Product Information.
N47 engine.

BMW Service

The information contained in the Product Information and the Workbook form an integral part of the training literature of Aftersales Training.

Refer to the latest relevant BMW Service information for any changes/supplements to the technical data.

Information status: November 2006

Contact: conceptinfo@bmw.de

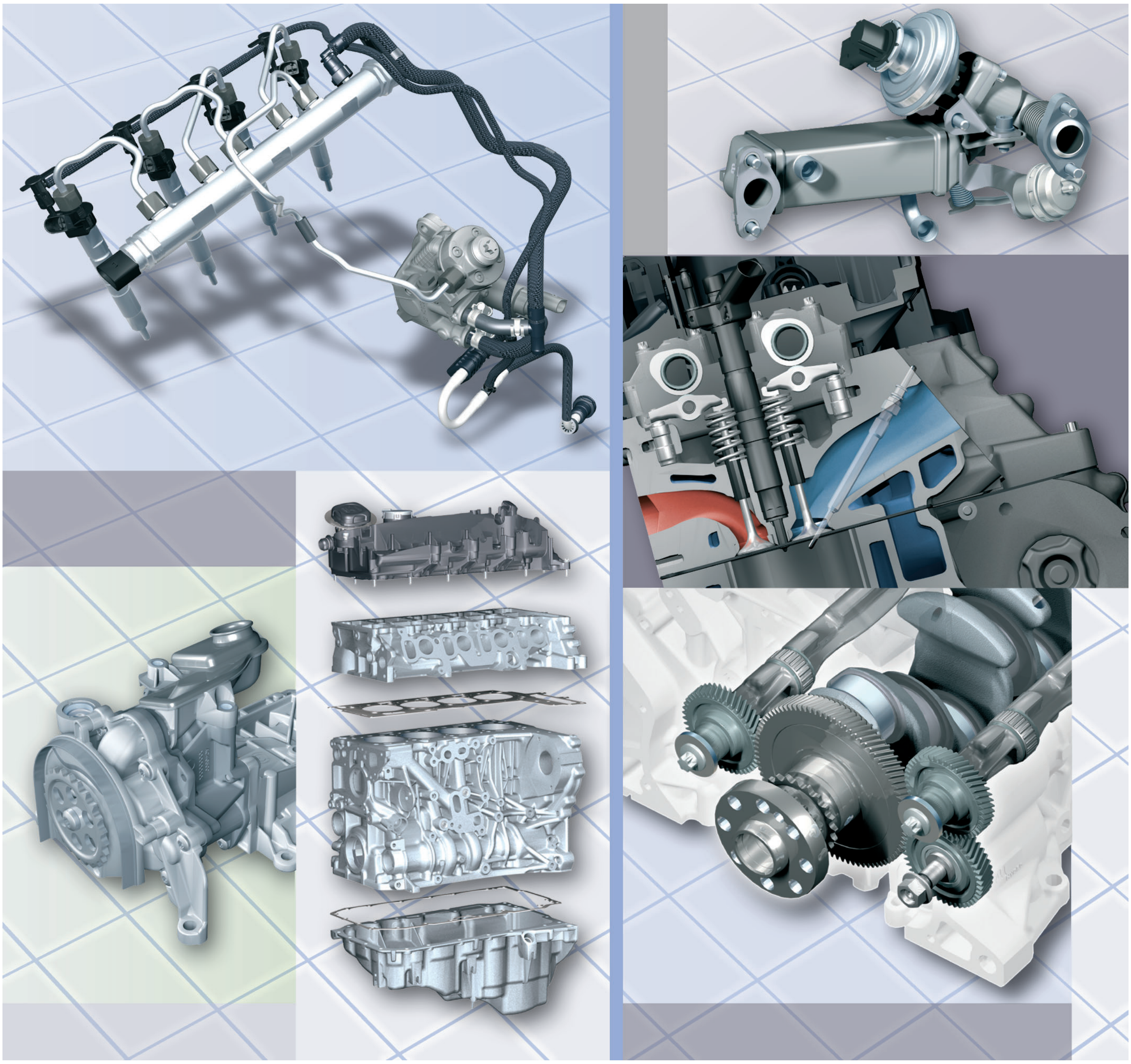
VS-12 Aftersales Training

Product Information.
N47 engine.

Rear chain drive

Vacuum pump in the oil sump

Balancing shafts in the crankcase



Notes on this Product Information

Symbols used

The following symbols are used in this Product Information to improve understanding and to highlight important information:

⚠ contains information to improve understanding of the systems described and their function.

◄ identifies the end of a note.

Information status and national variants

BMW vehicles satisfy the highest requirements of safety and quality. Changes in terms of environmental protection, customer benefits and design render necessary continuous development of systems and components. Discrepancies may therefore arise between specific details provided in this Product Information and the vehicles available during the training course.

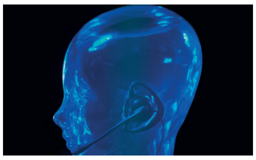
This documentation only describes European left-hand-drive variants. In right-hand-drive vehicles some control elements and components are arranged differently from what is shown in the graphics in this Product Information. Further discrepancies may arise from market- or country-specific equipment specifications.

Additional sources of information

Further information on the individual subjects can be found in the following:

- in the Owner's Handbook
- in the BMW diagnosis system
- in the Workshop Systems documentation
- in BMW Service Technik.

Contents.
N47 engine.



Objectives.
N47 engine.

Product Information and reference material for practical applications

This Product Information is intended to provide you with information on the design and operation of the N47 engine.

The Product Information is designed as a work of reference and supplements the contents of the BMW Aftersales Training course. The Product Information is also suitable for private study.

As preparation for the technical training course, this Product Information provides an insight into the new N47 4-cylinder diesel engine. In conjunction with the practical exercises carried out in the training course, the aim of the Product Information is to equip participants with the skills to carry out servicing work on the N47 engine.

Existing technical and practical knowledge of current BMW diesel engines will make it easier to understand the systems and their functions presented here.

Please remember to work through the SIP on this topic.
Basic knowledge provides surety in theory and practice.

Models.
N47 engine.

Engine variants

Models with N47 engine for market launch in March 2007.

Model	Model series	Engine	Cylinder capacity in cm^3	Bore/stroke in mm	Power in kW/bhp at rpm	Torque in Nm at rpm
118d	E81	N47D20U0	1995	90/84	105/143 4000	300 1750
120d	E81	N47D20O0	1995	90/84	130/177 4000	350 1750
118d	E87	N47D20U0	1995	90/84	105/143 4000	300 1750
120d	E87	N47D20O0	1995	90/84	130/177 4000	350 1750
320d	E92	N47D20O0	1995	90/84	130/177 4000	350 1750

History

Four-cylinder diesel engines at BMW.

