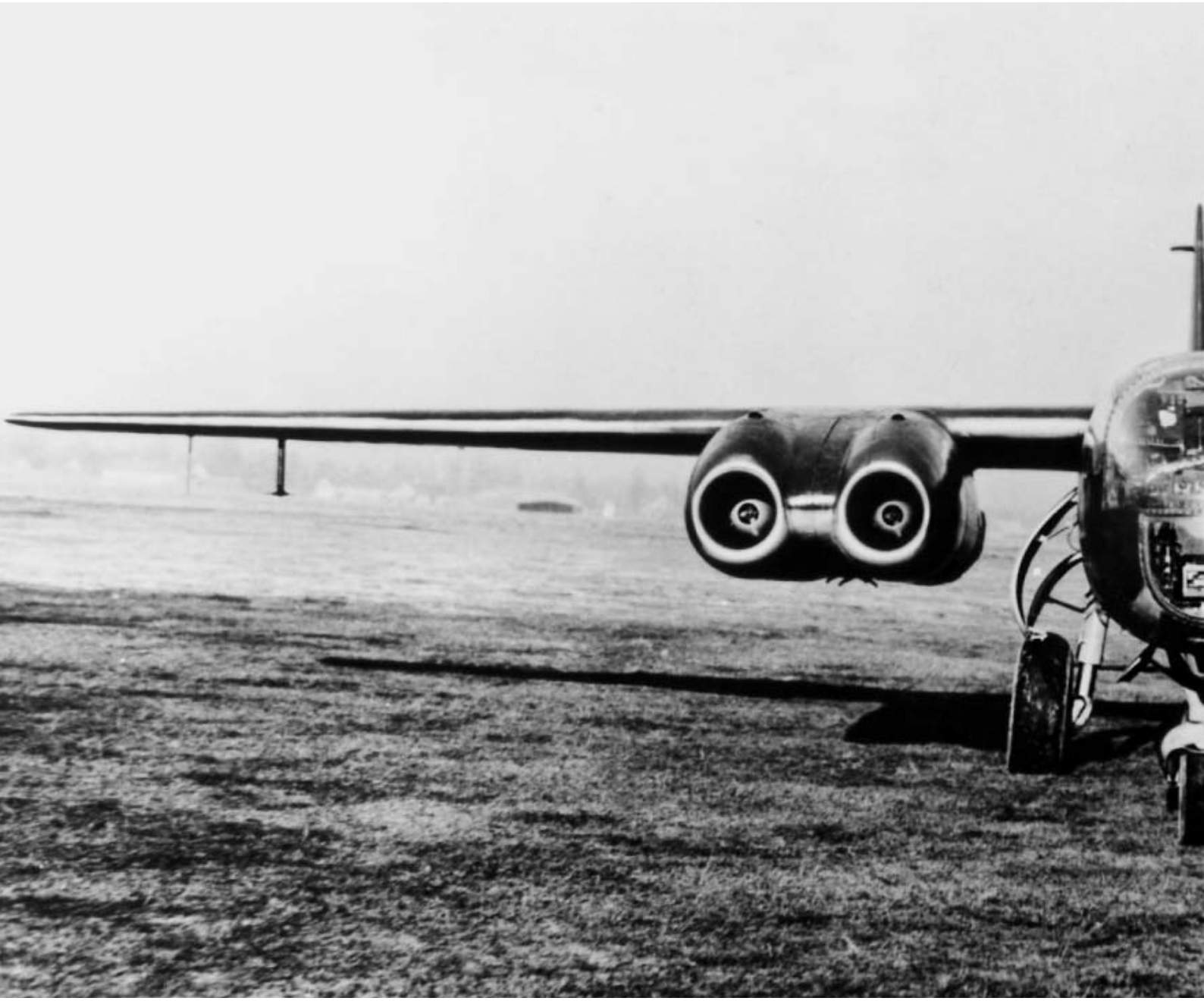
The BMW 003 jet engine

In the late 1930s the aviation industry underwent a technical revolution as German and British engineers began the race to build the first jet engines. The new technology represented a quantum leap forward for powered flight. And at the dawn of the jet age BMW was a world leader in engine development.

