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MAIN LINES OF SCIENTIFIC AND TECHNICAL RESEARCH AT THE  
JET PROPULSION RESEARCH INSTITUTE (RNII), 1933-1942<sup>†</sup>

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Over a period of one generation rocket technology developed from elemental experiments to a branch of industry that constitutes a rather large percentage in the state budget of all technically advanced countries. At first look it would seem that this rapid development of rocket technology started spontaneously just after World War II. However, considering this problem more attentively, it is obvious that the rapid development of rocketry in the USSR during the post-war years was due largely to pre-war activity; in particular, to investigations conducted in the Jet Propulsion Research Institute (RNII). For this reason the history of this institute is of special interest.

The history of RNII commenced on October 31, 1933, when the decree organizing the Jet Propulsion Research Institute was signed, creating in Moscow the first state-owned rocket research facility. RNII resulted from merging two rocket organizations: the Leningrad Gasodynamics Laboratory (GDL), and the Moscow Group for Study of Jet Propulsion (GIRD). Solid-propellant rockets were developed in the GDL from the beginning of its reorganization in 1927. Shortly thereafter, work began on jet-assisted take-off of aircraft and liquid propellant engines (generally with nitric acid as the oxidizer).<sup>†††</sup> In GIRD, projects of liquid-propellant rockets (generally with oxygen as the oxidizer), ram jet engines, rockets with and without wings, and rocket planes, were designed and investigated.

As the leading specialists of GDL and GIRD began to work in this new organization, these trends were continued in RNII. Thus, RNII was a collective of enthusiast-specialists in rocketry who believed in the great future of rocket technology, and, in

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<sup>†††</sup>See also, I. I. Kulagin, "Developments in Rocket Engineering Achieved by the Gas Dynamics Laboratory in Leningrad," and M. K. Tikhonravov, "From the History of Early Soviet Liquid-Propelled Rockets," in the Proceedings of the First and Second History Symposia of the International Academy of Astronautics, Smithsonian Annals of Flight, No. 10, 1974—Ed.

42  
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spite of a lack of funds, pursued intensive theoretical and practical studies. R.N.II was a real research and development organization that had at its disposal test facilities, scientific laboratories, work-shops, a flight test station, and launch complex. The scientific and technical board of the Institute met regularly. Scientific conferences were organized, and numerous scientific papers published. Over a period of 10 years, in fact, more than 120 papers were published in 19 editions and monographs. Many special reports (on the order of some hundreds) appeared, related to various concrete projects.

The projects completed in R.N.II were of different types. The purpose of some of them involved the practical application of rockets in the defense of the country. Many other projects dealt with the possibility of manned space flight. Various subjects of theoretical and applied sciences in rocketry were also studied (for example, problems of the gas dynamics, heat and mass transfer, etc.). The trends of R.N.II activity are considered briefly below.

#### SOLID-PROPELLANT ROCKETS AND THEIR APPLICATION IN ORDNANCE AND AVIATION

The fundamentals of chemical composition and production of homogeneous solid-propellant charges were developed in the GDL by V.A. Tikhomirov, B.S. Artemiev, B.S. Petropavlovsky, G.E. Languemac, and others. The technology was improved in R.N.II, and Yu. A. Pobedonostsev, L.E. Shvarz and other scientists achieved significant success in the design of charges and chambers.

Much attention centered on the problem of practical ordnance applications of solid-propellant rockets. A series of rocket missiles of 82 and 132 mm caliber were developed for launching from the ground or aircraft (Figure 1). The first successful use of these missiles from aircraft occurred in 1939 during combat operations at Khalkhin-Gol.<sup>†</sup>

To improve the aerodynamic characteristics of rocket missiles, engineers constructed the first Soviet supersonic wind tunnels in R.N.II under the direction of Yu.A. Pobedonostsev and M.S. Kisenko. Among them, the ejection-type wind tunnel of 400 mm diameter should be noted. Figure 2 shows a missile model in one of the first wind tunnels constructed in 1934-35.

Numerous studies were also carried out to improve rocket missile accuracy, which still left much to be desired. Significant progress was achieved in this field, and

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<sup>†</sup>See Yuri A. Pobedonostsev, "On the History of the Development of Solid-Propellant Rockets in the Soviet Union," in this Volume—Ed.