Engine	Model	Model series	Cylinder capacity in cm^3	Power in kW/bhp	Torque in Nm	Engine management	First used	Last used
M41D17	318tds	E36	1665	66/90	190	DDE2.1	9/94	9/00
M47D20O0	320d	E46	1951	100/136	280	DDE3.0	4/98	9/01
M47D20O0	520d	E39	1951	100/136	280	DDE3.0	9/99	5/03
M47D20U0	318d	E46	1951	85/115	240	DDE3.0	9/01	3/03
M47D20O1	320d	E46	1995	110/150	330	DDE5.0	9/01	3/04
M47D20U1	318d	E46	1995	85/115	240	DDE5.0	3/03	3/04
M47D20U1	318d	E46	1995	85/115	240	DDE506	3/04	3/05
M47D20O1	320d	E46	1995	110/150	330	DDE506	3/04	9/06
M47D20U2	118d	E87	1995	90/122	280	DDE603	9/04	3/07
M47D20O2	120d	E87	1995	120/163	340	DDE604	9/04	3/07
M47D20O2	X3 2.0d	E83	1995	110/150	330	DDE506	9/04	9/05
M47D20O2	320d	E90	1995	120/163	340	DDE604	3/05	Still current
M47D20U2	318d	E90	1995	90/122	280	DDE603	9/05	Still current
M47D20O2	320d	E91	1995	120/163	340	DDE604	9/05	Still current
M47D20O2	X3 2.0d	E83	1995	110/150	330	DDE604	9/05	Still current

Introduction.
N47 engine.

The new generation

After eight years, a successful model - yet to be equalled - is to be replaced. The M47 engine gave the diesel engine at BMW a respectable pedigree. Offering sporty acceleration and mighty power coupled with such low fuel consumption, it soon became one of the most favourite engines in the BMW repertoire.

To carry on the baton is the challenge that faces the successor model, the N47 engine.

Indeed, it is a challenge that it will gladly take on. With even more power and torque combined with low fuel consumption and weight, it is ideally equipped to carry on the success.

The N47 engine is a completely new development bestowed with a multitude of new applications. This has been combined with the latest diesel technology and a number of tried-and-tested solutions.

An overview of innovations, modifications and special features

Debuting on BMW diesel engines

- Chain drive and high-pressure pump on the force transmitting side (rear)
- Balancing shafts integrated in the crankcase with needle bearings
- Common oil/vacuum pump in the oil sump
- Double-sided belt drive
- All auxiliary equipment on the left-hand side of the engine
- Rotational vibration damper with freewheel
- Exhaust gas recirculation cooler with bypass (only upper power class with manual transmission)
- Starter on the right-hand side of the engine
- New CP4.1 single-piston high-pressure pump with 1,800 bar maximum pressure (lower power class: 1,600 bar)
- Majority of oil ducts cast using a new casting method
- DDE7 engine management
- Active crankshaft sensor with reverse rotation detection
- Ceramic glow plugs.

Modifications by comparison with the predecessor

- Aluminium crankcase with thermally-joined, grey cast-iron cylinder bushes
- PIEZO injectors (upper power class only)
- More compact roller cam followers
- Two-piece cylinder head
- Reinforcement shell for the crankcase
- Pressure-controlled electric fuel pump
- Fuel filter heating controlled by the DDE
- Crankshaft main bearing caps with indent fit
- Electronic oil level measurement with QLT.

Other key data

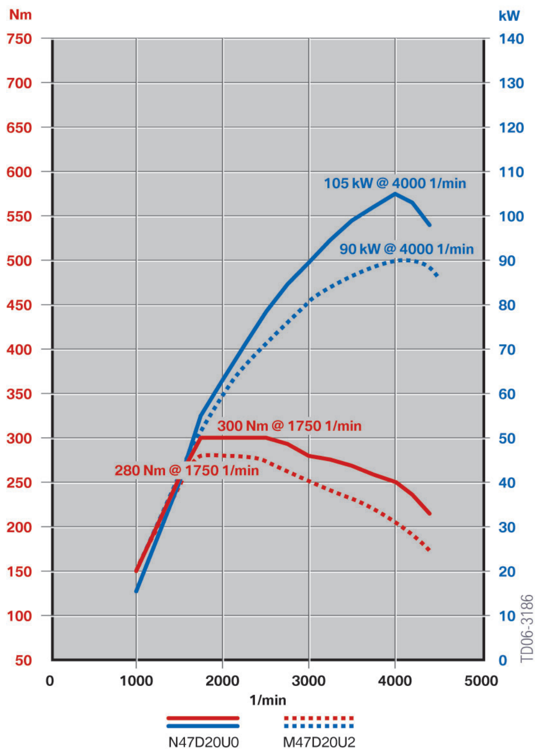
- Oil separation in the cylinder head cover with cyclone filters
- Composite camshafts built in accordance with the Presta method
- Electric swirl flaps (upper power class only)
- Exhaust turbocharger with electrically variable turbine geometry (VNT)
- Oxi-cat and DPF in a common, engine-side housing.

Technical data

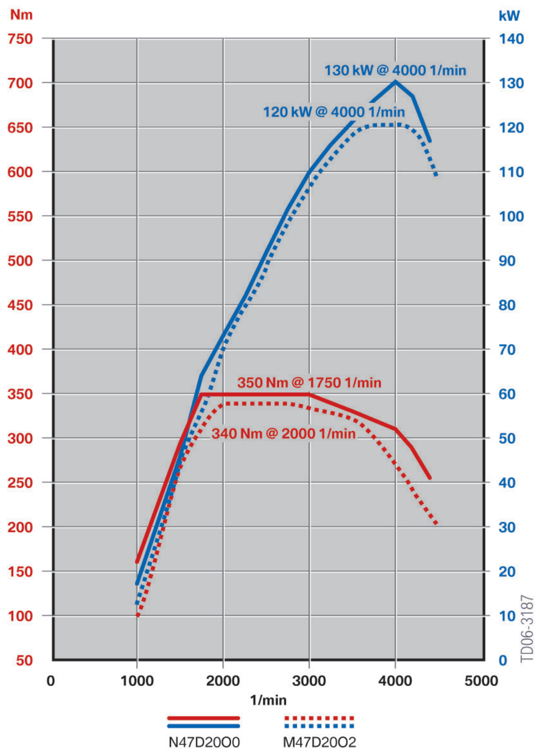
Designation		M47D20U2	N47D20U0	M47D20O2	N47D20O0
Engine type		4 inline	4 inline	4 inline	4 inline
Cylinder capacity	[cm^3]	1,995	1,995	1,995	1,995
Stroke/bore	[mm]	90/84	90/84	90/84	90/84
Output at engine speed	[kW/ bhp] [rpm]	90/122 4,000	105/143 4,000	120/163 4,000	130/177 4,000
Torque (1st gear) at engine speed	[Nm] [rpm]	240 1,750	240 1,750	280 2,000	280 1,750
Torque (remaining) at engine speed	[Nm] [rpm]	280 1,750	300 1,750	340 2,000	350 1,750
Cutoff speed	[rpm]	4,600	4,600	4,600	4,600
Power output per litre	[kW/l]	45.11	52.63	60.15	65.16
Compression ratio	ε	17.0	16.0	17.0	16.0
Cylinder gap	[mm]	91	91	91	91
Valves/cylinders		4	4	4	4
Inlet valve dia.	[mm]	25.9	27.2	25.9	27.2
Exhaust valve dia.	[mm]	25.9	24.6	25.9	24.6
Main bearing journal dia. of crankshaft	[mm]	60	55	60	55
Big-end bearing journal dia. of crankshaft	[mm]	45	50	45	50
Engine management		DDE603	DDE7.0	DDE604	DDE7.1
Emissions standard		EURO 4	EURO 4	EURO 4	EURO 4

Full-load diagram

The N47 engine is set apart from its predecessor by an increase in overall performance and a beefier torque curve.



