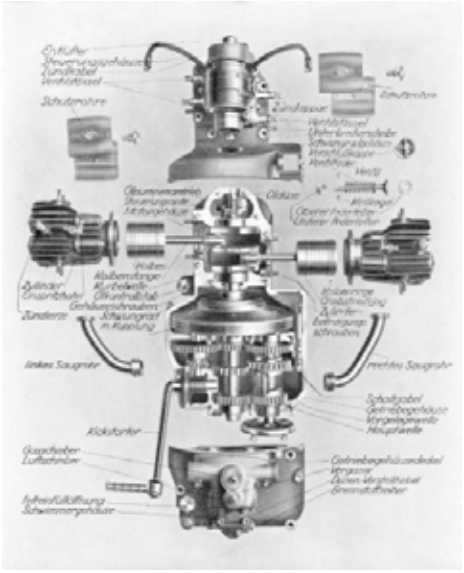
History of the reigning champion: the BMW Boxer engine

In historical terms, 90 years of BMW motorcycle production has produced more speed records, legendary motorcycles, technical and safety innovations than most motorcycle manufacturers. But such landmark events would not have occurred if it wasn't for the men and women behind the sharp end of a drawing pencil. Some would call them designers or engineers, while others would describe them as technical geniuses. But however you view these people, the fact remains that motorcycling would be a poorer place without them; and the legendary BMW Motorrad 'Boxer' engine would not have evolved into one of the longest surviving engine designs that has transported countless numbers of riders, millions of kilometres across the earth over the past nine decades. Enjoy our potted history of the much-loved Boxer engine…

Before the days of BMW, two men didn't just shape the future of motorcycling but kick-started it with hefty boots. In the mid-1860s, Nikolaus Otto, a German engineer, built the first working four-stroke engine based on the design and subsequent patent by Alphonse beau de Rochas. Because Otto's engine was the first practical demonstration of the four-stroke operation cycle, the term Otto cycle is used as a common reference to describe all four-stroke engine design.

In 1896, German engineer Karl Benz pencilled a new four-stroke engine. His flat horizontally opposed twin-cylinder engine involves two pistons that reach top dead centre and bottom dead centre at the same time. This piston action is likened to two prize fighter boxers trading blows and the term 'Boxer' engine is borne. The resulting engine is compact, reliable and a source of power for many applications.

Moving onto 1913 and engineer Karl Rapp along with an associate partner forms Rapp Motorenwerke to produce aircraft engines. Success for Rapp Motorenwerke isn't easy. Faced with growing competition, many of Rapp's engine designs were deemed unsuitable for the likes of the growing aviation industry and German military. It takes the involvement and engineering genius of Rapp MotorenWerke's new designer Max Fritz to rescue the dying company with a series of technical breakthroughs in aviation engine design. In 1917 Rapp Motorenwerke becomes one of two companies brought together to form Bayerische Motoren Werke GmbH, or BMW as it is commonly known today. Interestingly, the other company to form BMW is an aircraft manufacturer that started life under the guidance of Gustav Otto, the son of Nikolaus Otto.



The new controlling company Bayerische Motoren Werke GmbH continues to develop engines. One of its leading men, Martin Stolle, pulls apart his Armstrong 500cc flat twin and engineer Max Friz designs his own version of a small 'Boxer' engine to be used primarily for aviation and as a static generator engine. This 1920 engine design is designated as M2 B 15, or for quick reference the 'Bayern motor'. Because of the engine's compact nature it is also sold to up-and-coming companies eager to supply the growing market for cheap personal motorised bicycles, or motorcycles as they become known.