FIG. 1

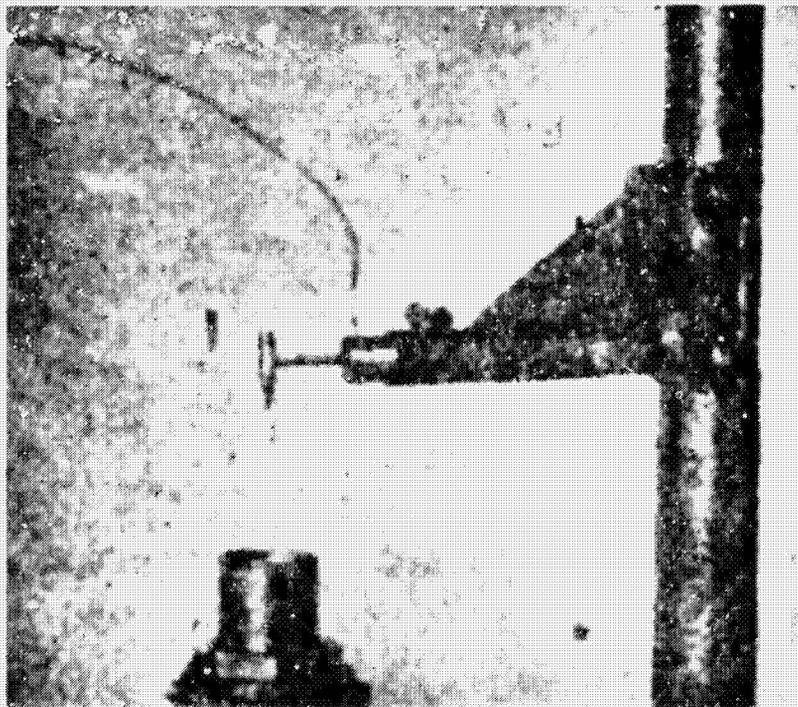


FIG. 2

rockets of different types were soon put into service by the Red Army. However, the accuracy of rocket missiles remained considerably inferior to that of conventional artillery; it was the most vulnerable point of this type of weapon. Naturally, a suggestion arose: use rocket missiles for blanketing fire. To meet that need, the section of I. I. Gvay (RNII) began to develop multibarrel rocket units. Thus, the famous "Katyusha," used extensively during World War II, appeared (Figure 3).

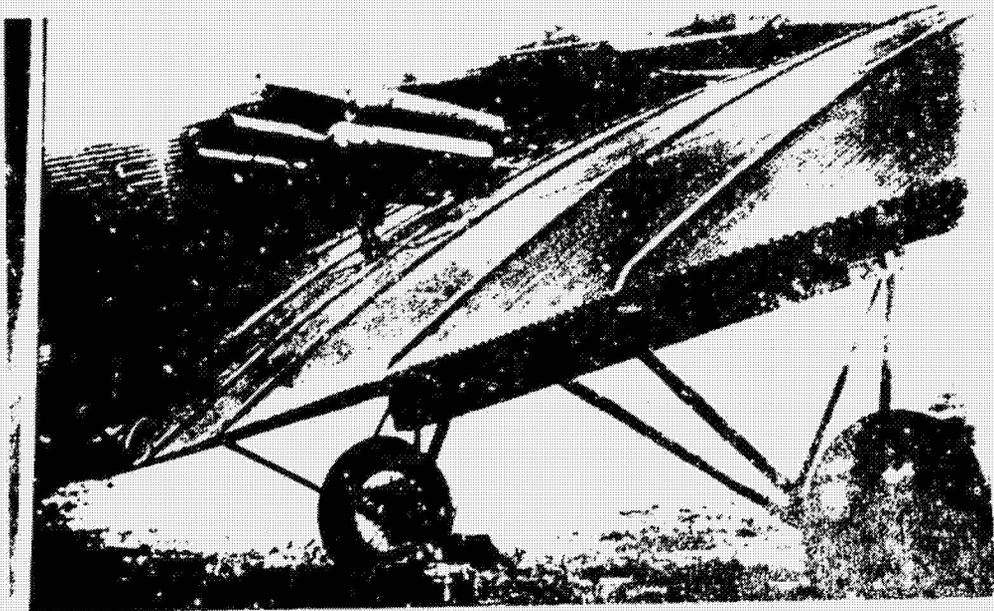
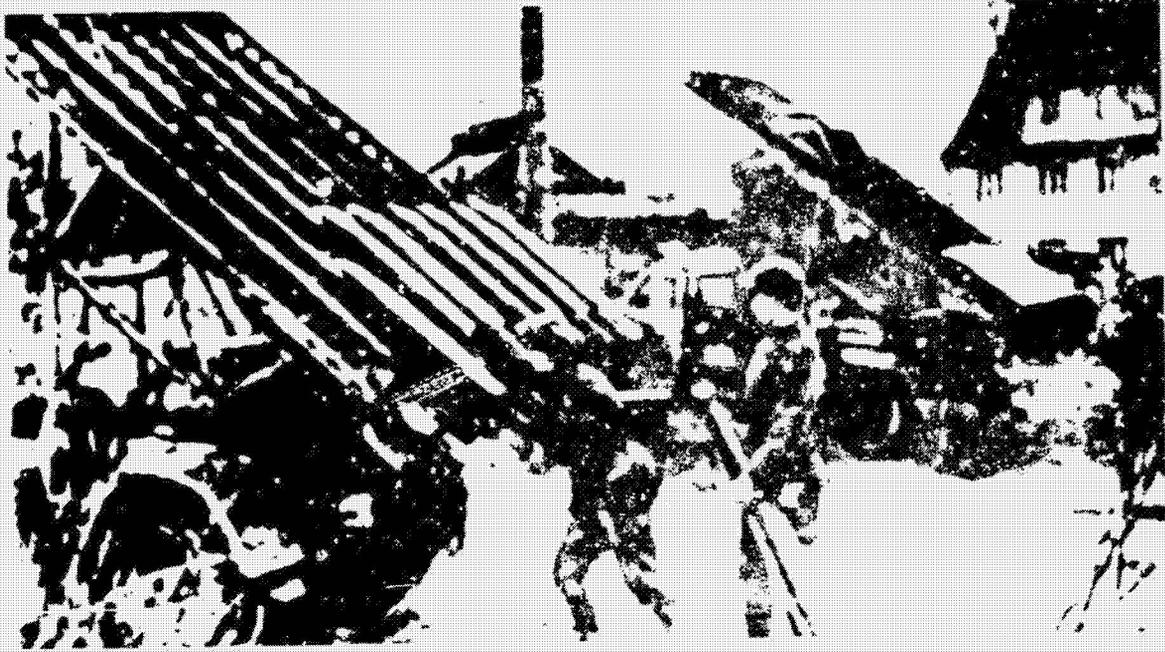
One important aspect of the practical application of solid-propellant engines involved the Jet-assisted take-off of aircraft—a concept which had been tested earlier in GDL under the direction of V.I. Dudakov. In RNII the jet-assisted take-off of the bomber TB-1 was fully developed (Figure 4), reducing the takeoff distance 20-to-25 percent. V.I. Dudakov's section also developed jet catapults.

