

Bereznyak-Isayev BI



[Berezniak-Isayev BI-1 pendant la seconde guerre mondiale](#)

L'Union Soviétique s'intéressa aux avions-fusée dès 1932 avec le projet de Sergey Korolev, le GIRD-6. Le Maréchal Mikhaïl Toukhatchevski lui-même soutint le projet. Le 28 février 1940, le premier appareil piloté, le RP-318-1 du même Korolev, prit l'air pour la première fois. Le TsAGI organisa dès le printemps une conférence sur ce thème. Le directeur de l'OKB-23, Viktor Fedorovich Bolkhovitinov, assistait à cette conférence avec 2 de ses meilleurs ingénieurs, Alexander Bereznyak et Aleksei Isaev. Ces deux ingénieurs étaient excités à l'idée de concevoir leur propre avion-fusée, idée approuvée par leur patron. D'autant plus que le conseil des ministres, le 12 juillet, réclama l'étude d'un appareil stratosphérique à haute vitesse. A l'automne 1940, ils montrèrent à l'un de leur collègue, Boris Chertok, une étude préliminaire intitulée Projet G. Ce projet était construit en contreplaqué et duralumin, pesait 1500 kg au décollage et était prévu pour un moteur-fusée encore à l'étude au RNII, développant 1400 kgp. Chertok fut surpris d'apprendre que l'appareil pourrait quasiment monter à la verticale. Lorsqu'ils visitèrent le RNII en mars 1941, ce moteur conçu par Leonid Dushkin n'était pas encore prêt. Il était désigné D-1-A-1100 car la puissance attendue était plutôt de 1100 kgp. Le A était pour Acide nitrique, ce qui soulevait une controverse dans le milieu. De plus, il était fabriqué avec les standards prévalant pour les moteurs à pistons. L'opération Barbarossa rendit urgente la conception d'un intercepteur à moteur-fusée. Beresnyak et Isayev, qui se concentraient depuis la veille sur un nouveau concept utilisant un compresseur à air et non plus la technologie de Dushkin, approfondirent leur concept en 3 semaines. Le 9 juillet, l'équipe rencontra le directeur du RNII, Andrey Kostikov. Dushkin était mécontent qu'on ne fasse plus appel à lui, mais il dut bien se soumettre face à l'ordre de Staline. Celui-ci, daté du 1er août, exigeait que le nouvel appareil soit prêt dans les 35 jours. En réalité, le travail avait déjà commencé et l'équipe vivait littéralement dans l'usine.





[Berezniak-Isayev BI vu de face](#)

Le nouvel appareil était désigné BI, pour Blizhnii Istrebitel (chasseur à courte portée), désignation parfois comprise comme renvoyant aux initiales de ses concepteurs. Il s'agissait d'un monoplane à ailes basses, armé de 2 canons ShVAK de 20 mm (et non plus 4 mitrailleuses comme prévu auparavant). Son revêtement était constitué de 2 millimètres de contreplaqué et de toile. À part les flaps en duralumin, la plupart des surfaces de contrôle était aussi recouverte de toile. À l'avant se trouvait 5 réservoirs d'air comprimé et 2 de kérosène. À l'arrière se trouvait 5 autres réservoirs d'air comprimé et 3 d'acide nitrique. Pressurisés à 60 atm, ces réservoirs étaient construits dans un alliage de chrome, de manganèse et d'acier au silicium pas spécialement résistant à la corrosion et qu'il fallait souvent remplacer. L'air comprimé servait également à déployer le train d'atterrissage et à activer les canons. Le 1er septembre 1941, le BI-1, le premier prototype, fut prêt pour les essais planeurs avec Boris N. Kudrin aux commandes. Quelques semaines plus tard, leur rival Yakovlev prit sur lui-même de tester l'appareil dans la soufflerie du Tsagi. Connaissant les relations tumultueuses entre Yakovlev et leur patron, Beresniak et Isayev prirent peur. Mais en réalité, Yakovlev leur donna de bons conseils, comme agrandir le gouvernail et ajouter 2 petites dérives sur l'empennage horizontal. L'OKB-293 et le RNII furent évacués vers l'Oural devant l'avance allemande en octobre. Un nouveau pilote fut affecté à l'équipe, Grigory Yakovlevich Bakhchivandzhi. Mais l'acide nitrique posait de graves problèmes, corrosion des réservoirs, brûlures de peau et gênes respiratoires. Le moteur explosa le 20 février 1942 pendant un test. Il projeta Bakhchivandzhi contre le tableau de bord et le blessa. Un blindage de 5,5 mm fut alors rajouté au siège. Le premier vol réel du BI-1 eut lieu le 15 mai 1942 avec Bakhchivandzhi aux commandes. L'atterrissage fut rude et le train d'atterrissage cassé, mais le pilote fut indemne et déclara que mis à part l'incident, l'avion se comportait bien.



