THE BMW CENTURY

2ND EDITION

TONY LEWIN

FOREWORD BY TOM PURVES


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BAYERISCHE MOTOREN WERKE
MÜNCHEN

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Cover: BMW's M2 does much to capture the spirit of the original E30 M3.
Back cover: The 2002 was the original BMW sport coupe.
Front endpaper: The svelte 507 is one of BMW's most beautiful designs.
Back endpaper: The original M3 faces off with BMW's latest M car.
Front case: BMW 2002 Turbo.
Back case: 2020 BMW M4.

On the title page: BMW's Berlin dealership in 1929. Clearly visible are the just-launched 3/15 sedan and the R62 motorcycle, complete with Steib sidecar.

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Courtesy Royal Automobile Club

Foreword

By Tom Purves, former Chairman of the Royal Automobile Club, Pall Mall, London

For twenty-five years I worked for BMW, first as sales director and then as managing director of BMW (GB) Ltd. in the 1980s and 1990s. Following this I was sales director of the Rover Group during the period of BMW ownership. I then spent nearly ten years as president of BMW North America and chairman of BMW US Holding Corporation before completing my professional career within the group as chief executive of Rolls-Royce Motor Cars Ltd. at Goodwood. As I had started my life in the automobile industry, forty-three years earlier, as a student engineering apprentice at Rolls-Royce's car division at Crewe, it was a fitting and fulfilling conclusion.

BMW is a company run by engineers. As an engineer turned sales and marketing man, I revelled in never having to justify poor design, poor development, or poor manufacturing: whilst I was always aware of the relatively low esteem in which sales people were once held at BMW, I considered that a price worth paying for an exemplary product to sell.

At its happiest as an engine maker—think of the power of the early radial aero engines, the torque of the boxer motorcycle engine, or the silky smoothness of the six-cylinder petrol engines that did so much to characterise the sports sedans of the post–Second World War era—BMW was innovative in all areas. The light weight of the 328 sports car in the 1930s, the early use of digital engine management systems in the 1970s, and the clever front fork design and pioneering ABS for the motorcycles of the 1980s—all these are examples of BMW's flair for innovation.

However, when Tony Lewin asked me to write the foreword to his book, I reflected on the single most important element which has given the company its enormous success in modern times. I worked under the group chairmanship of Eberhard von Kuenheim, Bernd Pischetsrieder, Joachim Milberg, Helmut Panke, and Norbert Reithofer. The single focus each one gave to the long-term success of the company and their clear insistence that no one, least of all the top man, was more important than the company, contributed more than anything else to the achievements of the organisation. The atmosphere in management ranks was never complacent: it was always demanding, and, like the engines powering the products, it was certainly highly efficient. These strong leaders, who never forgot they were directing a car company, all held the belief that if you built the best products, people would buy them. And this is how BMW has achieved its remarkable success.


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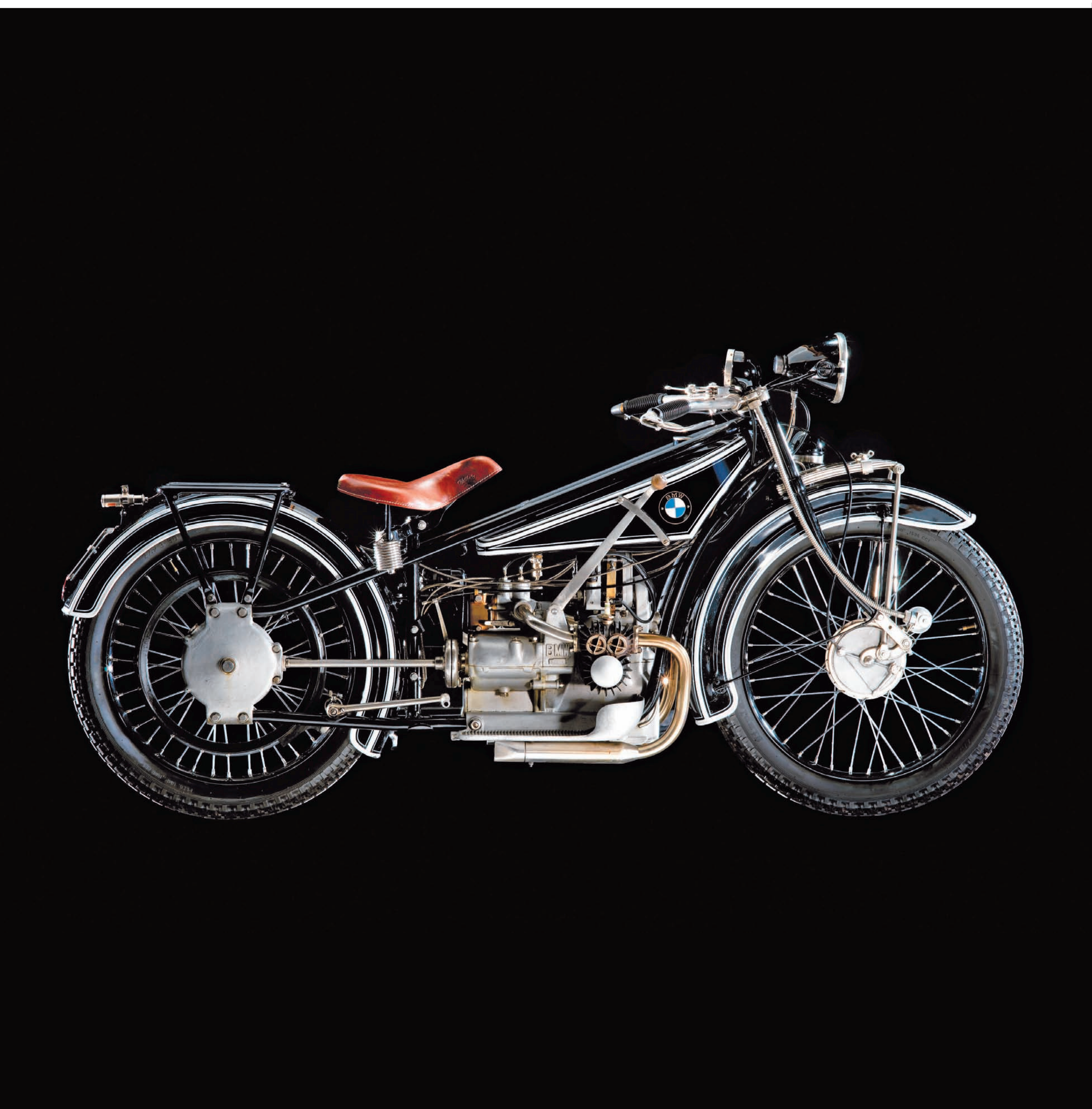


CHAPTER

1

High Flier from the Start

BMW has always liked to do things differently—and this held true even before its constituent parts took on the BMW name or began using the blue-and-white roundel badge.