Christian Pierer

Continuous improvements to airframes and engines throughout the first half of the 20th century brought a steady increase in aircraft flying speed. In spring 1939 a Messerschmitt Me 209 set a new speed record for a propeller-engined plane of 755 km/h, even if the purpose-built high-performance engine supplied by Daimler-Benz – a DB 601 ReV unit delivering 2,770 hp – enjoyed a lifespan of just a few minutes. The record nevertheless marked a watershed since it demonstrated that, given the technological limitations of the day, speeds above 800 km/h were not possible using propeller or piston engines.

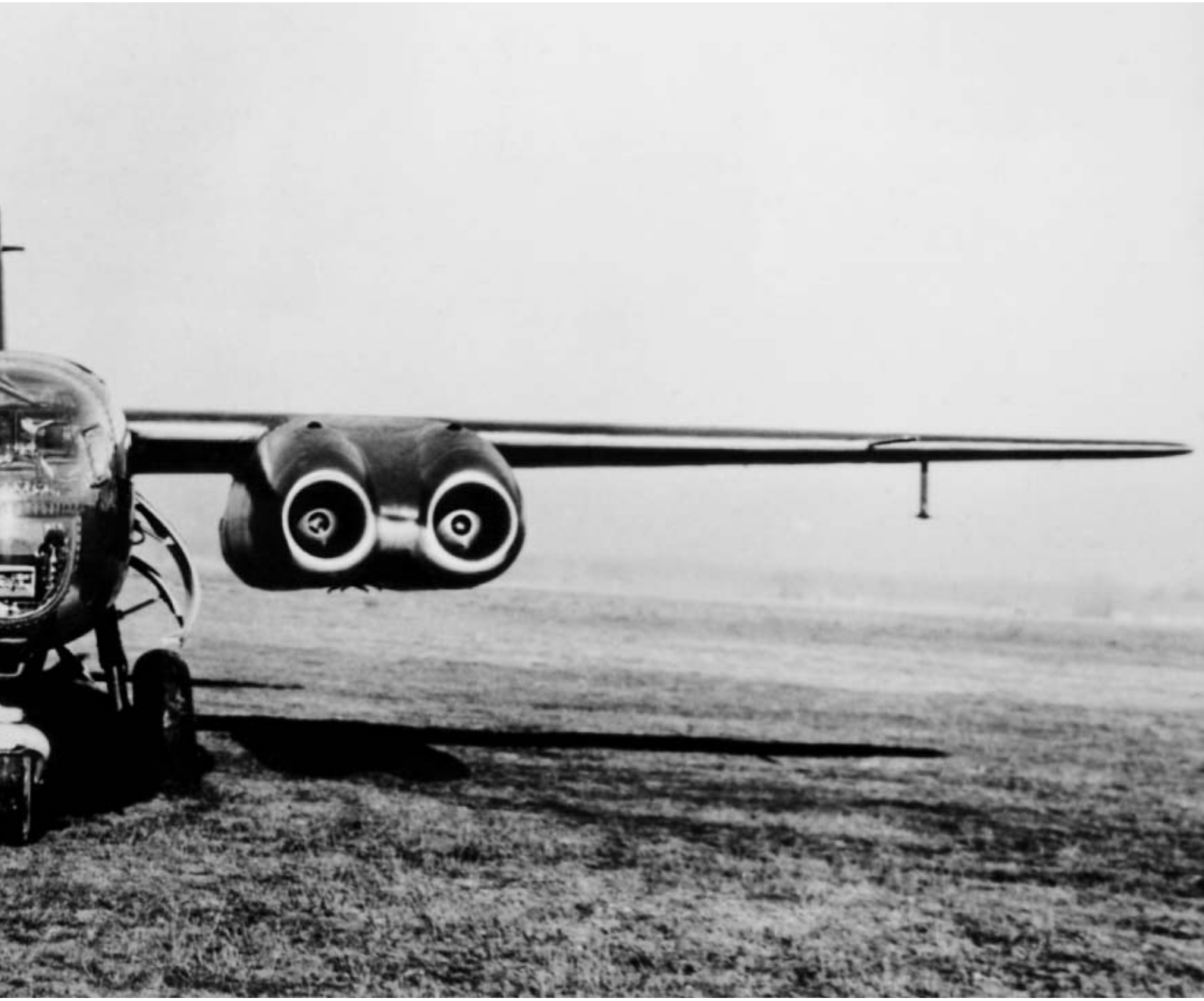


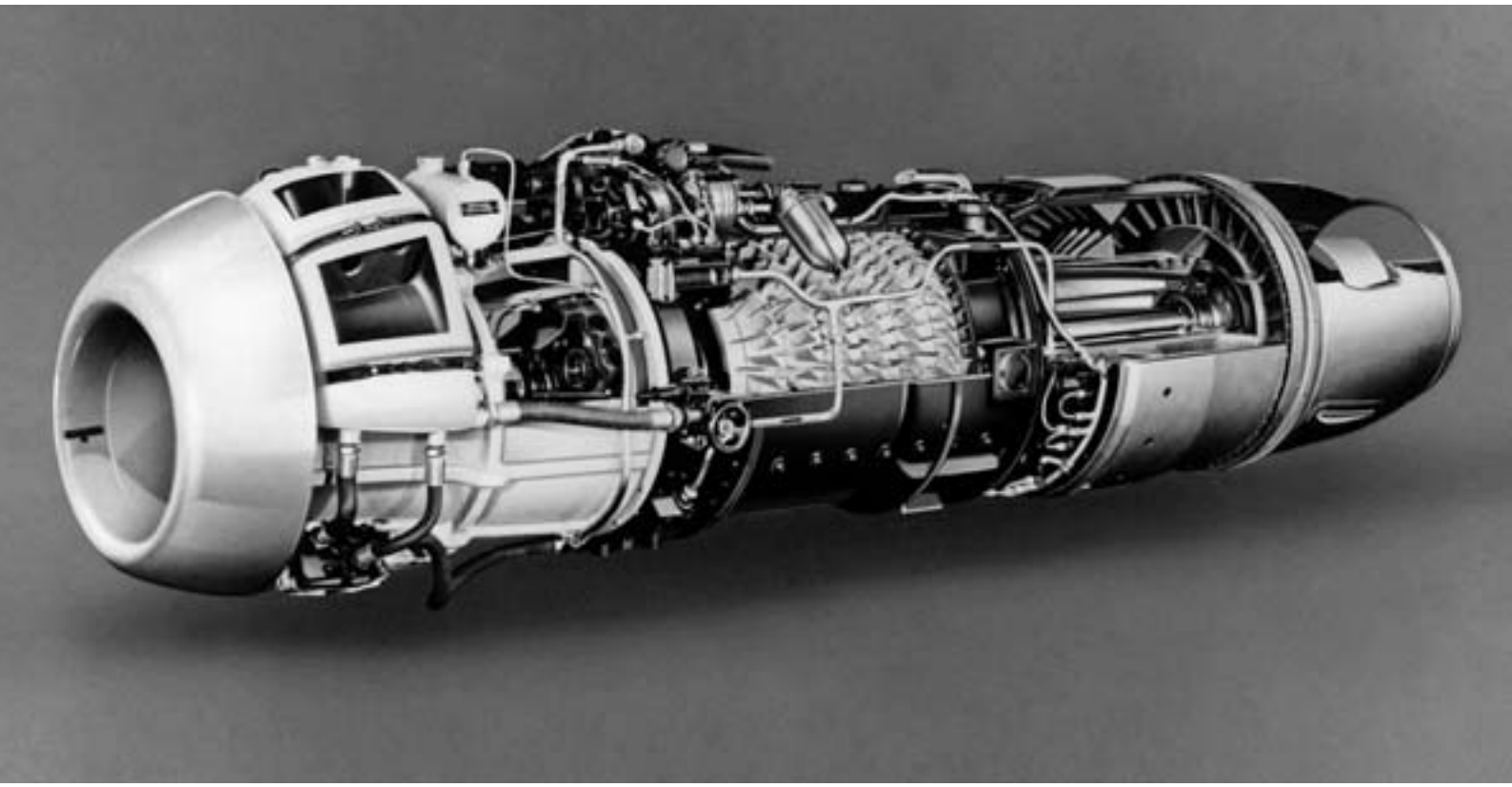
Engineers therefore increasingly turned their attention to alternative concepts of propulsion, one of which in particular was considered highly promising – the jet engine. In Germany, early development of this new technology was not carried out by one of the renowned aero engine manufacturers, but by Heinkel Flugzeugwerke AG. The company gave the task of designing the first German jet engine, the He S 3 B, to the young engineer Hans-Joachim Pabst von Ohain. This engine successfully passed its first rig test in 1938. As interest in the new propulsion concept grew, so the Reich Ministry of Aviation began awarding development contracts to the major German aero engine manufacturers from 1938 onwards. By now jet engine design had become a major focus of activity not just for Heinkel, but also for Junkers, Daimler-Benz, BMW and Brandenburgische Motorenwerke (Bramo). In the end, however, only BMW and Junkers survived, the two companies that successfully took jet engines to series production.

