Petrol Engines in the BMW Group/ PSA Peugeot Citroën Cooperation.

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1. Successful Cooperation. (Short Story)

In a cooperation the BMW Group and PSA Peugeot Citroën have joined forces in developing a new family of gasoline engines. These power units featuring the most advanced engine technology will be seen in future in models from Peugeot, Citroën, and future versions of MINI.

The new engine family is a significant move for both partners in fulfilling the self-commitment assumed by European car makers within their European Association (ACEA), promising to reduce fleet consumption and, as a result, CO_2 emissions to 140 g/km by the year 2008. The engines developed within the Project are able for the first time to elegantly solve the conflict of interests between demanding engine technologies and cost pressure in the small and compact car segment. The Project confirms that it is by all means economically possible to build fuel-efficient power units with innovative technologies also in the lower car segments.

New segment leader making its debut.
In developing the concept for the new family of engines, the Project Team has opted for two variants in technology. Without making the slightest concession in terms of performance and refinement, the normal-aspiration power unit with fully variable valve drive as well as the turbocharged direct-injection engine will set a new standard in their displacement category in terms of both technology, dynamism, economy, and their overall package.

The engines created by this new joint venture come with numerous features carried over from BMW's latest generation of straight-six gasoline power units. Examples are fully variable valve drive, the volume flow-controlled oil pump, single-belt drive of the engine's ancillaries, individual coils, and composite camshafts.

At the same time a whole series of innovative solutions is being implemented for the first time in this class. These include direct gasoline injection for even more power, the twin-scroll exhaust gas turbocharger, the on-demand mechanical coolant pump, and the new tightening unit for the poly-V-drive belt.

Both technology variants resting on a strong foundation.
The engine block as such meets all the demands and requirements of both partners in the joint venture. In terms of stiffness and acoustic features, the aluminium crankcase with its bedplate construction is absolutely unique and unparalleled. Optimisation of the crankdrive bearings and conversion of all mechanical valve drive transmission units to anti-friction rollers serve to provide the lowest level of frictional losses in this class.

Integration of numerous functions and ancillaries in the cylinder head as well as the crankcase make many of the usual add-on components superfluous, improve the engines' acoustics, and reduce both engine weight and dimensions. Single-belt drive of the engine units also helps to make all dimensions very compact.

Controlled volume flow for even greater fuel economy.
On-demand oil supply delivers exactly the amount of engine oil required, no more and more and no less. Accordingly, the oil pump controlled as a function of volume flow reduces fuel consumption by up to 1 per cent. Together with the oil/water heat exchanger, the on-demand water pump serves to further reduce fuel consumption and emissions. This again saves drive power and warms up the engine more quickly, coolant only being circulated when the engine has reached its operating temperature.

Normal-aspiration power unit with fully variable valve drive:
The benchmark in fuel economy and concept harmony.
Featuring innovative valve drive and 1.6 litres displacement, the normal-aspiration engine develops maximum output of 85 kW/115 bhp at 5,700 rpm. Engine torque reaches an impressive 140 Nm (103 lb-ft) at just 2,000 rpm, peaking at 160 Nm (118 lb-ft) at 4,250 rpm.

Without requiring a throttle butterfly, fully variable valve management controls engine output by infinite adjustment of valve lift and the intake valve opening times. This loss-free load management again reduces fuel consumption, cuts back exhaust emissions, and ensures superior engine response combined with enhanced motoring refinement. Apart from valve management, the overall control concept comprising a fully controlled oil pump and on-demand water pump as well as the optimisation of frictional losses makes the normal-aspiration engine the most efficient power unit in its entire segment.

High-performance turbocharged engine with direct gasoline injection.

Displacing 1.6 litres, the direct-injection high-performance gasoline engine with exhaust gas turbocharger and intercooler develops maximum output of 105 kW/143 bhp from 1.6 litres engine capacity at 5,500 rpm and maximum torque of 240 Nm/177 lb-ft from 1,400 rpm maintained consistently all the way to 4,000 rpm.

The cylinder head comes with conventional valve drive featuring two overhead camshafts, roller-type drag arms, and hydraulic valve play compensation. Fully variable adjustment of the intake camshaft ensures optimum output and torque on low fuel and clean emissions.

This is the first engine in its class to feature a twin-scroll turbocharger separating the ducts of two cylinders at a time from one another in the exhaust gas manifold and turbocharger. This serves to build up the charge effect from a low speed of approximately 1,400 rpm, torque developing virtually just as fast as in a compressor engine.