1 - Full load diagram of the N47D20U0 by comparison with its predecessor



2 - Full load diagram of the N47D20U0 by comparison with its predecessor

System overview.
N47 engine.

Engine identification

Engine designation

The engine designation is used in the technical documentation for unique identification of the engine.

The N47 engine has the following variants:

- N47D20U0
- N47D20O0

The technical documentation may also contain the abbreviated form of the engine designation, N47, which only makes it possible to identify the engine model.

This means:

Index	Explanation
N	BMW Group "New generation"
4	4-cylinder engine
7	Direct diesel injection
D	Diesel engine
20	2.0-litre capacity
U/O	Lower/upper power class
0	New development

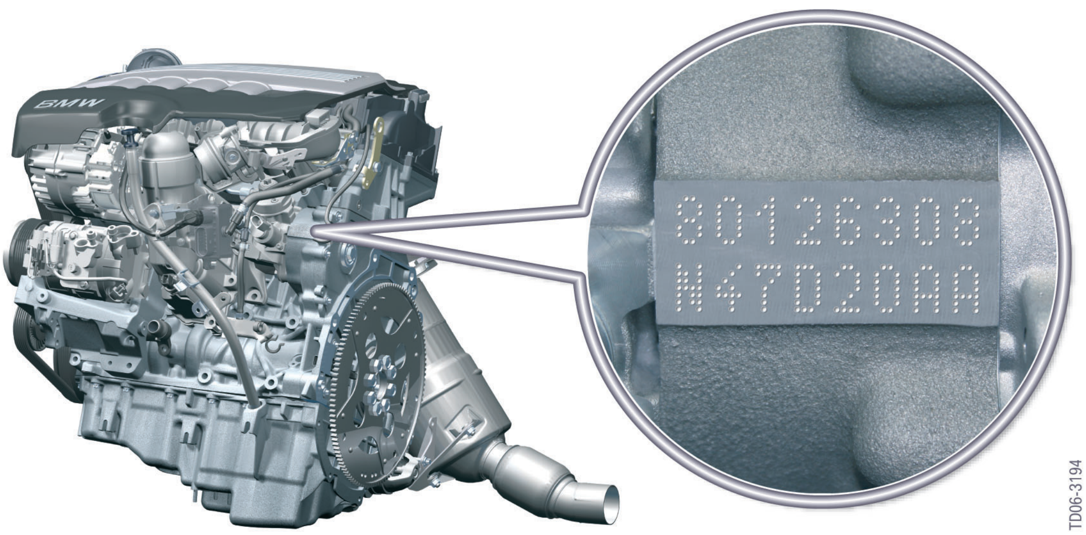
Engine identifier and number

The crankcase of the engine is marked with an identifier for unique identification and assignment of the engine. This engine identifier is also required for approval by the authorities. The first seven positions are relevant here.

With the N47 engine, the engine identifier is now a diesel engine identifier that has been changed so as to comply with the new standard whereby the first six positions are the same as the engine designation.

The engine number is a serial number that makes it possible to uniquely identify any individual engine.

The engine identifier and number are located on the crankcase on the bracket of the high-pressure fuel pump.



1 - Engine identifier and number on the N47 engine

System components.
N47 engine.

Overview of engine mechanicals

The engine mechanicals can be subdivided into three major systems:

- Engine casing
- Crankshaft drive system
- Valvegear

Those three systems are in a state of constant interaction with one another. This interaction has a very significant influence on engine properties.

Some important interrelationships, such as firing interval and firing order, will now be explained in more detail.

Interrelationships

The following table shows the key data for the N47 in respect of firing interval and firing order.

	N47 engine
Engine configuration/no. of cylinders	4-cylinder in-line engine
Crankshaft crank-pin offset	180°
Firing interval	180° CR
Firing order	1-3-4-2

Firing interval

The firing interval is the angle of crankshaft rotation between two successive ignitions.

In the course of a complete engine operating cycle, each cylinder ignites once. The four-stroke cycle (intake, compression, power, exhaust) of an internal combustion engine takes two complete revolutions of the crankshaft, i.e. 720° of rotation.

Having the same firing interval between all ignition points ensures that the engine runs evenly at all speeds. Such a firing interval is calculated as follows:

Firing interval = 720° / Number of cylinders

With a 4-cylinder engine like the N47, this produces a firing interval of 180° crankshaft.

The firing interval is determined by the crankshaft's crank-pin offset (the angular separation of the crank arms), i.e. the angle between the crank pins for successively firing cylinders (as determined by the firing order).

Firing order

The firing order is the order in which the cylinders of an engine are ignited.

The firing order is directly responsible for how smoothly an engine runs. It is determined on the basis of the engine configuration, number of cylinders and firing interval.

The firing order is always quoted starting from cylinder number 1.

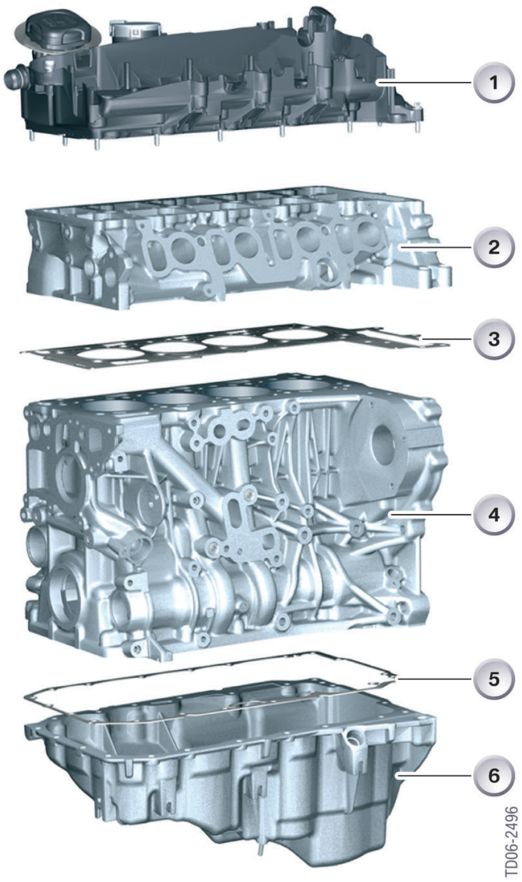
With a 4-cylinder in-line engine, a firing order of 1-3-4-2 has proven to be the most ideal and this is also used for the N47 engine.