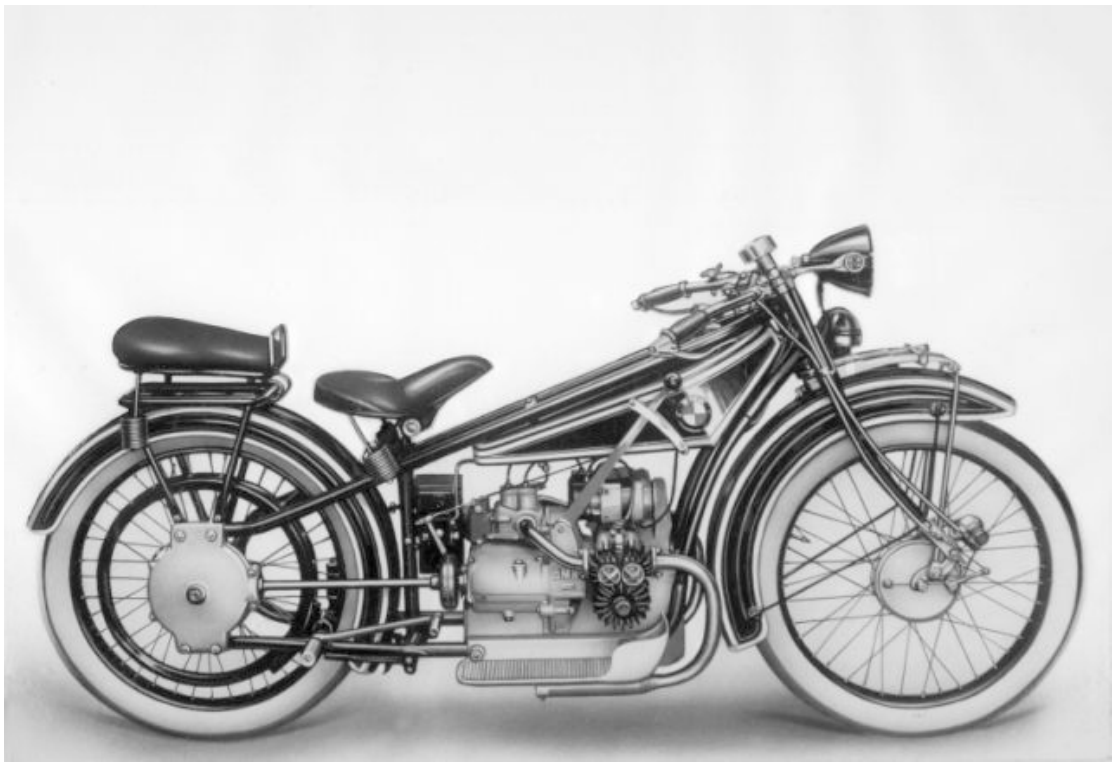
Heller, Biso, Corona and Victoria are some of the earliest recorded motorcycle manufacturers using the 'Bayern engine' to power their motorcycle designs. But while the M2 B 15 is reliable as a generator, the fact that it is installed in a motorcycle chassis so the two cylinders run in-line with the length of the frame, actually restricts the rear cylinder to the cooling effect of passing air. Despite overheating problems the engine's success is such that BMW eventually produces its own motorcycle using the engine but under the manufacturing name of Helios, a brand inherited in the original company merger.

The instant and growing success of motorcycling is recognised by BMW to the point it decides to produce its own motorcycle brand – the design of which is handed to the successful engineer Max Fritz, who goes on to pen a new chassis using the M2 B 15 engine.

Such was Fritz' ingenuity, he recognised the overheating problem could be solved simply by turning the M2 B 15 engine 90-degrees so that the cylinders ran across the width of the frame so both cylinders were open to fresh and passing air. This simple repositioning also allowed BMW to use Cardan shaft final drive because the crankshaft lined up with the gearbox, friction clutch and driveshaft. This proved to be a superior (direct and clean) method of delivering driving torque to rear wheel when compared to the usual chain and sprocket system.

With the crankshaft and three-speed gearbox all lined up and contained within its own cast cases – unlike the separate engine and gearbox 'pre-unit' powerplants of many European motorcycle manufacturers – the refreshed 500cc M2 B 15 engine was designated in production as M2 B 33 and would serve as the power unit for the Fritz designed motorcycle chassis.