Direct gasoline injection with common-rail technology, together with the turbocharger, is the main contributing factor ensuring the high level of engine output, superior fuel economy, outstanding refinement and exemplary emission management. The high-pressure valves inject fuel from the side directly into the combustion chamber at a pressure of up to 120 bar, ensuring a homogeneous fuel mixture within the chamber ($\lambda = 1.0$).

2. Successful Cooperation. (Long Story)

Joining forces in the joint venture, the BMW Group and PSA Peugeot Citroën have developed a new family of small petrol engines. These power units featuring the most advanced engine technologies are intended for use in Peugeot and Citroën models as well as future versions of MINI cars.

The new engine family is a significant step for both partners in maintaining the self-commitment assumed by European car makers within the ACEA Association of Car Manufacturers, promising to reduce fleet consumption and, as a result, CO_2 emissions to 140 g/km by the year 2008.

For the first time the project is able to elegantly solve the conflict of interests between demanding engine technologies, on the one hand, and the usual cost pressure in the small and compact car segment, on the other.

Advantageous for both sides.
Both partners have contributed their know-how in technology and their experience in large-volume production to the project, and now both parties benefit in the same way. In other words, this is a win-win situation to which each partner has contributed all its know-how and expertise. The project proves that fuel-efficient power units with innovative engine technology may also be built economically in the lower car segments.

Each manufacturer has contributed special competences and skills both in the area of engine development and in using the world's best and most advanced production methods.

PSA Peugeot Citroën will be building the new engines at its plant in Douvrin, France. Planned capacity in production is up to 2,500 units a day.

2.1 Curtains Open for a New Engine Family.

Developing the concept for the new engine family, the project team has opted for two technology variants. The derivatives of these two very different variants will define a new standard in their class in technological terms and in terms of their dynamism, economy, and long running life.

The engines are characterised by the exchange of know-how between engine development specialists on both sides, since, in developing and implementing the engine concept, the same attention was given to both BMW's principle of efficient dynamics and the PSA Peugeot Citroën principle of minimum fuel consumption.

These new engines will offer exceptional power and a muscular torque curve in their class throughout a very wide useful speed range, at the same time reducing both fuel consumption and weight to a minimum.

The engines developed in this joint venture incorporate numerous features carried over from BMW's trendsetting power units, for example from the latest generation of straight-six petrol engines.

Some examples:
- Fully variable valve drive
- Flow-controlled oil pump
- Single-belt drive of all ancillary units
- Individual ignition coils
- Composite camshafts
- Weight-optimised roller-type drag arms
- Cylinder head produced by lost-foam casting

The following new concepts and solutions have also been implemented in the project:
- Direct gasoline injection for extra power and performance
- Twin-scroll exhaust gas turbocharger
- On-demand water pump
- Poly-V-belt with built-in tensioner
- Lightweight concept (including an aluminium crankcase, intake manifold and cylinder head cover made of a special plastic material)

Optimised fuel economy plus remarkable power.
The first two products in this joint venture will feature a 1.6-litre petrol engine with fully variable valve drive, maximum output of 85 kW/115 bhp, and maximum torque of 160 Nm/118 lb-ft.

One of the most significant objectives in developing this normal-aspiration power unit was to achieve a muscular torque curve at the highest possible level combined with best-in-class fuel economy and emission management on low weight.

High-performance turbocharged power unit with direct fuel injection.
The second engine in the range is a direct-injection high-performance gasoline engine with an exhaust gas turbocharger. Displacement is 1.6 litres, maximum output 105 kW/143 bhp, and maximum torque a significant 240 Nm/177 lb-ft.

Direct petrol injection in this engine serves in particular to combine high specific output with exemplary fuel economy. Further advantages are a high standard of refinement and outstanding emission management.

The compact four-cylinder will be featured both in sports-oriented models as well as PSA Peugeot Citroën cars in the lower segments of the market, where it will be replacing large-volume normal-aspiration power units. The reason for this strategy is that small, turbocharged engines with a high level of power density offer a significant advantage in fuel economy over normal-aspiration engines of larger capacity.

These two engines are the first members in a complete family of power units which will ultimately range in output from 55 kW/75 bhp all the way to 125 kW/170 bhp.

2.2 A New Standard Ensured by Successful Implementation of Innovative Solutions.

From the start, the specifications defined for the project made clear demands of the new engine family and the standards it was to meet:

Without making any concessions in terms of power, performance, and motoring refinement, the engines have moved up the benchmark once again inter alia in terms of specific fuel consumption, their torque curve, anti-friction smoothness, and in terms of the overall engine package, thus setting new standards in every respect.