Most of the successful carmakers of the early twentieth century could point—often with great pride—to origins that exactly paralleled the growing desire for greater mobility among their customers. Typically, these resourceful operators emerged in the late 1800s, first making bicycles, then moving on to crude motor-assisted cycles, and then producing motorcycles, multiwheeled cyclecars, lightweight cars, and finally proper cars with decent engines, steering, and brakes. Others, such as BSA, Škoda, and Hotchkiss, had a different trajectory, beginning as weapons manufacturers and subsequently moving into motorcycle and car production.

But with BMW it was a different story, and one that almost immediately plunged the fledgling company into an area of operation where extreme performance and technical sophistication were not just luxuries but essential for survival. For BMW, initiation took place in the heat of aerial combat on the western front in the Great War.

The need for a successful aero engine to combine extraordinary maximum power with minimum weight and faultless reliability when pushed to extremes prompted BMW's founding designers to seek sophisticated engineering solutions, exotic materials, and novel manufacturing techniques. This approach was innovatory in placing quality and performance above cost and transitory convenience. And it was this approach of complete engineering integrity that would be the key to BMW's ascending reputation as the century unfolded, and that would underpin landmark designs such as the R32 motorcycle, the prewar six-cylinder 328 sports car, and even the Neue Klasse sedans of 1961—not to mention the host of immaculately engineered products that by 2005 had powered BMW to its present standing as the global leader in the market for premium vehicles.

The Engine Builder, the Plane Maker, and the Deal Maker

The three separate elements that, in 1917, combined to form Bayerische Motoren-Werke, or BMW, could trace their origins to well before World War I. Karl Friedrich Rapp, an entrepreneurial engineer, set up shop as an aero engine builder in Munich, next to aircraft maker Gustav Otto, son of the man who gave his name to the four-stroke engine. Rapp began supplying Otto with four-cylinder water-cooled engines of his own design, for both aircraft and marine use, but before long came an urgent request to manufacture V-12 aero engines designed by Ferdinand Porsche at Austro-Daimler under a lucrative wartime subcontract. On March 7, 1916—the date regarded as the official beginning of the enterprise that became BMW—Otto's company was reconstituted as Bayerische Flugzeugwerke AG, while the following year Rapp Motorenwerke became known as

Where it all began: Gustav Otto's aircraft works at Oberwiesenfeld airfield in Munich. BMW's modern headquarters is still on the same site.

Bayerische Motoren-Werke GmbH; the two were combined in 1922 to form BMW AG.

Two men brokered the aero engine deal: Franz Josef Popp, a talented engineer who, even at the age of thirty-two, was already very well connected in Viennese military and financial circles; and Camillo Castiglioni, a colorful Vienna-based financier. Popp was to play an important part in BMW's development until he was forced out by the Nazi Ministry of Aviation in 1942 in a disagreement over aero engine production quotas. Castiglioni's wheeler-dealings saw him successfully finance BMW's early expansion—as well as help strike the key deal to build the Austin 7 car—before his exit in 1929.

With Rapp's early aero engines having been less than successful, he was persuaded by Popp to hire Max Friz, with whom Rapp had worked at Daimler in Stuttgart. Friz, too, was a clear engineering talent, having worked on both Grand Prix cars and aero engines. His first engine for BMW was to be a spectacular success and was the first product to wear the blue-and-white roundel badge.

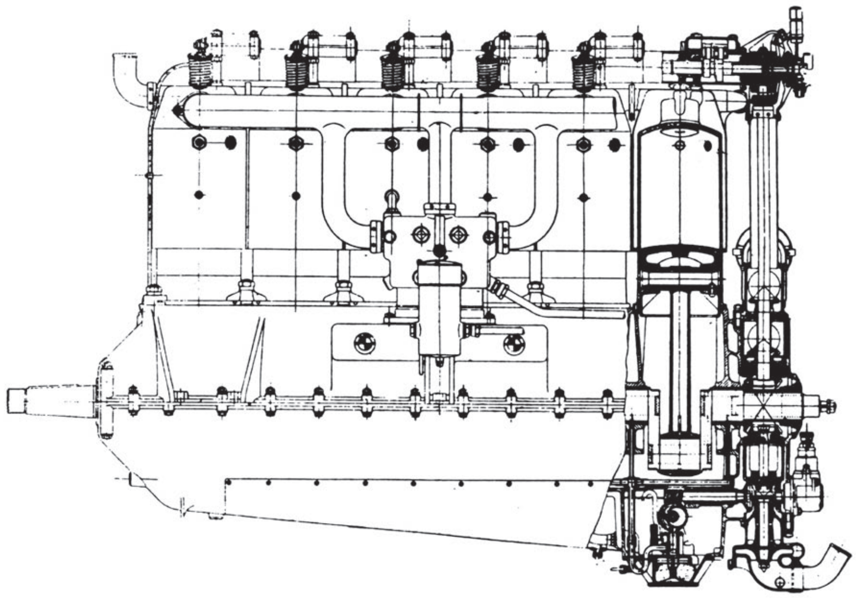
The six-cylinder Type IIIa, which Friz had already begun to design while at Daimler, was best known as the engine that powered the Fokker D.VII fighter, making it one of the very best combat aircraft of the Great War. Most notably, the IIIa performed well at altitude thanks to its special carburetor, giving

Three key men: aspiring engineer Karl Friedrich Rapp (left); master manager Franz Josef Popp (center), who would steer BMW until 1942; and engine genius Max Friz (right), creator of high-altitude aero engines and the famous boxer motorcycle.

a first hint of its later potential as a peacetime record breaker in a succession of ever more advanced derivatives.

The IIIa already displayed the eagerness to embrace advanced design and new materials that would characterize BMW's product design into the twenty-first century. The only problem was finding the materials and the space to build the engines: the contract to build the Austro-Daimler V-12 was occupying all the facilities on the Oberwiesenfeld airfield site where BMW still has its headquarters today, and a new assembly hall would not be ready for several months. Thus the air ministry, convinced by the six-cylinder engine's performance, made the decision to allocate V-12 production to Opel in order to enable BMW to produce the IIIa.

Following the armistice in 1918, however, BMW was forced to completely restructure its business away from anything connected with the military; the production of aero engines was expressly forbidden. Thus, following the departures of both Rapp and Otto, the firm began contract production of railway brakes and rejigged the IIIa as a four-cylinder engine



The straight-six BMW IIIa and IV engines were developed by Max Friz for high-altitude performance, enabling pilot Franz Zeno Diemer to reach a record 9,760m in 1919.

BMW made frequent use of altitude record breaking in its advertising.

for industrial and agricultural applications. Yet all along, on the quiet, Friz had been working on the IIIa and its Type IV derivative to boost their high-altitude performance still further. He reasoned that while the war reparations forbade the *manufacture* of aero engines, the rules said nothing about developing or improving those existing engines.