The studies of solid-propellant rockets conducted by RNII placed the USSR ahead of other great powers in this field. The war demonstrated that the quality of German solid-propellant rockets was considerably inferior, in spite of the efforts in rocketry of some prominent German scientists.

#### LIQUID-PROPELLANT ROCKETS

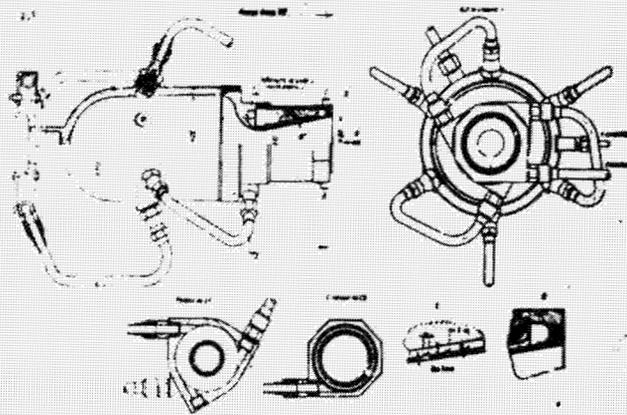
Another important trend in RNII activity was the development of efficient liquid-propellant rocket engines. These studies involved nitric acid engines (V.P. Glushko), and oxygen engines (M.K. Tikhonravov, L.S. Dushkin and others). Very large, systematic studies were undertaken to improve the performance and reliability of nitric acid engines and to improve design methods. Among other engines, the ORM-65 (170 kg thrust), and the ORM-52 (300 kg thrust) (Figure 5) should be noted. In spite of numerous difficulties and failures (detonation explosions at engine start, for example) the performance of these engines were brought up to the design values. Nitric acid engines were developed further in 1938-41. In this period the RDA-1-150 (150 kg thrust) and DIA-1100 (1100 kh thrust) engines were manufactured. The high level of development achieved with this type of engine is substantiated by the fact that they were installed and operated practically in all of the prototype vehicles developed at RNII in the last pre-war years (the rocket plane RP-318, ballistic rockets 521 and 604, the rocket fighter BI-1, and others).

Numerous important results were also obtained in the field of oxygen rockets. In particular, it is of interest to note that the development of the modified engine OR-2 (100 kg thrust), which had been started by F.A. Tsander. Although work terminated in 1934, this engine was installed in the winged rocket 216. The development of the engine series 12K (300 kg thrust, Figure 6) was initiated in 1934 by the specialists led by L.S. Dushkin. Engines of this type were installed in the rocket "Aviavnto." Figure 7 shows the engine 205 (100 kg thrust), developed in 1936-1937. Although development of oxygen engines stopped in the last pre-war years—and during the war—it resumed again after the war when the success of oxygen rockets was of world-wide significance.



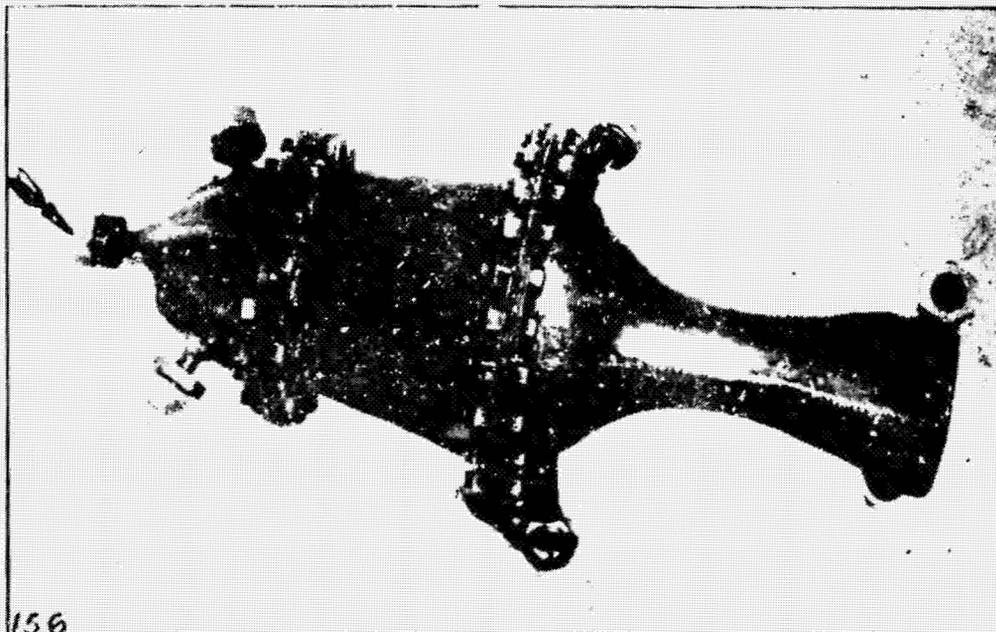
Двигатель ОРМ-52, разработанный в 1933 г. и усовершенствованный в 1935 г., предназначался для экспериментальных ракет и морских глиссирующих торпед.