This success is attributable in part to numerous innovations and solutions adding up to make the new engine family a new benchmark in its class.

- **Fully variable valve drive.**
  Without requiring a throttle butterfly, fully variable valve drive controls engine output by infinite adjustment of valve stroke and intake valve opening times. This loss-free load management reduces fuel consumption, cuts back emissions, and ensures better engine response with an enhanced standard of motoring refinement.

- **Twin-scroll turbocharger.**
  On the twin-scroll turbocharger the ducts of each set of two cylinders are separated from one another in the exhaust gas manifold and the turbocharger. This serves to build up a charge effect from just about 1,400 rpm, with torque being generated just as quickly as on a compressor engine.

- **Direct gasoline injection.**
  High-pressure gasoline injection (120 bar), together with advanced turbocharger technology, is the main reason of the high level of specific output, low fuel consumption and the exemplary emission management ensured by the turbocharged engine.

- **Fully controlled oil pump.**
  On-demand oil supply delivers only as much oil as is actually required. Depending on operating conditions, the volume flow-controlled oil pump requires up to 1.25 kW less drive energy and reduces fuel consumption by up to 1 per cent.

- **On-demand water pump.**
  Driven by a friction gear, the water pump is not activated until the engine has reached its normal operating temperature, thus enabling the engine to warm up more quickly. This serves both to reduce fuel consumption and improve emissions at the same time.

- **Aluminium crankcase in bedplate design.**
  Offering best-in-class stiffness, excellent noise management, and the integration of numerous functions and ancillary units, the aluminium crankcase is quite unique in every respect.

- **Optimum friction management on both the crankdrive and valve drive.**
  Optimum configuration of the bearings and the conversion of all mechanical transmission elements in the valve drive to roll friction serves to minimise friction losses to the lowest level in this engine category.

- **Optimum package dimensions.**
  Integration of numerous functions and ancillary units into the cylinder head and crankcase avoids the use of conventional add-on systems, improves the engine's noise management, and reduces both weight and dimensions. Single-belt drive of engine components and modules also makes a significant contribution to the compact design and dimensions of the engine.

2.3 The Engine Block: Setting the Foundation for Two Very Different Variants in Technology.

A strong foundation is obviously the basic prerequisite for a successful engine concept. Hence, the engine block is conceived and designed to meet the requirements of both technology variants in every respect and without the slightest concession.

For production reasons, the geometrical dimensions of the new engine family are to a large extent identical in all derivatives of the engine. Inter alia, this includes the distance between cylinders of 84 mm (3.31´), the bore of 77 mm (3.03´), and the height of the crankcase. The two 1.6-litre power units also share the same stroke of 85.5 mm (3.36´) and a capacity of 1,598 cc.

Innovative crankcase with outstanding qualities.
The two-piece bedplate construction of the aluminium crankcase made up of the cylinder block and the bearing housing is an elaborate achievement in technology carried over from motorsport. Together with its reinforcement ribs, this strong structure gives the engine an extremely high level of stiffness and sets new standards in this class of motoring.

This special structure is also the reason for the engine's excellent acoustics and noise control quite comparable to the features of a much heavier grey-cast iron engine block and indeed marking the very best among engines with an aluminium block. The aluminium bedplate housing the crankshaft is fitted to and bolted on the cylinder block. In the turbocharged engine the bedplate incorporates sintered steel inserts for the crankshaft bearing taking the higher forces acting on the engine into account. A further sign of distinction is that the cast-in grey-cast iron liners end flush at the top with the cylinder head gasket (open liner design).

The crankcase has open cross-sections at the top reducing any pump losses caused by the movement of the crankdrive.

Integrated functions for enhanced quality.
The chain housing integrated in the engine block offers the advantage of not requiring any additional seals, with the complete chain drive entering the assembly process as a partly pre-assembled module.

The mounts cast into the engine block for ancillaries such as the alternator and a/c compressor also reduce the complexity of the entire unit, at the same time cutting back weight and shortening the period required for assembly. And last but certainly not least, this kind of integration improves sound management and provides even stiffer, firmer fastening points for the ancillary units.

Low-friction crankdrive reducing fuel consumption.
Since, given the right configuration, the combination of a four-cylinder power unit and front-wheel drive will not cause any noise problems, the project team has chosen a design concept without balance shafts, which would only have meant unnecessary weight.