Friz's long sessions in the workshop proved to be time well spent, for in June 1919 test pilot Franz Zeno Diemer began his series of altitude-record breaking flights using BMW power (see Chapter 2). Yet while these well publicized achievements did much to enhance BMW's standing in the German aircraft industry, and indeed with the general public, the uncomfortable reality remained that with the cancellation of all military contracts there was huge excess manufacturing capacity across Germany and Europe. Postwar inflation was threatening to turn into hyperinflation, and BMW was relying on tenuous, small manufacturing subcontracts and the future resumption of aero engine production to take it forward. That, at least, was the outward position, but Popp—who by now was in full charge as general director—already had a longer-term plan that aimed to give BMW three main lines of business for genuine stability. His recipe was to continue the production of the profitable industrial engine pending the resumption of aero engine manufacture, and to supplement this business with the development of a motorcycle, which would in turn lead to a move into the car market. The company had already taken a small step in the motorcycle direction when Friz designed a much smaller portable industrial engine. For simplicity, balance, and cooling, Friz chose the layout of an air-cooled flat twin of 500cc—and this was the genesis of the famous "boxer" configuration that would bring BMW motorcycles racetrack glory, commercial success, and an unmatched global identity extending well into the following century.

Yet in 1919, with the flat twin engine predating any motorcycle construction under the BMW name, it fell to other firms to be the first to use Friz's motor in a two-wheeled application. First Victoria motorcycles, then Helios—which was connected with Bayerische Flugzeugwerke before it merged into BMW AG in 1922—installed the flat twin. Friz, however, knew instinctively that the Helios's layout, with the flat twin stretched lengthways in the frame, was wrong: the rear cylinder would be starved of cooling air and would run too hot. His

quick solution was to improve the substandard cycle parts of the Helios machine, sell the existing stock, and move on to design a proper BMW bike that reflected his long-held vision of advanced motorcycle design.

It is difficult from today's perspective to imagine the magnitude of the impact the BMW R32 must have had on the crowds who thronged to see it displayed at the 1923 Paris show. As a bold step into the future, an abrupt break with old-fashioned habits that owed more to nineteenth-century bicycle craft than modern engineering, it must have been as much of an eye-opening sensation as the Citroën DS was in 1955, the Austin Mini in 1959, or, for that matter, BMW's own thrillingly futuristic i8 plug-in hybrid sports car in 2013. With the R32 the motorcycle had suddenly come of age, maturing into a coherent and fully integrated modern product with a design language all its own. Overnight, most other machines, composed as they were from a hodgepodge of proprietary components bought in from traditional suppliers, looked accidental and improvised. It was a tantalizing glimpse of a new era.

Max Friz's breakthrough was to mount the flat twin's cylinders across the frame—as is now familiar from countless generations of BMW R-series motorcycles—and to package the engine, the gearbox, and all the most important ancillaries within a smooth and attractive unit-construction aluminum casting. Most importantly of all, with the engine's crankshaft now inline with the machine's axis, it became natural to drive the rear wheel with a simple shaft, at a stroke doing away with the oily and troublesome mess of an exposed chain or belt to the wheel.

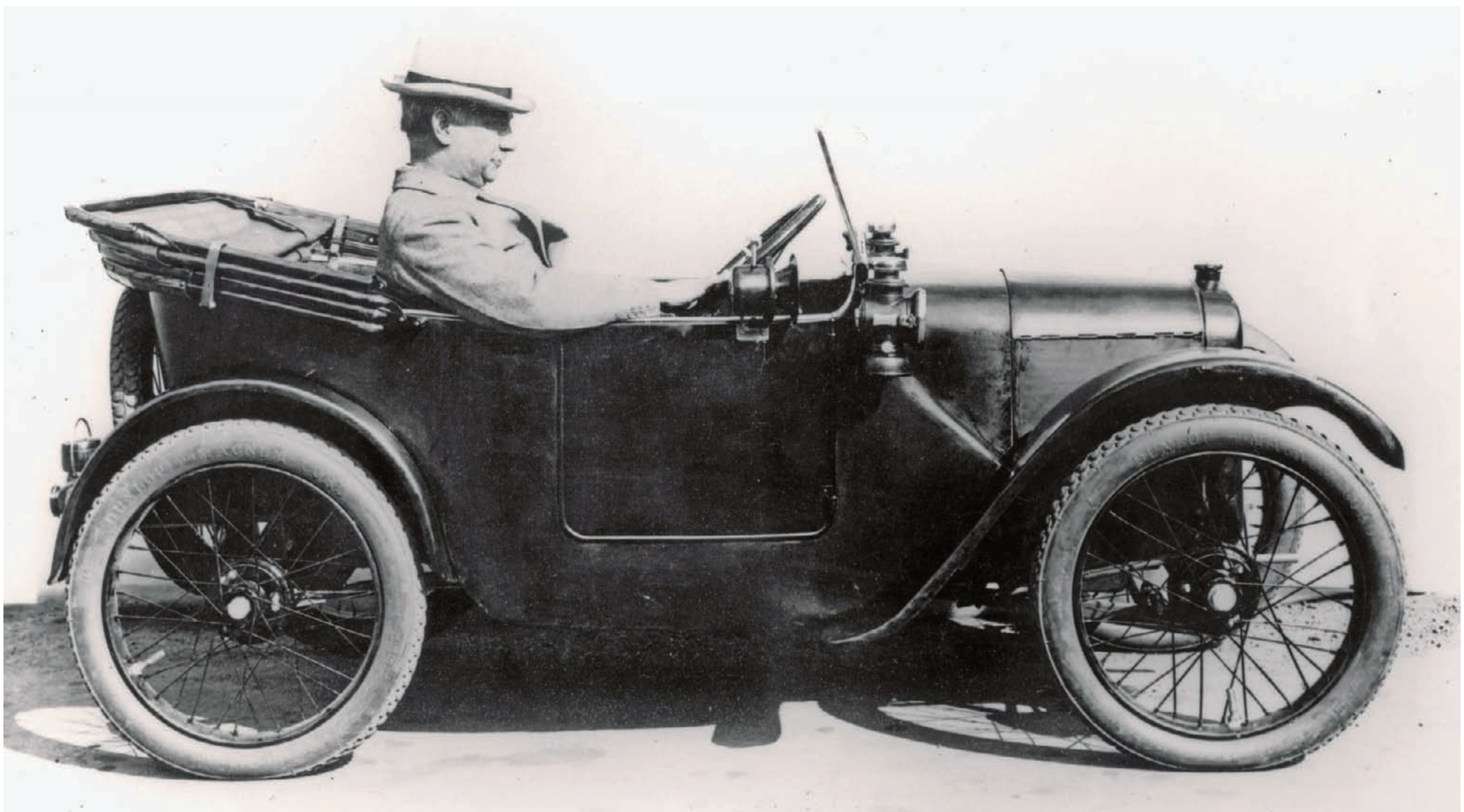
Friz's elegant engine module was housed in a chassis of equal stylishness. Forming a smooth triangle around the engine and with its apex at the rear wheel, the smart black double-cradle frame wore its white pinstriping and its high-mounted BMW badge with pride. The design scored on many fronts—the R32 was neat to look at, its mechanical layout allowed a low center of gravity and a low seat height for smaller riders, and it made for better reliability. And with enclosed valve gear and wet-sump rather than total-loss lubrication, it was much easier to maintain and keep clean.

