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Die neue Boxermotorenfamilie von Porsche

The new family of flat engines from Porsche

Abstract

A completely new family of turbocharged flat engines was developed for the new generation of the Porsche Sports Cars 911 Carrera and 718 Boxster. Turbocharged flat engines are used for the first time in these Sports Car models instead of naturally aspirated engines. The engine family features a displacement range from 2.0 to 3.0 litres with a power spectrum from 300 to 420 hp.

The unique, more than 60-year-old concept of Porsche flat engines is combined with the 40-year-old tradition of Porsche turbocharging in these new engines – tradition and innovation therefore join forces in a new direction, and the flat engine concept has been interpreted in a completely new and exciting way.

The main focus of development was sharpening the typical Porsche driving experience. A typical flat engine sound, a significantly higher torque curve, responsiveness at Sports Car level and a useful rpm range up to 7,500 rpm open up new dimensions of driving performance. In addition to the benefits from the reduction in displacement and number of cylinders, efficiency is also enhanced by a newly developed combustion process as well as major changes in the areas of lightweight construction, friction, oil supply and thermal management.

The new flat engine family embodies the Porsche philosophy more than ever before: the combination of great driving pleasure with high efficiency as well as first-class sportiness with outstanding everyday usability.

1. Introduction

The foundation for the Porsche success story and the typical engine concept was already established in 1948 in the first 356 No. 1 Roadster – with a flat-four engine. This was a mid-engine concept, which was also used in the Porsche 550 models from 1953 and in the Porsche 781 from 1957. This concept has made a decisive contribution to the Porsche legend of today. The flat-four engines from Porsche in the 50s and 60s were not just used in road vehicles, but also achieved numerous victories in motor sports. In the 60s, the flat-six engine was introduced for the first time in road vehicles in the new 911 model. This engine then successively replaced the four-cylinder engines in the following years.



Figure 1: 718 RS 60 Spyder (1959/1960)

Today, the four-cylinder flat engine concept has been re-interpreted by Porsche and, recalling once more the legendary Porsche 718 (Figure 1), the new Boxster models have again been given these digits as the model designation: 718. The tradition of the flat-four engine is combined with the latest innovations to realise outstanding performance while at the same time reducing fuel consumption. The familiar excellent performance – also on the race track – is significantly improved by turbo downsizing together with the reduction in the number of cylinders, without neglecting the everyday usability typical for a Porsche. In the standard model, the 2.7-litre six-cylinder naturally aspirated engine is replaced by a 2.0-litre four-cylinder turbo engine with 300 hp, while in the S model the 3.4-litre six-cylinder naturally aspirated engine is replaced by a 2.5-litre four-cylinder turbo engine. The engine power is up to 35 hp higher than in the previous model for both vehicle types. The displacement spread of the two new engines permits optimum downsizing/rightsizing in the different power classes and makes it possible to achieve vehicle characteristics typical for Sports Cars such as sporty responsiveness.

The new flat-four engines were developed in a common family (internal designation 9A2) together with the new flat-six engines for the new 911 Carrera. The six-cylinder engines have a displacement of 3.0 litres with a power range from 370 to 420 hp PS and replace the six-cylinder naturally aspirated engines with a displacement of 3.4 litres and 3.8 litres (see Figure 2).

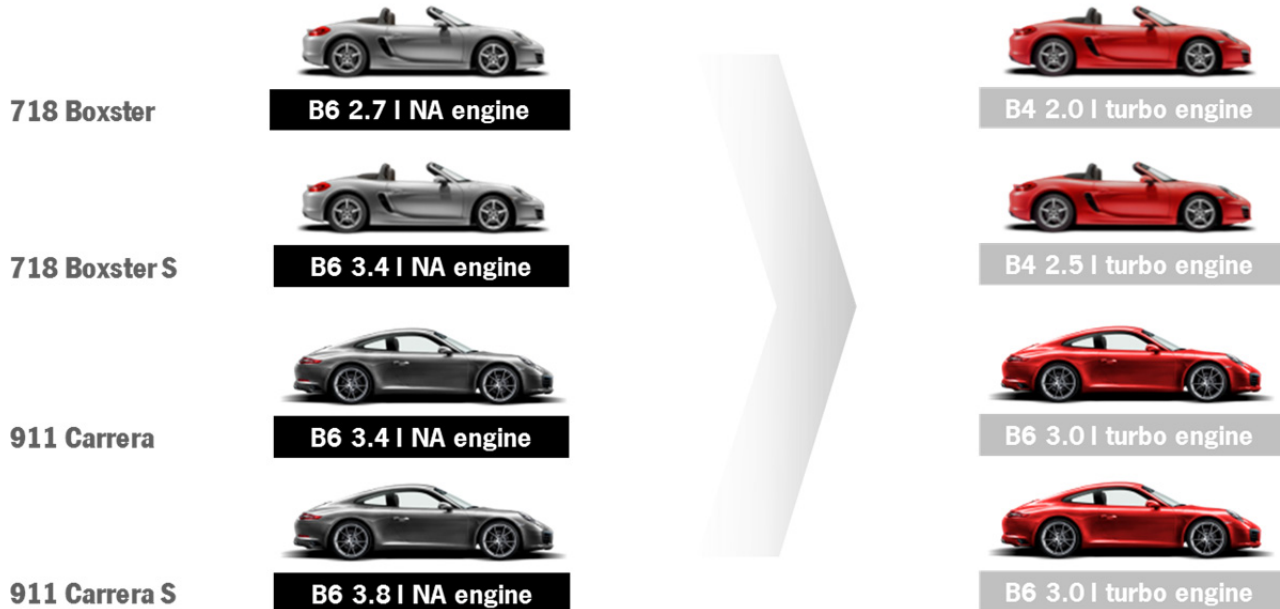


Figure 2: Turbo downsizing of the Porsche sports cars

2. The engine concept of the flat-four engine

The flat-four engine revives the classic engine concept with the genes of the Porsche flat engines. The new engine features all the characteristics of a typical Porsche sports engine: outstanding performance, large rpm range and very good responsiveness. The objective was to realise authentically Porsche and competitive engines for the new Porsche 718 Boxster vehicles. The goal was to also exploit the typical advantages of flat engines, such as excellent mass balancing, high revving ability, low centre of gravity and typical sound, in the four-cylinder engines.

A four-cylinder turbo concept is not just a successful concept for the past – but also has plenty of future-oriented potential. By winning the 24 Hours of Le Mans as well as the Manufacturers' and Drivers' Championships in the FIA World Endurance Championship in 2015, the Porsche 919 Hybrid impressively showed that competitively superior Sports Cars can also be powered by a four-cylinder turbo engine. The new flat-four engines directly transfer technology elements from the winning Le Mans engine to series production – these include the cylinder spacing, short-stroke design, central direct fuel injection as well as the use of variable turbine geometry (VTG), to name just a few examples (see Figure 3).

The requirements for a flat-four turbo engine in the 718 Boxster include the following:

- Preservation of the mid-engined layout and the typical Boxster design
- Low engine height and low centre of gravity
- Significant increase in performance
- Reduced fuel consumption
- Typical Sports Car responsiveness and high revving ability
- Low weight
- Unique sound of a flat engine typical for Porsche
- Compliance with the latest legal requirements and social acceptance

The Porsche flat-four engines are based on consistent application of Porsche modular technology:

- Direct fuel injection with central injector position
- Four-valve technology with valve-lift adjustment (VarioCam Plus) and additional exhaust camshaft adjusters
- Modular turbocharging technology with wastegate turbochargers and optional variable turbine geometry
- Effective gas cycle with large cylinder bore and small stroke (short-stroke design)
- Integrated dry sump with a fully variable oil pump
- Closed-deck aluminium crankcase with an iron (Fe) liner coating
- One-part cylinder head with cross-flow cooling for maximum cylinder outputs
- Thermal management with a switchable water pump and map-controlled thermostat



Figure 3: The new flat-four engine from Porsche

2.1 Vehicle integration of turbocharging in mid-engine installation position

As an ideal solution for

- the mid-engine package
- exhaust gas aftertreatment and
- the gas cycle
- acoustics and comfort requirements

the new flat-four turbo engines have a mono turbocharger located in front of the engine. A lateral mono turbocharger layout would have resulted in great differences in the exhaust manifold lengths and large gas cycle asymmetries (see Figure 4). The central mono turbocharger arrangement permits installation of different turbocharger sizes and technologies. For example, the top-of-the-range model – the 718 S – is equipped with variable turbine geometry in order to also guarantee optimum responsiveness of the 2.5-litre engine even with a large turbine wheel diameter.

A four-point drivetrain mount system with switchable hydraulic bearings is used due to the specific vibration behaviour of a four-cylinder engine. This system permits optimum design for acoustics, comfort and driving dynamics. In addition, there are also advantages for the layout of the turbocharger variants as well as for exhaust gas routing and the catalytic converter compared with the three-point mount system of the predecessor.