In the development process the reduction of frictional forces to a level never seen before in this class was given very high priority for reasons of fuel economy alone. With the crankshaft contributing significantly to frictional forces, the decision was taken to use relatively small bearing journals measuring just 45 mm or 1.77´´ in diameter. To minimise oil consumption and, as a result, frictional losses, the bearing shells on all engines have been split up into five categories in order to limit bearing play in the main crankshaft bearing.

A further highlight of the engine's lightweight concept is the optimisation of crankshaft weight. As a result, crankshaft stiffness decreases from rear to front, which also offers benefits in terms of vibration management.
The forged crankshaft on the turbocharged engine comes additionally with four smaller balance weights over and above the four counterweights.

Weight-optimised trapezoidal connecting rods for even greater running smoothness.
Seen from the side, the upper conrod opening in the trapezoidal connecting rods is trapezoidal in shape. The connecting rod opening is thus tapered at the top in the interest of lower weight at this decisive point. Given a mean operating speed of 18.5 m/sec, that is the speed at which the connecting rods move up and down, every gram of oscillating masses saved in this way serves to improve engine vibration.

The trapezoidal connecting rods are made in cracked technology, meaning that the lower connecting rod opening is broken at a predetermined point in the machining process.

The pistons on the turbocharged direct-injection power unit come with four valve pockets and the combustion chamber trough right in the middle in order to stratify the cylinder charge. And to reduce thermal loads, the pistons are cooled by splash oil. On the normal-aspiration power unit the pistons feature valve pockets without any further modifications or improvements.

On-demand oil supply without any loss of oil.
Equipped with a volume flow-controlled oil pump, the new power units rank unique in their class also in terms of their oil supply.

Operating as a function of oil pressure, the external gear pump driven by a chain delivers precisely the amount of oil required under all operating conditions. In other words, there is no need for a bypass feeding back excess oil or extra volume not needed. Benefitting from this optimised on-demand management without any unnecessary energy or forces, the volume flow-controlled oil pump consumes up to 160 W less drive energy than a conventional pump, reducing fuel consumption in the European driving cycle by approximately 1 per cent. And under normal driving conditions with the car in the hands of a customer, the reduction in fuel consumption is far greater, with a power saving of 1.25 kW or 1.7 bhp at 6,000 rpm.

Looking at the oil filter, the development engineers have opted in favour of a solution highly beneficial to the environment. As a result, the oil filter is not a metal cartridge difficult to recycle as special waste, but rather a paper filter insert easy to dispose of from its usual position in an easily accessible aluminium case with a plastic cover on top.

With turbocharged engines being subject to significant thermal loads and forces, an oil/water heat exchanger integrated in the oil filter housing keeps the engine oil temperature at a safe level even when running under full load. A further point is that the heat exchanger, by heating up the coolant more quickly, shortens the warming-up period and reduces both fuel consumption and exhaust emissions in the process.

The engines are filled initially with 4.2 litres of light running oil, with 3.7 litres being required when changing oil.

The cylinder head – the main sign of distinction.
The two engine variants differ primarily through the concept of the cylinder head and the fuel supply system. This explains why they share only a few common features in this area, to be specific the two camshafts, four valves per cylinder with a shaft diameter of 5 mm or 0.20˝, one valve spring on each engine and the spark plug fitted vertically in position.

The large valve angle allows optimum design of the combustion chambers combined with low overall engine height. And converting all mechanical transmission elements to anti-friction rollers (roller-type drag arms), the engineers have significantly reduced friction forces.

Integration of numerous functions and components such as the oil dipstick, the vacuum pump, the high-pressure pump, thermostat housing and intake silencer serves additionally to meet the great demands made of the engine package.

Two engine variants cast in different processes.
Two different casting processes are used in production of the cylinder head: While the cylinder head on the direct-injection power unit is manufactured in a low-pressure die-casting process, the normal-aspiration engine is made in the innovative lost-foam casting process developed for the first time to production level in a six-cylinder power unit in the light-alloy foundry at BMW's Landshut Plant.

Since the cylinder heads are made by PSA Peugeot Citroën, the BMW Group has supported PSA Peugeot Citroën in introducing this process for large-volume production by providing appropriate know-how in production technology. Both processes are particularly well-suited for perfectly rendering the elaborate internal contours together with their hollow cavities for the air ducts as well as the oil and coolant circuits.

Contrary to conventional casting technologies, lost-foam casting is a positive process helping to further reduce the weight of the engine. In this case, an identical cylinder head model made of polystyrene is covered by a ceramic layer, shaken into a bed of sand and completely surrounded by casting sand with the exception of one duct cast into the cylinder head. The fluid aluminium then runs into the casting duct during the automated casting process, completely replacing the polystyrene model and taking on the shape of the cylinder head itself.

