cooled with water, with the water passed into the combustion chamber. The engine operated on liquid oxygen and oil.

According to calculations, the addition of water, while lowering the temperature, would have little effect on the thrust. This rocket was equipped with a parachute that could be automatically deployed by a powder ejection ch rge.

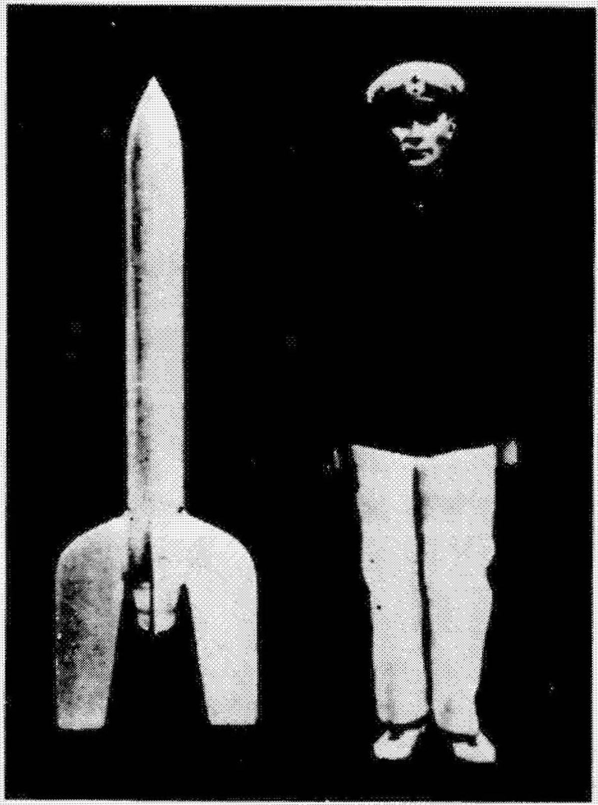

Fig. 7

<u>The L. S. Dushkin and M. K. Tikhonravov Rocket</u>. Construction of this stratospheric rocket, designed in 1937 to reach an altitude of 30 km, was not completed. Nonetheless, models of the rocket were made and tested using black powder motors. The powder motors were old ones, having been supplied to the Czarist army in Russia in 1916, but they sufficed to test the stability of the rocket models. Among various models built, mention must be made of some that arranged the propellant tanks in a torus design. In one version, a tank in the shape of a torus was made and tested for strength, though the rocket itself was not built.

The L. S. Dushkin Rocket. Designed by Dushkin in 1937, this vehicle was built in the following year. It contained a gyroscopic control unit designed by S. A. Pivovarov, and featured automatic control rudders on the stabilizers. The rocket had a removable nose cone with a parachute, an automatics compartment, and a propellant tank section between which was located a propellant-pressure accumulator. This original method of propellant supply had been conceived in 1935. The rocket also used a ceramic-lined 205 engine with a metal nozzle designed by Dushkin that delivered a thrust of 150 kg. This engine, a further improvement of the 12k engine, and its propellant supply system were developed and bench tested. One rocket and four automatic control systems were produced. Since this stratospheric rocket was designed for vertical flight and did not carry out tactical tasks, further finances were unavailable, and it was not produced.

The R-05 Rocket. O. Ku. Schmidt initiated construction of this rocket, with the work supported by the Geophysical Institute of the U.S.S.R. Academy of Sciences. The rocket's altitude ceiling was to be 50 km—and that capability interested the Institute of Technical Physics (Leningrad), where researchers wished to use the vehicle to study space radiation. Towards the end of 1937 Design Office No. 7 accepted the assignment for building the liquid-propellant rocket, designating it R-05.[+] A. I. Polyarny and P. I. Ivanov created a joint project between the Design Office and Geophysical Institute.

In the summer of 1938, P. I. Ivanov carried out special work to stabilize the vehicle with a gyroscope, rigidly connected inside the rocket body. Six models were constructed with small liquid-propellant motors burning ethyl alcohol and liquid oxygen. The model with Ivanov's gyroscope weighed 12 kg. These models flew and gave satisfactory results.