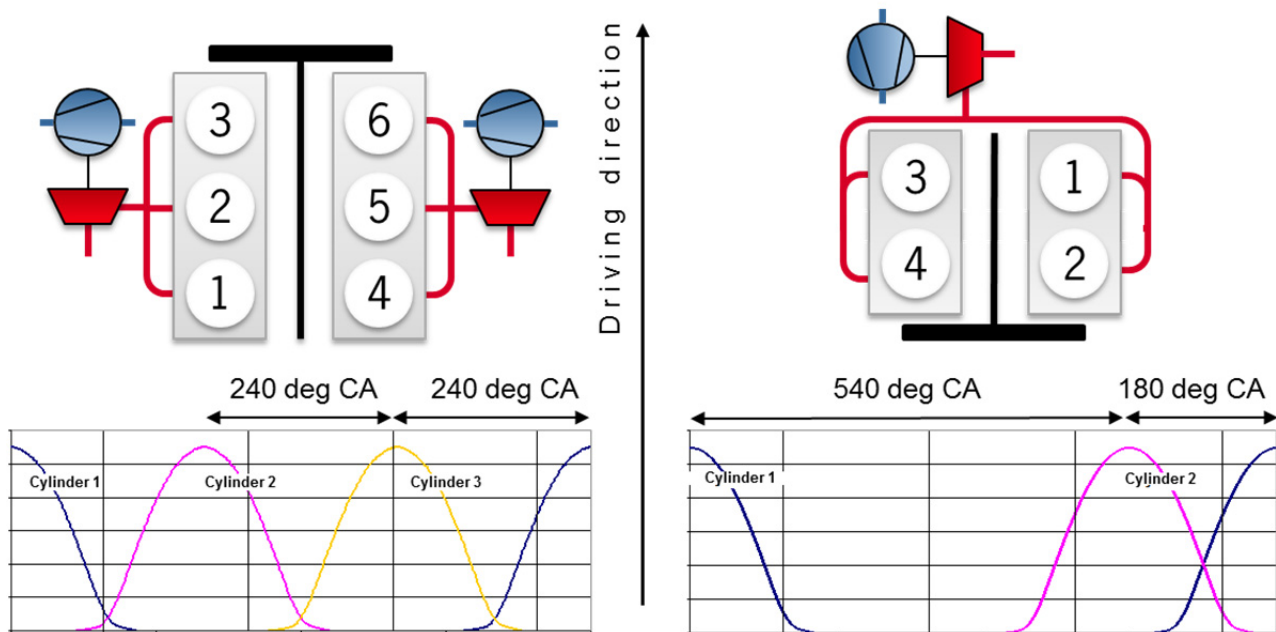


Figure 4: Gas cycle (outlet valve lift of one cylinder bank) of flat-six and flat-four engines

2.2 Gas cycle and machine dynamics

Compared with four-cylinder inline engines, the concept of the flat-four engine means that this engine type has the advantage of inherently balanced mass forces. As a result, only second-order free moments occur, which can be absorbed by the new four point engine mounting. However, the firing order 1-4-3-2 means that particular attention must be paid to designing the gas cycle in order to ensure equal distribution for the left and right banks on both the intake and exhaust sides. Asymmetrical event lengths are used on the exhaust side to compensate for the typical short ignition interval on a cylinder bank and the gas-dynamic cross-interference of the cylinders during exhaust valve closing. Valve lift adjustment on the exhaust side shortens the event length for the important low-end torque range and exhaust opening and the exhaust pressure wave initiated by this are retarded to such an extent that residual gas entrainment is largely avoided (see Figure 5). Valve lift adjustment takes place mainly as a function of load on the intake side and as a function of engine speed on the exhaust side. The design of the intake manifold ensures that unequal charge distribution does not occur for the firing order.

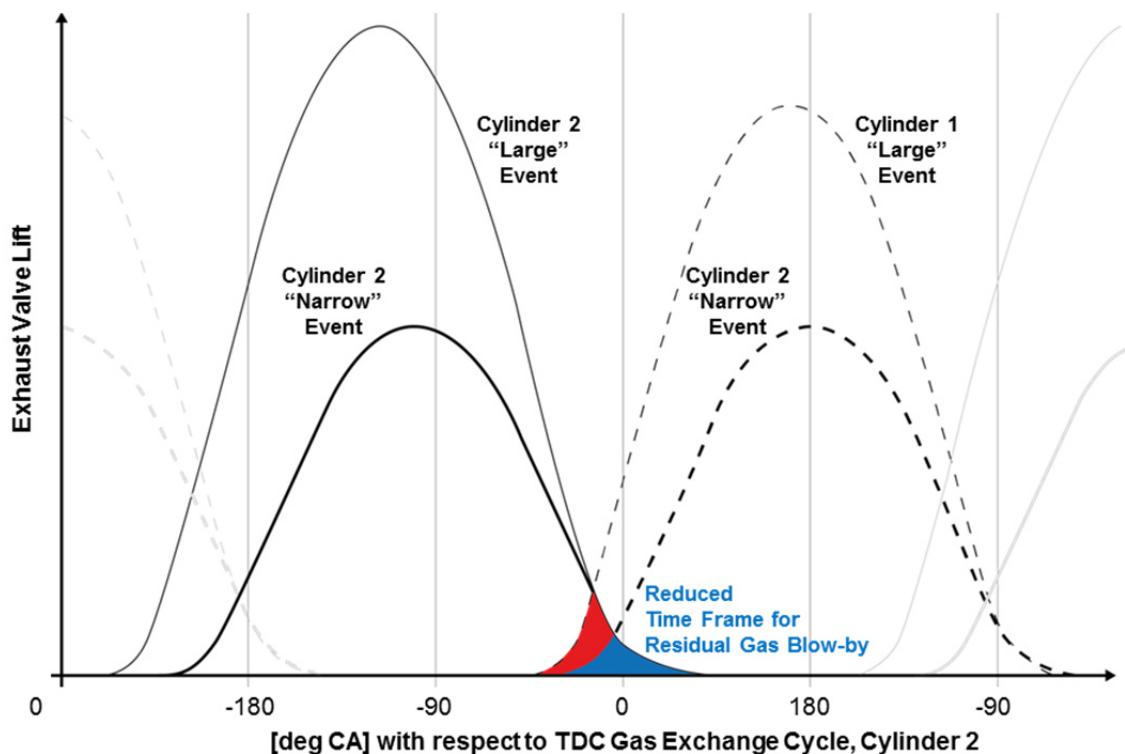


Figure 5: Influence of the outlet valve lift adjustment on residual gas fraction of nearby cylinders

2.3 Charge-air cooling

One of the most important development goals – alongside low fuel consumption combined with significantly improved performance values – was to achieve good charge-air cooling efficiency for sporty power development in transient operation while at the same time preserving the vehicle characteristics typical for Boxster models such as mid-engine layout, luggage compartment volume and naturally the unique styling. Process air intake, engine compartment scavenging and charge-air cooling are realised by means of the body

openings on both sides. This makes it possible to preserve the purist roadster design without additional air intakes (see Figure 6).

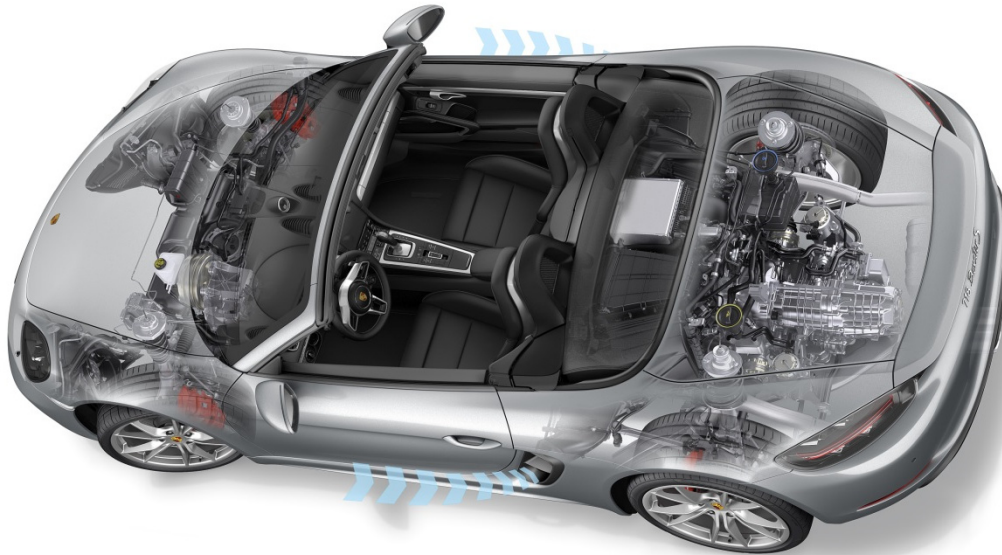


Figure 6: 718 Boxster (Type 982)

An integrated charge-air cooling system with a separate low-temperature cooling circuit is used to achieve the demanding performance figures in spite of the very compact package dimensions. The low-temperature cooling system comprises two laterally arranged low-temperature radiators and an indirect charge-air cooler located centrally on the engine (see Figure 7).