[Berezniak-Isayev BI - Réplique exposée vue de côté](#)

Le BI-1 finit par être trop endommagé par l'acide nitrique pour continuer à voler et fut remplacé par le deuxième exemplaire, le BI-2, pour la suite des tests. Le deuxième vol eut lieu le 10 janvier 1943, suivi d'un troisième le 12 janvier. Au cours de ce vol effectué par Konstantin Gruzdev, la puissance fut portée à son maximum, permettant à l'avion d'atteindre la vitesse de 675 km/h et l'altitude de 2190 mètres. Le BI-3, lui, fut testé à partir du 11 mars 1943. Une vitesse ascensionnelle de 83 m/s fut atteinte, ainsi que l'altitude de 4000 mètres. Le BI-4 était le premier exemplaire à être doté de canons, et le premier vol avec une dotation d'obus eut lieu le 21 mars. Cependant, il semble qu'aucun tir n'ait jamais été réalisé. Le pilote Backchivandzhi se tua le 27 mars au cours d'un vol à basse altitude, l'avion ayant soudainement plongé à 45° avant de s'écraser. Le contrôle du BI-1 avait été perdu à cause des effets du vol transsonique. Les estimations de la vitesse maximale portaient entre 800 et 990 km/h, mais les instruments de mesure étaient trop endommagés. L'OKB-293 revint vers Moscou en mai 1943 et Bolkhovitinov rédigea un rapport sur la nécessité d'explorer le vol transsonique. A partir de 1944, les exemplaires BI-5 à 9 furent construits. Au printemps 1944, le BI-6 fut équipé de statoréacteurs DM-4, mais malgré trois essais conduits par Boris Kudrin, ils ne démarrèrent jamais en même temps. Isayev conçut un autre moteur, le RD-1, qui fut terminé et testé en octobre 1944. Il équipa le BI-7 qui vola 2 fois, le 24 janvier et le 9 mars 1945. Celui-ci recevait également d'autres modifications, dont une dérive plus grande. Les essais montrèrent une tendance aux vibrations, inexistantes lors de vols planés. Mais au 29 mai, le BI-7 était trop endommagé par l'acide nitrique pour continuer à voler. Le BI-5 reçut les mêmes modifications que le BI-7, mais sans les moteurs. Le BI-6 fut envoyé au TsAGI et le BI-9 le remplaça. Quant au BI-8, son destin est inconnu. L'apparition du réacteur fit baisser l'intérêt de tels chasseurs, d'autant plus que son autonomie était limitée à 15 minutes. Mais l'expérience accumulée permirent à Bereznyak de fonder l'OKB-155 destiné à concevoir des missiles de croisière et à Isayev de fonder l'OKB-2, spécialisé dans les moteurs-fusées à ergols liquides pour la conquête de l'espace. Le Berezniak-Isayev BI effectua 12 vols motorisés : le BI-1 2 fois (2 et 15 mai 1942), le BI-2 deux fois (10 et 12 janvier 1943), le BI-3 quatre fois (11, 14, 21 et 27 mars 1943), le BI-6 trois fois au printemps 1944 et le BI-7 deux fois (24 janvier et 9 mars 1945). 7 tests furent effectués avec le D-1-A-1100, 3 avec les DM-4 et 2 avec le RD-1. En définitive, le BI était le pendant soviétique du Me 163 allemand. Contrairement à ce dernier, il n'atteignit pas le stade opérationnel, mais aurait certainement été tout aussi dangereux pour ses pilotes. L'exemplaire exposé à Monino semble être une réplique.