The full-scale R-05 rocket, built later in 1938, incorporated an engine produced by F. L. Yakaytis that operated on liquid oxygen and 96 percent ethyl alcohol. This propellant supply system—a propellant-pressure accumulator—had been developed in 1937. It should be noted that the use of a propellant-pressure accumulator was made possible by the duraluminum propellant tanks. The rocket itself was to be accelerated out of a launch tower by two solid-propellant booster motors. The Yakaytis liquid engine had the following characteristics: thrust, 185 kg with a specific impulse of 210 sec; burning time 25 seconds. The launch weight of the rocket with its solid-propellant boosters was 60.5 kg, and possessed a caliber of 200 mm. The burning time of the boosters was 2.58 seconds; the average thrust of one booster: 200 kg. The capacity of the liquid oxygen tank was 20.5

[+]This rocket should not be confused with the GIRD 05 rocket. The numbering of machines at the GIRD involved a two-digit sequence: 01, 02, 03, etc., without letters. The numbering of the Design Office No. 7 rockets also used a two-digit sequence, but began with the letter R: R-01, R-02, R-03, etc.

liters, and it was filled to 85 percent capacity; the volume of the alcohol tank was 13 liters, and it was filled to 91 percent capacity. The pressure created in the tanks during engine operation was 25-28 atmospheres.

Up to an altitude of 10 km, engineers intended to maintain the vehicle's vertical trajectory by using a source of infrared rays that would react upon photoelectric cells on the stabilizers. The rudders, automatically controlled, would keep the rocket in the narrow infrared beam. In 1938 the Ukrainian Physicotechnical Institute developed the photoelectric cell system for the R-05 rocket. But in April 1939, organizational complications caused all work on the R-05 to be suspended. However, at the beginning of 1940, the Moscow Higher Technical School (MVTU), supporting the initiative of the rocket's developers, agreed to complete the R-05 rocket on the condition that a customer be found. The Hydrometeorological Service at the Council of People's Commissars of the U.S.S.R. soon agreed to finance this work, but the war terminated these efforts a few months later.

The P. I. Ivanov Rocket. In 1943, with the war still underway, the P. N. Lebedyev Physical Institute of the U.S.S.R. Academy of Sciences expressed interest in building a rocket that would carry instruments up to an altitude of 40 km to investigate the intensity of cosmic radiation. The Institute proposed to launch a rocket from the Academy of Sciences' mountain station in Pamir at an altitude of 4000 meters. P. I. Ivanov accepted this assignment, and in April 1944 began the design work. Ivanov directed the calculations and design effort, with the participation of V. V. Abramov, and, later, I. V. Yaropolov. They completed this work in June 1945.

In October 1945, M. K. Tikhonravov, in whose laboratory the design work had been carried out, gave a lecture on the results at the Lebedyev Physical Institute's Technical Council. A few months later, in December 1945, upon the invitation of Academician S. I. Vavilov, Ivanov submitted a report on the project in a meeting at the Institute. In both cases, the project was approved. In March 1946, the Lebedyev Physical Institute of the Academy of Sciences authorized the construction of ten rockets, with delivery by May 15, 1946.

The P. I. Ivanov stratospheric rocket belonged to the type of rocket that involves successive separation of stages. The rocket consisted of three tandem solid-propellant powder rockets (Figure 8) with an internal chamber geometry of a 132-mm caliber rocket shell. The chambers were made from duraluminum and connected in series. A slow-burning pyrotechnic compound compressed in a special tube ensured ignition of the final stages. The external diameter of the rocket was 138 mm; the length of the entire vehicle, 3420 mm. Solid-propellant powder motors were chosen exclusively in order to produce the stratospheric rocket as quickly as possible. Subsequently, Ivanov suggested the development of a liquid-propellant rocket.