Cylinder numbering order

Even though the N47 engine has the timing gear at the rear, the numbering order begins on the opposite side from which force is transmitted, like in all BMW engines. The first cylinder is therefore at the front.

Engine casing

The graphic shows the components of the engine casing.



1 - N47 engine casing

Index	Explanation
1	Cylinder head cover
2	Cylinder head
3	Cylinder head seal
4	Crankcase
5	Sump gasket
6	Sump

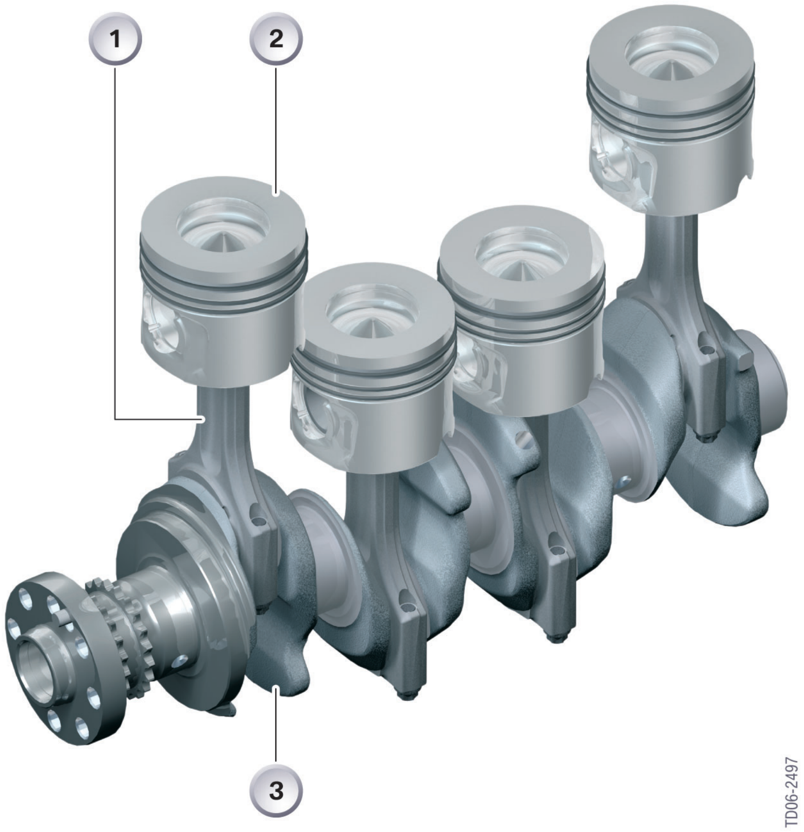
In addition, gaskets and bolts are also part of this system so that it can perform its job.

That job consists essentially of the following tasks:

- Containing the forces generated by operation of the engine
- Sealing functions for the combustion chamber, engine oil and coolant
- Holding the crankshaft drive system, valvegear and other components

Crankshaft drive system

The crankshaft drive system, also known as the power unit, is a function group that converts the combustion chamber pressure into kinetic energy. In the process, the crankshaft converts the linear motion of the pistons into a rotary motion. The crankshaft drive system represents the optimum in terms of work utilization, efficiency and technical practicability for the task in question.



2 - N47 engine crankshaft drive

Index	Explanation	Index	Explanation
1	Connecting rod	3	Crankshaft
2	Piston		

Nevertheless, the following technical limitations and design challenges have to be dealt with:

- Engine speed limitation due to inertial forces
- Uneven power delivery over the course of an operating cycle
- Generation of torsional vibrations that place stresses on the crankshaft and drive train
- Interaction of the various frictional surfaces

Valvegear

The engine has to be supplied with air in a regular cycle, while the exhaust gases that it produces must be expelled. The intake of fresh air and the ejection of exhaust gas is referred to as the charge or gas exchange cycle. In the course of the gas exchange cycle, the inlet and exhaust ducts are periodically opened and closed by the inlet and exhaust valves.

The inlet and exhaust valves take the form of poppet valves. The timing and sequence of the valve movements are determined by the camshaft.

The entire mechanism for transferring cam lift to the valve is known as the valvegear.

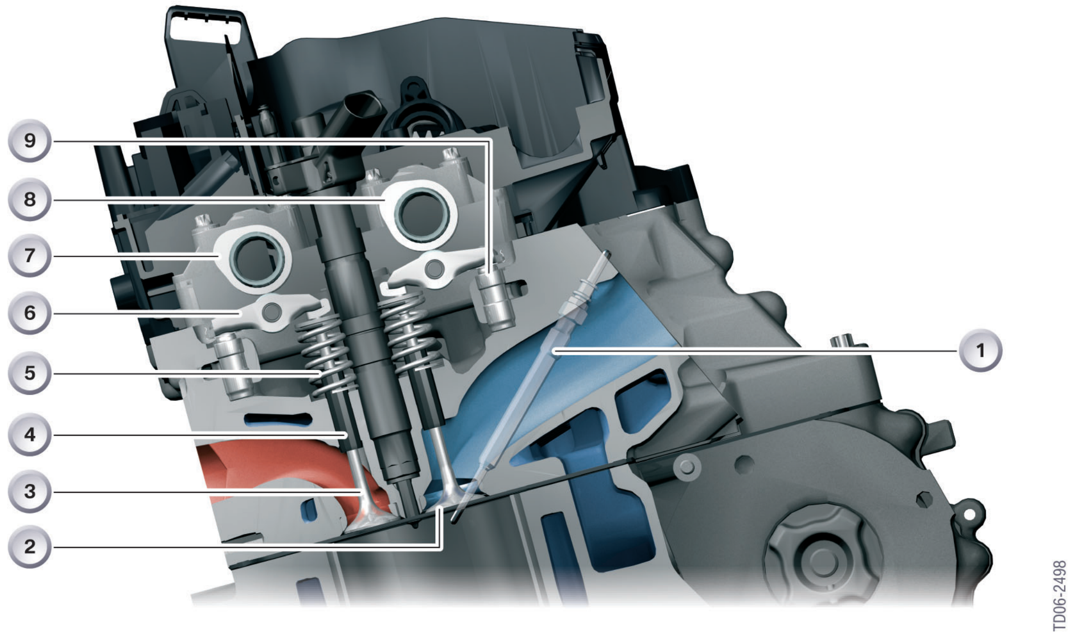
In the N47 engine, the crankshaft and camshaft are mechanically linked by a timing chain. Timing is therefore fixed.

Design

The valvegear is made up of the following components:

- Camshafts
- Transmitting elements (roller cam followers)
- Valves (complete valve assemblies))
- Hydraulic valve clearance adjustment (HVA).

The following graphic shows the design of the valvegear in the four-valve cylinder head of the N47 engine.



