

# The new V8 Power Unit for the BMW M3. Contents.



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# The new V8 Power Unit for the BMW M3.

## Description in Brief.



- First eight-cylinder for the BMW M3 sports car.
- Supreme performance ensured by 309 kW/420 hp from 4.0 litres.
- Maximum torque of 400 Newton-metres (295 lb-ft) at 3,900 rpm, 85 per cent of maximum torque over a speed range of 6,500 rpm.
- Unique thrust and muscle ensured by consistent implementation of the M high-speed engine concept, maximum engine speed 8,300 rpm.
- Consistent lightweight construction of engine and ancillary units, new V8 power unit one of the lightest eight-cylinders in the world, lighter than the straight-six power unit in the former model.
- Variable camshaft control, low-pressure double-VANOS for an optimum charge cycle, system offering full power and performance even with normal engine oil pressure.
- Eight individual throttle butterflies for spontaneous engine response.
- Consistent and reliable oil supply with longitudinal and lateral acceleration up to 1.4 g ensured by two oil pumps and wet sump oil lubrication optimised for supreme dynamic behaviour.
- Exhaust system optimising cylinder charge, optimised for weight and function by means of internal high-pressure remoulding, exhaust emissions fulfil EU4 and LEV 2 standards.
- Upgraded MSS60 engine control unit for optimum coordination of all engine functions with the various control systems in the car.
- Ion flow technology recognising and distinguishing engine knocking phenomena as well as misfiring and miscombustion by measurement of ion flow in the combustion chambers.
- Brake Energy Regeneration with intelligent alternator control.

## More in Every Respect: The new V8 Power Unit for the BMW M3. (Short Version)



Its name alone spells out the epitome of ultimate driving pleasure: the BMW M3. And now the new version of BMW M GmbH's most successful high-performance sports car bears out this claim once again, at the same time providing a thrilling answer to the question asked by so many sports car fans around the world whether a further improvement is still possible at all. And the answer is yes – for the new BMW M3 offers more in every respect.

This applies not only – but particularly – to the power unit: After 15 years and two model generations, the trendsetting six-cylinder has now found its successor. The new BMW M3 is entering the market with an eight-cylinder power unit – more cylinders, larger capacity, more power, higher engine speed. And it is fair to say from the start that this will also mean an even more thrilling experience on the road.

The benchmark the new power unit was required to exceed could hardly have been greater: BMW's 3.2-litre straight-six has gained fame and admiration the world over, receiving a long list of awards and prizes. Acknowledged several times as the "Engine of the Year" and developing a supreme 252 kW/343 hp in its last version, this power unit made the BMW M3 not only the ultimate performer in the segment of high-performance sports cars, but also a genuine best seller.

The fact still remains, however, that everything has its time. And now the time has come for the six-cylinder to bow out and leave the stage. The time has come for the advent of the new V8 in the new BMW M3.

The specifications of this new high-performance power unit alone clearly confirm the enormous progress this engine has to offer. Engine displacement is 3,999 cc, maximum output is 309 kW/420 hp. Peak torque of 400 Newton-metres or 295 lb-ft is just as impressive as the top engine speed of 8,300 rpm. So clearly, the new BMW M3 is striking out for the top right from the start through its thrilling performance.

### **Ideal dimensions for performance at its best.**

Displacing 500 cc per cylinder, the new V8 power unit meets the ideal concept of the most demanding engine designers right from the start through its engine dimensions alone. And the other design criteria – all the way from the engine's dimensions and filling capacities through the number of components to the weight of the engine – likewise represent the very best achievable today.

Over and above these qualities, the new eight-cylinder offers all the typical M-tuned features of BMW's regular production cars such as double-VANOS, individual throttle butterflies, and high-performance engine electronics. At the same time the number of cylinders, the M high-speed engine concept, and the low weight of the engine clearly prove that the responsible engineers, in creating this power unit, were inspired and guided by the eight-cylinder featured in the BMW Sauber F1. For the new engine has many features in common with the latest power unit highlighted by BMW in Formula 1, with various technological concepts and principles, production processes and materials carried over from the Formula 1 engine to the drivetrain of the new BMW M3.

In terms of specific output, the new V8 significantly exceeds the benchmark of 100 hp per litre acknowledged as a convincing sign of sporting power and performance. But even so, power is not everything. Rather, the dynamic driving experience provided by a car depends to a great extent on its acceleration and handling, resulting, not least, from the weight of the car and the actual thrust of the engine. The thrust or traction acting on the drive wheels, in turn, results from engine torque and the overall transmission ratio.

The M high-speed engine concept allows optimum transmission and final drive ratios further enhancing the impressive thrust and power of the engine. Indeed, BMW M's engineers have found a new dimension in developing the engine of the new BMW M3, with the eight-cylinder achieving maximum engine speed of 8,300 rpm.

The second factor crucial to thrust and performance on the road, engine torque, amounts to a mighty 400 Newton-metres or 295 lb-ft at 3,900 rpm on the new V8 power unit. And about 85 per cent of the engine's maximum torque is available throughout the enormous engine speed range of 6,500 rpm, with 340 Newton-metres or 251 lb-ft available from just 2,000 rpm.