Двигатель работал на топливе азотная кислота и перокси. В 1933 г. прошел свечные стендовые испытания.



ОСНОВНЫЕ ДАННЫЕ ДВИГАТЕЛЯ

1. Тяга у земли	250 + 310 кг
2. Удельная тяга	210 сек
3. Давление в камере	20 + 25 атм
4. Коэффициент избытка окислителя	1,08
5. Система подачи топлива	баллонная
6. Давление подачи	40 атм
7. Зажигание	химическое
8. Объем камеры сгорания	2,23 л
9. Вес двигателя	14,5 кг



156

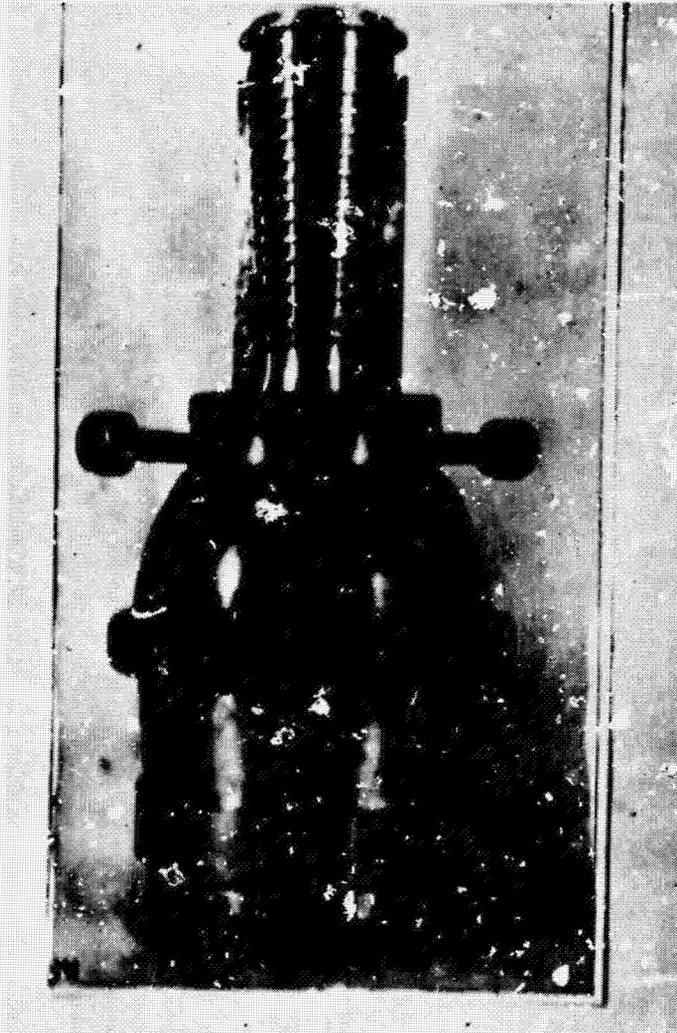


Fig. 7

#### BALLISTIC LIQUID-PROPELLANT ROCKETS

Work on ballistic rockets, or "long range rockets" (as they then were known) in RNII, was of an exploratory nature. Besides the oxygen rocket 09, which had been first launched by GIRD, the flight tests of the rockets 07 and 10, the rocket "Aviavnto" with the engine 12k (Figure 8), and others, were realized in the RNLI by M.K. Tikhonravov and his colleagues. In 1939-40 ballistic rockets 521 and 604 using the combined solid-



Fig. 8

propellant and nitric-acid engine<sup>+</sup> (about 100 kg thrust) were developed and tested by RNI<sup>7</sup> (Figure 9). Ranges of 19-20 km were obtained in these tests. It should be noted that not only single rockets were tested, but 8-14 rockets were tested in series. Unfortunately, these promising investigations ceased at the beginning of the war because the funds needed to improve the accuracy and reliability of this type of rocket were available.

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<sup>+</sup>Grains of solid fuel were introduced into the combustion chamber of the nitric-acid engine; upon ignition of the grains, a short but strong thrust impulse occurred. The grains having burned out, the nitric-acid and kerosine were introduced automatically into the combustion chamber and the engine began to work as a liquid-propellant one.