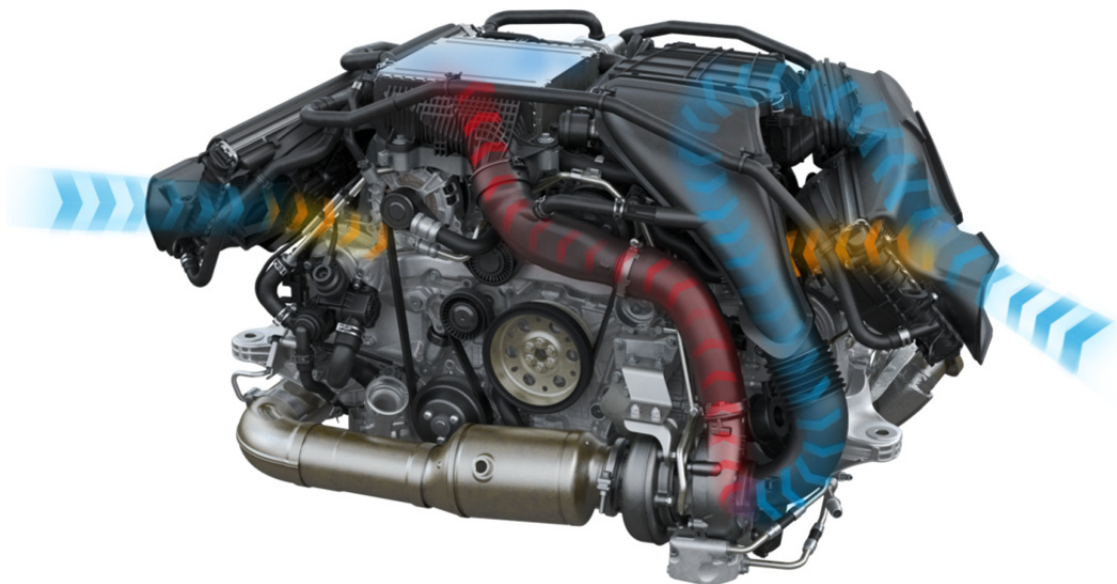


Figure 7: Charge-air cooling of the flat-four engine in the 718 Boxster

Both cooling circuits are supplied with coolant via a common coolant expansion tank. Additional active actuating elements were not used. The two cooling circuits are separated by means of two check valves. The required pressure gradient for opening and closing the check valves is regulated by means of the engine control by activation of the electric water pump, which is required for turbocharger afterrunning, as well as the electric water pump in the low-temperature cooling circuit. The control function is configured dependent on the engine speed so that the lowtemperature cooling circuit is reliably vented in the warm-up phase and after every engine start. This guarantees maximum efficiency of the low-temperature cooling system.

2.4 Exhaust system

The turbocharger located centrally at the front is followed by the close-coupled 400-cell catalytic converter. In order to optimise the exhaust backpressure and achieve the typical Porsche engine sound, the exhaust gas is routed in two branches to two main silencers located at the rear which are connected by means of a crossover point and a resonance tube (see Figure 8). The standard model has an oval tailpipe and the S model a twin tailpipe – both in the typical Boxster central position. A sports exhaust system is optionally available. The oxygen sensors upstream of the catalytic converter are located in front of the turbocharger for each cylinder bank.

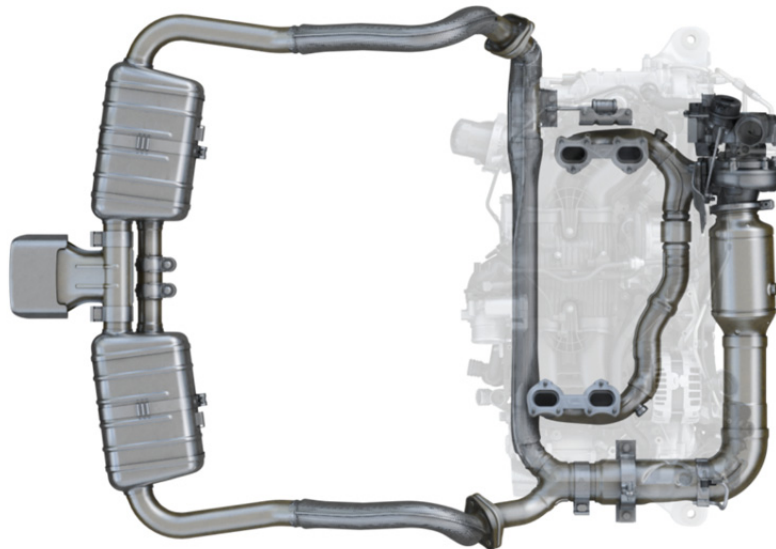


Figure 8: The exhaust system of the flat-four engine

3. The new four- and six-cylinder engine family

The new flat engine family 9A2 was developed to meet the requirements of turbo downsizing. The new flat-four engines were therefore developed together with the flat-six engines. In addition to the new design of the engines with the specific requirements for rear and mid-engine layouts (see Figure 9), significant synergies and identical part platforms were generated between the four- and six-cylinder engines.

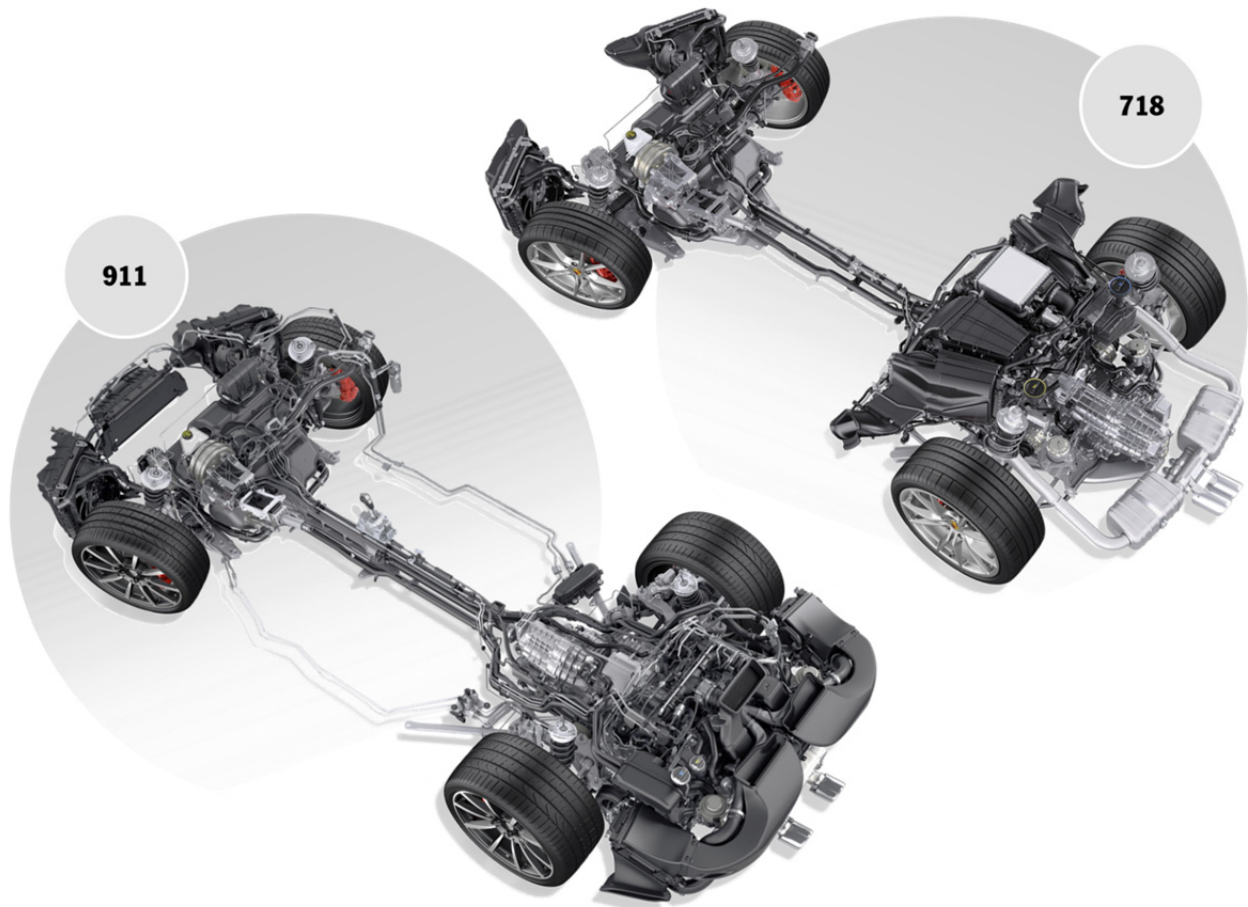


Figure 9: Drive concepts of 911 (rear engine) and 718 (mid-engine)

In addition to a high share of identical parts in the areas of

- Connecting rods
- Connecting rod and crankshaft bearings
- Timing drive
- Belt drive
- Valve drive
- Fuel system
- Sensors and actuators
- High-load threaded joints (such as connecting rod, cylinder head and thrust block)

great importance was attached to the economical manufacture of components for variants. For example, the crankcases of the flat-four and flat-six engines have the same design concept. The 2.0 l and 2.5 l flat-four crankcases are cast from the same mould in spite of the

different displacements. The variants are produced by means of specific cooling jacket cores and cylinder sleeves. In addition, the same combustion chamber and port core tools are used for the cylinder heads of the flat-four 2.0 l and flat-six 3.0 l engines. Even with different numbers of cylinders, the modular design permits machining on the same production lines. From an economic viewpoint also, this approach is ideal for variant production taking into account the technical characteristics of individual derivatives (see Figure 10).