Given the very high precision of this casting process, even filigree features such as oil ducts, reflow pipes and blow-by channels can be properly integrated within the overall module. This, in turn, helps to avoid numerous production processes formerly required in the machining phase.

Ideal package dimensions thanks to single-belt drive.
For package reasons one of the objectives in the development process was to make the engine as short and compact as possible. Hence, both the alternator and the a/c compressor are driven by only one poly-V-belt tightened by means of a single-arm torsion-spring tensioner. With the coolant pump being driven via a friction gearing, there is no need for a second belt level, which makes the engine one of the shortest four-cylinders in its class.

Intelligent thermal management with an on-demand water pump.
On-demand management of the coolant volume delivered is one of the numerous measures taken to reduce fuel consumption. A friction gear mounted on a bearing arm is positioned between the water pump gear and the pulley on the crankshaft. An electrically operated eccentric gear serves to change the position of the gear wheel, and the water pump may be switched off when starting the engine cold in order to warm up the engine more quickly.

To save drive power and expedite the warming-up process, coolant is not circulated until the engine has reached its normal operating temperature. Then, when it has reached the appropriate temperature, the engine is held steady at that point by a thermostat masterminded by the engine's electronic "brain", ensuring the most fuel-efficient coolant temperature at each respective operating point.

Service-friendly range of engines.
Ease of service and an appropriate maintenance concept were essential features in determining the engines' specifications. Depending on running conditions and the driver's style of motoring, oil service intervals will be approximately 30,000 km or 20,000 miles. The spark plugs and air filter, in turn, only have to be exchanged approximately every 60,000 km or 40,000 miles. The timing chain driving the camshafts is not only very precise and reliable, but also remains maintenance-free throughout the full running life of the engine. And automatic hydraulic valve play compensation serves last but not least to rule out any service or maintenance on the valve drive.

2.4 Naturally Aspirated Power Unit with Fully Variable Valve Drive: Best-in-Class in Every Respect.

With its compression ratio of 11:1, the naturally aspirated power unit develops maximum output of 85 kW/115 bhp at 5,700 rpm and revs up to a maximum speed of 6,500 rpm. Engine displacement of this four-cylinder is 1.6 litres, with torque reaching 140 Nm or 103 lb-ft at just 2,000 rpm and peaking at 160 Nm/118 lb-ft at 4,250 rpm. The wide useful engine speed range provided in this way offers an optimum combination of driving pleasure and fuel economy from this compact power unit.

Fully variable valve management as well as a wide range of features extending from the fully controlled oil and water pumps all the way to the optimisation of friction losses make this normal-aspiration power unit one of the most efficient engines throughout its entire segment, even including engines with direct gasoline injection.

Fully variable valve drive for enhanced fuel economy and even more dynamic performance.
Fully variable valve management applies the principle of throttle-free load control, masterminding engine power through the infinite adjustment of valve lift and the intake valve opening times. This technology based on the BMW Group's VALVETRONIC concept allows truly outstanding driving dynamics and performance on low fuel consumption.

In a conventional internal combustion engine output is controlled by means of the throttle butterfly. The engine is required to draw in fresh air particularly at part load against the resistance of the butterfly closed entirely or in part, which means a certain loss of power and efficiency as well as unnecessary fuel consumption.

The innovative valve management system used in this case controls both valve lift as well as the valve opening period and timing without requiring a throttle butterfly as a function of the gas pedal position. Almost free of losses, this control concept reduces fuel consumption, cuts back exhaust emissions, and ensures a far better engine response with greater refinement.

How this innovative valve management works.
This revolutionary engine technology is based on BMW's variable camshaft adjustment: Turning the two camshafts relative to one another, valve opening times can be infinitely adjusted for their beginning and end, but engine output can only be controlled within certain limits. Such individual, highly efficient control is now allowed by variable valve lift for infinite adjustment of both the opening cross-section and the intake valve opening periods.

In this case the camshaft no longer acts directly on the follower lever operating the valve, but rather on an intermediate lever placed in the middle of a roller forming the surface contour followed by the cam. The lower end of the lever rests on the roller running on the follower lever, while in the middle the lever rests on an eccentric shaft via a second roller.