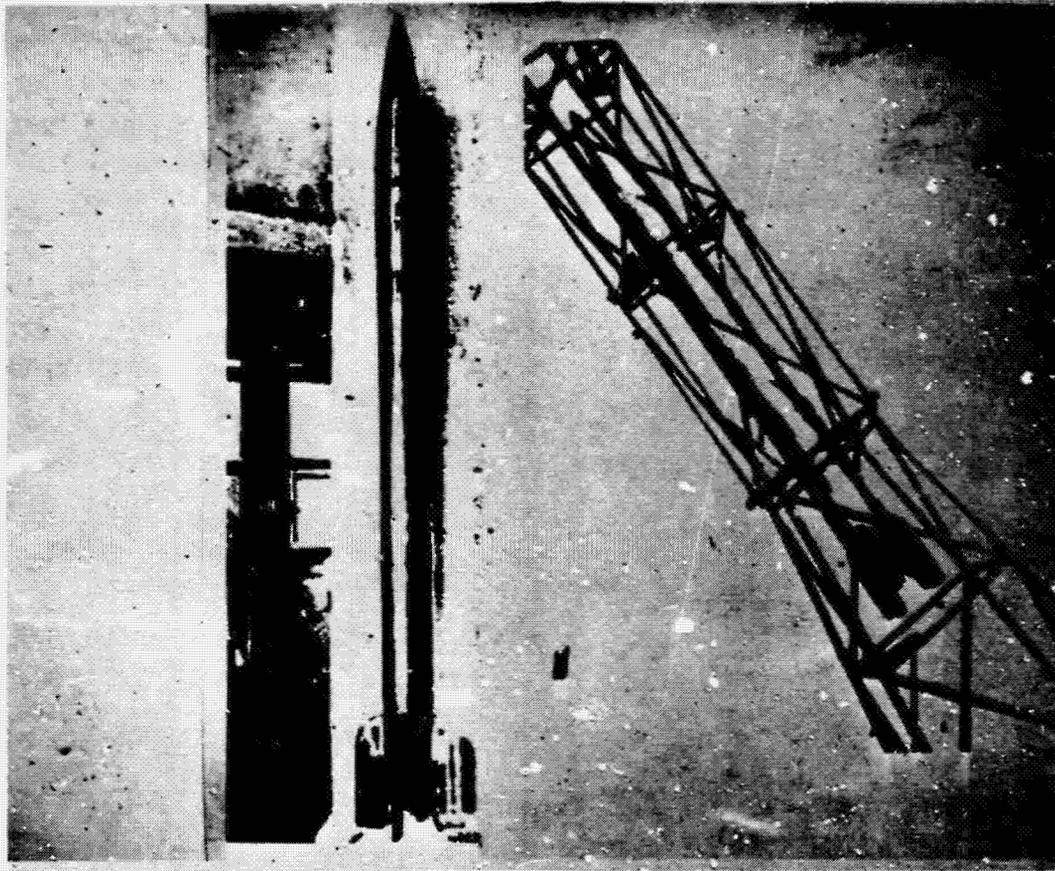


Fig. 9

#### WINGED LIQUID- AND SOLID-PROPELLANT ROCKETS

Over the period of 1933-39, RNI also developed winged liquid- and solid-propellant rockets. The main purpose here was to investigate the flight dynamics of winged jet vehicles with a large thrust/weight ratio, and the practical application of these rockets in air defense and ordnance systems (computations showed that for a short flight range the initial weight of a winged rocket was lower than that of the ballistic one).

In 1933-36 the rocket 20 (80 kg initial weight), powered by the liquid oxygen engine 02 (OR-2) and equipped with autopilot GPS-2, was developed under the guidance of

the author of this paper. A drawing of this rocket is presented in Figure 10. The gyroscope autopilot GPS-2 developed in RNII by S.A. Pivovarov controlled the elevator and ailerons. For the first time in the USSR, initial acceleration of the rocket 216 at launch was provided by a solid-propellant rocket catapult. A drawing of the catapult launching truck appears in Figure 11. Five 216 rockets were tested, but their trajectories and ranges were far from the design values because of the low reliability of the subsystems.

Specialists paid considerably more attention to the reliability of the subsequent winged rocket 212, developed by S.P. Korolev. The model of this rocket is shown on the launching truck in Figure 12. The nitric acid engine ORM-65 was installed in this