The **Bereznyak-Isayev BI-1** was a Soviet short-range rocket-powered interceptor developed during the Second World War.

Early design

Soviet research and development of rocket-powered aircraft began with [Sergey Korolev's GIRD-6](#) project in 1932. His interest in stratospheric flight was also shared by Marshal [Mikhail Tukhachevsky](#) who supported this early work. After a long series of unmanned tests of vehicles, Korolev's [RP-318-1](#) rocket aircraft flew on 28 Feb 1940. That Spring, [TsAGI](#) ([ЦАГИ – Центральный аэрогидродинамический институт – Tsentralniy Aerogidrodinamicheskiiy Institut](#) Central Aerohydrodynamic Institute) hosted a conference for aircraft chief designers on the subject of ramjet and rocket propulsion. On 12 July the SNK (*Sovet Narodnykh Komissarov* – council of peoples commissars) called for the development of a high-speed stratospheric aircraft. Aircraft designer and head of OKB-293, [Viktor Fedorovich Bolkhovitinov](#) attended the TsAGI conference along with two of his top engineers, [A. Ya. Bereznyak](#) and [A. M. Isaev](#). The young Bereznyak had made an impression in 1938 with a high-speed airplane design that some thought could break the world speed record. Bereznyak and Isaev were excited by the idea of designing a rocket-powered aircraft, and their "patron" Bolkhovitinov approved. By the autumn of 1940, they were able to show fellow engineer [Boris Chertok](#) a preliminary design of "Project G". The design, made up mostly from plywood and [duralumin](#) had a take-off weight of 1,500 kg (3,300 lb), and they planned to use the new 13.734 kN (3,088 lbf) rocket engine under development in the [RNII](#) (*Raketnyy Nauchno-Issledovatel'skiy Institut* – reaction engine scientific research institute). Chertok was astounded that the aircraft could almost climb vertically. Bereznyak, Isaev and Chertok visited RNII in March 1941, but the new rocket engine was not working yet. The engine was designed by [Leonid Dushkin](#), who had made the [RD-A-150](#) for the [Korolyov RP-318-1](#). Powered by tractor kerosene and [red fuming nitric acid](#), it fell short of the hoped for 13.74 kN (3,090 lbf) thrust and the [D-1-A-1100](#) was expected to reach 10.8 kN (2,400 lbf). The "A" stood for Nitric Acid ("Azotnokislotny" in Russian), versus K for Liquid Oxygen ("Kislородny" in Russian), a distinction of unusual importance and controversy among Soviet rocket scientists. Dushkin's turbine propellant pump was causing considerable problems, driven by hot gas and steam from a small combustion chamber fed with rocket propellants mixed with water, but this system was perfected a few years later for the [RD-2M](#) engine. The D-1-A-1100 was built from S54 steel (a 12% chromium alloy). At this point in time, Russian rocket engines were built with typical aviation piston-engine manufacturing technology, weighing 48 kg (106 lb), it could be broken down into discrete forged-steel sections – a conical head with 60 centrifugal injectors, the cylindrical chamber, and the nozzle – joined with bolts and copper gaskets. It was ignited with a nichrome glow plug, later replaced with silicon-carbide and was cooled regeneratively by both propellants, the chamber walls by a spiral flow of incoming fuel (kerosene) and the nozzle section by the flow of oxidizer (Nitric Acid).