Though priced at a premium compared to most other machines in the 500cc class, the R32 was an immediate success, capturing the popular imagination. BMW was quick to follow up with a steady stream of improvements and fresh derivatives, including sportier models with overhead-valve versions of the boxer engine. There was even a single-cylinder version—still retaining the classy shaft drive—and before long BMW bikes were winning Grands Prix and, in the hands of works rider and development engineer Ernst Henne, vying for the title of fastest motorcycle on earth. Most crucially, however, BMW production bikes achieved their considerable variety in the marketplace by the astute use of different engine variations. The core engine, though steadily improved, remained common, and the same tubular frame was shared by all models. But—again as a foreshadowing of what would characterize BMW's later bikes and cars—the BMW look remained the same and its appeal was, if anything, enhanced.

In parallel with their highly bankable work with motorcycles, Friz and his design colleagues had found time to map out a fresh generation of aero engines (see Chapter 2) in time for the resumption of production in 1925. They had also turned their thoughts to the eventual long-term goal of moving into the car business.

The company had for some while been testing prototypes of an advanced small car designed and built by the noted aerodynamicist Wunibald Kamm. The board, however, seemed incapable of making any decision, and in July 1928 the idea was shelved. It was suggested by some,

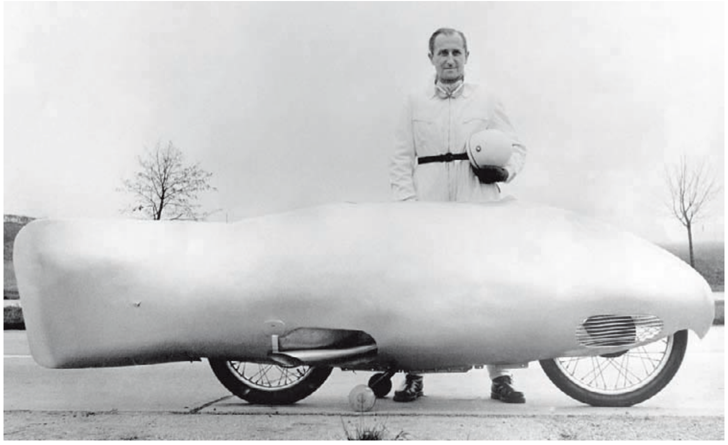
Sir Herbert Austin in the tiny Austin 7, which would form the basis of the Dixi, BMW's first car.



perhaps maliciously, that the decision was influenced by board members who also sat on the board of Daimler-Benz. The suspicion was that the famous names of Daimler and Benz, who had merged in 1926, privately feared the likely impact on their business of a BMW passenger car.

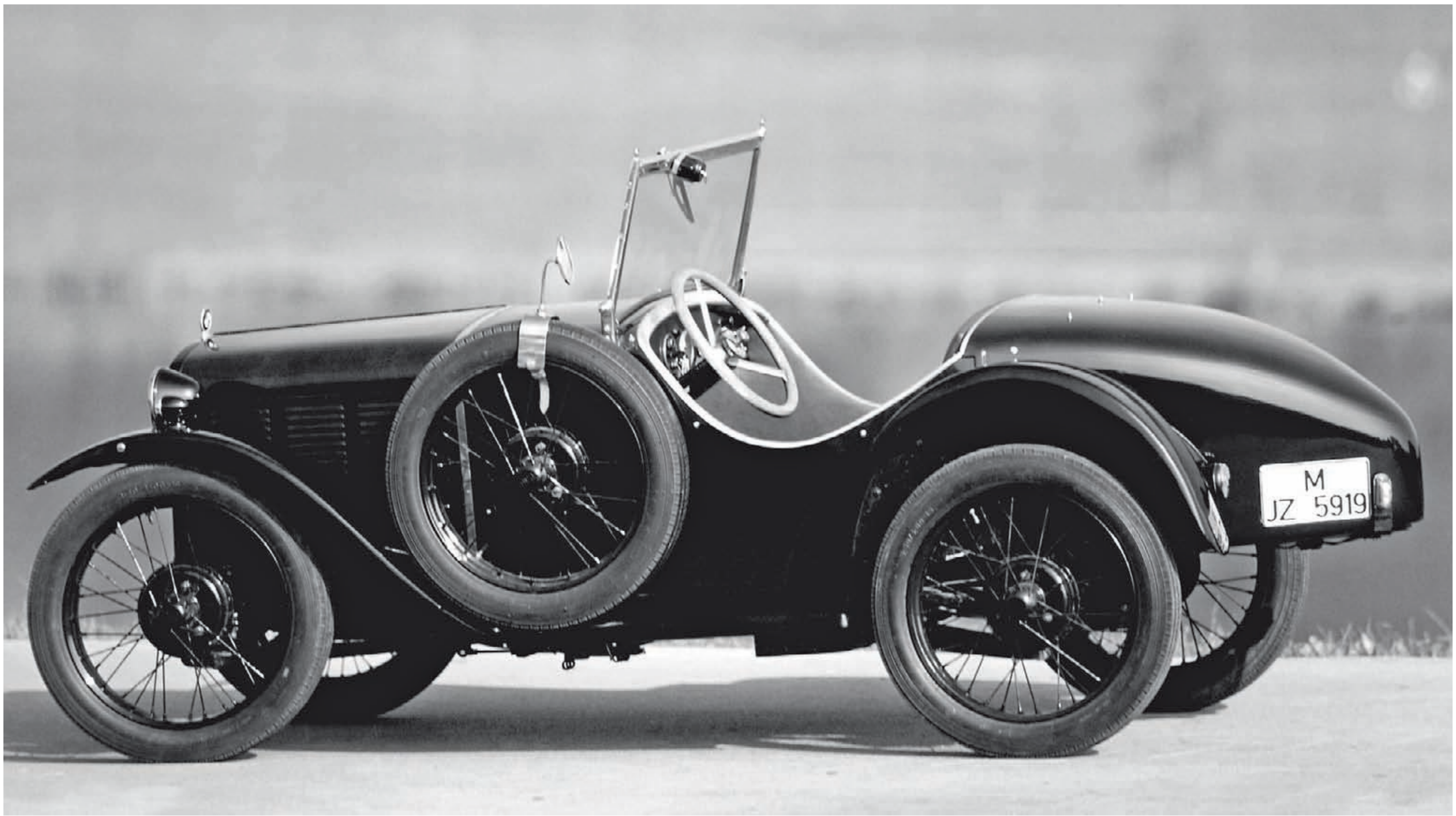
The eventual decision was that BMW should indeed build a car, but not one that would compete with Daimler-Benz. Instead, it would be small and of good quality, and preference was to be given to taking over the production of an existing model.

Thus, in October 1928, BMW took over Dixi-Werke, based in Eisenach, some 400km north of Munich. Had BMW known that the Wall Street crash and the subsequent Great Depression were just twelve months away, the directors might have thought differently, but Dixi offered just what Popp and his fellow strategists wanted. Dixi had secured a licensing agreement with Austin of England to build the tiny Seven four-seater, and the lightweight model, renamed Dixi DA1 in its German incarnation, had been selling well since its launch in December of the previous year.



BMW works rider and development engineer Ernst Henne with one of his speed-record machines in the 1920s.

The 1930 BMW 3/15 DA3, improved significantly from its Austin origins.