When turning, the camshaft now moves the intermediate lever to and fro. Exactly when and where the lever exerts its effect is determined by the swivel point on the pivot lever itself. Driven by an electric motor, the eccentric shaft modifies this rotating point, thus varying valve lift infinitely from 0.2–9.5 millimetres (0.008–0.374´) as a function of the rise or "hump" on the intake cam.

The electric motor fitted directly on the cylinder head and adjusting the eccentric shaft by means of a worm gearing moves the lever in just 300 milliseconds from minimum to maximum lift. During the same period the intake camshaft is turned by up to 70°, the outlet camshaft by up to 60°.
To achieve this enormous adjustment speed, valve management is controlled by an extremely fast, high-performance 32-bit engine management computer directly networked to the engine control unit.

Potential reduction of fuel consumption by up to 20 per cent.
Depending on the route taken and traffic conditions, variable valve drive may reduce average fuel consumption by up to 20 per cent, with a saving in the EU test cycle of approximately 9 per cent. This innovative technology now making its debut in the small and compact car segment with this new naturally aspirated engine operates independently of fuel quality and the oil grade and does not require sulphur-free fuel, meaning that it is fully suited for all markets worldwide. Both the BMW Group and PSA Peugeot Citroën nevertheless advocate the ongoing improvement of fuel quality, in particular the de-sulphurisation of fuel.

Mechanical production technology of the highest standard.
This highly advanced valve management system demands the utmost in terms of production technology. The contours of the intermediate lever determining valve lift, for example, are ground down to an accuracy of 8/1,000ths of a millimetre.

The camshafts on both engines are composite structures, meaning that cam rings made of high-strength stainless steel are shrunk on to a cast shaft and subsequently machined. In the final fine-polishing process the cams are then machined to an accuracy of 1 micron (1/1,000 mm). For reasons of weight the eccentric shaft is also made in this process for the first time, likewise with tolerance levels in the micron range.

Optimised combustion process for exemplary emission management.
An electric pump delivers fuel into the plastic injection rail housing the four injection valves. The optimum injection volume is calculated by the engine control unit taking numerous parameters into account, fuel being injected into the intake duct at a pressure of approximately 5 bar.

Individual coils on each spark plug provide exactly the right ignition voltage again controlled individually by the electronic management system. An anti-knocking sensor monitors the combustion process within the combustion chambers, retarding the ignition angle where necessary. Benefitting from this highly efficient knock control, the engine is able to run on fuel grades between 91 and 98 octane.

The emission management system incorporating a ceramic catalyst and two oxygen sensors is connected directly to the exhaust manifold.

Ancillaries: everything in place.
While the engine with fully variable valve drive still has a throttle butterfly, its only purpose is to provide a failsafe and diagnostic function. Under normal running conditions, therefore, the butterfly is always open. An additional vacuum pump at the rear end of the outlet camshaft generates the underpressure required for the brake servo.

For reasons of safety the ancillaries and peripheral components in all areas exposed to impact energy in a collision are designed to absorb and destroy energy in a well-defined process in the event of an impact, before penetrating the interior of the car under any such forces.

2.5 The High-Performance Power Unit: A Turbocharged Engine with Direct Fuel Injection.

The turbocharged fuel injection power unit combines the torque curve of a diesel with the benefits of a modern reciprocating-piston engine. Maximum torque of 240 Nm or 177 lb-ft comes at just 1,400 rpm, remaining virtually unchanged all the way to 4,000 rpm. This ensures significant thrust and muscle from low engine speeds, powerful acceleration, a perfect response, and maximum driving pleasure. Together with its maximum output of 105 kW/143 bhp at 5,500 rpm, this engine guarantees sporting performance wherever you go.

Cylinder head with conventional valve drive.
Contrary to the normal-aspiration engine, the cylinder head on the turbocharged four-cylinder with conventional valve drive features two overhead, composite camshafts, friction-optimised roller-type follower levers, and hydraulic lash adjusters. Valve drive has also been optimised for weight, reflecting the engine's fast-revving performance. Precisely this is why the valve shafts measure only 5 mm or 0.20´´ in diameter, with the hollow shaft outlet valves being filled with sodium. The closing function is ensured by a valve spring building up the pressure required.

Fully variable adjustment of the intake camshaft guarantees maximum power and torque on very good fuel economy and emission management.

Direct gasoline injection for even more power.
Mounted at the rear end of the intake camshaft, the mechanically driven two-piston high-pressure pump delivers fuel to the injection valves via a stainless-steel distributor rail. These high-pressure valves inject fuel directly into the combustion chambers from the side at a pressure of up to 120 bar, in the process maintaining a homogeneous distribution of the fuel/air mixture in the combustion chambers ($\lambda = 1.0$).