War-time development

On 21 June Isaev proposed a new design using compressed air instead of a pump to force propellant to the engine. The next day, [Operation Barbarossa](#) brought the Soviet Union into World War II, and the rocket-powered interceptor suddenly became important. Bereznyak and Isaev began a new more detailed design, which they finished in three weeks. On 9 July Bolkhovitinov and his project-G team met with [Andrey Kostikov](#) the head of RNII. Dushkin was not happy about the idea of bypassing his fuel pump design, but they backed the plan and cosigned a letter that was eventually shown to [Joseph Stalin](#). After giving a report at the Kremlin, they were ordered to build the aircraft and were given only 35 days to do so. The official order was dated August 1, but work began in late July. The engineers were given leave to visit their families, and then literally lived at the factory until the aircraft was finished. The new design was called "BI" for *Blizhnii Istrebitel* (close-range fighter), but the letters were also understood by everyone to stand for its inventors: Bereznyak and Isaev. The original plan to include four machine guns was replaced by a design with a pair of 20 mm (0.79 in) [ShVAK cannon](#). The new aircraft was a low-wing monoplane 6.4 m (21 ft) long, with a wingspan of 6.5 m (21 ft) and an estimated take-off mass of 1,650 kg (3,640 lb) (dry mass 805 kg (1,775 lb) and had a maximum propellant load of 705 kg (1,554 lb). The [D-1-A-1100](#) engine was capable of throttling between 400 kg and 1,100 kg and with 705 kg (1,554 lb) of propellant, the engine could burn for almost two minutes.^[1] Working around the clock, local furniture workers were employed to build the first two prototypes (BI-1 and BI-2).

The skin was 2 mm (0.08 in) plywood with a bonded covering of fabric. The ailerons, elevators and rudder were fabric covered, and the flaps were duralumin. In the forward section were 5 compressed air tanks and 2 kerosene tanks. In the aft were 5 compressed air tanks and three nitric acid tanks. Pressurized to 60 bar (6,000 kPa), the tanks were made from a high-strength chromium-manganese-silicon steel ("[Chromansil](#)") that was not especially resistant to corrosion. Thus, the acid tanks had to be replaced periodically. Compressed air was also used to retract and deploy the landing gear and to power the built-in cannon. On 1 September 1941 the BI-1 was completed and ready for gliding tests by pilot Boris N. Kudrin as Dushkin's engine was still not ready. A few weeks later, rival aircraft designer [A.S. Yakovlev](#) took it upon himself to tow the prototype to [TsAGI](#) for windtunnel testing. This alarmed Bolkhovitinov's team, because their patron had a rocky history with Yakovlev, but Alexander Sergeevich and aircraft designer [Ilya Florov](#) studied the test results and gave them sound advice for improvements. Yaw instability was corrected by enlarging the rudder and adding two circular plates to the tail horizontal stabilizer.