3 - N47 engine valvegear

Index	Explanation	Index	Explanation
1	Glow plug	6	Roller cam follower
2	Inlet valve	7	Exhaust camshaft
3	Exhaust valve	8	Inlet camshaft
4	Valve guide	9	Hydraulic valve-clearance adjuster
5	Valve spring		

Design types

There are a variety of valvegear designs. They are distinguished according to the following features:

- Number and position of the valves
- Number and position of the camshafts
- Method of actuation of the valves
- Method of valve clearance adjustment

The designation of the type of valvegear depends on the first two attributes. The possible variations are listed below.

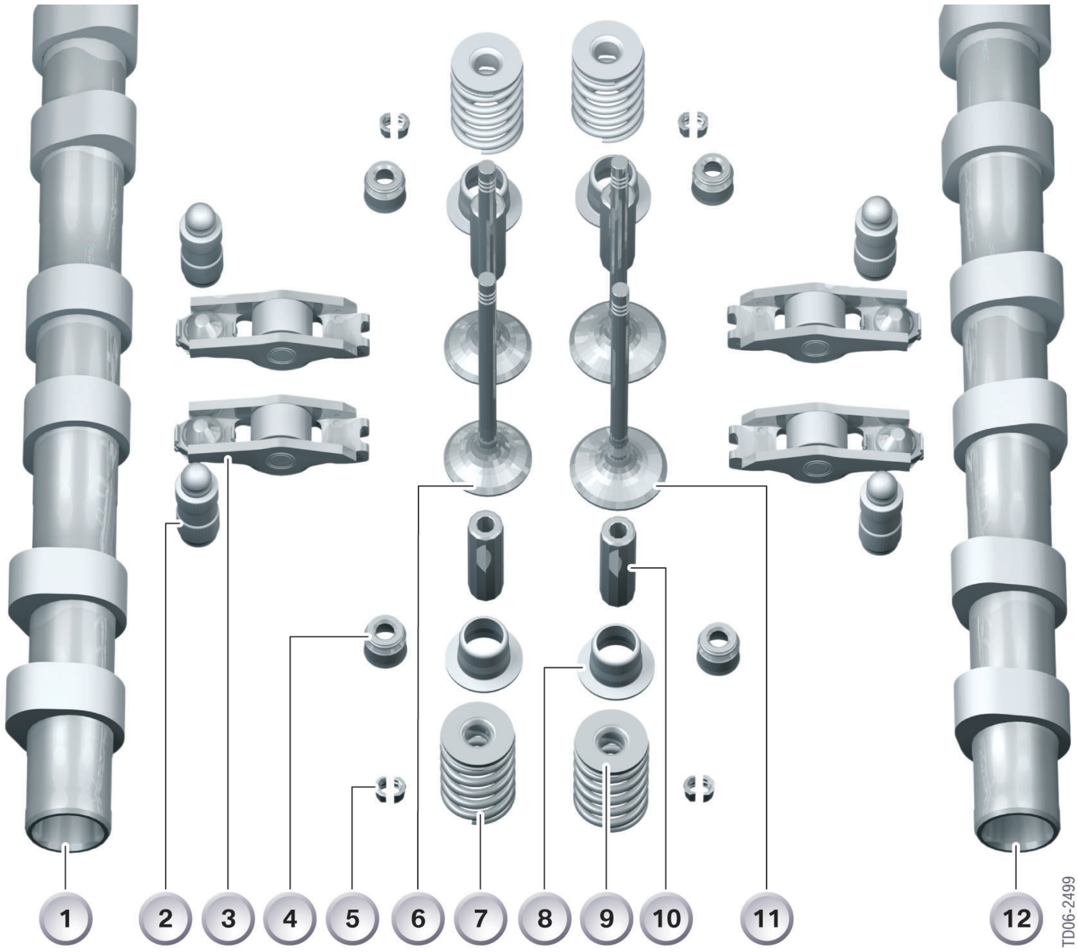
Like all current BMW diesel engines, the N47 engine has a **DOHC** valvegear layout.

This stands for "**d**ouble **o**ver**h**ead **c**amshaft" and means that the engine has overhead valves with two camshafts located above the cylinders. One camshaft is used for the intake valves, the other for the exhaust valves.

Cam movement on the N47 engine is transferred from the camshaft to the valve by roller cam followers in the same way as it is on all current BMW diesel engines.

The N47 is equipped with valve clearance adjustment (HVA) to ensure that the correct amount of play is maintained between the cam of the camshaft and the roller cam follower.

The following graphic shows the components of the valvegear on the N47 engine.

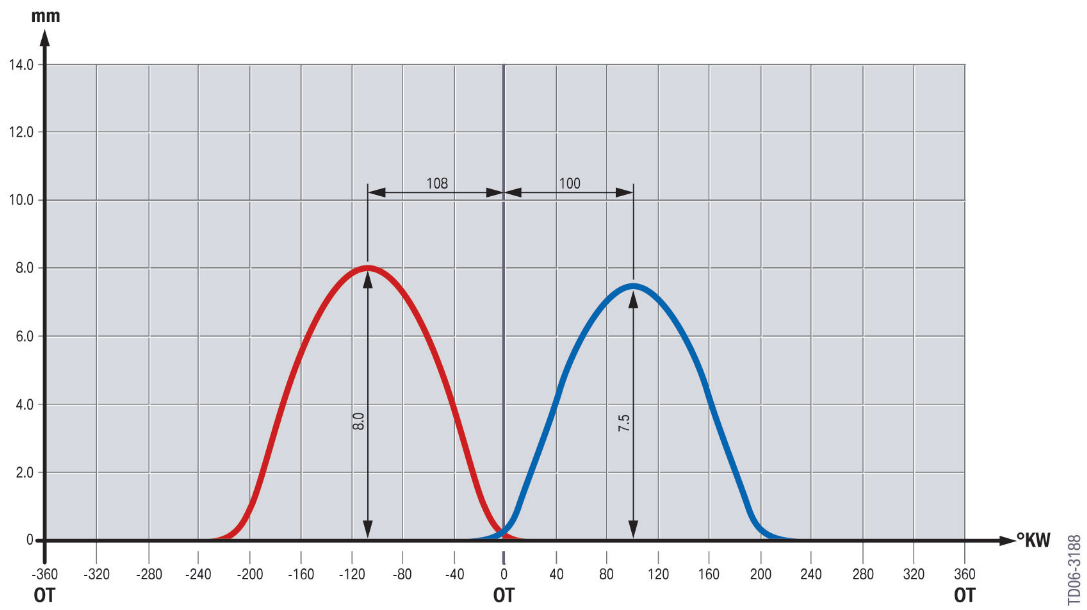


4 - N47 engine valvegear components

Index	Explanation	Index	Explanation
1	Inlet camshaft	7	Valve spring
2	Hydraulic valve-clearance adjuster	8	Lower valve spring retainer
3	Roller cam follower	9	Upper valve spring retainer
4	Valve stem seal	10	Valve guide
5	Valve collets	11	Exhaust valve
6	Inlet valve	12	Exhaust camshaft

Lower valve spring retainer (8) and valve stem seal (4) form a single component.