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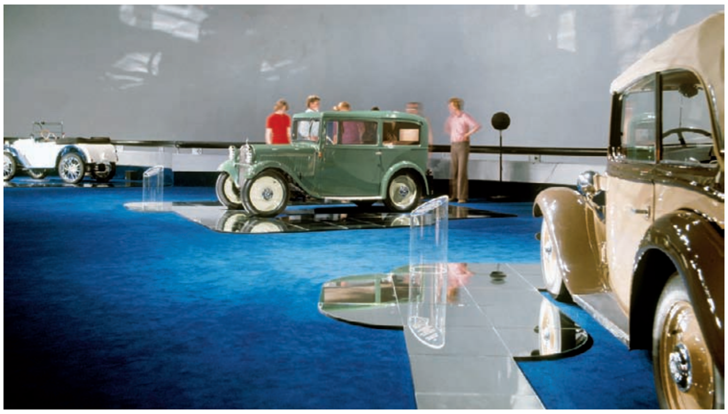


^ **The 3/20 replaced the 3/15 in 1932 and featured an overhead-valve engine and much-revised chassis.**

‹ **An early Dixi, showing how narrow the Austin-based design was—even for its era.**

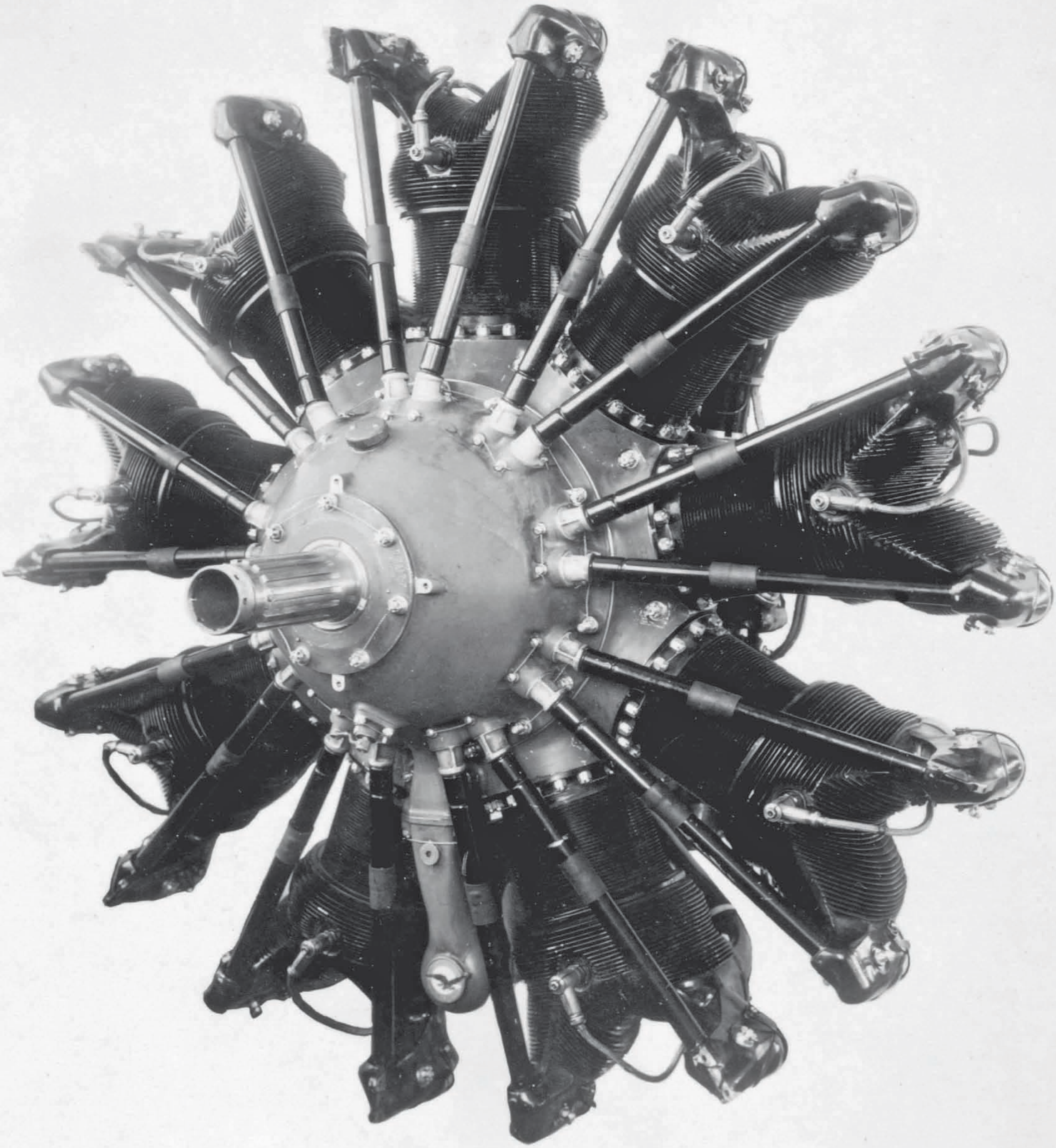
˅ **The 3/20 was notably smarter and better built than the lightweight Austin 7 and Dixi models.**

It was the perfect move for BMW, allowing it to apply its undoubted management and engineering expertise to a product that, though innovative and appealing in concept, was rough at the edges and built down to a very low price. By early 1929 BMW had made improvements to the DA1's body, its windows, and, crucially, its braking system. By the summer of that same year, the model was wearing BMW badges and had become much more substantial in its appearance and construction.

Friz, however, was becoming frustrated with the clear limitations imposed by the very basic Austin hardware. In the course of his work on the DA1, he had managed to add independent front suspension and an overhead-valve update of the still tiny engine. At the same time it was redesignated 3/15 to signal the important engineering updates. But even with the Depression beginning to take hold, there was a sense within BMW that it might achieve better results with a more modern car of its own design. In 1931 Friz proposed and tested a front-wheel-drive design using a twin-cylinder two-stroke engine, but its performance was judged disappointing, and he resigned to take up a position at Daimler-Benz. Popp urged his new team to come up with a fresh and entirely Austin-free design, and by mid-1932 the AM-1 (the initials standing for Automobile München) was ready. Known commercially as the 3/20, it had a new backbone chassis, independent suspension all round, and an all-steel body initially manufactured by Daimler-Benz. The 3/20 was larger than the Austin-derived 3/15 that had kept BMW sales going, but though its space and refinement gained praise, contemporary commentators were less sure about its steering and handling—something that would later be addressed and that would become a powerful part of BMW brand identity.

Even though the 3/20 was a qualified success in those difficult times, the engineering team under Alfred Böning continued to evolve the design, giving the gearbox a fourth speed. More prophetically, however, Böning had been encouraged by the sporting successes of the 3/15 and was struggling to improve the performance of the still Austin-based engine. Rudolf Schleicher, who had become head of engine testing in 1931 after a spell at luxury carmaker Horch, suggested that rather than develop an all-new four-cylinder unit, BMW should simply add two more cylinders to take the existing engine to 1.2 liters and 30 hp. It was thus that, at the Berlin Motor Show in February 1933, the six-cylinder BMW 303 made its public debut.