### **High engine speed, low weight.**

Mass (which, ultimately, means weight) is bad for acceleration – it makes any physical body seeking to accelerate slower and more sluggish. Precisely this is why BMW's new V8, weighing a mere 202 kg or 445 lb, is a genuine lightweight, saving some 15 kg or 33 lb versus the six-cylinder power unit in the previous model. In other words, the new engine easily sets off the weight of two extra cylinders. And a further point is that the high-speed engine concept allows a light drivetrain and very short transmission ratios.

Even so, the limits to physics inevitably approach step-by-step with increasing engine power: At 8,300 rpm, each of the eight pistons is moving at a speed of 20 metres or almost 66 feet per second, obviously exposing all materials to enormous loads. Precisely this is why BMW M's designers and engineers have focused on the minimisation of masses on the new eight-cylinder.

### **Engine block straight from BMW's Formula 1 foundry.**

The engine block of the new eight-cylinder comes straight from BMW's light-alloy foundry in Landshut near Munich, where BMW also builds the engine blocks for the Company's Formula 1 racing cars. The cylinder crankcase, in turn, is made of a special aluminium silicon alloy, conventional cylinder liners being replaced by hard silicon crystals. The iron-coated pistons, finally, run directly in the uncoated, honed cylinder bore.

High engine speeds, compression forces and temperatures cause extreme loads acting on the crankcase. Hence, the crankcase is compact in its dimensions and comes in torsionally resistant bedplate design ensuring very precise crankshaft bearing and running conditions. The relatively short, forged crankshaft is likewise very stiff in terms of its flexural and torsional qualities, but weighs only 20 kg or 44 lb.

### **Double-VANOS with low-pressure operation.**

With its extremely short control times, variable double-VANOS camshaft management perfects the cylinder charge cycle, reducing charge losses and improving engine output torque and response, as well as fuel economy and emission management.

Developed especially for the new eight-cylinder, the M double-VANOS now featured on the new engine requires no more than normal engine oil pressure in order to operate at maximum speed. As a function of load and engine speed, this sophisticated unit consistently sets the optimum valve angle synchronised to the ignition timing and injection volume.

### **Consistent and reliable oil supply even under extremely dynamic driving conditions.**

Two volume-flow controlled pendulum slide cell pumps supply the eight-cylinder efficiently with lubricant, consistently delivering exactly the right amount for the engine. Wet sump lubrication optimised for engine dynamics, in turn, ensures appropriate lubrication also in extreme braking manoeuvres.

The entire system features two oil sumps – a small one in front of the front axle subframe and a larger sump further back. A separate reflow pump, in turn, extracts oil from the front oil sump and pumps it to the sump at the rear.

### **Eight individual throttle butterflies with electronic control.**

Individual throttle butterflies for each cylinder, a technology commonly used in motorsport, are the ideal solution to give the engine an immediate, direct response at all times. The new power unit in the BMW M3 therefore comes with eight individual throttle butterflies, four on each row of cylinders operated by separate actuators. This high-tech throttle butterfly management is fully electronic and extremely fast, giving the engine a smooth and sensitive response at low engine speeds and an immediate reaction to the driver's commands whenever he wishes to use the full power of the engine.

### **Flow-optimised air intake.**

To ensure an immediate response and superior dynamics of the engine at all times, the throttle butterflies in the intake manifolds are positioned very close to the intake valves. The specific length and diameter of the intake funnels also benefit the oscillating pipe charge principle. To minimise weight, finally, both the intake funnels and air collector are made of a light composite material with a 30 per cent share of glass-fibre.

### **Innovative exhaust system.**

Through its design and configuration, the exhaust system for the new V8 power unit optimises the cylinder charge cycle, ensuring an optimum surge of power and torque at all times. And again, this component has been designed and built from the start for consistent lightweight qualities.

The exhaust manifolds are made in an internal high-pressure remoulding process, the desired contours of the stainless-steel pipes being shaped from inside under pressure of up to 800 bar. The result is extremely thin walls measuring just 0.65–1.00 millimetres (0.0256–0.0394") in thickness, optimising flow conditions with minimum resistance, light weight, and optimum response of the catalytic converters.

Exhaust emissions are cleaned by no less than four catalysts and the engine naturally complies both with the European EU4 standard and the US LEV 2 requirements.

### **Even better performance than before: the engine control unit.**

The engine control unit featured on the V8 has also been upgraded to an even higher standard than before, ensuring optimum coordination of all engine functions. Taking more than 50 input signals, for example, the control unit determines the optimum ignition timing individually for each cylinder and operating stroke, the ideal flow conditions, exactly the right amount of fuel injection, and the optimum injection timing. At the same time the system calculates and sets exactly the right camshaft angles (angle spread), as well

as the respective position of the eight individual throttle butterflies. And last but not least, the control unit enhances and masterminds specific BMW M functions such as the clutch, transmission, steering, and brakes.

Yet a further function of the engine control unit is to perform a wide range of on-board diagnostic functions with various diagnostic routines for servicing at the workshop as well as other functions and the efficient management of peripheral units and systems.

### **An outstanding highlight in engine management: ion flow technology.**

A particular highlight in engine management is ion flow technology detecting any knocking in the engine as well as the risk of misfiring or miscombustion. Contrary to conventional processes and technologies, this function is now performed directly where it counts, that is right there in the combustion chamber itself. To provide this highly efficient control, each cylinder is monitored and controlled via the spark plug to determine any knocking tendency. At the same time the system checks the ignition for smooth and correct operation, and recognises any misfiring.