A key factor in the development of the first BMW jet engine was the takeover in 1939 of the company's rival, Bramo. Both BMW and Bramo had been working on their own separate engine designs since 1938. But Bramo, with its headquarters in Berlin, had made the greater progress. So after the takeover BMW decided to focus its entire engine development activities on Berlin and abandon work on the original BMW engine in favour of the P3302 project already underway at Bramo.

The P3302 project was the starting point for the company's first jet engine, the BMW 003. As the design of a jet engine was fundamentally different from that of the piston engine, the company had very limited experience to fall back on when starting development

Below I Arado 234 with four BMW 003 engines, 1944.





Above | Cutaway drawing of the BMW 003 jet engine, 1945.

of the BMW 003. Even work on the compressor demonstrated to BMW engineers the magnitude of the challenge they faced with the new technology. Although two types of design were available – the radial and the axial compressor – the Göttingen Aerodynamic Research Institute (AVA) had shown the axial design to be fundamentally superior. The advantage of the axial compressor lay above all in its smaller profile, which therefore meant lower air resistance. The AVA not only carried out computations to prove this, but also built prototypes for a six-stage compressor. BMW then took over these design plans, adding a seventh compressor stage after several test runs.

But whereas BMW could depend on the expertise of other institutions for help with designing the compressor, when it came to developing the combustion chamber it was entirely on its own. For this reason the company was forced to rely on exhaustive testing as the basis for its design. In early trials, air was delivered by the turbocharger of a Bramo 323 aero engine. But because of the high throughput velocity of the air, it was found that combustion could only be sustained by creating a swirl effect inside the chamber. A further headache was finding a satisfactory method to inject the fuel. After much experimentation it was decided to construct a ring-type combustion chamber equipped with 16 fuel jets. Ignition was achieved by means of electrodes.