Though still an upright-looking sedan with a sober air, the long-hooded 303 was BMW's largest car so far, as well as the first to house a straight six-cylinder engine and sport the double-kidney grille topped with the BMW roundel. And with the arrival of these vital ingredients, the stage was set for the BMW story to really begin.



CHAPTER

2

The Power to Fly

BMW IIIa, 1917: BMW Prepares for Takeoff

BMW's first aero engine (pictured page 11) was remarkable not only because it was arguably the highest-performing aircraft engine of the First World War but also because it gave rise to the founding of the BMW company itself.

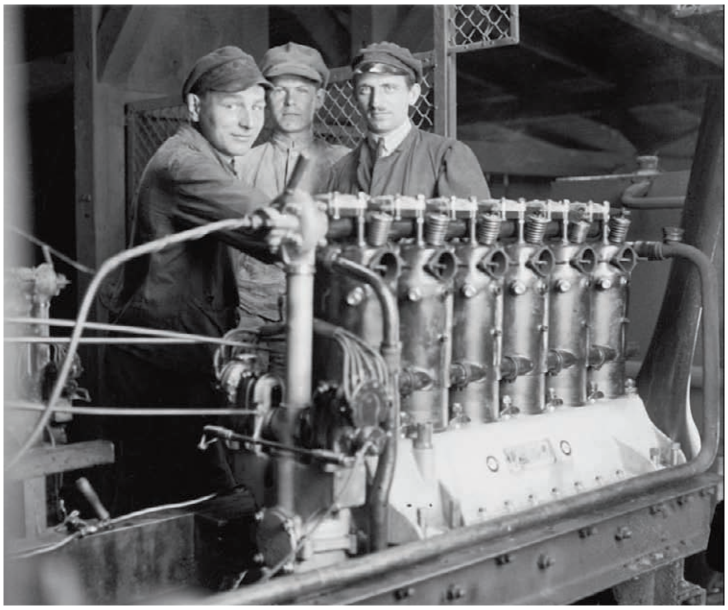
In 1913 Rapp Motorenwerke was established in Munich by chief designer Karl Friedrich Rapp; however, his engines proved unremarkable, and in 1917 designer Max Friz was brought in to draw up a new engine. Friz's design used the same six-cylinder inline configuration as the Rapp III, but the result proved infinitely superior. Rapp left the company, which was subsequently renamed Bayerische Motoren-Werke GmbH; the Friz design was designated BMW IIIa, and volume production started early in 1918.

The smooth-running, 201-hp, 19.1-liter, water-cooled inline six-cylinder engine was light, with an aluminum crankcase and pistons. One-piece cylinder heads and cylinders did away with the need for head gaskets—the valves were opened by a single overhead camshaft driven from the crankshaft by a vertical shaft.

The breakthrough IIIa was a high-altitude design successfully running a relatively high compression ratio of 6.4 to 1 and fueled by a "high-altitude carburetor." This comprised three mixing chambers, three air and fuel jets, and five throttle butterflies. Two levers in the cockpit allowed the pilot to set the engine for low and high altitude. High altitudes were crucial to gaining an advantage in air combat, and when the IIIa was fitted to a Fokker D V.II, it could outclimb all the Allied opposition.

BMW IV, 1917: BMW Flies High and Ramps Up the Volume

The BMW IIIa was easily the best and highest-performing aero engine of World War I, but, luckily for the Allies, it arrived too late. In September 1919 BMW's second aero engine set a world record for a passenger aircraft when Franz Zeno Diemer flew eight people to an altitude of 6,750m in a Ju F.13 monoplane powered by this engine.

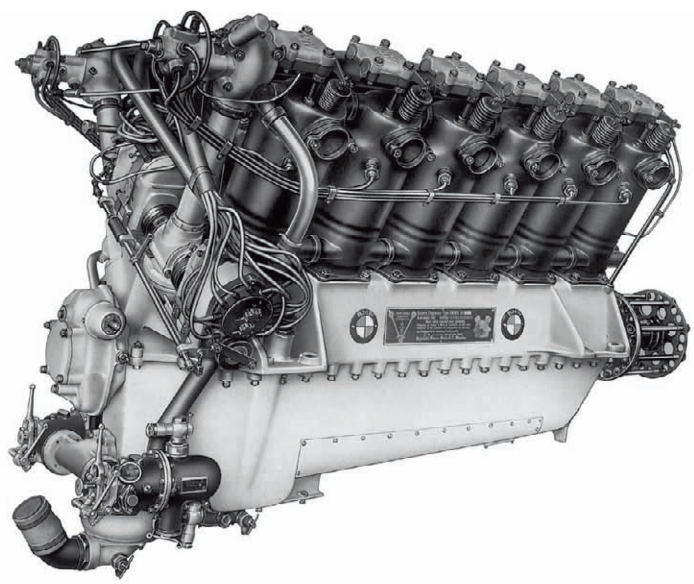


Prior to that, in June 1919, Diemer broke an "absolute" altitude record by flying a DFW F37/III single-seater biplane to an altitude of 9,760m. The aircraft was not powered by a BMW IIIa but by an evolution of it, the BMW IV (pictured previous page). Both engines were water cooled, but the IV had been further optimized compared to its predecessor to produce 241 hp. It took Diemer eighty-seven minutes to climb to the record altitude, a mean rate of climb of 113m per minute. By contrast today's Eurofighter Typhoon, co-developed by European nations including Great Britain, Germany, and France, has a rate of climb of 19,077m per minute.

BMW VI, 1926: First V-12 Is a Round-the-World Success

The end of hostilities in 1918 meant that BMW was prevented from producing aero engines until 1922, and it was 1923 before production resumed on the IIIa and IV. However, the world of aviation was moving apace, and demand quickly grew for higher performance power units. Thus in 1924 Max Friz was instructed to start work on a 46.9-liter, 60-degree V-12 monster producing 644 hp. This would be BMW's first ever V-12 engine, and it was called BMW VI (below). Another advanced, high-performance design, the V-12 used the six-cylinder as a basis, a technique that today would be called a "modular and scalable" approach.

Series production began in 1926, and the engine quickly set a new benchmark. At the start of the 1932, it was used to power the Schienenzeppelin (rail Zeppelin), an experimental railcar that resembled a Zeppelin airship. On June 21, 1931, the Schienenzeppelin set a world record for a fuel-powered rail vehicle of 230.2km/h. More significantly, it powered a Dornier Wal flown by Wolfgang von Gronau on a transatlantic flight from Sylt in Germany to New York via Iceland, Greenland, and Labrador. The flight established the northern air route over the Atlantic in forty-seven hours.