The twin-cylinder flat twin had bore and stroke measurements of 68 x 68mm to give capacity displacement of 494cc and produced 8.5HP at a claimed 3200rpm – not bad considering the engine was in its infancy. As such, materials and tuning technology wasn't fully employed within the early design stage but it was only a matter of time before it was grabbed with open and excited BMW engineer hands.



The Fritz designed engine and chassis finally came together as a perfect marriage in the form of the 1923 BMW R 32 motorcycle and was an immediate success. With one 22mm BMW Special carburettor feeding two cylinders of just 5.0:1 compression ratio via one inlet side-valve per cylinder (the one exhaust valve was also side-valve), the R 32 was good for 90-100km/h (56-62mph) and 80mpg (3.5litres/100km). Its success also comes from its beautifully crafted aesthetics created by the seemingly artistic and supreme mind of engineer Max Fritz. Success can be measured in unit volume with just over 3000 R 32 machines produced and sold between 1923 and 1926.

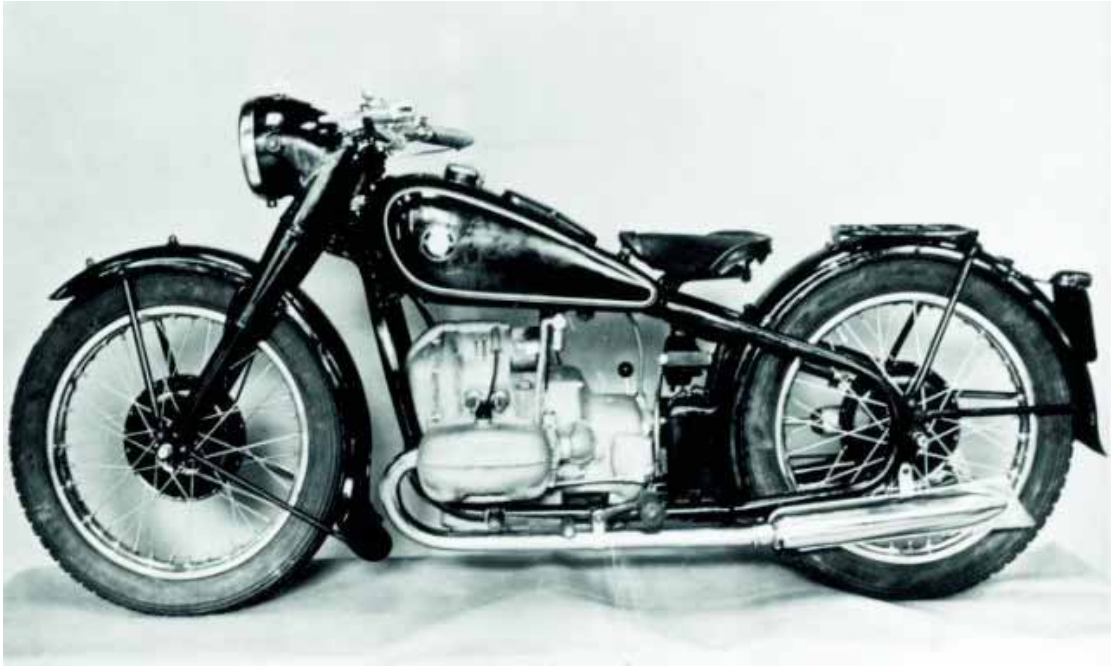
The next major step forward for the R 32 Boxer engine was a prototype to feature overhead valves. This new development by engineer Rudolf Schleicher was tested and officially approved when Schleicher rode the development machine at the 1924 ADAC Winter Rally – and won! This OHV design was incorporated into the M2 B 36 engine of the 1925 R 37. With nearly double the engine performance (16HP) the R 37 was an impressive machine to ride; over 80 road races were won by R 37 riders in 1925.

At the same time, the R 32 was further developed and emerged as the R 42 in 1926. Although still side valve operation, engine output had increased to 12HP and now featured lighter aluminium cylinder heads with free-flow cooling fins. With updated

chassis details and a cheaper price tag than the original R 32, the R 42 was an instant sales success with over 6,500 machines produced in just two years.