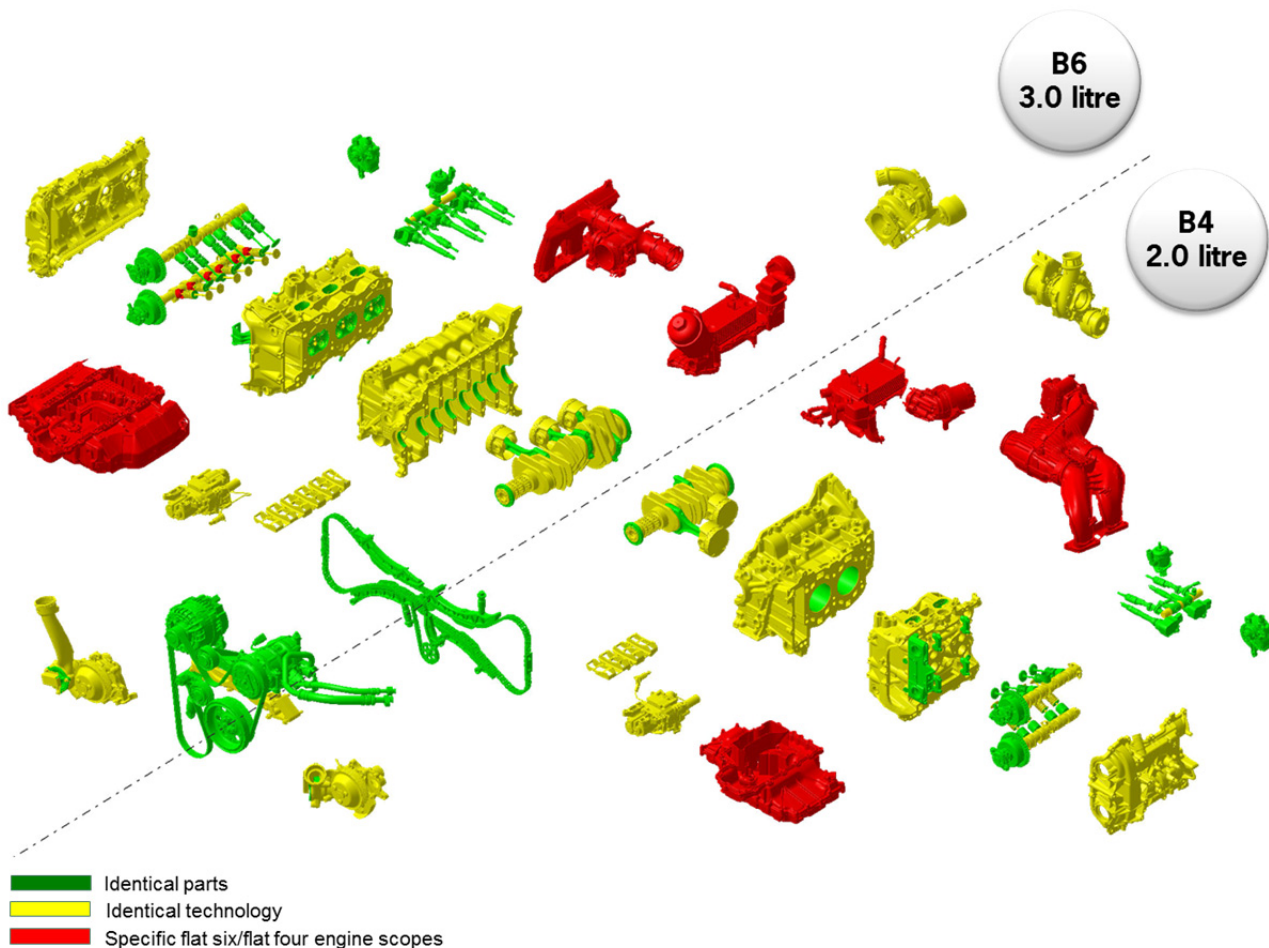


Figure 10: Identical part and identical technology scopes of the new 9A2 engine family

The identical part concept ensures that production is still possible on one assembly line in Stuttgart Zuffenhausen and permits mixed production of all four- and six-cylinder engines in combination with all existing flat-engine derivatives.

The most important technologies of this engine family (see Figure 11). are described below.

		718 Boxster	718 Boxster S	911 Carrera	911 Carrera S
Engine		Petrol engine			
Type		Flat engine			
Number of cylinders		4		6	
No. of valves/cylinder		4			
Firing order		1-4-3-2		1-6-2-4-3-5	
Displacement	[cm ³]	1,988	2,497	2,981	
Bore	[mm]	91	102	91	
Stroke	[mm]	76.4			
Cylinder spacing	[mm]	118			
Main bearing diameter	[mm]	63			
Connecting-rod bearing diameter	[mm]	53			
Compression ratio		9.5:1		10:1	
Turbine wheel diameter	[mm]	50	55	45	
Compressor wheel diameter	[mm]	58	64	49	51
Max. boost pressure (relative)	[kPa]	1.4	1.0	0.9	1.1
Rated power at 6,500 rpm	[kW]	220	257	272	309
Max. torque	[Nm]	380	420	450	500
Max. engine speed	[rpm]	7,500			
Emission category		EU6/LEV3			

Figure 11: Technical data (model year H)

3.1 Efficiency

In order to achieve maximum efficiency of the new engines, Porsche focussed development work on the following areas:

- Downsizing
- Combustion process
- Weight
- Internal engine friction
- Thermal management
- Enhancement of the coasting and Auto Start Stop functions

3.1.1 Downsizing

A further increase in the power of the flat-six naturally aspirated engines to over 105 hp/litre while maintaining the everyday usability typical for Porsche would have meant an increase in the displacement, something which contradicts the goal of achieving significant reductions in fuel consumption. For this reason, a solution with displacement and cylinder downsizing was realised.

As with all Porsche flat engines, the new turbo engines are characteristically short-stroke engines. The cylinder spacing is traditionally 118 mm. In order to meet the specific boundary conditions of flat engines, the turbocharged flat-four and flat-six engines have a stroke of

76.4 millimetres. The bore diameter is 91 millimetres for the 2.0 l and 3.0 l engines. These two engines thus share the combustion chamber geometry for the cylinder volume of 500 cm³. The 2.5 l flat-four engine was realised with the same cylinder stroke as the 2.0 l and 3.0 l engines by means of a bore variant of 102 millimetres (see Figure 12). Bore-specific optimisation measures were implemented for the combustion chamber geometry, valve angle, charge motion and injector design.

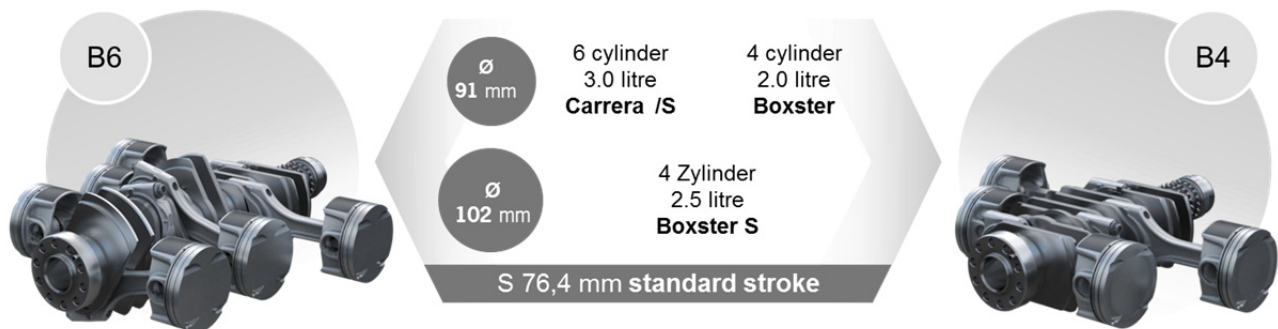


Figure12: Crankshaft drive of the 9A2 flat-six and flat-four engines

Both the cylinder crankcase with the steel-coated liner and the production process were newly developed for the new 9A2 flat engine generation. The proven closed-deck concept of the cylinder crankcase ensures high structural rigidity and low cylinder distortion under turbo-specific engine loads. The pre-machined cylinders are first mechanically roughened, then coated with a rotating plasma beam using the RSW process (RSW: Rotating Single Wire) and subsequently finished in a multi-stage special fixture honing process during which oil pockets are systematically incorporated into the cylinder liner (see Figure 13).