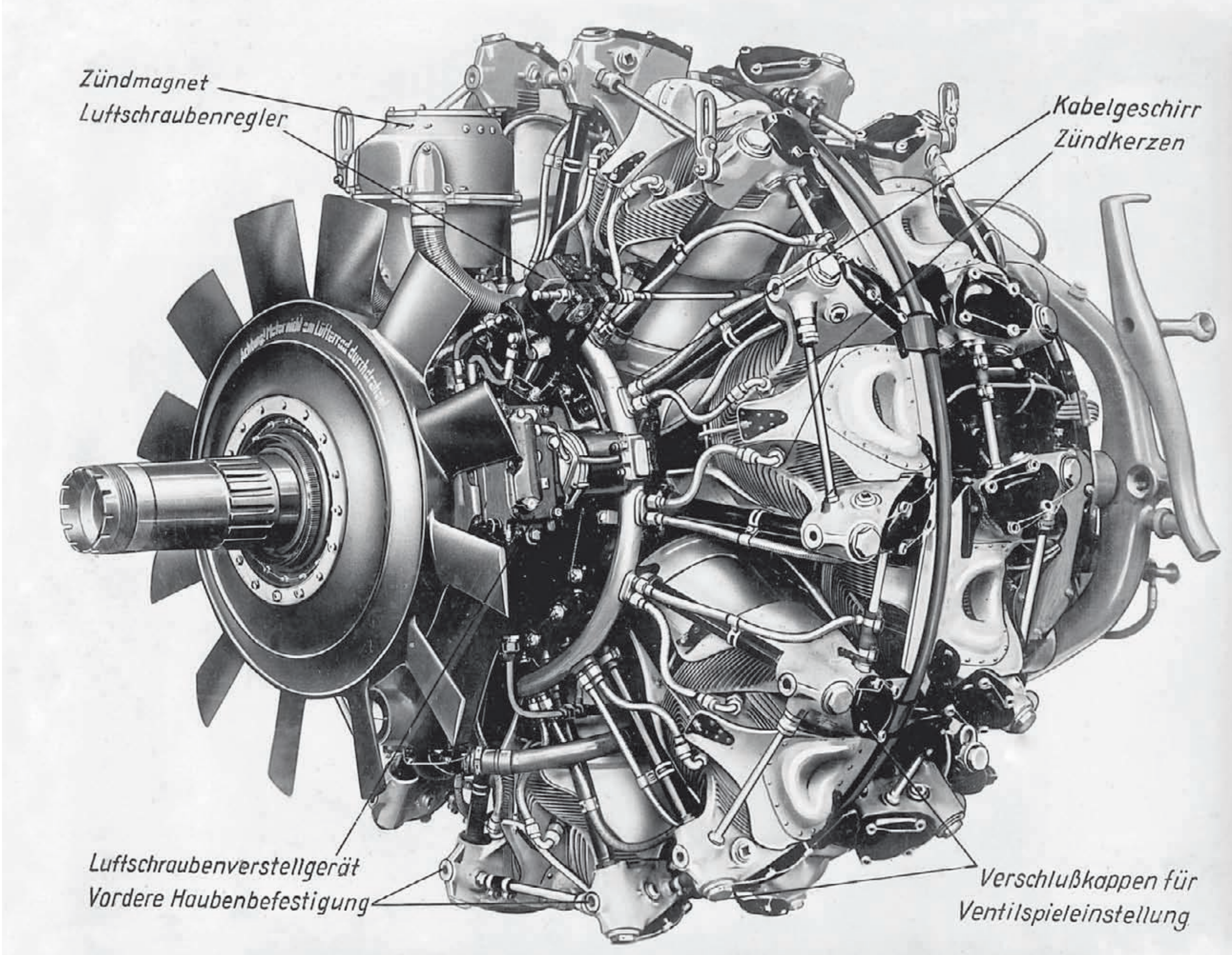


In 1932, von Gronau flew a second Dornier Wal around the world, powered by a BMW VII that was equipped with a 0.62 ratio-reduction gearing system for the propeller. The V-12 also formed the basis of BMW's first experiments with direct fuel injection in 1933.

BMW 132, 1932: Lufthansa Insists on BMW Radial Engines

In 1929 BMW bought the rights to manufacture Pratt & Whitney Hornet and Wasp radial engines. The arrangement was canceled in 1931, but in 1932 events took a turn for the better. Junkers revealed its new civil airliner, the three-engined Ju 52 (opposite, below), which was originally going to be fitted with Junkers Jumo engines. However, the manufacturer's main customer, Lufthansa, insisted the aeroplane be powered by BMW radial engines. BMW quickly refreshed its license with Pratt & Whitney and developed an improved version of the R-1690 Hornet called the BMW 132. The nine-cylinder engine had a displacement of 27.7 liters. Radial engines are distinct from the rotary engines used during World War I in that the main body of a radial is static and the crankshaft rotates, like an inline engine; in contrast, a rotary engine revolves about a fixed crankshaft.

The civilian engines used on the Ju 52 were fed fuel through carburetors, but BMW produced several versions of the engine and also used it to experiment with direct fuel injection. A large number of derivatives were built, developing 715 to 947 hp, the most powerful being direct fuel injected. As well as the Ju 52, the 132 would go on to power World War II fighting aircraft such as the Ju 86 bombers, Arado Ar 196 floatplanes, Focke-Wulf Fw 200 patrol bombers, and several others. Prior to hostilities breaking out again in 1939, the first nonstop flight from Berlin to New York had been made by an Fw 200 Condor S-1 powered by four BMW 132 engines.



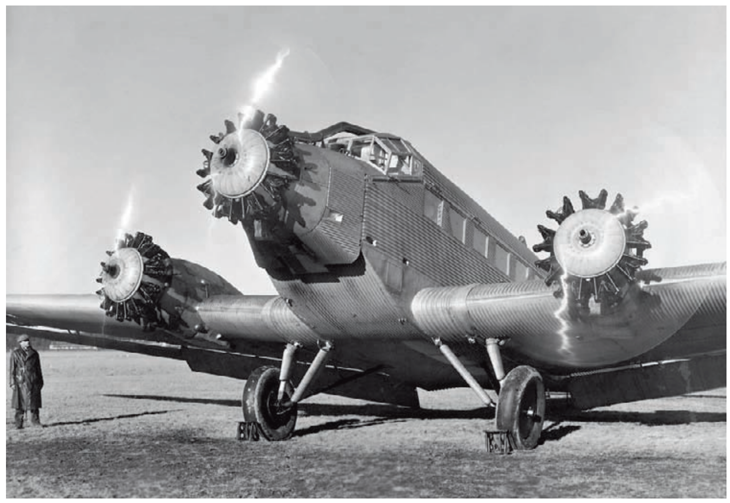
BMW 801, 1939: The Feared and Revered Two-Row Radial