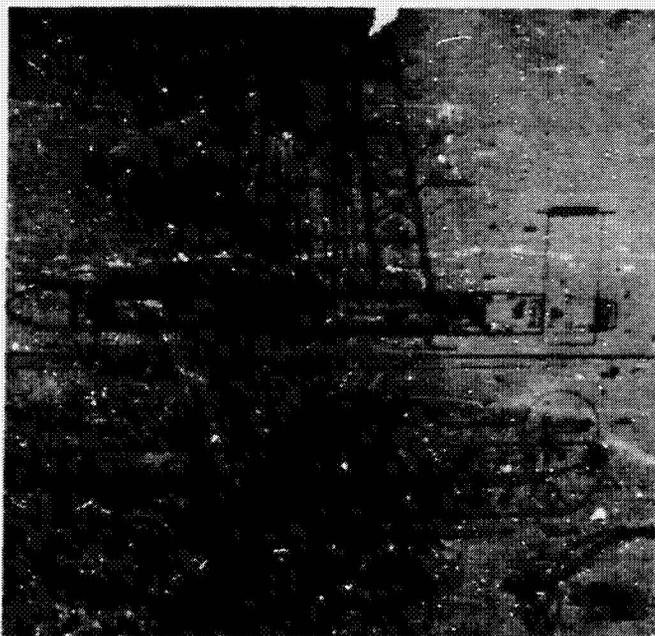


Fig. 10

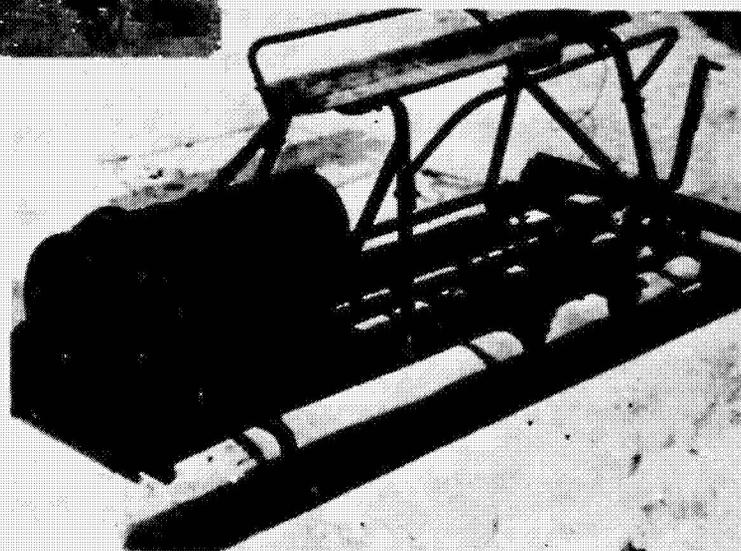


Fig. 11

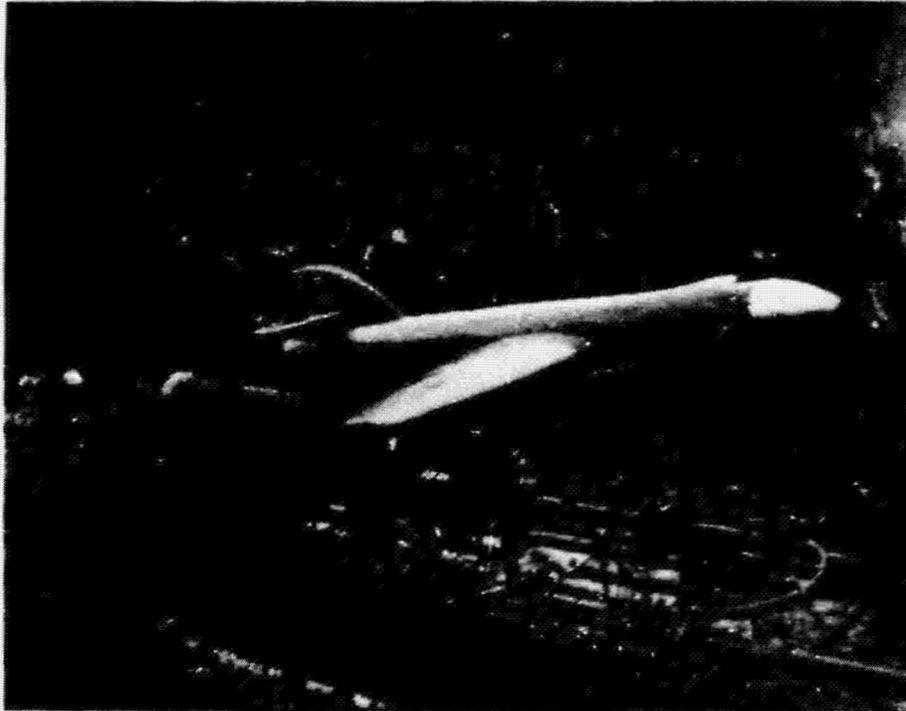
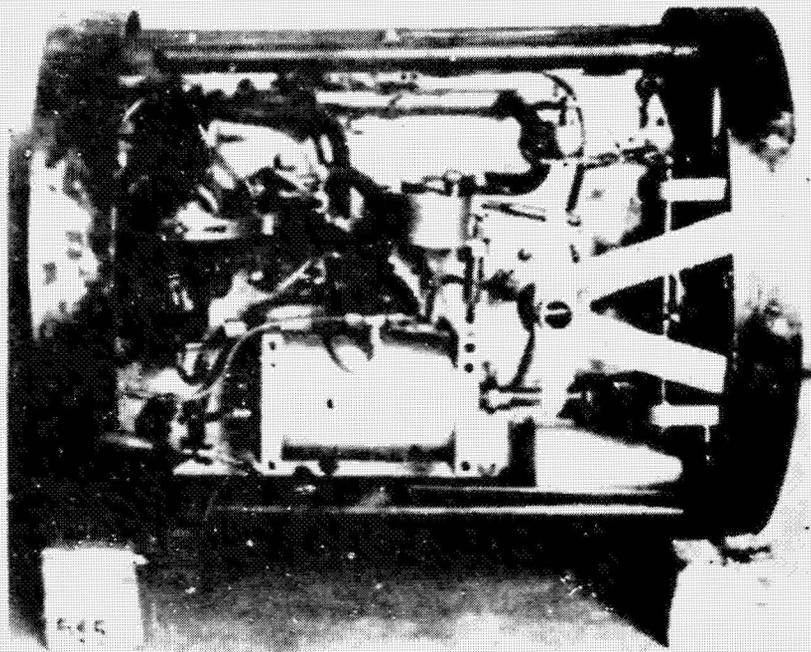