The spark plug therefore serves as an actuator for the ignition and as a sensor observing the combustion process, distinguishing in this way between miscombustion and misfiring. And through this double function performed by the spark plug, diagnostic requirements in maintaining and servicing the engine are also facilitated.

### **Greater efficiency and dynamics provided by Brake Energy Regeneration.**

To further enhance the efficiency of the new V8 power unit, Brake Energy Regeneration ensures intelligent engine current management concentrating the generation of electric power for the on-board network on the overrun phases and the application of the brakes. This serves to charge the car's battery without tapping on engine power and, accordingly on the energy contained in the fuel burnt. As long as the engine is running under power, on the other hand, accelerating and pulling the car, the alternator generally remains disconnected.

Apart from particularly efficient generation of electric current, this also helps to provide more drive power when accelerating, making the car even more dynamic and agile on the road.

## **More in Every Respect: The new V8 Power Unit for the BMW M3. (Long Version)**



An exceptional power unit for an exceptional sports car: The V8 power unit featured in the new BMW M3 raises the driving pleasure offered by BMW M GmbH's high-performance two-door sports car to a level never seen before. And so the combination of this power unit with such a unique car concept offers a supreme motoring thrill virtually unparalleled on the road.

V8 power units have always been acknowledged as fascinating machines making the heart of the genuine aficionado skip a beat – particularly if the power unit involved is a fast-revving naturally aspirated engine in an uncompromising sports car.

A similar thrill is provided in Formula 1, the highest and most challenging level of motorsport, where once again the eight-cylinder sets the standard and marks the latest development in technology. And the similarities between the BMW Sauber F1 Team's power unit, on the one hand, and the power unit featured in the new BMW M3, on the other, are unmistakable.

To round off this perfect combination, the BMW M3 teaming up with the new V8 power unit provides the ultimate in thrilling performance on the road. Already a legend in the world of sports car motoring, the BMW M3 with V8 power now once again sets the standard in its class. Indeed, it is further increasing its leadership over the competition as the largest and most powerful engine ever seen in a regular production BMW M3.

The engine's specifications alone clearly prove the enormous progress achieved in changing over from the straight-six power unit which has dominated the scene for more than 15 years to the new eight-cylinder: Engine capacity is 3,999 cc, maximum output 309 kW/420 hp. Peak torque of 400 Newton-metres or 295 lb-ft is just as impressive as maximum engine speed of 8,300 rpm.

So 20 years after the first BMW M3 established the then brand-new segment of high-performance sports cars, the fourth generation paves the way into an unprecedented dimension of driving pleasure.

### **After 15 years: goodbye to the six-cylinder, hello to the V8.**

Following the rule that “there is always room for improvement”, even the engine of the “Car of the Century”, as the French motor magazine “Auto Plus” euphorically lauded the second-generation BMW M3 15 years ago, is now giving way for an even more outstanding, truly supreme successor. Especially because the ever-increasing power and muscle of the third generation of the BMW M3, for the first time offering more than 100 hp per litre, already made maximum use of the technical potential of the straight-six engine. And any further increase in engine power and performance would have had unwanted effects on the car’s driving dynamics, since various parts and components exposed in this way to even greater loads would have had to be even more stable and, consequently, heavier than before.

So in introducing the fourth generation of the BMW M3, BMW M is also making a change within the engine compartment, opening up the door to the brand-new V8.

Maximum output of 309 kW/420 hp also sets an appropriate distance to the top engine in the “regular” BMW 3 Series, the 3.0-litre straight-six with Twin Turbo technology and maximum output of 225 kW/306 hp. So the new BMW M3 proudly retains the unique character of a high-performance sports car from BMW M GmbH.

### **The ideal formula for the engine designer: 8 x 500 = 4,000.**

Eight cylinders, four litres capacity. Specifications of this kind alone make the dream of the engine designer come true on the new power unit.

Quite simply because combustion chambers displacing 500 cc per cylinder are acknowledged as ideal. A similarly powerful six-cylinder, therefore, would inevitably have deviated from this ideal geometry of a genuine sports engine. The V8, on the other hand, in its dimensions, filling quantities, the number of components and in its weight, represents the optimum concept in both theory and practice.

### **High-speed engine concept entering a new dimension.**

The designers and engineers responsible for the new power unit have nevertheless remained faithful to the high-speed engine concept so typical of BMW M. Indeed, they have even raised this concept to an unprecedented level, the new V8 reaching maximum engine speed of 8,300 rpm, a figure so far seen only in motorsport engines and a handful of exotic, hand-built cars. To this day, hardly any engine designer or engineer responsible for a series production engine has dared to enter this terrain.

The high-speed engine concept is however a traditional forte of BMW M GmbH's high-performance natural aspiration engines, generating enormous power and performance from high engine speeds. This avoids the conventional wisdom of simply increasing the size of the engine or using a turbocharger, often involving an undue increase in weight and fuel consumption.

Through the high-speed engine concept, the engine development specialists at BMW M GmbH thus ensure that the spontaneity of the engine, its instantaneous response to the driver's wishes, reflects the great demands made of an M Car and its overall concept. And so, in its performance potential, the development of power, in its dimensions and weight, the V8 power unit is a typical BMW M engine through and through.