At a compression ratio of 10.5:1, the turbocharged engine is compressed to a relatively high level for an internal combustion engine of this type. Precisely this is why the combustion process is monitored also in this case by anti-knock control correcting the ignition angles and charge pressure whenever required.

Elaborate twin-scroll turbocharger technology avoiding the usual turbo "lag".

For the first time in this class, the direct injection engine in the new family comes with a twin-scroll turbocharger. Featuring this technology, the ducts of each two cylinders in the exhaust manifolds and turbochargers are different from one another in their design. Reducing exhaust gas counterpressure at low engine speeds, twin-scroll charger technology capitalises on the dynamic effect of the pulsing gas columns in the exhaust manifolds. The result is additional power and thrust on even less fuel, enabling the turbocharger to boost engine output from an earlier point. This effect is clearly noticeable, with the charger building up extra power from roughly 1,400 rpm, almost completely avoiding the "turbo lag" often criticised on turbocharged engines, and generating torque almost as fast as in a compressor engine.

The flow of exhaust gas accelerates the turbine wheel to a speed of up to 220,000 rpm. And at the same time the compressor running on the same shaft compresses the fresh air fed into the system. A wastegate complete with a check valve monitors the maximum turbocharger pressure of 0.8 bar.
In addition, overpressure in the system is controlled by a dump valve activated when coasting with the intake manifold closed. To increase the charge level, the pre-compressed fresh air is cooled down in an intercooler before flowing into the combustion chamber. The intercooler itself is fitted in the car at a predetermined point meeting all the requirements of this particular configuration.

Maximum exhaust gas temperature is monitored by the electronic engine "brain" and is limited to 950 °C (1,742 °F). To prevent excessive build-up of heat in the oil- and water-cooled turbocharger after the engine has been stopped, an additional electrical water pump starts automatically as soon as the car comes to a standstill, dissipating any excess thermal energy from the system.

3. Specifications.

Four-cylinder gasoline engine with fully variable valve drive (85 kW/115 bhp).