Timing diagram



5 - N47 engine timing diagram

		M47TU2 inlet	**N47 inlet**	**M47TU2 exhaust**	**N47 exhaust**
Valve diameter	[mm]	25.9	27.2	25.9	24.6
Max. valve lift	[mm]	7.5	7.5	7.5	8.0
Lobe separation	[°crankshaft]	100	100	108	108
Valve opens	[°crankshaft]	352.0	352.0	142.0	140.7
Valve closes	[°crankshaft]	568.0	568.0	364.0	362.5
Valve open duration	[°crankshaft]	216.0	216.0	222.0	221.8

Inlet valve

The diameter of the inlet valve has been increased by comparison with the M47TU2. With no difference in timing, a wider opening cross section yields improved inflow characteristics, facilitating the charge cycle.

Exhaust valve

The diameter of the exhaust valve has been reduced by comparison with the predecessor. Nevertheless, a greater valve lift produces better flow characteristics during ejection. The opening duration has been marginally reduced.

Crankcase

General information

The crankcase, also known as the cylinder block or engine block, comprises the cylinders, the cooling jacket and the crankshaft housing.

The crankcase of the N47 engine is an entirely new development.

The special features of the crankcase of the N47 engine are:

- Crankcase made of aluminium
- Balancing shafts integrated in the crankcase
- Chain drive located on the force transmitting side
- Majority of pressurized oil ducts are pre-cast
- Main bearing cap made of sintered metal.

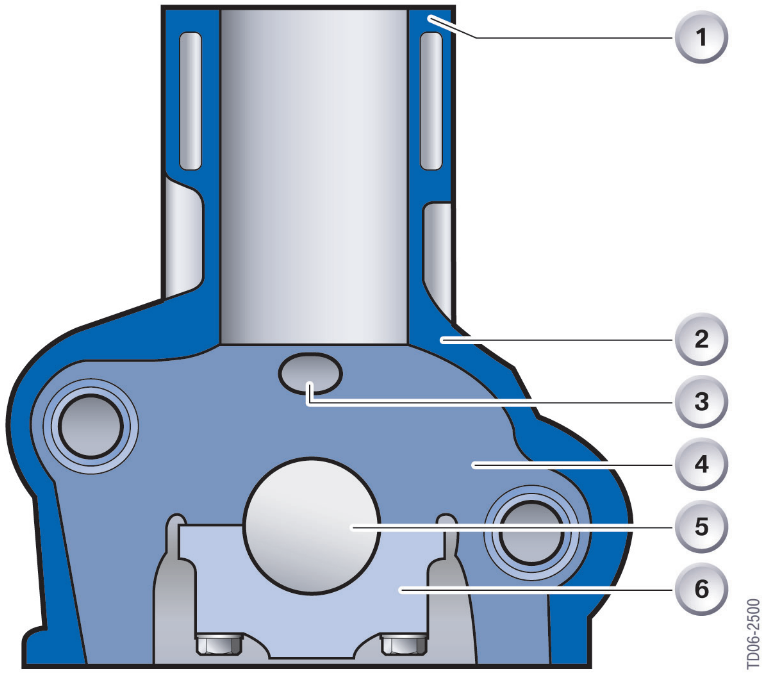
Further technical attributes include:

- Closed-deck design
- Main bearing pedestal with side walls that extend downwards and individual main bearing caps
- Main bearing caps with indent fit
- dry, thermally-joined, grey cast-iron cylinder bushes.

Design

To provide a better description of the type of crankcase design, this has been subdivided into various sections. The types of design can be classified according to the design of the following items:

- Deck
- Main bearing pedestals
- Cylinders



6 - Layout of the N47 engine crankcase

Index	Explanation	Index	Explanation
1	Deck	4	Bearing pedestal
2	Crankcase	5	Hole for crankshaft
3	Ventilation window (aperture)	6	Main bearing cap

Deck

The design of the deck affects not only the choice of casting method but also the rigidity of the crankcase. A distinction is made between an open-deck and closed-deck design.

The N47 engine is equipped with a crankcase with a closed-deck design.

As the name suggests, a closed deck is, to a large extent, closed in the area surrounding the cylinders.

There are holes and openings for oil pressure and return channels, coolant circulation channels, crankcase vents and cylinder-head bolts.

The coolant-channel openings connect the coolant chamber surrounding the cylinders with the coolant jacket in the cylinder head.

While this design does have certain disadvantages in respect of cylinder cooling in the TDC range, its benefits outweigh those of the open-deck design what with the greater rigidity of the deck and thus less deck deformation, less cylinder twist and better noise characteristics.

Main bearing pedestals

The design of the main bearing pedestal area is therefore of particular importance because this is where the forces acting on the crankshaft bearings are absorbed.

The different types of design are distinguished by the partition between the crankcase and the sump and the design of the main bearing caps.

In the N47 engine, the partition is below the centre of the crankshaft; the side walls of the crankcase extend downwards. Individual main bearing caps are used.

This design provides high rigidity and is cost-effective to manufacture.

Bearing pedestal

The bearing pedestal is the top half of a crankshaft main bearing in the crankcase. Bearing pedestals are always integrated into the cast of the crankcase.

In the N47 engine, there are ventilation windows in the bearing pedestals above the crankshaft.

When the engine is running, the air and vapour inside the crankshaft cavity are continuously in motion. The action of the pistons has a pump-like effect on those gases. The ventilation windows reduce these losses because they facilitate pressure compensation in the entire crankcase.

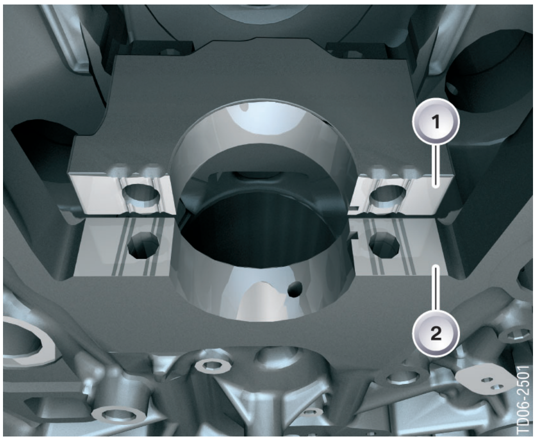
Main bearing caps

The main bearing caps form the lower seals for the bearing pedestals and are rigidly bolted to them. When the crankcase is manufactured, the bearing pedestals and caps are machined as one. Therefore, precise fixing of their relative positions is absolutely imperative. This is normally done by locating dowels or cut-away surfaces at the sides of the bearing pedestals. If the crankcase and main bearing caps are made of the same material, the two components may be made as one and then split by cracking.