### **Taking Formula 1 as a role model and paving the way through BMW M engineering.**

A further significant point is that the eight-cylinder boasts all the features and qualities so typical of BMW M, such as double-VANOS, individual throttle butterflies, and high performance engine electronics. At the same time the number of cylinders, the high-speed engine concept and the low weight clearly indicate that the engineers responsible for the new eight-cylinder have been inspired by another eight-cylinder – the unique engine featured in the BMW Sauber F1, the engine currently raced by the Team in the highest realms of motorsport. And indeed, the two power units share a number of features not only in their basic technological principles, but also in their production methods and materials clearly borne out by the transfer of technology from motorsport to series production.

One difference, however, will always remain: The BMW M3 is required to offer outstanding performance not only on racing weekends and therefore features a high-performance power unit fully suited for everyday use and reliability on all roads, in all kinds of weather, and in years of tough motoring the world over.

### **Twenty per cent more power – a new dimension in driving dynamics.**

A new BMW M3 must offer one feature in particular: even more power. And this is precisely why the fourth generation of the BMW M3 gives its proud owner about 20 per cent more power than before, the engine churning out a substantial 309 kW/420 hp.

In its specific output, the eight-cylinder easily exceeds the benchmark of 100 hp per litre acknowledged as the standard for a particularly sporting and dynamic power unit. But even so, power is not everything. Instead, the dynamic experience offered by a car is borne out in particular by its acceleration and performance in gear at all speeds resulting also from the weight of the vehicle and the sheer thrust and muscle of the engine.

The engine is an important factor in determining the weight of a car, that is the mass to be accelerated – after all, it is one of the heaviest modules within the car to begin with. So precisely here, the new BMW M3 again sets a new standard with engine weight of just 202 kg or 445 lb, making this V8 one of the lightest eight-cylinder engines in the world.

By comparison, the 294 kW/400 hp V8 in the predecessor to the current BMW M5 weighed 240 kg or 529 lb. So despite the extra power, the new engine is more than 15 per cent lighter. Indeed, it is approximately 15 kg or 33 lb lighter than even the six-cylinder power unit in the former BMW M3. So the extra weight of the two additional cylinders is more than set off by intelligent lightweight technology on the new engine.

### **High-speed engine concept for superior power and torque in practice.**

The second factor crucial to driving dynamics, the power and thrust actually conveyed to and by the drive wheels, results from engine torque and the overall transmission ratio. At 400 Newton-metres or 295 lb-ft at 3,900 rpm, maximum torque of the new eight-cylinder is approximately 10 per cent higher than the peak torque of the former straight-six, and the engine develops an equally superior 340 Newton-metres or 251 lb-ft at just 2,000 rpm. No less than some 85 per cent of the maximum torque is indeed maintained consistently over a speed range of 6,500 rpm very broad indeed for a sports car engine.

This is clearly reflected by the performance characteristics of the new BMW M3 not only offering a supreme standard of dynamic power, but also all the qualities for cruising smoothly on winding country roads or in city traffic.

Last but certainly not least – and indeed quite crucial in terms of overall qualities – the high-speed engine concept with its M-specific features allows use of the optimum transmission and final drive ratios and thus guarantees a perfect rendition of muscle and performance on the road under practical driving conditions.

The effect provided in this way is borne out by a clear example: Whenever a cyclist shifts down on an uphill gradient, he has to turn the pedals faster, but in return he can ride up virtually any hill. Should he, on the other hand, remain in the same gear or even shift up, he will have to pedal harder or even get off his bicycle. And given the same power and muscle, the cyclist able to turn the pedals faster will always be the winner.

### **High speed, low weight.**

The fact remains that more power alone – that is higher torque – is not sufficient to be a winner. And so the BMW M3 outperforms competitors focusing on the torque concept alone, wherever those models require a massively reinforced and, accordingly, heavy drivetrain to convey their extremely high level of torque, since this extra weight and mass must first be accelerated and propelled to a higher speed. The high engine speed concept, on the other hand, enables the engineer to opt for a much lighter drivetrain and choose a far shorter transmission ratio.

The other side of the coin is that the M high-speed engine concept is extremely demanding in technological terms: While the former straight-six was still limited electronically to maximum engine speed of 8,000 rpm, the new eight-cylinder exceeds this mark by far, revving all the way to 8,300 rpm. This is indeed the fastest-revving V8 power unit in the world built in numbers going beyond a small model series.

Given this kind of power and such unique technology, the engine of the new BMW M3 shifts the limits of technology in series engine production to a much higher level than before – quite simply because the higher the speed of an engine, the closer you come to the highest limit physically achievable. At a speed of 8,000 rpm, each of the eight pistons covers a distance of 20 metres or almost 66 feet per second – piston speed found until recently only in the exclusive world of motorsport. The conventional wisdom so far was indeed that this kind of speed and the loads exerted on the materials in the process were simply too much for series construction.

### **Targets in the design and construction process: compact, stiff, light.**

In developing BMW's new eight-cylinder power unit, the engineers and other specialists sought to reduce all moving masses to an absolute minimum, focusing above all on the crank and valve drive in their search to ensure minimum rotating and moving masses. Precisely this is why they decided to combine two rows of four cylinders at a V angle of 90° and an off-centre arrangement of 17 millimetres or 0.67" to make the entire power unit extremely compact and efficient.

The decision to choose a 90° angle was taken on account of the efficient compensation of mass forces provided by this geometry, serving to minimise vibrations and maximise motoring comfort. By and large, therefore, this specific geometry offers the optimum solution to the conflict of interests resulting from maximum smoothness free of vibrations, on the one hand, and maximum stiffness of all relevant components, on the other.