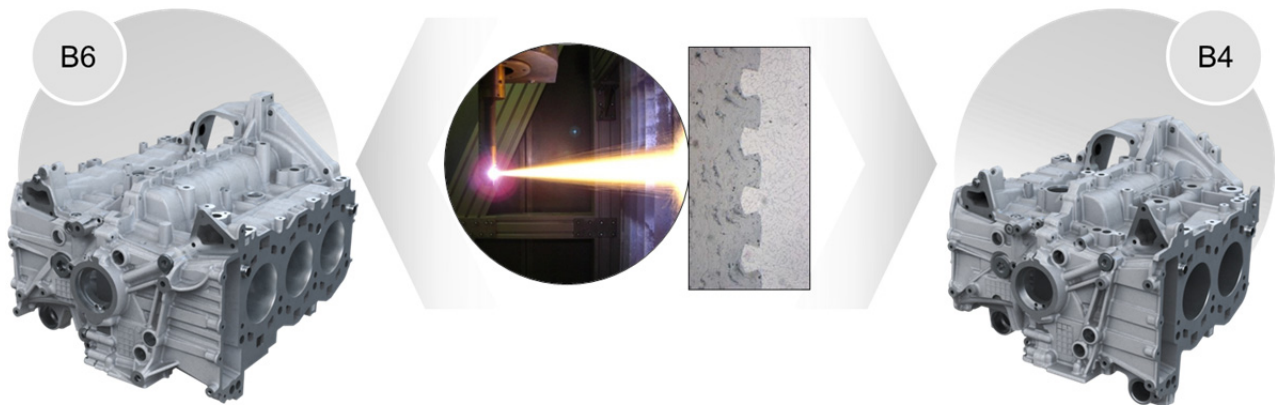


Figure 13: 9A2 flat-six and flat-four crankcase with iron liner coating

One of the main technical features here was use and development of a mechanical roughening process for the first time in order to ensure reliable bonding of the sprayed-on iron coating with the aluminium. In addition, the coating process using the RSW method was integrated in the existing crankcase production line and adapted to the requirements of the flat engines. Use of the Fe-coated liner permits functional separation between the liner and crankcase structure and thus the choice of a light, hypoeutectic and highly thermally conductive aluminium alloy AlSi7MgCu0.5 with a simultaneous increase in strength due to an optimised casting process – in comparison with a hypereutectic

aluminium alloy – with targeted heat treatment (T6 Air). This made it possible to reduce the weight of the crankcase by 1.5 kg compared with the predecessor. In addition to the reduction in weight, this technology also permits further optimisation of the friction pairings for increased peak pressure levels. It thus also contributes to reducing CO₂ emissions and ensures the suitability for worldwide use as well as the bad-fuel compatibility required for this.

3.1.2 Combustion process

The typical short-stroke design of flat engines is the proven prerequisite for their proven high load capacity as well as for compliance with the demanding package requirements of a rear or mid-engine drive system. The newly developed combustion process for all 9A2 engines helps to meet these demands through the following characteristics:

- Central injector position
- Tumble intake ports
- Symmetrical intake and exhaust valve lifts for the flat-six engines
- Symmetrical intake valve lifts and asymmetrical exhaust valve lifts for the flat-four engines
- Catalytic converter heating with internal engine measures and optimised injection strategy

The central injector position helps to achieve a significant improvement in efficiency and emissions compared with the previous engines, particularly under the boundary conditions of turbocharged operation. The interaction between the charge motion characteristics and the injection parameters plays a key part here:

- Detailed optimisation of the spray hole design on the valve seat of the injector
- Targeted spray design in close coordination with the combustion chamber geometry
- Exploitation of the existing fuel high-pressure potential
- Computer analysis of charge motion and mixture formation

Targeted spray design and symmetrical injection mass distribution across all individual spray jets make it possible to achieve good spatial chamber coverage with an extremely low wall wetting tendency. An increase in the injection pressure to up to 250 bar serves to support fuel-side mixture formation during the warm-up phase. In combination with the charge motion (tumble), the 9A2 engines thus offer efficient combustion with low raw emissions. On the combustion air side, the particular focus is on maximum efficiency of the intake port design with an optimum combination of tumble level and flow rate, while simultaneously taking into account mechanical requirements, emissions and fuel consumption (see Figure 14).

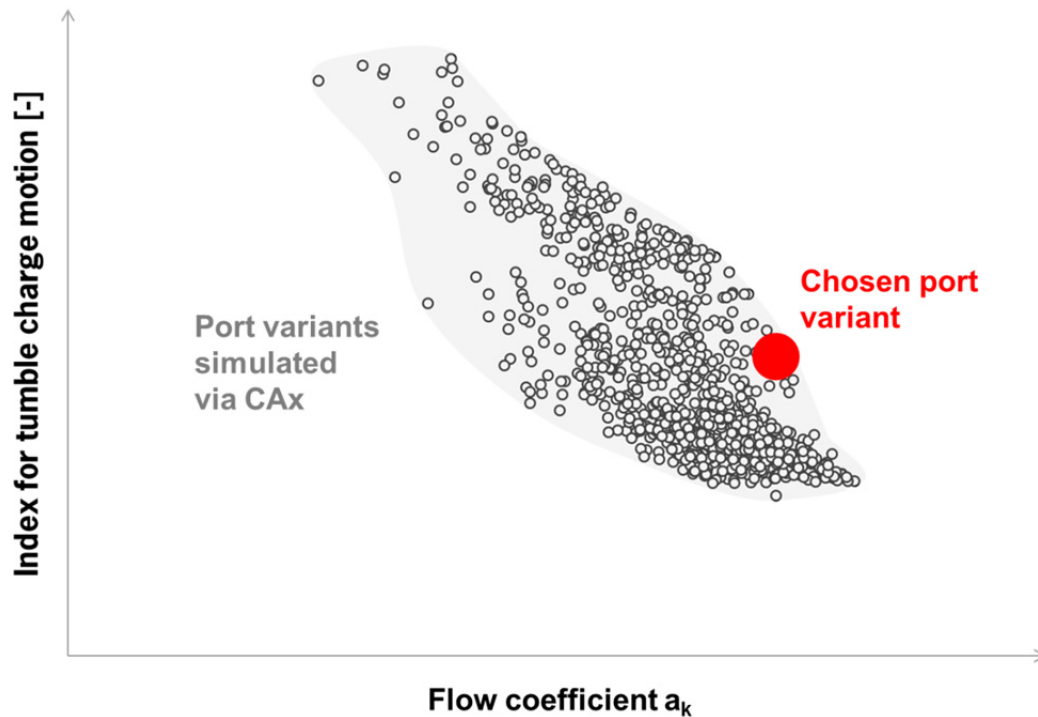


Figure 14: Intake port development for example of 2.5 l engine

In addition to development of the intake ports, the typical Porsche cross-flow cooling of the cylinder heads was also optimised to meet the demands of the higher-power turbo engines. The reduction in the material temperatures makes it possible to reduce the wall thicknesses by up to 40 percent. The oil galleries for supplying the VarioCam Plus system are precast and thus permit central positioning of the high-pressure injectors (see Figure 15). The proven aluminium alloy AlSi7MgCu0.5 is also used here.

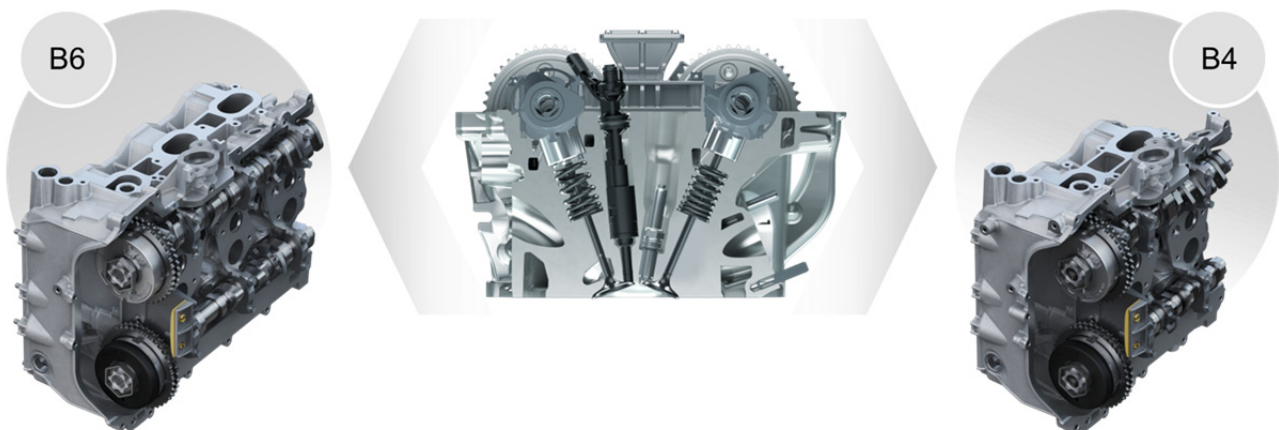


Figure 15: 9A2 cylinder head for flat-six and flat-four engines with central injector position

3.1.3 Weight

The use of turbocharging initially involves additional weight due to additional components such as turbocharger and charge-air cooler as well as higher requirements for the overall cooling system. Further lightweight construction potentials were therefore consistently exploited to compensate for this, e.g. up to 1.5 kilograms for the crankcase, up to 1.7 kilograms for the oil pump and 2.0 kilograms for the oil pan on the flat-six engine.