In the N47 engine, a relatively new method is employed to ensure precise positioning. This involves an indent fit in the contact surface between the bearing pedestal and the main bearing cap. This technology was first used on the M67TU engine.

This positioning method ensures there is an absolutely flush surface junction between the bearing pedestal and main bearing cap in the bore for the main bearings even after dismantling and reassembly.

Main bearing caps with an indent fit are designed with a profile. During the initial tightening of the main bearing bolts, this profile is indented into the housing-side bearing pedestal surface and creates a positive lock along the transverse and longitudinal axis of the engine.



7 - N47 engine main bearing cap with indent fit

Index	Explanation
1	Main bearing cap
2	Main bearing pedestal

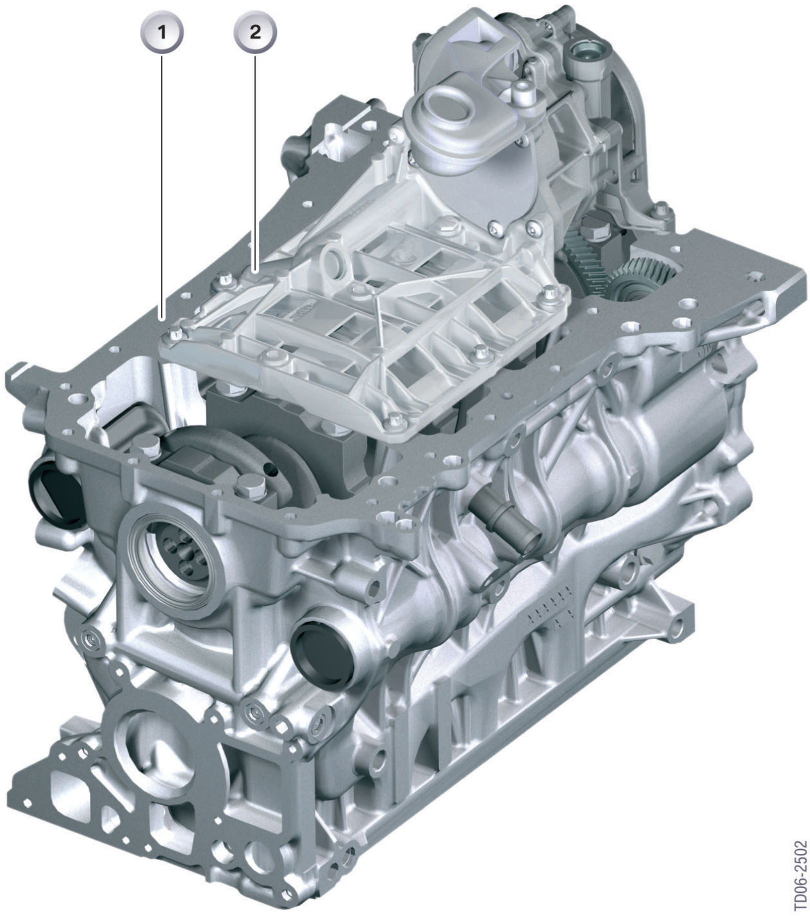
To provide positive lock along the longitudinal axis of the engine, the profile must be shorter than the housing-side contact surface. In this way, the profile does not protrude but instead has a limit position. To avoid making the bearing pedestal any wider than necessary, the bearing cap is slightly tapered near the profile.

Unlike the M67TU, only two rather than six profile elements per contact surface are used.

The main bearing cap is made of an extremely rigid, sintered iron material.

Reinforcement shell

A reinforcement shell bolted onto the crankcase from underneath provides the crankcase and crankshaft bearings with additional reinforcement.

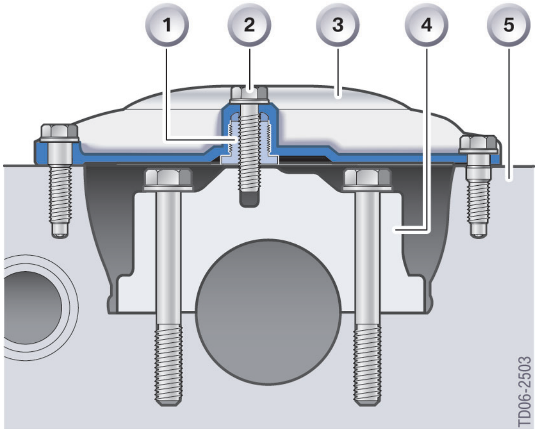


8 - Crankcase with reinforcement shell in the N47 engine

Index	Explanation
1	Crankcase
2	Reinforcement shell

The reinforcement shell is similar in function to the reinforcement on the M67TU engine; the only difference is that there are no individual reinforcement brackets used, but a common reinforcement shell covering the three centre crankshaft bearings.

This reinforcement shell reinforces the crankcase itself and additionally forms a connection to the main bearing caps. To this end, the reinforcement shell is bolted to the crankcase and the main bearing caps.



9 - Connection between reinforcement shell and main bearing cap

Index	Explanation
1	Spacer sleeve
2	Bolt in the main bearing cap
3	Reinforcement shell
4	Main bearing cap
5	Crankcase

A spacer sleeve is screwed into the reinforcement shell to exert a defined pressure on the main bearing cap. After the reinforcement shell has been connected to the crankcase, the spacer sleeve is tightened to a defined torque against the main bearing cap. The reinforcement shell is then bolted to the main bearing cap. This method produces an extremely rigid system overall.

⚠ Before the reinforcement shell is fitted, it is essential that the spacer sleeves be screwed into the reinforcement shell fully, otherwise there is a risk of damage. The procedure in the repair instructions must be observed. ◄

The reinforcement shell has the additional task of being an oil deflector. It is also connected to the oil/vacuum pump and contains the untreated and purified oil ducts.

Cylinder

As part of the combustion chamber, the cylinder is subjected to high thermal loads and pressures. With its finely machined surface, the cylinder liner provides good anti-friction and sealing characteristics in interaction with the piston rings. In addition, the cylinder carries the heat to the crankcase or directly to the coolant.

Since the aluminium of the crankcase is unable to meet requirements, the N47 engine is equipped with cylinder bushes.

These are made of grey cast iron and are thermally joined. Thermally joined means that the cold cylinder bushes are inserted into the heated crankcase. As it cools, the crankcase contracts, thereby ensuring firm seating of the cylinder bushes.