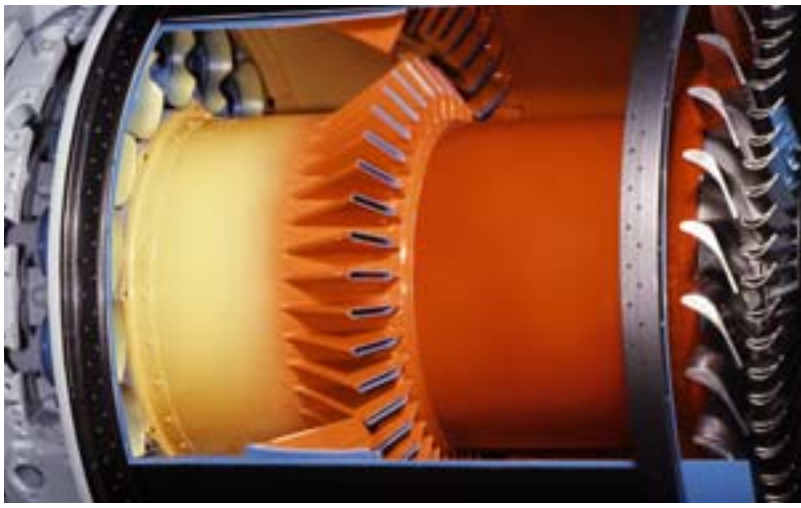
The turbine played a crucial part in the working of the engine. In the case of the BMW 003 the turbine was a single-stage design. Because of the high temperatures involved, great attention had to be paid to the heat resistance of the materials used. Design of the turbine blades also proved a special challenge. Pressed from two-millimetre sheet steel, these were hollow in design and cooled by the air circulating within them. Since welding the blades to the turbine wheel proved unworkable, BMW successfully found a method using pin connectors.

But it took much longer than had been hoped to get all components working properly and have the first BMW jet engine live up to expectations. Between 1939 and 1941 the company built no fewer than ten prototypes, sporting the designations V1 to V10. In 1941, about two years after the start of development, one of these engines was ready for the test rig. But its static thrust of 150 kp was well below the 600 kp stipulated by the Reich Ministry of Aviation in its contract, a figure the Ministry was subsequently to revise to 800 kp. By making a few adjustments the development team succeeded in extracting a little more thrust, but by 1942 the engineers were forced to concede they had designed an engine with insufficient power. A comprehensive overhaul of the design was called for. In particular, it was hoped a substantial increase in output would be achieved by boosting air throughput by 30 percent. Finally the modifications paid dividends. In 1944, rig tests succeeded in producing endurance runs of 20 and even 50 hours with the required thrust of 800 kp. These results meant that nothing now stood in the way of series production, and BMW began manufacturing the engines that same year. The BMW 003 and the Jumo 004 were the only two production jet engines made by German manufacturers prior to 1945.

Rig testing and trial flights were an essential part of the development process for the BMW 003. But since the engine was a wartime project, the engineers were under considerable pressure and enormous time constraints to succeed. This inevitably led to overhasty testing. The maiden test flight of a jet-engined Me 262 on 25 March 1942, for example, used two BMW units that were far from flight-qualified. It was a risk consciously acknowledged by all involved. But shortly after take-off the compressor blades began to break up and the aircraft suffered double engine failure. Fortunately there were no fatalities. Since the test plane had also been equipped with a piston engine, the pilot was able to land safely despite the loss of both jet engines.

BMW was in no way deterred by such setbacks. Once comprehensive improvements had been made there followed further test flights in which the engine proved itself a success. In October 1943, for example, a BMW 003 was fitted to the hull of a Ju 88, which had been converted for use as a flying test rig. Specially installed instruments and controls enabled test engineers to monitor operation of the engine. In September 1944, less than a year after this groundbreaking and successful test flight, an Arado Ar 234 equipped with BMW engines reached a cruising altitude of 13 kilometres. With that the BMW 003 had shown itself to be an engine capable of functioning at high altitude. Test flights were conducted by the Reich Ministry of Aviation, the aircraft manufacturers and by BMW itself. For this purpose the company had a number of aircraft at its disposal. To begin with BMW used an airstrip at Berlin-Schönefeld, but it later moved its test flight department to Oranienburg before finally relocating to Magdeburg. On account of the war, however, relatively few flights were undertaken. Flying hours never exceeded 20 per month.