Test flights in the Urals

In October, both OKB-293 and RNII were evacuated to the Urals, along with most of Moscow's war industry. Bolkhovitinov's team was stationed in Bilimbay, and Dushkin's team in Sverdlovsk, about 60 km (37 mi) away. A test stand was built on the shore of frozen lake Bilimbay, with a dynamometer cradle to hold the BI-1 during engine testing. A new test pilot, [Grigory Yakovlevich Bakhchivadzhi](#), was assigned to the team. Dushkin was increasingly absorbed by other work, including RNII's own rocket aircraft project, the [Kostikov-302](#). He assigned his engineer [Arvid V. Pallo](#) to oversee the installation and testing of the rocket engine.^[2] Nitric acid presented a constant problem, corroding parts and causing skin burns and respiratory irritation. Tanks of sodium carbonate solution were kept around to neutralize acid spills. On 20 February 1942, the engine exploded during a full system test. The nozzle section was blasted into the lake, and the engine head struck the back of the pilot's seat, knocking Bakhchivadzhi against the instrument panel and injuring him slightly. Pressurized nitric acid from a broken propellant line drenched Pallo. Fortunately, quick thinking mechanics dunked him head-first into a tank of soda solution. His face was yellow from the characteristic acid staining, but his glasses saved him from being blinded. To protect the pilot in the future, a 5.5 mm (0.22 in) steel plate was added to the back of the seat. By April 1942, BI-1 was ready for testing at nearby Koltsove airfield. A test commission was formed, with representatives from OKB-293, RNII and the [NII VVS](#). On 2 May the pilot let the aircraft lift off to 1 m (3 ft 3 in) under low thrust. On 15 May at 19:02 (UTC), Bakhchivadzhi made the first real flight of BI-1, reaching an altitude of 840 m (2,760 ft) and a maximum speed of 400 km/h (220 kn; 250 mph). The mass of the aircraft had been reduced to 1,300 kg (2,900 lb) (only 240 kg (530 lb) of nitric acid and 60 kg (130 lb) of kerosene loaded), and the engine was de-rated to 4.9 kN (1,100 lbf). The pilot shut the rocket engine off after about one minute, when a light indicated it was overheating. On landing, the aircraft descended too rapidly because of insufficient forward speed, breaking the main-landing-gear on touchdown. The pilot was unhurt and reported that, aside from the rough landing, the aircraft handled well. The flight lasted only 3 minutes and 9 seconds. In July, Dushkin recalled Pallo to help work on the "302" rocket-aircraft project, meanwhile Bolkovitinov asked Isaev to take over and master the technology of liquid fuel rocket engines. Isaev got permission to visit [Valentin Glushko](#), the leading Soviet expert on rocket engines, who was then working in [a special lab for political prisoners](#). Glushko taught Isaev the complex techniques of chamber-wall heat transfer calculation and engine design, developed by himself and [Fridrikh Tsander](#) in the early 1930s. Isaev's propellant feed system was simple, but it produced an uneven fuel pressure that diminished as compressed air was used up. Bolkovitinov and his engineers wrestled with this problem, designing pressure regulators and even a piston fuel pump driven by compressed air, but none of these improvements were realized. Too damaged by acid to fly safely, BI-1 was retired and the second prototype BI-2 was made ready. Bakhchivadzhi made the second flight on 10 Jan 1943, reaching 1,100 m (3,600 ft) but with the engine still throttled back for a maximum speed of 400 km/h (220 kn; 250 mph). The first flight had been with landing gear kept down, and some vibration was observed. For the second flight the landing gear was retracted, and no vibration was observed at the same speed. The third flight was made on 12 Jan (some sources say 10 Feb) by a temporary test pilot, Konstantin Gruzdev, while Bakhchivadzhi was consulting on Kostikov's "302" project. This time the engine was opened up to full thrust of 10.79 kN (2,430 lbf) and a speed of 675 km/h (364 kn; 419 mph) was achieved and a maximum altitude of 2,190 m (7,190 ft). During the winter, the landing gear was switched from wheels to skis. On one of Gruzdev's flights, one ski broke off during take-off, but he was able to land safely.

Bakhchivandzhi returned to make flights in the third prototype BI-3 on 11 March, 14 March and 21 March, reaching a maximum altitude of 4,000 m (13,000 ft) with a maximum rate of climb of 83 m/s (16,300 ft/min). The 21 March flight was with a full load of ammunition, however most of the BIs did not carry weapons, and although some reports claim that BI-4 was used for live ammunition tests, the guns were never fired in flight. The BI-4 model was also reportedly to be used as the template for mass production of 30 to 50 BI-VS aircraft by [Andrey Moskalev](#)'s factory, with Moskalev augmenting the twin ShVAK cannon with a load of ten thermite bombs. On 27 March, during a low-altitude test flight, BI-1, piloted by Bakhchivandzhi, entered a 45-degree dive and crashed into the ground, killing Bakhchivandzhi.^[3] The accident put a halt to flight tests, and a lengthy investigation began. Eventually, after wind tunnel testing, it was determined that BI-1 lost control due to transonic effects on the pitch controls / stabilisers. Estimates of Bakhchivandzhi's final velocity range from 800 to 900 km/h (430 to 490 kn; 500 to 560 mph), but the recording instruments were too damaged by the crash for a reliable measurement. The 27 March is considered a black day in Soviet aviation history, also being the date that [Yuri Gagarin](#) died in a [MiG-15UTI](#) crash. In 1973, Bakhchivandzhi was posthumously elevated to [Hero of the Soviet Union](#).