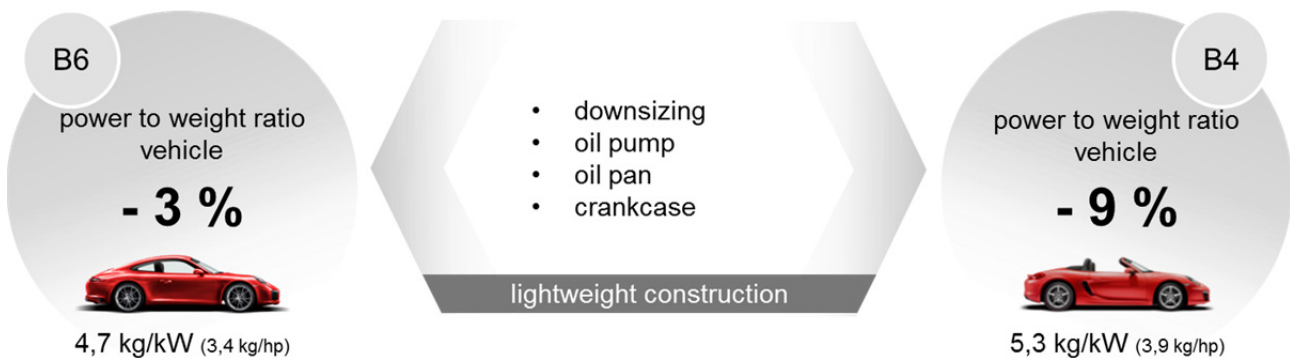


Figure 16: Improvement of power to weight ratios for example of S models

While the additional weight of the flat-six 3.0 l turbo engine is only 17 kilograms compared with the naturally aspirated engine in the predecessor vehicle in spite of the additional turbocharger-related components, the flat-four 2.0 l engine is eight kilograms lighter than its flat-six predecessor. Figure 16 shows the power-to-weight ratios of the vehicles.

3.1.4 Friction

The frictional mean pressures were improved in comparison with the predecessor engines through use of Fe-coated cylinder liners, reducing the friction losses in the timing drive by means of a lower chain tensioner force, decreasing the drive power of the water pump and optimising the oil supply system including the oil pump.

When designing the oil circuit, the focus was on ensuring maximum efficiency. For example, one development goal was to keep the oil volume flow to a minimum. The fact was exploited here that the cylinder head requires a lower oil pressure than the crankshaft drive due to its consumers. This is particularly true at high engine speeds. An orifice plate is used to obtain the corresponding behaviour. A simulation model (see Figure 17) was used in order to determine the optimum position of the orifice plates and their diameter. It was taken into account here that camshaft control and lift switchover also need a sufficient volume flow in addition to the pressure in order to guarantee fast actuation. As an optimum result, a restrictor with a diameter of 4.0 millimetres was chosen in the oil duct to the respective cylinder head in combination with a restrictor with a diameter of 2.0 millimetres in the intake oil gallery. The resultant reduced oil volume flow in the cylinder head leads to a reduction in drive power for the pressure stage of the oil pump.

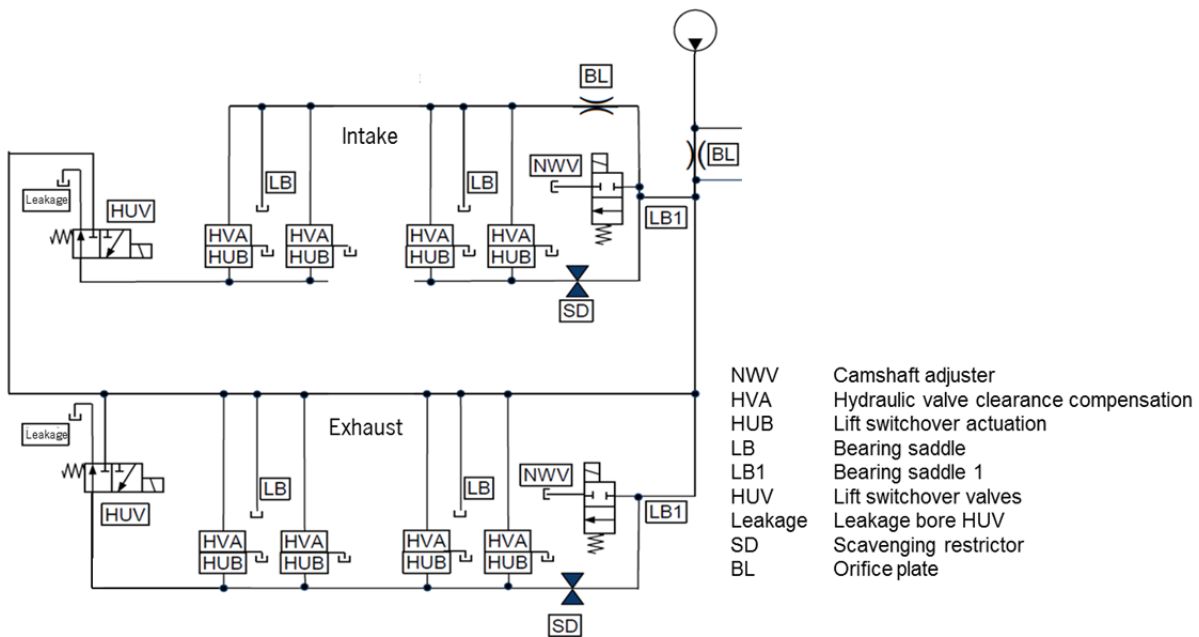


Figure 17: Schematic representation of test setup for restrictor design

The flat-four oil pump is derived from the flat-six turbo unit (see Figure 18). The pressure stage – an identical part from the flat-six engine – is designed as a friction-optimised, fully variable vane pump. Whereas the oil pump for the flat-six engine has an additional parallel gear pressure stage, the flat-four engine does not need this due to its lower oil volume flow. As part of the modular system, the additional pressure stage for the flat-six engine is used with slight modifications as a suction stage for the flat-four mono turbocharger. The higher suction power for the two flat-six turbochargers is realised by means of a separate turbocharger suction stage.

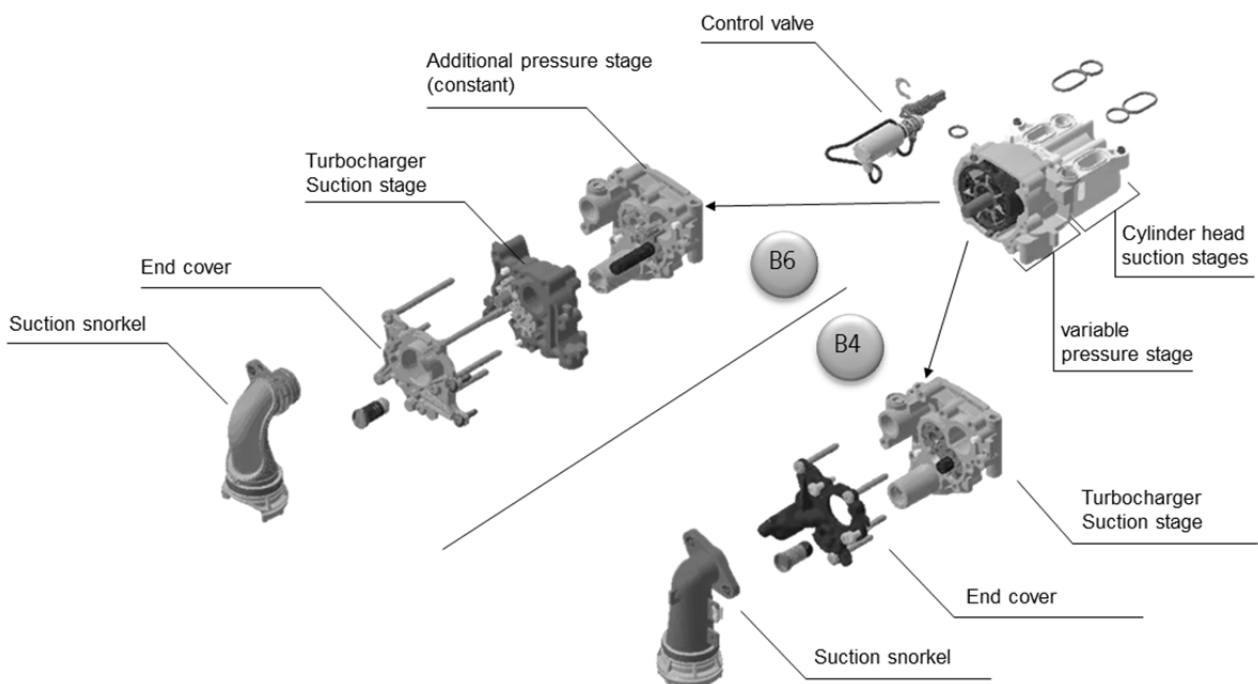


Figure 18: Fully variable oil pump

The control for the fully-variable oil pump also contributes to the reduced drive power. The minimum oil pressure was reduced from 2.0 bar to 1.8 bar compared with the previous unit. The map range in which the minimum oil pressure is regulated was also extended. A further reduction in the drive power of the oil pump was implemented by a modification on the suction stage side in comparison with the predecessor engines. The cylinder head suction stages were designed so that suction is possible at two locations with one stage, i.e. one suction stage is used in each case for one cylinder head – front and rear.