From 1944 onwards the BMW 003 unit was also tested in the low-pressure chamber codenamed “Herbitus” at BMW’s Munich plant. The Herbitus facility could simulate altitude conditions up to 11,000 metres and flying speeds of Mach 1. The pressurised chamber of the test rig was effectively a horizontal cylinder 3.8 metres in diameter and 8 metres in length. In order to simulate conditions at various altitudes, fresh intake air was first compressed and then cooled. This made it possible to achieve different atmospheric densities and temperatures ranging from +55° Celsius to -70° Celsius. As operation of the test facility required an extremely high energy input of up to 30,000 kW, testing was restricted to the night hours. In addition to testing BMW engines, the facility also conducted tests for the company’s competitor, Junkers. Even in international terms the Herbitus facility was a pioneering achievement. Unsurprisingly, the Allies used the low-pressure test rig to inspect their own and expropriated German aero engines after the war. To begin with this testing was carried out at the BMW plant in Munich. Then in 1946 the entire test facility was dismantled and shipped to the USA.

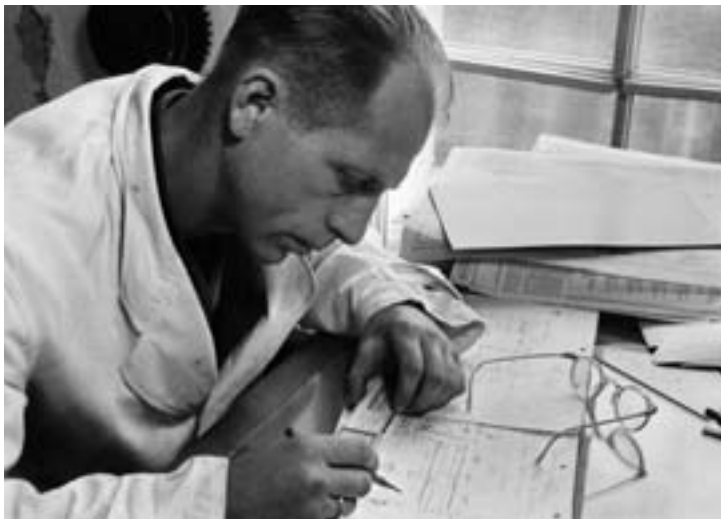


Above I View inside a BMW 003 unit. Visible from left to right: combustion chamber with air blending fins, cooling stators and turbine, 1978.

The latter years of the Second World War were dominated in particular by the battle for the skies. While the Allies attempted to engineer the fall of the Third Reich by deploying huge fleets of bomber aircraft, the Reich Ministry of Aviation increasingly focused

Below left I Construction of the Herbitus low-pressure test facility in Munich, 1943-1944.

Below right I BMW designers planning the Herbitus low-pressure test facility, 1940-1945.



on aerial defence. This explains a marked increase in production of fighter aircraft in Germany from 1943 onwards. In addition to the piston-engined Fw 190 and Bf 109, one of Germany's key fighter aircraft was the Messerschmitt Me 262. Since the Me 262 was already equipped with jet engines, Germany effectively switched to jet-powered technology right in the middle of the war. The maiden flight of the Me 262 was made with BMW engines; but Jumo 004 units were used when the aircraft went into series production.

The BMW 003 was also used in conjunction with other aircraft. For example, a series of Arado Ar 234 prototypes were equipped with BMW engines. Early designs of this aircraft featured an unusual take-off and landing procedure. A tricycle dolly was attached to the fuselage for taxiing and take-off which was jettisoned once the plane was airborne. With retractable skids used for landing, this system accounted for a considerable saving in weight. Unfortunately it proved conceptually flawed, however, and eventually conventional landing gear was fitted. For power the Ar 234 relied either on dual Jumo 004 units on a team of two or four BMW 003 engines. Originally designed for reconnaissance work, the Ar 234 was converted to bomber capability when the war situation worsened. A total of 210 units were built by the end of the war.