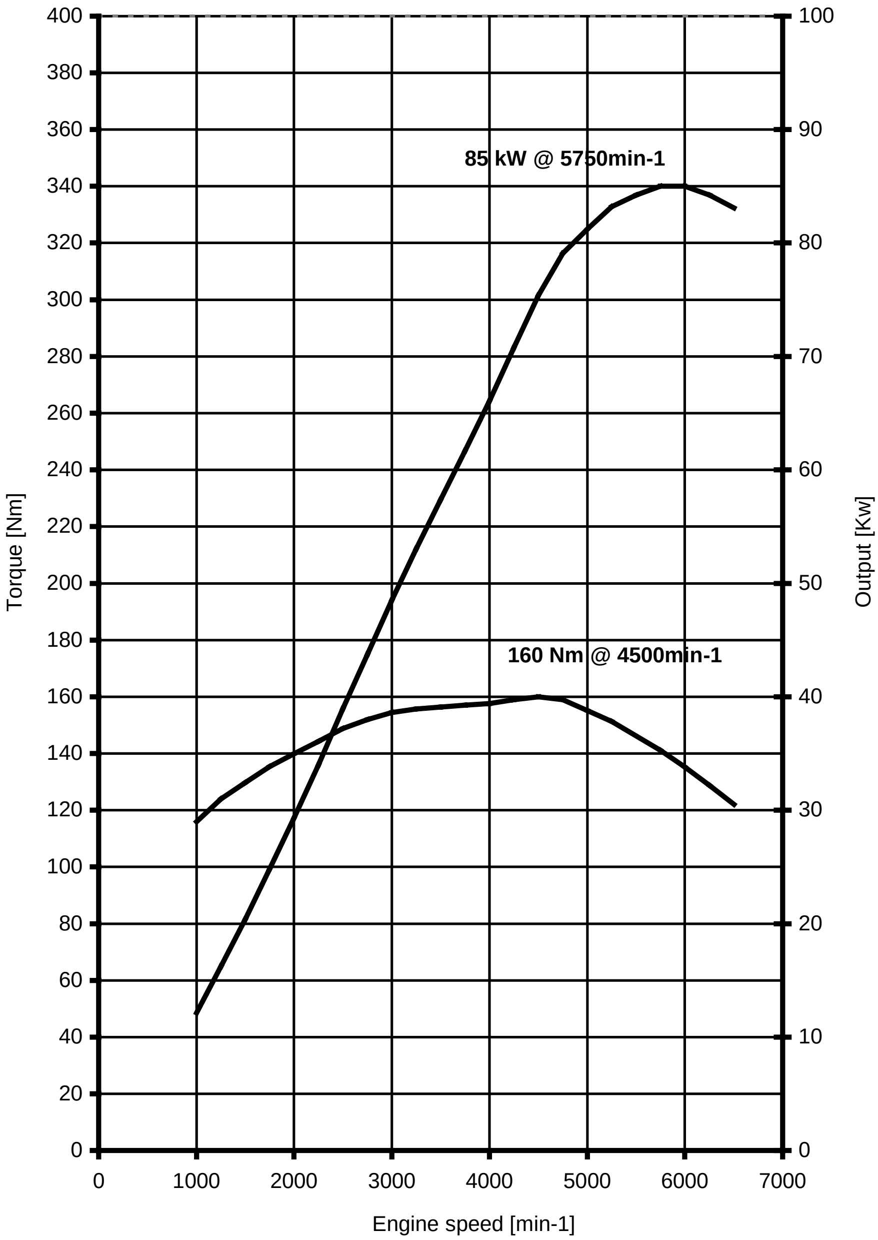
Design and configuration	–	Straight-four
Maximum output	KW/PS	85/115 at 5,700 rpm
Maximum torque	Nm/lb-ft	160/118 at 4,250 rpm
Combustion process	–	Normal-aspiration power unit/λ = 1.0/load management with fully variable valve drive
Capacity, effective	cc	1,598
Compression ratio	–	11.0:1
Bore/stroke	mm	77/85.8
Crankcase material	–	Aluminium; cylinder liners made of grey-cast iron
Distance between cylinders Length of crankcase Height of crankcase	mm	84 420 210
Connecting rods	mm	Crack technology, trapezoidal connecting rods
Camshafts	–	2 chain-driven, composite camshafts
Camshaft adjustment	–	Hydraulically, infinitely variable phase adjustment of intake and outlet camshafts
Valve drive		Roller-type drag arms; hydraulic valve play compensation
Valve lift intake/outlet	mm	0.2–9.5/8.5
Valves per cylinder		4
Engine weight according to BMW Group standard	kg	114
Engine management/fuel supply/ignition	–	Digital Motor Electronics with integrated management of valve drive/sequential multi-point intake manifold injection/individual coils, knock control
Fuel grade	RON	91–98 (power rating to RON 98)
Certified emission standard	–	EU4/ULEV II
Exhaust system	–	Multiple manifold with three-way main catalyst close to engine
Cooling		On-demand mechanical coolant pump, map-controlled coolant temperature

Four-cylinder gasoline engine with turbocharger and direct injection (105 kW/143 bhp).

Design and configuration	–	Straight-four
Maximum output	KW/PS	105/143 at 5,500 rpm
Maximum torque	Nm/lb-ft	240/177 at 1,400–4,000 rpm
Combustion process	–	Turbocharged gasoline engine with direct fuel injection/λ = 1.0/twin-scroll exhaust gas turbocharger
Maximum charge pressure	bar	0.8
Capacity, effective	cc	1,598
Compression ratio	–	10.5:1
Bore/stroke	mm	77/85.8
Crankcase material	–	Aluminium with sintered steel inserts; cylinder liners made of grey-cast iron
Distance between cylinders Lenght of crankcase Height of crankcase	mm	84 420 210
Connecting rods	mm	Crack technology, trapezoidal connecting rods
Camshafts	–	2 chain-driven, composite camshafts
Camshaft adjustment	–	Hydraulically, infinitely variable phase adjustment of intake camshaft
Valve drive		Roller-type drag arms; hydraulic valve play compensation
Valve lift intake/outlet	mm	9.0/9.0
Valves per cylinder		4
Motor weight according to BMW Group standards	kg	130
Engine managment/fuel supply/ignition	–	Digital Motor Electronics/sequential high-pressure direct fuel injection/ individual coils, knock control
Injection pressure	bar	120
Fuel grade	RON	91–98 (power rating to RON 98)
Certified emission standard	–	EU4/ULEV II
Exhaust system	–	Grey-cast iron manifold with three-way main catalyst close to engine
Cooling		On-demand mechanical coolant pump, knock-controlled coolant temperature

4. Torque and Output Diagram.

Four-cylinder gasoline engine with fully variable valve drive (85 kW/115 bhp).



Four-cylinder gasoline engine with turbocharger and direct fuel injection (105 kW/143 bhp).