The R 32's Boxer engine was the foundation stone for all future BMW Boxer powered motorcycles. By and large the design of the BMW Boxer engine didn't change dramatically for a number of years after the successful 1928 release of new 750cc models (side valve R 52 and R 62, OHV R 57 and R 63). With the capacity increase and further development of all its engines, power and reliability increased like for like. Land speed records and racing success achieved with BMW motorcycles were significant factors for the huge increase in sales

In 1936, BMW served up the R 5. An entirely new model, the R 5 was design-wise a technically advanced and beautiful machine and powerful to boot – valid reasons why the R 5 is considered by classic BMW riding fans as the very best of pre-war BMW Boxer motorcycles.



As far as the engine goes, the R 5 retained the 'classic' 494cc and 'square' 68 x 68mm bore/stroke dimensions but featured two chain-driven camshafts above the crankshaft resulting in shorter pushrods actuating the overhead valves and lifting the rpm ceiling. A healthy compression ratio of 6.7:1 and an Amal 5/423 carburettor for each cylinder led to a peak power output increase to 24HP at 5500rpm. All the mechanicals including the new four-speed foot operated gearbox (auxiliary manual gearchange was available) were housed in an aluminium one-piece crankcase.

Continuous refinement of the R5 engine continued and appeared in various models. Much of the updates were as a direct feedback of BMW's serious racing programme with the Kompressor model. This commitment resulted in the first TT win for BMW when Georg Meier won the Senior TT – a first for a foreign rider to win on a 'foreign' machine.

In 1949, post-war restrictions were dropped and BMW was finally allowed to resume production of large-capacity machines. Due predominantly to lack of finance, only revised versions of the 1938 R 51 series of bikes were initially produced. Further development also floundered in the mid-to late 1950s when motorcycling fell from grace

with the advent of cheap four-wheel transport. The one model that did very well was the 1955-1960 R 69, a 594cc Boxer that delivered 35bhp. This was later bettered by the 1961 R 69S with an incredible 42HP delivered at 7000rpm.

The next major engine introduction came in the guise of Type 246, the /5 series of machines – R 50/5 (498cc), R 60/5 (599cc) and R 75/5 (745cc). Development of the new engine was overseen by Alex von Falkenhausen and Ferdinand Jardin, and the resulting engine was considered to be the first true modular BMW engine.

All three models used the new engine with the significant difference being the cylinder bore size changed according to capacity the stroke dimension of 70.6mm was retained. The overall shape of the engine took on a curvaceous look to make it exquisitely modern – it was a successful styling exercise built on the need to incorporate new technology and set a new identity and benchmark for future BMW motorcycles. This also included the possibility of a big-bore Boxer engine, which was realised with the fantastic 898cc R 90/6 and R 90 S in 1974 and later R 100 machines.

Within /5 engine's taller crankcase that rose up to the fuel tank was situated the electric starter motor. The traditional pushrods were placed under the cylinders to leave the topside of the cylinders free from clutter and allow greater airflow across the deep cooling fins (a very plausible reason why this is engine is commonly referred to as the 'Airhead engine'). This was achieved by placing the camshaft under the crankshaft and was driven by a Duplex chain. The crankshaft itself was a one-piece item for rigidity and emphasised with increased bearing journal diameters.

To say the /5 engine was all-new is an understatement. Reliability was at the forefront of design rather than outright power. Oil pumping, oil scavenging feed and return design were key points and were reflected in the Eaton-type oil pump that could deliver 1400 litres of life-giving oil at 6000rpm. Fuel delivery was care of Bing carburettors carefully selected for each capacity, e.g., the R 50/5 used two slide carburettors while the R 75/5 ran with two of the latest Constant Depression carbs.

1993 and the 70th anniversary of BMW motorcycle production brought about the introduction of another milestone in BMW motorcycle engine design with the appearance of engine Type R259. This engine carried a new valve train of four valves per cylinder, made up of two inlet and two exhaust. Married to an increase in capacity to

1085cc, this engine was instantly 30HP up on the previous Airhead model to a peak of 90HP.