The timing drive mechanism features two hydraulic chain tensioners. The design principle means that one of these is located in “overhead” position. In order to allow consistent reduction of the spring preload force by 50 percent, an oil reservoir was made available to the chain tensioner that guarantees the hydraulic function when the engine is started.

The Fe liner coating also permitted exploitation of further potentials from the point of view of engine friction. The very robust tribological system of piston/cylinder liner made it possible to achieve a frictionally optimum design of the piston rings and throughput through the piston cooling nozzles.

Like in the flat-six engine, a switchable water pump is also used in the flat-four engine. The hydraulic power of the water pump can be almost completely avoided by switching off the water pump as a function of the thermal management control strategy.

3.1.5 Thermal management with switchable water pump

During further development of the thermal management system, attention was paid to achieving a further reduction in fuel consumption in the part-load range without any disadvantages during full-load operation as well as to ensuring fast control response and a low weight. In addition to the single-slider map-controlled thermostat already installed in the previous engines with a shut-off valve in the bypass circuit, a switchable water pump is additionally used in the 9A2 engines for demand-based cooling (see Figure 19).

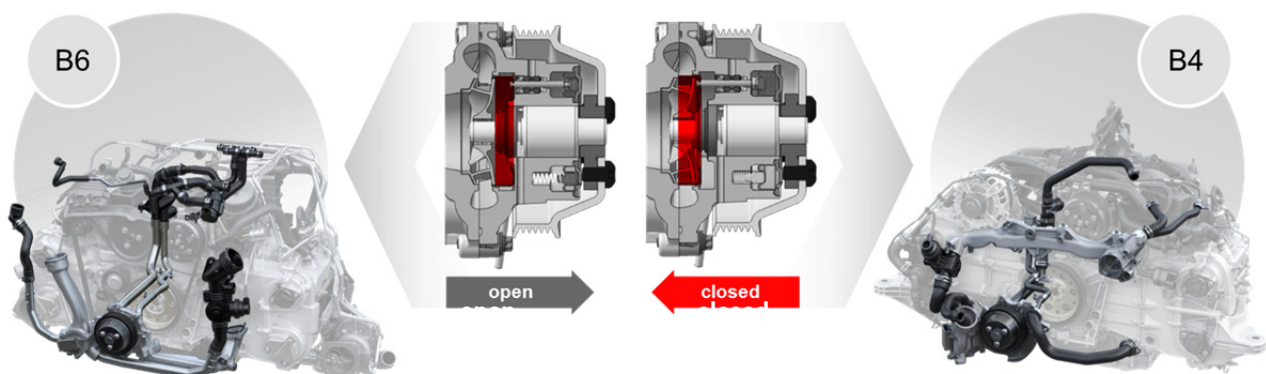


Figure 19: Thermal management flat-six and flat-four with switchable water pump

3.2 Performance

The following objectives were the main focus for improving the sporty driving experience:

- Significant increase in engine power
- Outstanding, higher torque even from low engine speeds
- Typical Sports Car engine speed range up to 7,500 rpm
- Direct responsiveness
- Oil supply suitable for race track operation

The following measures were implemented during development in order to achieve these goals:

- Use of exhaust turbocharging
- Valve drive optimisation for high-revving turbo engines
- Enhancement of the integrated dry sump with fully variable oil pump

3.2.1 Exhaust turbocharging

The design of the turbochargers takes into account the demands of high specific power outputs and a high-revving engine characteristic up to the rev-limiter on the one hand and the required potential for an early low-end torque on the other. The power from the nominal engine speed up to the maximum engine speed is less than five percent for all 9A2 engines (see Figure 23).



Figure 20: Turbochargers for flat-six and flat-four engines

A wastegate turbocharger with a compressor/turbine wheel diameter ratio of 1.16 was chosen for the 2.0 l standard version of the 718. The higher performance demands are reflected in the turbocharger technology of the 718 S 2.5-litre engine. A fully variable design is used here on the turbine side: VTG with additional wastegate. When the wastegate is open, its bypass mass flow ensures that the guide blade system always obtains the maximum possible efficiency from the VTG turbine. This leads to lower exhaust gas pressures in front of the turbine, which in turn results in reduced gas cycle losses in the high-load range. At the same time, the VTG is able to ensure a comfortable low-end torque availability with closed wastegate and tangential guide vane position. This single-stage turbocharger variant thus creates an even larger spread between low-end torque rpm and sporty revving behaviour

with high cylinder outputs. Two wastegate turbochargers in the familiar biturbo configuration are used in the 3.0 l engines (see Figure 20).

Whereas indirect charge-air cooling is used for the 718 vehicles with mid-engine layout – as already described – the 911 models feature direct charge-air cooling, which is more favourable for rear engines.

3.2.2 Valve drive optimisation for high-revving turbo engines

The engine speed band of the 9A2 turbo engines was specifically designed to match the level of naturally aspirated engines. The optimum between emotion and efficiency currently lies at a maximum engine speed of 7,500 rpm. The valve drive masses were optimised for this purpose. The valve drive is based on an enhanced VarioCam Plus system with valve lift adjustment and camshaft control on the intake side. The system was supplemented by camshaft control on the exhaust side to optimise dethrottling during the gas cycle. The flat-four engine also has the already described Valve lift adjustment on the exhaust side. As on the previous model, aluminum camshaft adjusters and assembled camshafts are used which drive the radially located fuel high-pressure pumps (see Figure 21).



Figure 21: Valve drive of the 9A2 flat-six and flat-four engines

3.2.3 Oil circuit

The oil circuit is an important part of the engine that makes a decisive contribution to making it possible to experience the driving dynamics of a Porsche. In addition to coping with high longitudinal dynamics, the oil circuit must also deal with the high lateral dynamic forces that are typical for a genuine Sports Car. The typical Porsche integrated dry sump is also used in the flat-four engine. This was intelligently enhanced and adapted to the even more compact engine package as well as for use in the Boxster.



Figure 22: Flat-six and flat-four with integrated dry sump

The horizontal cylinder heads of the flat engine require efficient oil extraction. The oil is then supplied to an oil tank integrated in the oil pan, from where it is made available to the intake snorkel of the oil pump in a targeted way. In addition to the oil from the integrated oil tank, oil is also separated from the crankcase drive by means of an oil windage tray and routed to the intake snorkel via guide ribs integrated in the oil pan. This oil pan system developed especially for the flat-four engine makes it possible to meet maximum driving dynamics requirements in a minimal package. The flat-six oil pan is made of plastic for the first time. The air/oil separator, the partition insert and oil lines are integrated into the oil pan (see Figure 22).

Alongside the new oil pans with this special design, the heart of the oil circuit is the oil pump. Oil pressure control has also been optimised on all 9A2 engines for greater performance. The setpoint values for the oil pressure can be increased as required depending on the vehicle dynamics. In contrast, the values can also be reduced – with low dynamic forces – in order to consistently increase the efficiency of the engine.

The crankcase ventilation system with maximum separation levels also permits realisation of an oil circuit typical for Porsche. The blow-by gas is extracted from both cylinder head covers. A labyrinth separator integrated in the cylinder head covers performs coarse oil separation before this gas is supplied to the fine oil separator newly developed for the flat-four turbo engine. Fine oil separation is performed by so-called “Polyswirls”, which are switched depending on the pressure losses. This system is characterised not just by separation rates of max. 0.2 g/h in 50 percent of the map, but also by maximum values that are lower than 1.0 g/h in the entire map. In addition to the very good separation behaviour, the crankcase ventilation system also has very good characteristics with respect to oil throwing. The limit for this is 240 l/min and thus provides the capacity for double the quantity of own blow-by gas. The crankcase ventilation system is therefore another component that guarantees the suitability for race track driving typical for Porsche.

3.2.4 Result of increased performance

The use of turbocharging results in a much higher torque curve and thus significantly increased performance. While the nominal power of the 9A2 flat-six engine was increased by 20 hp, the nominal power of the flat-four engine is up to 35 hp higher than that of its six-cylinder predecessor. The torque spread extends from 380 Nm for the 2.0-litre engine up to 500 Nm for the 3.0-litre S engine (see Figures 23 and 24).