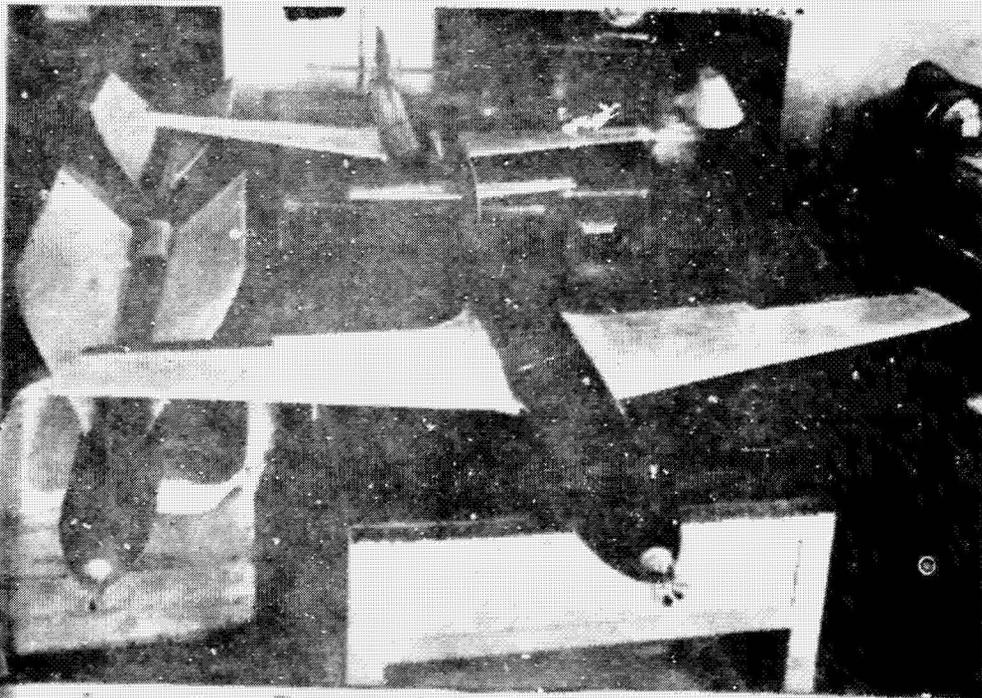
Fig. 12

rocket, which was equipped with the autopilot GPS-3 to control the elevator, rudder, and ailerons (Figure 13). Numerous bench tests to adjust the systems of the rocket 212 were carried out. Unfortunately, only two rockets were prepared for launching in 1939. It could not be expected, of course, that the rocket's performance would be brought up to design values by launching such a small "series" of rockets.

In addition to winged rockets with liquid-propellant engines, air defense winged rockets with solid-propellant engines were developed in 1935-38 under the guidance of M.P. Dryazgov. Winged rockets of different aerodynamic configurations were tested (Figure 14). Better stability characteristics were obtained for the four-winged rocket 217/II with a low aspect ratio. In 1937-38 RNII conducted negotiations with a specialized experimental design bureau for the radio-controlled autopilots and homing heads which were supposed to be installed in these rockets. In 1938 the theory of controlled winged rocket flight developed by M.P. Dryazgov appeared.



545



Фиг. 2. Механизм, подготовленный к работе.

REPRODUCTION OF THE  
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## ROCKET PLANES

Studies related to rocket-powered aircraft were first conceived in GIRD. There, F.A. Tsander and S.P. Korolev developed the rocket glider RP-1; however, it was not possible to realize this project then. RNII renewed more detailed studies of these aircraft. S.P. Korolev and the author of this paper carried out theoretical investigations in 1936 that showed the rocket-propelled aircraft RP-218, powered with a cluster of three OPM-52 engines, had a new quality compared to the usual propeller-driven aircraft, namely, a very swift rate of climb. After the Korolev report had been heard at a session of the RNII scientific and technical board, officials decided to implement the flight of the man-carrying rocket glider SK-9, named RP-318 (rocket plane 318, Figure 15) as the first phase of the rocket flighter program. The OPM-65 engine was at first chosen for this glider. Numerous detailed ground tests of power plant were performed, including tests of electrical and control systems, fuel system, etc. On the basis of the experience obtained, the new engine RDA 1-150 was manufactured. In October 28, 1940 the first flight in the USSR of a manned rocket plane with this liquid-propellant engine was realized by pilot Fedorov. Figure 16 shows the experimental characteristics of this engine installed on RP-318.