### **Engine block from BMW's Formula 1 foundry.**

The engine block featured on the new BMW M3 comes from BMW's light-alloy foundry in Landshut near Munich, which also builds the engine block for BMW's Formula 1 racing cars. The cylinder crankcase is made at the foundry in a low-pressure die-casting process from an over-eutectic aluminium-silicon alloy, with at least 17 per cent silicon. The cylinder liners, in turn, are formed by exposing the hard silicon crystals, the iron-coated pistons running directly in these uncoated honed cylinder bores and thus not requiring any additional lining. Cylinder stroke is 75.2 millimetres or 2.96", cylinder bore 92 millimetres or 3.62", adding up to provide overall capacity of 3,999 cc.

Since high engine speeds, high compression forces and high temperatures exert extreme loads on the crankcase, the crankcase is very compact in its design and dimensions and built as a very stiff bedplate structure, a concept which has already proven its qualities in motorsport. Made of die-cast aluminium, the bedplate features grey-cast-iron inlays ensuring very precise support of the crankshaft. In particular, this structure keeps main bearing play throughout the entire range of operating temperatures within close limits, the grey-cast-iron inlays reducing thermal elongation of the aluminium housing. As a result, oil flow remains almost unchanged at all times. And to form a positive engagement with the aluminium frame, the inlays have open cut-outs integrating them directly in the frame.

With the distance between cylinders measuring only 98 millimetres or 3.86", the crankshaft made of forged, high-strength steel is relatively short, making it very stiff in terms of flexural and torsional strength and reducing the weight of the crankshaft to just 20 kg or 44 lb. Running in five bearings, the crankshaft has a main bearing measuring 60 millimetres or 2.36" in diameter, with bearing width of 28.2 millimetres or 1.11". In each case two connecting rods act on one of the four crankpins offset from one another by 90°.

### **Lightweight construction specifically on all moving masses.**

The weight-optimised box-type pistons are cast out of a high temperature-proof aluminium alloy and coated with iron. This reduces their weight to a mere 481.7 grams including the piston pins and rings. Compression height is 27.4 millimetres, with a compression ratio of 12.0 : 1.

The pistons are cooled by oil spray jets connected to the main oil pipe. Measuring 140.7 millimetres or 5.54" in length, the cracked trapezoidal connecting rods are made of a high-strength steel-magnesium alloy. Including the bearing shells, each connecting rod weighs just 623 grams, which significantly reduces the oscillating masses.

The single-piece aluminium cylinder heads feature four valves per cylinder in characteristic BMW style. The valves weighing 42 grams each are activated by ball-shaped cup tappets with hydraulic valve play compensation. Tappet diameter is only 28 millimetres or 1.10", while the intake and exhaust valves measure 35 and respectively 30.5 millimetres (1.38 and 1.20") in diameter. Measuring only 5 millimetres or 0.20" across, the valve shaft has hardly any influence on flow conditions in the intake manifold, while the hydraulic valve play compensation rules out any change in valve play, ensuring lasting reliability and at the same time reducing the cost of maintenance.

### **The engine always keeps a cool – cylinder – head.**

Compared with conventional systems, the cross-flow cooling concept featured on the new V8 power unit significantly reduces pressure losses in the cooling process, spreading out temperatures smoothly and consistently throughout the cylinder head and thus reducing temperature peaks at all critical points. To ensure a perfect flow of cooling around each cylinder, the coolant flows from the crankcase via the exhaust side crosswise through the cylinder head and the collector rail on the intake side to the thermostat and, respectively, to the radiator.

### **Double-VANOS – but with low instead of high pressure.**

Focusing on the engine concept, the engineers at BMW M sought from the start to increase engine output through an optimum charge cycle at high engine speeds. Quite simply, this is because reduced charged cycle losses offer not only more power, but also an improved torque curve and optimum engine response as well as a further reduction of fuel consumption and lower emissions. And precisely these are the benefits offered by variable double-VANOS camshaft control introduced in the BMW M3 for the first time worldwide back in 1995.

With its extremely short adjustment times, double-VANOS now also perfects the cylinder charge cycle in the eight-cylinder power unit of the new BMW M3. Under low loads and at low engine speeds, for example, double-VANOS ensures a higher valve overlap and, as a result, better internal recirculation of exhaust gasses. This, in turn, reduces charge cycle losses and helps to minimise fuel consumption.

The level of power delivered by the engine depends on the position of the gas pedal and engine speed. So double-VANOS adjusts the precision and angle spread on the camshafts infinitely to these two parameters with precise management by a control map. Unlike the ten-cylinder power unit featured on the BMW M5 and BMW M6, the eight-cylinder uses a double (and not a single) chain to connect the crankshaft and sprocket. The sprocket, in turn, is connected to the camshaft by a step motor/actuator, and not by a helical gearing.

The advantage is that the low-pressure M double-VANOS developed for the eight-cylinder is able, unlike the high-pressure VANOS featured on the V10, to run with regular engine oil pressure acting on the step motor. In other words, there is no need for a separate high-pressure system of pipes to turn the crankshaft versus the sprocket in a relative motion at maximum speed and with utmost precision. This means that the angle on the intake camshaft may be varied by up to 58°, the angle on the exhaust camshaft by up to 48°. Maximum angle adjustment speed, in turn, is 360° per second crank angle, low-pressure adjustment thus ensuring very short adjustment times and providing the optimum adjustment angle synchronised to ignition timing and injection volume as a function of load and engine speed.