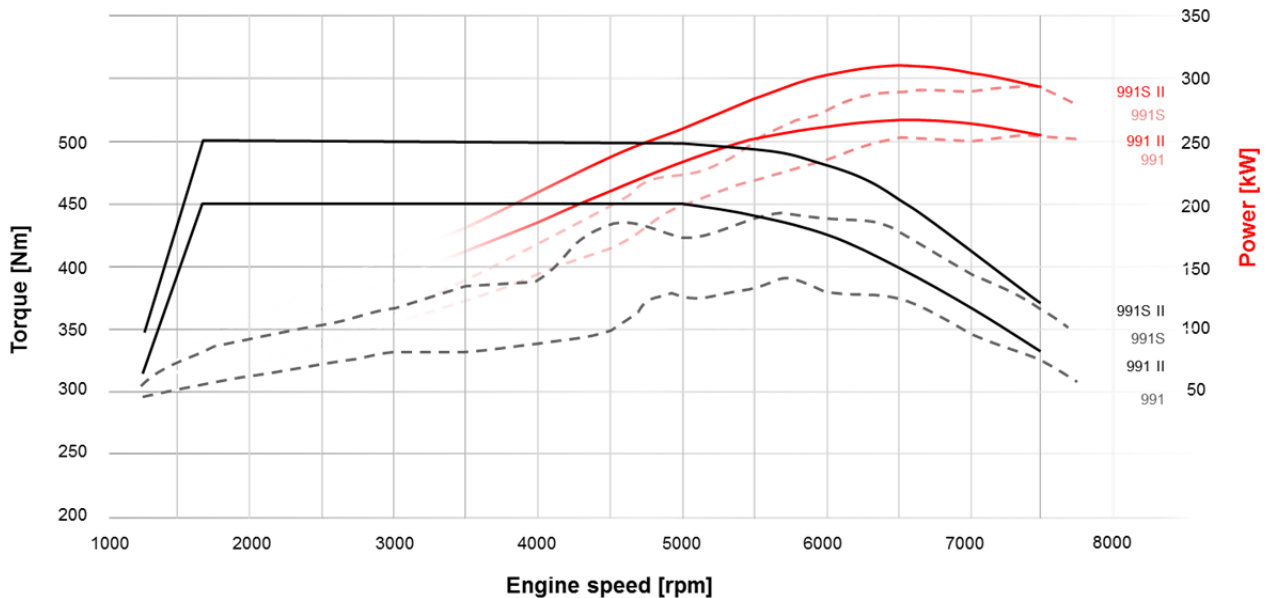


Figure 23: Full load curves of the 9A2 flat-six turbo engines

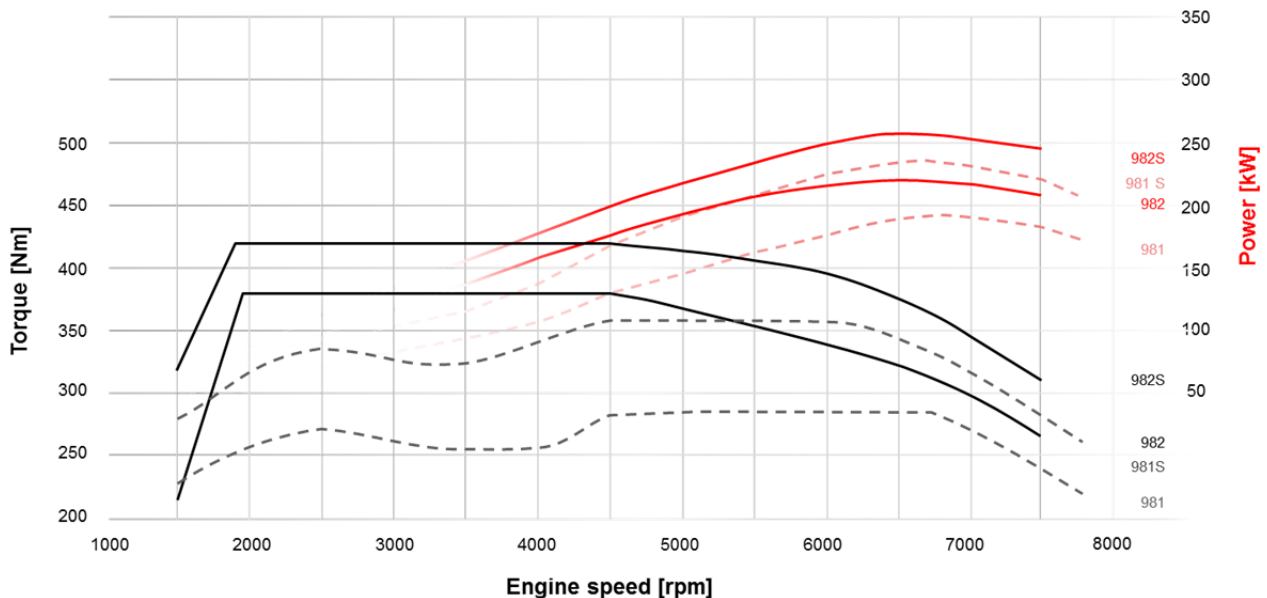


Figure 24: Full load curves of the 9A2 flat-four turbo engines

With the power-enhanced engines, the acceleration values are improved by up to 13 percent for the 718 Boxster and 5 percent for the Carrera. At the same time, the standard fuel consumption is reduced by up to 13 percent (see Figure 25).

Efficiency: Standard consumption		Performance: Acceleration 0-100 km/h (0-62 mph)	
13 %	B4 718	% 13	
11 %	B4 718 S	% 11	
10 %	B6 911	% 5	
12 %	B6 911 S	% 5	

Figure 25: Improvement in fuel consumption and acceleration compared with the predecessor (PDK)

3.3 Emotion

As always, Porsche consistently placed the focus on an emotional driving experience when designing the new engine generation. The flat-four engine offers unique potential here based on the Porsche tradition. The modern interpretation of this concept therefore required a development focus in the following areas:

- Torque curve/torque characteristic
- High rpm together with turbo technology
- Brand-typical sound which can be further intensified by optionally available sports exhaust systems (see Figure 26)
- Asymmetrical exhaust gas routing in the area of the exhaust manifold for the flat-four engine
- Application measures such as “overrun burbling” and shift boosting

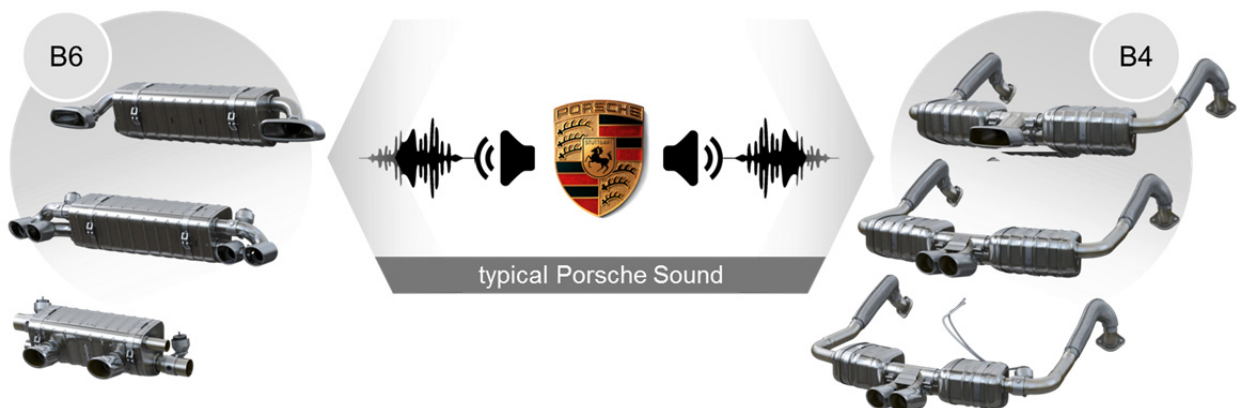


Figure 26: Exhaust systems for 911 (from top: standard, S model, sports)

All these measures combined produce an emotional driving experience that is tailored to the different 718 Boxster and 911 Carrera models – just as one expects from a Porsche.

Summary

The new flat engine generation from Porsche with four- and six-cylinder turbo engines sets new standards in the areas of performance, emotion and efficiency. The engine family features a displacement range from 2.0 to 3.0 litres with a power spectrum from 300 to 420 hp. The maximum torques extend from 380 Nm (from 1,950 rpm) on the 718 Boxster up to 500 Nm (from 1,700 rpm) on the 911 Carrera S.

In addition to the use of turbo technology with powerful charge-air cooling systems, the new engines were consistently enhanced in the areas of combustion process, internal engine friction, race track suitability and lightweight construction, without neglecting the links to tradition and emotionality that are typical for Porsche.

In accordance with the “Porsche Intelligent Performance” strategy, the performance was increased enormously by higher nominal power outputs and higher torques. The engines exploit the entire speed range up to 7,500 rpm for this purpose. The superior torque curve of a turbo engine is combined with the emotional characteristics of a naturally aspirated engine while at the same time achieving outstanding standard consumption values.

Porsche has therefore succeeded once more in combining pure driving pleasure and first-class sportiness with high efficiency and outstanding everyday usability.