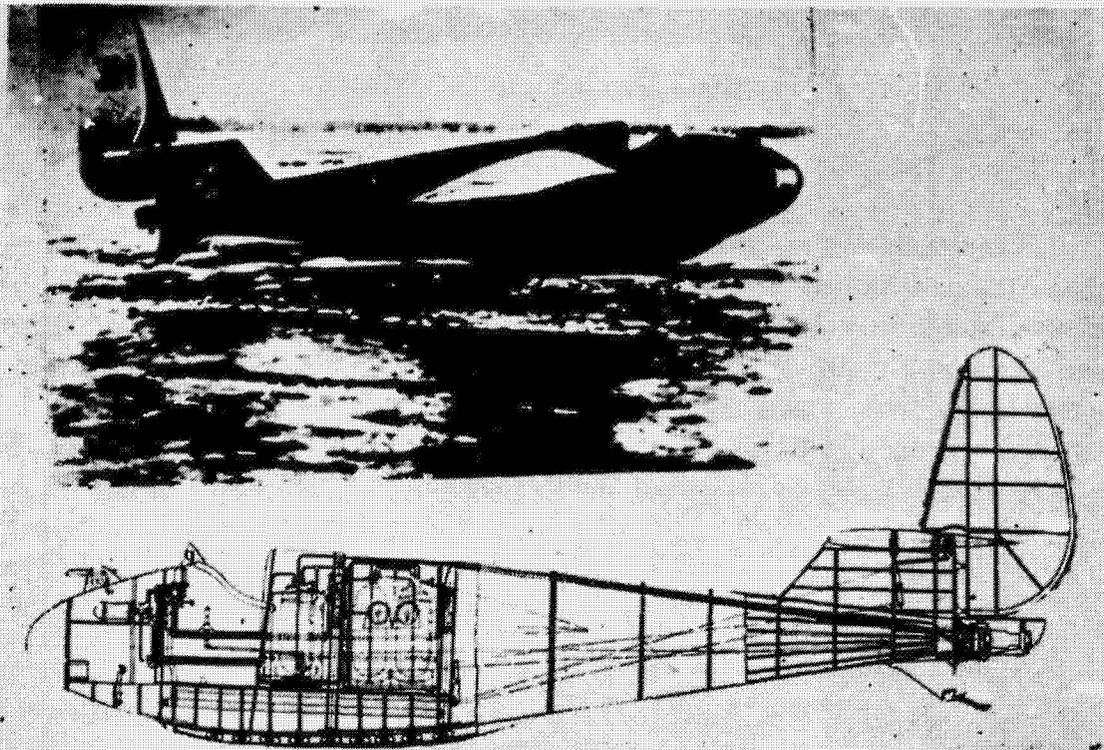


Fig. 15



Fig. 16

Development of the rocket fighter BI-1, constructed by V.F. Bolkhovitinov (Figure 17), continued developments in this program. The DIA-1100 engine (1100 kg thrust), also developed in RNII, was installed in this aircraft. Bakhchivandzy piloted the first flight of the BI-1 on May 15, 1942. However, an attempt to increase the flight speed resulted in his death. Among the factors which may have been responsible for this catastrophe was the poor knowledge of the air compressibility effect on aircraft controllability; in particular, the dangerous shift of the center of pressure rearward was not yet known.

#### CONCLUSION

This review of the basic trends of RNII activity and the list of works carried out in 1933-42 is far from complete. In particular, the studies of ram jet and pulse jet

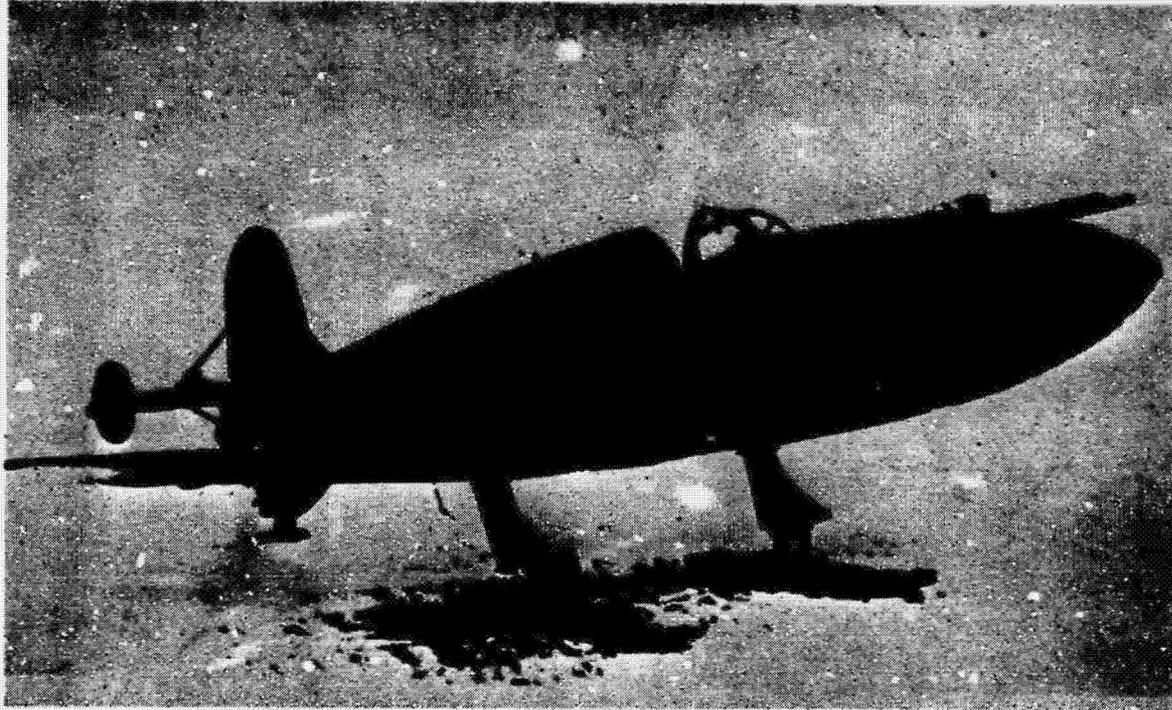


Fig. 17

engines, liquid- and solid-propellant gas generators, automatic control systems for jet vehicles, etc., have not been considered. What were the main results of this RNII activity in the period of 1933-42? Evident success was achieved in the field of rocket missiles ("Katyusha"), and jet-assisted take-off of aircraft, as the design parameters were realized; these systems played an important role during World War II. Though other projects were not completed, valuable scientific and technological results were obtained in the process of the research and development. A great reserve of knowledge for future studies was provided, experience gained in the field of production technology, and design and test techniques related to various jet vehicles and engines perfected.

But perhaps the most valuable result of RNII pre-war activity was the training of scientific and technological cadres that later brought the unprecedented progress in Soviet rocket technology after the war. We mean specifically the mechanics and test engineers, designers and mathematicians, scientists and project managers.