### **Reliable oil supply even under extremely dynamic conditions.**

The high standard of driving dynamics offered by the BMW M3 obviously calls for a sophisticated supply of oil to and within the engine. Indeed, the engine oil supply is conceived for longitudinal and lateral acceleration of up to 1.4 g – far more than the forces acting on a passenger's body when taking off and landing in a jet aircraft.

The eight-cylinder is reliably supplied with lubricant in all driving situations by two volume flow-controlled pendulum shift cell pumps consistently providing exactly the right amount of oil required by the engine. This is ensured by a change in eccentricity (off-centre arrangement) of the inner rotor in the pump versus the pump housing as a function of oil pressure in the main oil duct.

In consideration of the physical forces and loads encountered in an extremely dynamic driving situation, it is conceivable that when the driver applies the brakes particularly hard, for example, the supply of oil to the oil sump serving as an interim storage reservoir would not be sufficient, particularly as the oil sump is positioned behind the front axle subframe for reasons of space. So if the worst came to the worst, lubrication would be interrupted completely. This is however prevented by the concept of "optimum-dynamic wet sump lubrication", a system with two oil sumps: a small oil sump in front of the front axle subframe and a large oil sump behind the first one. A separate recirculation pump draws oil from the small oil sump at the front under all conditions and feeds the oil to the larger sump at the rear. The larger sump, in turn, is carefully sealed off in order to avoid any splash losses and the formation of foam.

The new eight-cylinder power unit from BMW M also comes with electronic oil level control determining the level of oil by means of a sensor fitted in the oil sump. The data thus measured is transmitted by a serial databus to the engine management evaluating this data by means of various algorithms. The value thus obtained, corrected by the car's lateral and longitudinal acceleration, is then presented to the driver in the instrument cluster.

### **Eight individual throttle butterflies with electronic management.**

In motorsport this is standard technology, in “regular” cars it is quite rare – the use of a separate, individual throttle butterfly for each cylinder.

But precisely this mechanically very sophisticated system is unsurpassed in giving the engine a spontaneous response and supreme performance.

And precisely that is what counts in a BMW M Car.

The power unit of the BMW M3 so closely related to motorsport comes with eight individual throttle butterflies, four butterflies on each row of cylinders being driven by one actuator in an electronically controlled process.

To provide this precise electronic management, the position of the gas pedal is scanned by a touch-free hall potentiometer 200 times a second and evaluated immediately, the engine management registering any change in the position of the pedal and adjusting the individual throttle butterflies accordingly via the two actuators in an instantaneous, split-second process.

As a result, it takes the throttle butterflies only 120 milliseconds to reach their maximum opening point – about as long as a routined driver needs to press down the gas pedal. The result, first, is a sensitive and smooth response of the engine at low engine speeds and, second, an immediate, direct reaction of the car whenever the driver calls up more power from the engine.

### **Flow-optimised air intake.**

To give the engine an instantaneous, immediate response, the air volume on the intake side of the throttle butterfly must be reduced to an absolute minimum. The problem in this case, however, is the large intake cross-section and air collector volume required by a high-performance power unit of this calibre. So to meet both of these requirements, the throttle butterflies in the intake manifolds are positioned right in front of the intake valves.

From front to rear, the entire flow of intake air in the new eight-cylinder power unit does not require the usual hot-film air mass flow meter with its obligatory sensors. Instead of determining engine load by means of such elaborate sensors, therefore, which would also create disadvantages in air guidance due to the geometry of the components involved, the V8 power unit of the new BMW M3 uses the engine control unit to perform this function. To do this, the system determines engine load under current driving conditions by taking the position of the throttle butterfly and idle adjuster, the position of the VANOS control unit, engine speed, air temperature and air pressure into account. This, in turn, gives the engineers at BMW M GmbH new freedom in the configuration and optimisation of the engine air intake process. And at the same time this management concept operates with maximum reliability.

The length and diameter of the eight intake funnels also helps to ensure an optimum charge effect in the oscillating tube. Like the single-piece, extra-large air collector, the funnels are made of a light composite material with a 30 per cent share of glass fibre. The air filter cartridge in the air collector, in turn, uses the maximum filter area possible, the air collector being supplied with air by an extra-large intake air silencer with three intake air openings.

### **Innovative exhaust system.**

Though its design and configuration, the exhaust system also serves to optimise the cylinder charge cycle. To give the eight-cylinder power unit optimum power and torque behaviour, the focus is on keeping counter-pressure as low as possible, which is why exhaust gas flows through two chambers into the rear-end silencer.

The development engineers have likewise given their full attention to consistent lightweight engineering also in developing the exhaust. To achieve these and other targets, the dimensions of the exhaust manifold, the entire exhaust system, as well as all suspension and fastening elements were calculated by means of the CATIA CAD computer system, the 3D data obtained in the process being used consistently also in production and quality assurance.

### **High-thrust innovation for ultra-thin pipes.**

BMW M GmbH's particular innovative strength in engine construction is also borne out by the production methods used. Indeed, one example dates back all the way to 1992, when BMW M GmbH became the first company to use the inner high-pressure moulding process for the then BMW M3 – and since then this process has been consistently refined.