R259, or the 'Oilhead' was not merely a revision but a makeover to again compete with large-capacity Japanese motorcycles. It also showed the world that BMW's belief in the Boxer engine design was not fading and there was still very much life in what had become BMW's signature engine… it also proved there was much more to come.

It wasn't just a matter of capacity increase and moving the chain driven camshafts to mid-head to allow the use of short rockers to actuate the valves and extend the power range, fuel injection now featured along with the latest digital engine electronics to ensure the new Boxer range complied with ever tightening emissions restrictions. As it was the new R 1100 RS was first to appear with this new engine and once again BMW rubber stamped its authority on the large-capacity touring and roaster segment.

In 2004 a second-generation 4-valve engine materialised to power the 1170cc range of bikes. Lovingly referred to as the Hex-Head because of the restyled rocker covers, the 'Evo-Boxer' also featured a 'high cam' and rocker layout complete with a balancer shaft set within the countershaft to offset oscillation from the increased piston mass from their offset positioning. Although the dual weight-carrying balance shaft did an excellent job, the new engine lost none of the character associated with a Boxer engine. It was, quite simply, an update for the Boxer engine's future longevity.

The HP2 Sport of 2007 gave more than an insight into the next chapter of Boxer engine development. The HP2 was essentially the road-going version of the BMW Motorrad endurance racing machine that had given good account of itself amongst more powerful in-line four-cylinder machines in the World Endurance Championship. When the Motorrad racing machine first appeared on circuit – and for a long time after – nobody realised this machine was actually a rolling test bed for double overhead cam valve actuation.

The HP2 Sport proved to be the fastest and most powerful road-going Boxer engine to date, with a claimed 133HP. Of course this engine carried the usual lightweight materials associated with HP machinery within its central tube crankcase, and also without a balancer shaft to improve engine response. Even so, the R-based models that followed in 2010 were not short on power or torque either.

The twin-cam heads were not arranged in typical one cam per valve set in the traditional way because of the inlet tract and exhaust manifold positioning. BMW Motorrad's answer was to turn the camshafts 90-degrees so that each of the two cams per head actuated one inlet and one exhaust valve.

Performance-related components were also revised. For example, valve sizes and compression ratio both increased. This also gave an additional boost in output and torque up to 110HP (81 kW) and ftlb (115Nm) at 5500 rpm depending on the model (R 1200 GS, R 1200 RT/ST etc).

Aficionados of BMW Boxer engines believed this latest engine to be the pinnacle of BMW Boxer technology – if a Boxer engine is viewed as a bastion of air/oil cooling then they are right. But the simple truth is a Boxer engine is a horizontal flat twin regardless of it being air/oil-cooled… or liquid-cooled.

The next page in BMW Boxer-engine history has been turned with the advent of the model year 2103 R 1200 GS and its all-new partially liquid-cooled engine. Savage emissions rules have,

fortunately, helped BMW Motorrad produce an engine that is now lean and fitter than ever before.
Air and oil still maintains 65% of the new engine's cooling dynamics, while the other 35% is done via a glycol-water mix through two radiators and 'precision cooling', that is the coolant is channelled directly to the hottest part of the engine – around the combustion chamber – thus avoiding a hefty weight penalty with a large coolant capacity. Two cams per cylinder operation is retained but, thanks to vertical inlet tracts and lower exhaust port, are now dedicated inlet and exhaust camshafts. This allows the ability to alter cam timing to suit future model applications. The cams are still driven by a central chain operated geared shaft.

A new crankshaft with smaller main bearing diameters reduces drag. This compact crank also assists in reducing vibration along with the counterbalance shaft. The actual cast aluminium engine housing is still the old tunnel-type but within the revised design sits both gearbox and clutch; a wet multi-plate slipper clutch.

Equipped with the latest Canbus electronics, engine control and fuel injection, the new R 1200 GS engine is a lean 1170cc thoroughbred built in the traditional BMW way – by engineers who ride motorcycles.