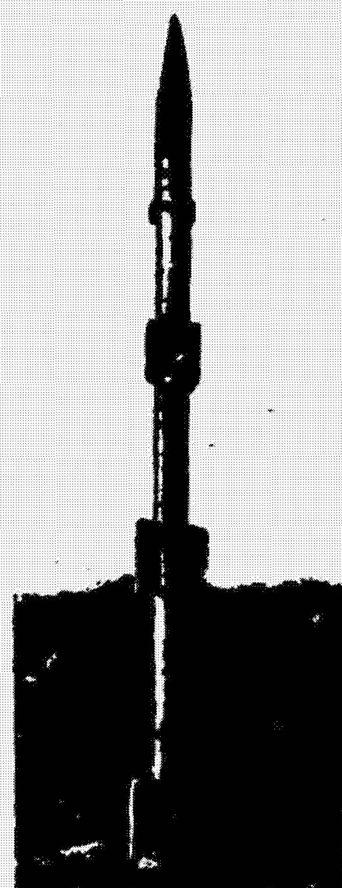

Fig. 8

A solid-propellant starting booster motor, which lengthened the rocket to 4230 mm (Figure 9), was used to increase the speed at which it left the launcher to 100 m/sec. The launcher itself possessed a guiding length of 10.5 meters. The weight of the rocket with its starting booster, completely equipped, was 87.2 kg. Without the starting booster, the three-stage rocket weighed 62.5 kg. After jettisoning of the individual stages, the weight reduced to 41.4 kg, and finally, to 22.1 kg, respectively (with propellant). The weight of the rocket at the highest point of the trajectory was 14.9 kg with instruments.+

+When the war ended, among the German rocket equipment recovered in 1945, there was a Rheinbote solid-propellant, multistage rocket which, except for the propellant charge, hardly differed in overall design from the P. I. Ivanov stratospheric rocket. The dates shown above indicate that the Ivanov rocket was developed quite independently in the Soviet Union.

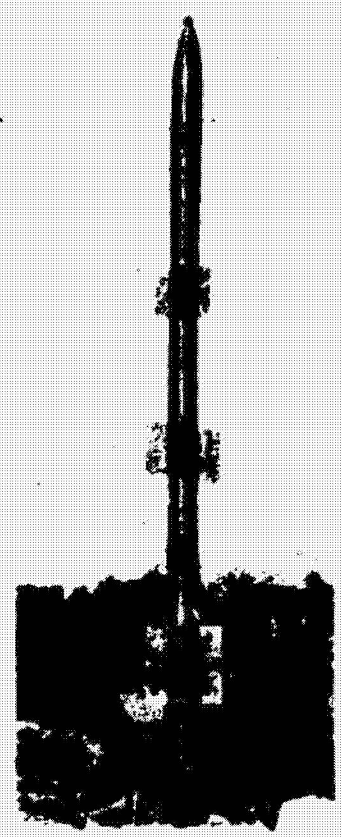

Fig. 9

The rocket could attain an altitude of 48 km on the condition that the launch took place at an altitude of 4000 meters. When launched from sea level, the ceiling would be 35 km. Test firings were made from a proving ground on March 19, 1946, to demonstrate decoupling and stability. A modified rocket employing steel combustion chambers in place of the duraluminum chambers produced satisfactory results.

During the second half of June 1946, experimental launchings were conducted with the Ivanov stratospheric rocket. These tests were conducted for the purpose of an economic evaluation by the P. N. Lebedyev Physical Institute of the U.S.S.R. Academy of Sciences, which was testing special research instrumentation.+ Three rockets were prepared

+It should be noted that the maximum acceleration during launch was 13[illegible] [illegible] the scientific instruments had to withstand this force.

for launch. The combustion chamber of one of them disintegrated at launch; the second changed course erratically when the booster disconnected upon leaving the launch tower; the center of gravity of the third rocket was artificially moved forward, and it flew well.

Radar was employed to determine the altitude attained on the third flight in late June. Probably, this was the first attempt to use radar to determine the trajectory of a rocket. The Lebedyev Physical Institute ceased using the Ivanov rocket at the end of the summer of 1946 because it lacked sufficient power to lift the desired scientific instruments. By this time, however, work on liquid-propellant stratospheric rockets had progressed considerably. These later vehicles reached greater altitudes, and contained heavy, large, modified scientific instruments.

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