Inner high-pressure moulding serves to shape the seamless stainless-steel exhaust pipes from inside under a pressure of up to 800 bar. The result is pipes with extremely thin walls between 0.65 and 1.0 millimetres (0.0256 and 0.0394"). Clearly, this helps to optimise both the weight of the exhaust system and the response of the catalytic converters.

At the same time this sophisticated technology allows moulding and shaping processes previously not conceivable, as well as even better geometric tolerances. And since all primary and secondary pipes are made of one single piece despite their complex shape and dimensions, many of the former connectors and welding seams are no longer required. Similarly, there are no folding points or tight bends changing the cross-section of the pipes. Instead, the pipes retain their maximum cross-section at all points, minimising any flow resistance in the process.

### **Exceptionally clean and audibly dynamic.**

Generally, only racing engines feature a fan-type exhaust manifold leading out of the cylinders. But it almost goes without saying that the new V8 also boasts this technology, the two 4-in-1 fan manifolds made of stainless-steel optimised for consistent length and diameter in elaborate computer processes capitalising on the gas-dynamic configuration of the entire system.

The two catalytic converters – one in each exhaust pipe – are positioned close to the engine. These primary catalysts quickly reach their optimum operating temperature since the thin walls of the exhaust manifolds minimise any thermal inertia of the material while warming up, thus ensuring a very fast response after starting cold.

Two particular features of the catalytic converters are their low pressure loss and the high standard of mechanical strength.

Two additional tri-metal-coated catalytic converters then come further downstream, integrated in the underfloor of the car. Interacting with one another, the four catalysts clean the exhaust gases very effectively. Hence, BMW M's new V8 power unit fulfils all the requirements of the European EU4 standard and the US LEV 2 classification.

Noise emissions are likewise exceptionally low. Apart from the two interim silencers, particularly the single-piece rear muffler in crosswise arrangement with its very large volume of 35 litres serves to reduce the noise level.

The new V8 power unit nevertheless boasts an exceptional sound and audibly sporting character once again typical of BMW M and at the same time offering a unique touch of racing performance for all senses.

### **Brake Energy Regeneration for greater efficiency and dynamic performance.**

Brake Energy Regeneration also serves on the new V8 power unit in the BMW M3 to enhance all-round drivetrain efficiency to an even higher level, concentrating the generation of electrical energy for the car's on-board network on the engine's overrun mode and application of the brakes.

This highly efficient energy management related to actual driving conditions is made possible by intelligent control of the alternator. The two advantages offered by Brake Energy Regeneration in practice are that, first, specific, on-demand generation of electrical energy serves to reduce fuel consumption, while, second, the driver benefits directly from the disconnection of the

alternator when the engine is running under load: With the generation of electric power being cut off when running under load, more drive power is available to accelerate the car, meaning not only greater all-round economy, but also extra driving pleasure.

With the number of charge cycles increasing as a result of such intelligent power generation, BMW combines this Brake Energy Regeneration technology with modern AGM (absorbant glass mat) batteries able to withstand a much greater load than conventional lead acid batteries. In an AGM battery, the acid is held in micro-glass-fibre mats between the individual layers of lead, the battery thus remaining able to store energy over a long period even when charged and discharged regularly.

### **Even greater performance: the new engine management system.**

The MSS60 engine management system is the central “brain” responsible for the car’s excellent performance and emission data. The system is an evolutionary development of the engine control unit already featured in BMW M GmbH’s V10 drivetrain, raising the standard of control functions to an even higher level: While the control unit on the V10 engine, featuring more than 1,000 individual components, already offers a level of package density quite unparalleled by the competition, the number of components in the MSS60 control units is even higher.

Benefiting from this highly sophisticated concept, MSS60 coordinates all functions of the engine with the various other control units on the car. The three 32-bit processors are in a position to handle more than 200 million individual operations a second, taking, for example, more than 50 incoming signals to calculate the optimum ignition timing individually for each cylinder and operating cycle, the ideal cylinder charge, the injection volume and injection timing. At the same time, the MSS60 control unit calculates and sets the optimum camshaft angle, just as it sets the positions of the eight individual throttle butterflies.

Electronic throttle butterfly control measures loads and forces for optimum management, measuring the driver’s commands by means of the potentiometer on the gas pedal and converting this signal into the appropriate response. The Drive Power Manager then adjusts this signal by adding additional input from ancillary units such as the climate compressor or the alternator. Signals from the idle speed control, exhaust management and knock control are also coordinated and compared with the maximum and minimum force signals obtained from DSC Dynamic Stability Control and EDFC Engine Drag Force Control. The final signal obtained in this way is then sent to throttle butterfly management, taking the current ignition angle into account.

### **Engine management with a wide range of additional functions.**

The MSS60 control unit is more than “just” a conventional engine management system in the direct sense of the word. With its hardware, software and functions having been developed completely by BMW M GmbH, MSS60 is able to support numerous M-specific functions on the clutch, transmission, steering and brakes.

Precisely this is why the driver of the new BMW M3 is also able, simply by pressing the Power Button on the selector lever cover, to activate an even more sporting and dynamic driving program. This provides an even more progressive control map for accelerator travel acting on the throttle butterfly opening, with the dynamic transition functions on electronic engine management showing an even more direct, spontaneous response.

As soon as the driver starts the engine, the control system automatically switches to the more comfortable of the two programs. The driver nevertheless has the option to preconfigure and activate the change in programs in the MDrive control unit, which also offers another, extra-sporting and dynamic program.