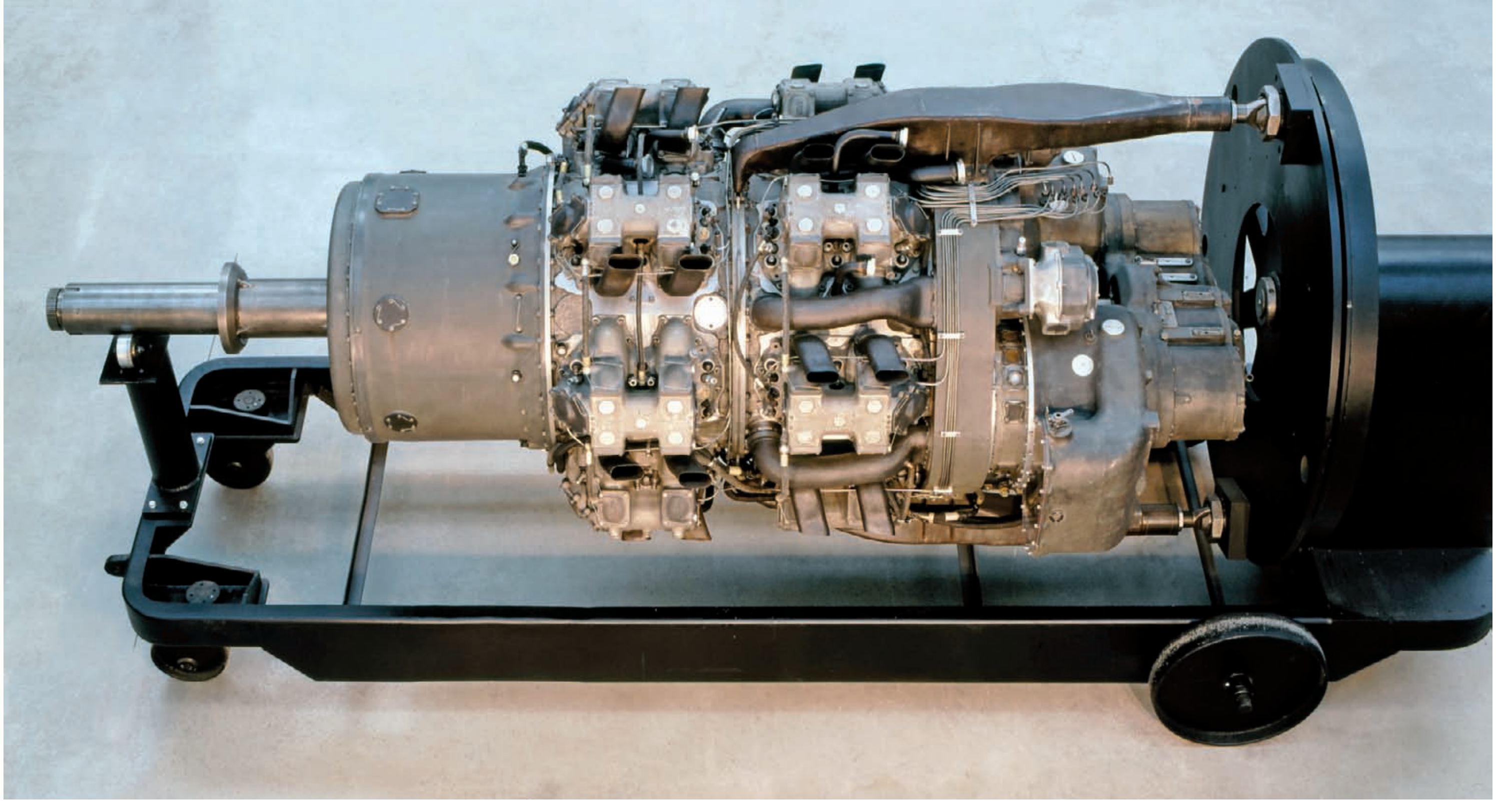
One of the most respected and feared fighting machines of World War II, the formidable Focke-Wulf Fw 190, was powered by one of BMW's finest ever aero engines: the air-cooled, twin-row, fourteen-cylinder 801 radial (above). More than twenty-eight thousand of these engines were built during the course of the war, and all delivered phenomenal performance.

BMW acquired a competitor, Bramo, in 1939; the 801 was the result of merging the BMW 139 with the Bramo 329, both of which had been funded by the German Ministry of Aviation in 1935. Surprisingly, the 801 was equipped with just two valves per cylinder, while the inline engines of the time were already using four valves per cylinder to improve engine breathing and performance. The 801, however, did feature sodium-cooled exhaust valves and direct fuel injection.

The initial design, which first ran in 1939, was for a pair of engines—the 801A and 801B—to be used in twin-engined aircraft. The engines were equipped with gearboxes that rotated the airscrews in opposite directions, canceling out the torque effect. The 801C, with improved cooling, was the first power unit fitted to the Fw 190.

The 801 was continually developed as the war progressed, with the performance of the British Spitfire, powered by the Rolls-Royce Merlin, and that of the Fw 190





leapfrogging one another with each successive advance. BMW improved its original supercharger to increase performance at higher altitudes, and the power outputs of operational 801s eventually rose to a mighty 2,400 hp. Ultimately, the 801 would power a range of aircraft in addition to the Fw 190, including the much-feared twin-engine Ju 88 fighter-bomber.

BMW 803, 1942–1944: A Twenty-Eight-Cylinder Monster

The BMW 803 (above) was an ambitious project consisting of two 801 radial engines grafted together and water cooled to avoid problems of overheating. The engine was intended to power larger versions of the Focke-Wulf Ta 400 long-range bomber and other similar multi-engine aircraft, as well as single-engine fighters.

In order to avoid reliability problems and other difficulties associated with engineering a single long crankshaft, the 803 became fiendishly complicated. As the 801 was a twin-row fourteen-cylinder engine, the 803 had twenty-eight cylinders arranged in four rows, but each pair of rows retained separate crankshafts inline with one another. The front unit drove the forward airscrew directly, but the rear unit drove the rear airscrew through a series of shafts and a gearing system. As a result, a large gearbox was attached to the front of the engine, a hollow shaft driving the rearmost airscrew, with the crankshaft from the forward fourteen cylinders passing through it.

A further challenge in having two separate crankshafts was how best to drive ancillary components. The most important of these was the supercharger, which on an engine of this size consumed hundreds of horsepower. The decision was made to drive it from the rear engine, reducing the power available to drive the rear airscrew, but the engine still delivered a substantial output of 3,847 hp. This made it the most powerful German piston engine to date, but it was so heavy that the power-to-weight ratio was poor compared to alternatives. The 803 never entered production, and with the resources of the Nazi war machine steadily dwindling, neither did the aircraft for which it was intended.

BMW 003, 1944: BMW's First Jet Engine Ends the Piston Era

Both Sir Frank Whittle and Hans von Ohain are credited with the invention of the jet engine, Whittle securing a patent for his centrifugal design in 1930 and Ohain for his axial principle in 1936. However, it was the German engine that flew first, in 1939, with the Whittle unit not making its first flight until 1941. Eventually the axial design would be adopted by the world's jet engine manufacturers in postwar years.

The BMW 003 engine (opposite, top) was equipped with a seven-stage compressor and sixteen burners set into an annular combustion chamber. First tests of the 003 took place in 1940, with the engine attached to the underside of a twin-engine Messerschmitt Bf 110. Disappointingly, it only produced 150kg of thrust—half the expected amount. Development was slow, partly because of the scarcity of the very high-grade metals needed to build the internal components of a jet engine, such as nickel, cobalt, and molybdenum.

A second test took place using a modified twin-engine Messerschmitt Me 262, also equipped with a conventional BMW 801 "safety" engine attached to the nose. The test