Return to Moscow, Isayev's engine

In May 1943, OKB-293 returned from its evacuation and set up operation in Khimki, a suburb of Moscow. On May 18, Bolkhovitinov wrote a detailed report "On Rocket Aircraft and Further Prospects". He emphasized the need to study the dangerous regime of "shock stall", and to safely transition through transonic speed and beyond. He proposed the goal of a new rocket aircraft capable of 2,000 km/h (1,100 kn; 1,200 mph). The next year, Bolkhovitinov had five more aircraft produced, BI-5 through BI-9. In the spring of 1944, BI-6 was fitted with a pair of [Igor A. Merkulov](#)'s DM-4 ramjet engines. It did not contain a rocket engine, so it was towed into the air. The pilot, Boris Kudrin, flew the BI-6 three times, but was never able to get both ramjets to start at the same time. The aircraft was taken to TsAGI for further tests in the T-101 wind tunnel. The DM-4 auxiliary motor was also tested on the [Yak-7b](#) fighter. With the loss of the D-1-A-1100 engine, Isayev began designing a new engine. The RD-1 was completed and tested in October 1944. The general form of the engine was the same as Dushkin's, but with numerous improvements. Isayev fashioned the sections from 12Kh13 stainless chromium steel (13% chromium, 0.12% carbon content). The head had 85 swirling injectors arranged in a honeycomb pattern that promoted improved fuel-oxidizer mixture. It also used a more reliable electric arc starter instead of a glow plug. Isayev also improved the regenerative cooling, increasing the flow rate around the nozzle. BI-7 was flown twice with the RD-1 engine, on January 24 and March 9, 1945. Pallo reports there was an emergency with the landing gear during the January flight. In addition to the new engine, various changes were made to the aircraft's design: a larger rudder, smaller false keel, and different wing fillets. During the test flights, the pilot Boris Kudrin, noticed some tailfin [flutter](#). On May 29, the pilot M.K. Baykalov tested the BI-7 in glider mode, without starting the engine, and the flutter was not detected. At this point, the aircraft was too corroded by nitric acid to fly again, and it was retired. To further investigate the flutter problem, BI-5 was modified in the same fashion as BI-7 (but with no engine) and tested in glider flights; however, the problem was not reproduced. After BI-6 was sent to TsAGI, BI-9 was put into service as a replacement (marked with a "6" on its tail). Flown by Boris Kudrin and M.A. Baikalov, it was used in glider tests with extra payload weight. The fate of BI-8 is unknown. As [turbojet](#) aircraft began to appear in the mid 1940s, the lack of prospects for further development of rocket aircraft in general, and BI in particular, primarily due to limited flight time became evident. However, the experience accumulated by Bolkhovitinov design bureau became invaluable, and the design bureau alumni went on to become prominent figures in soviet rocket and space technology. Two BI engineers became the founders of two design schools: Bereznyak founded OKB-155, which was the USSR's leading design bureau in development of [cruise missiles](#), and Isayev became the founder of OKB-2, which specialized in low and medium thrust [liquid-propellant rocket](#) engines for rockets and space vehicles.

Specifications

General characteristics

- **Crew:** 1
- **Length:** 6.40 m (21 ft 0 in)
- **Wingspan:** 6.48 m (21 ft 3 in)
- **Height:** 2.06 m (6 ft 9 in)
- **Wing area:** 7 m² (75 sq ft)
- **Empty weight:** 805 kg (1,775 lb)
- **Max takeoff weight:** 1,650 kg (3,638 lb)
- **Powerplant:** 1 × [Dushkin D-1A-1100](#) liquid-fuel rocket motor, 10.79 kN (2,430 lbf) thrust

Performance

- **Maximum speed:** 800 km/h (500 mph, 430 kn) estimated
- **Service ceiling:** 12,000 m (39,000 ft)

Armament

- **Guns:** two nose-mounted 20 mm ShVAK cannon, 45 rounds per gun, two rocket RS-82