Last but certainly not least, engine management also performs a wide range of on-board diagnostic functions using various diagnostic routines for servicing at the workshop, just as it offers other sophisticated functions and masterminds various peripheral units around the engine.

### **The highlight in engine management: ion flow technology.**

One of the highlights of the engine control unit is ion flow technology serving to determine the risk of the engine knocking as well as misfiring and miscombustion. This significant innovation from BMW was introduced as a standard feature for the first time on the V10 power unit in the BMW M5. Now, in its latest configuration, ion flow technology no longer requires an ion flow satellite, whose function has been integrated in the ignition coil.

“Knocking” is undesired selfignition of fuel in the cylinder. Engines without knock control have a lower compression ratio and their ignition point comes later (retarded ignition), since the engine would suffer from going beyond the knock limit. However, this “safety margin” costs fuel, engine power, and torque.

By contrast, active knock control allows the engine to run with optimum ignition timing and protects the engine from damage. It also offers the highest standard of efficiency.

With conventional anti-knock control sensors measuring body sound are fitted outside on the cylinder. But the ability of such sensors to detect knocking in the combustion process decreases with increasing engine speed and a growing number of cylinders – and particularly such accuracy and reliability is essential on a fast-revving eight-cylinder in order to optimise combustion quality in the cylinders and, as a result, the service life of the battery and the exhaust emissions. Hence, ion flow technology measures the risk of knocking exactly directly where this phenomenon occurs – within the combustion chamber.

In this process the system uses a physical phenomenon resulting from the high temperatures of up to 2,500 °C encountered in the combustion chamber during the combustion process. These high temperatures and the chemical reactions occurring during combustion serve to partially ionise the fuel/air mixture inside the combustion chamber, this gas becoming electrically conductive particularly along the flame front due to the generation of ions resulting from the separation and deposition of electrons (ionisation). The so-called ion flow generated in this way is measured between the electrodes by an electronic measurement unit electrically isolated from the cylinder head and interacting with engine management. This unit is integrated in the ignition coil and interacts with the spark plug electrode to which a specific direct current is applied to generate the signal required. This signal, in turn, depends on the degree of gas ionisation between the electrodes.

Measurement of ion flow thus provides information on the combustion process directly where combustion takes place. The electronic “brain” integrated in each ignition coil receives the signal from the spark plugs on all of the eight cylinders, reinforces the signal and conveys this data to the engine management unit. Analysing this incoming data, engine management then controls the cylinders as required, for example by adjusting the point of ignition ideally to the combustion process for the purpose of efficient knock management.

Using an innovative semi-conductor circuit to measure the control voltage required and reinforcing/multiplying the incoming signals in a variable process, the engineers at BMW M have raised ion flow technology to an even higher level in an important new step. And now this circuit control is integrated directly in the ignition coil together with the terminal stage of the ignition for the first time in the new BMW M3, detecting the ion flow signal even more directly within the combustion chamber, then reinforcing the signal and breaking it down into individual elements for even finer measurement.

### **Spark plugs taking on additional control functions.**

This technology thus uses the spark plug in each cylinder to sense and, if necessary, control the risk of knocking. At the same time it supervises the ignition and recognises any misfiring. In other words, the spark plug serves as a calculator for the ignition and as a sensor monitoring the entire combustion process, distinguishing between misfiring and mis-combustion. And precisely this dual function performed by the spark plug facilitates diagnostic processes in the maintenance and service of the car.

# Specifications.

| Feature/entity                      | 2 <sup>nd</sup> engine of the M engine family                                                                    |           |
|-------------------------------------|------------------------------------------------------------------------------------------------------------------|-----------|
| Fuel                                | Otto RON 98 (95)                                                                                                 |           |
| Max output                          | hp (kW)                                                                                                          | 420 (309) |
| at                                  | min <sup>-1</sup>                                                                                                | 8,300     |
| Max torque                          | Nm                                                                                                               | 400       |
| at                                  | min <sup>-1</sup>                                                                                                | 3,900     |
| Max engine speed                    | min <sup>-1</sup>                                                                                                | 8,400     |
| Stroke                              | mm                                                                                                               | 75.2      |
| Bore                                | mm                                                                                                               | 92.0      |
| Displacement                        | cm <sup>3</sup>                                                                                                  | 3,999     |
| Distance between cylinders          | mm                                                                                                               | 98        |
| Cylinder arrangement                | 8-cylinder V-engine                                                                                              |           |
| Valve plate diameter, intake        | mm                                                                                                               | 35.0      |
| Valve plate diameter, outlet        | mm                                                                                                               | 30.5      |
| Compression ratio                   | 12.0                                                                                                             |           |
| Fuel injection                      | Intake pipe fuel injection                                                                                       |           |
| Fuel injection pressure             | bar                                                                                                              | 3–6       |
| Average combustion chamber pressure | bar                                                                                                              | 12.6      |
| Maximum combustion chamber pressure | bar                                                                                                              | 100       |
| Engine weight to BMW standard       | kg                                                                                                               | 202       |
| Output per litre                    | hp/L                                                                                                             | 105       |
| Power-to-weight ratio               | kg/kW                                                                                                            | 0.65      |
| Crankcase                           | Aluminium                                                                                                        |           |
| Valvetrain                          | Infinite camshaft adjustment<br>and hydraulic valve clearance adjustment<br>for intake and outlet (double VANOS) |           |

# Output and Torque Diagram.