With German military prospects deteriorating rapidly, last-ditch efforts were made to turn fortunes around. In September 1944, for example, the Reich Ministry of Aviation invited tenders for the design of a new fighter aircraft – one built from simple and readily available materials. The production start date set by the Ministry was January 1945. Heinkel came forward with a design, the He 162, which satisfied many of the Ministry's stipulations. Power for the He 162 – the so-called Volksjäger or "People's Fighter" – was supplied by a centrally mounted BMW 003 engine. Test flights were conducted in December 1944. With raw materials in short supply, the aircraft's wings were made of wood. This led to a variety of problems. The use of inferior ersatz glue for the wings, not to mention other quality and construction problems, meant the He 162 never achieved its top speed before the war had run its course. The He 162 was the first aircraft to be equipped as standard with a BMW 003 engine. But with the collapse of the Third Reich imminent, the Volksjäger arrived too late to make a major impact on the German war effort.

BMW jet engine technology was not used in Germany alone. In 1944 the company entered into negotiations with an envoy representing the Japanese navy. On conclusion of the talks, the two partners signed a licence agreement which provided for the handover of the BMW 003 drawings and design documentation and their transfer to Japan in a U-boat. The Japanese engineers used the BMW plans to develop their own Ne-20 engine, a unit first tested in an aircraft in August 1945.

Left I An Arado 234 taking off, with two Jumo 004 engines, 1944.

Below I A Heinkel He 162 with BMW 003 engine, 1944.

With the intensity of Allied air attacks growing, the National Socialist regime was forced to relocate many of the industries vital to the war effort. One such case was the BMW engine development department, which was moved from the exposed Berlin plant to a salt mine near Staßfurt south of Magdeburg. In April 1945, when the American troops took control of Staßfurt, the US Army transported all complete engines and design documentation to BMW's Munich parent company. The company's top engineers were also forced to leave Staßfurt for Munich. When the war was over, the Americans withdrew from Staßfurt and handed control of the BMW premises to the Soviet troops, who enlisted all remaining engineers to continue developing the BMW 003, 018 and 028 engines for the Russian armed forces. Work on the BMW 018 proved particularly difficult because the Americans had taken all drawings and calculations with them. The engine parts therefore had to be redesigned from scratch. But once preliminary successes had been achieved, the Russians were sufficiently satisfied with progress to move the entire development facility and specialist workforce back to the Soviet Union on 22 October 1946. The German engineers were not allowed to return home until some years later, their expertise having been key to helping the Soviet Union develop its own aviation industry. The MIG-9, for example, was the first jet aircraft to leave this famous aircraft factory equipped with engines derived from the BMW 003.

German specialists were not just working for the Soviet Union, however. The western Allies also secured their cooperation. The Americans had all leading BMW designers brought to corporate headquarters in Munich for extensive interrogation. Hermann Oestrich, the man in charge of BMW jet engine development, was given the opportunity to continue his work in the USA. He accepted instead an offer from the French air ministry. In 1945 France recruited about 120 engineers with the aim of designing a new jet engine. Oestrich was appointed head of this group. His employees had previously worked for top German engine manufacturers such as BMW, Junkers and Heinkel. In 1948 the development team was ready to put the ATAR 101 engine through its paces for the first time on the test rig. Although it was a completely new development, certain elements of the BMW 003 featured in its basic design. In this respect BMW engineers also played a significant role in the development of the first French jet aircraft.

After 1945 BMW engine technology spread rapidly around the world. One key reason for this was that BMW engineers placed their expertise at the disposal of American, French and Soviet contractors. But former BMW employees also made an important contribution to the development of independent aviation industries in the two post-war German states.