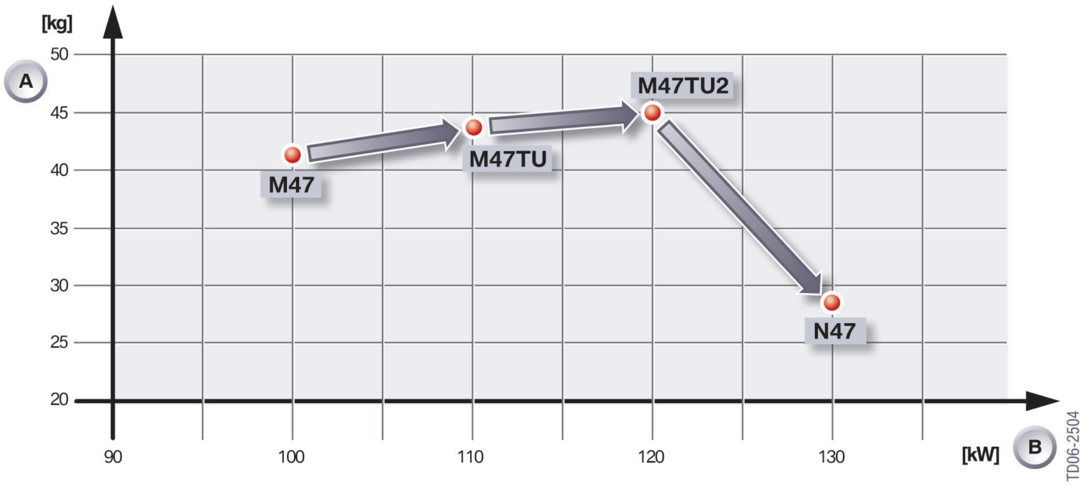
Dry bushes are used in the N47 engine. This means that the cylinder bush has no direct contact with the water jacket. The water jacket is completely enclosed by the crankcase cast.

Material

The N47 engine has a crankcase made of aluminium alloy, while the M47 engine has until recently been manufactured with a grey cast-iron crankcase. Aluminium crankcases were introduced on the M67TU and M57TU2 engine.

The crankcase is one of the heaviest individual components anywhere on the vehicle. It is also located in a position critical to driving dynamics, i.e. above the front axle. For this reason, it makes sense to exploit any potential for weight reduction to the maximum.

The density of aluminium alloys is about a third that of grey iron. However, that cannot be converted one-for-one into a weight advantage because the lower strength of the material means the crankcase has to be made thicker. Nevertheless, its use still sees a remarkable advantage in terms of weight. Indeed, the crankcase of the N47 engine is 38 % lighter than that of the M47TU2 - and this is despite the fact that the N47 is able to offer higher output.



10 - Development of crankcase weight and engine output

Index	Explanation	Index	Explanation
A	Weight of the crankcase	B	Engine output

Engine	Power output	Weight of the crankcase
M47	100 kW	43 kg
M47TU	110 kW	44 kg
M47TU2	120 kW	45 kg
N47	130 kW	28 kg

Other properties of aluminium alloys are:

- good heat conductivity
- good chemical resistance
- positive strength qualities
- good machinability

Pure aluminium is not suitable as a casting material for crankcases because its strength properties are inadequate. This is why the heat-treated alloy AlSi8Cu3, already tried-and-tested on many a BMW engine, is used for the crankcase of the N47 engine.

Cylinder head and cover

General information

There is hardly an engine assembly more influential on such operating properties as output efficiency, fuel consumption, and torque, exhaust emissions and noise characteristics than the assembled cylinder head. The cylinder head accommodates virtually the entire engine management system.

The cylinder head of the N47 engine largely conforms to the standards for current diesel engines. A special feature, however, is that the cylinder head comprises two large cast parts. The camshafts are integrated inside their own camshaft carrier.

The cylinder head of the N47 engine stands out for the following technical features:

- Material: AlSI7MgCu0.5
- Two-piece cylinder head with camshaft carrier
- Crossflow cooling
- Integrated EGR duct
- Four valves per cylinder
- Parallel valve arrangement (axes parallel with the cylinder axes)
- Tangential duct and swirl duct.

Design

The shaping of the cylinder head is determined to a very large degree by the components that it accommodates. The following factors fundamentally affect the shape of the cylinder head:

- Number and position of the valves
- Number and position of the camshafts
- Position of the glow plugs
- Position of the injectors and injection method
- Shape of the inlet and exhaust ducts

One of the requirements of the cylinder head is that it should be as compact as possible.

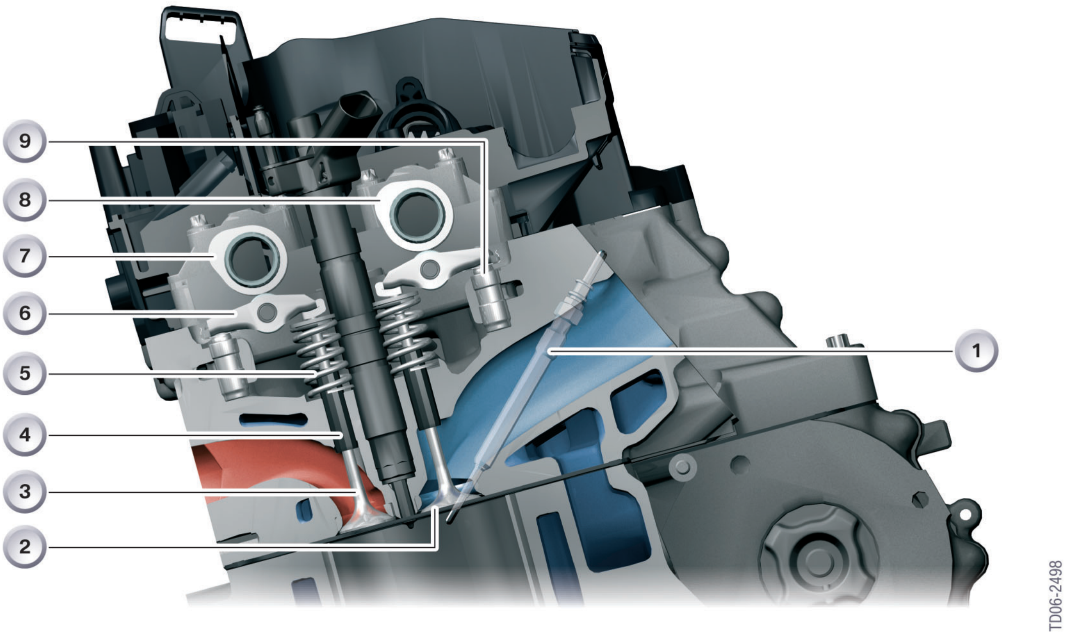
Essentially, cylinder heads are classified according to the following criteria:

- Number of components
- Number of valves
- Cooling method

Two-piece cylinder head

A cylinder head is described as two-piece if it comprises two cast parts. Bolts, bearing caps and small attachment parts are not included.

The N47 cylinder head comprises the main cast part, as good as the actual cylinder head, and a carrier for the camshafts.



11 - N47 engine cylinder head

Index	Explanation	Index	Explanation
1	Glow plug	6	Roller cam follower
2	Inlet valve	7	Exhaust camshaft
3	Exhaust valve	8	Inlet camshaft
4	Valve guide	9	Hydraulic valve-clearance adjuster
5	Valve spring		

Both camshafts are mounted in this camshaft carrier. This layout simplifies the manufacturing process.

The camshaft carrier is made of the aluminium silicon alloy AlSi9Cu3(Fe).

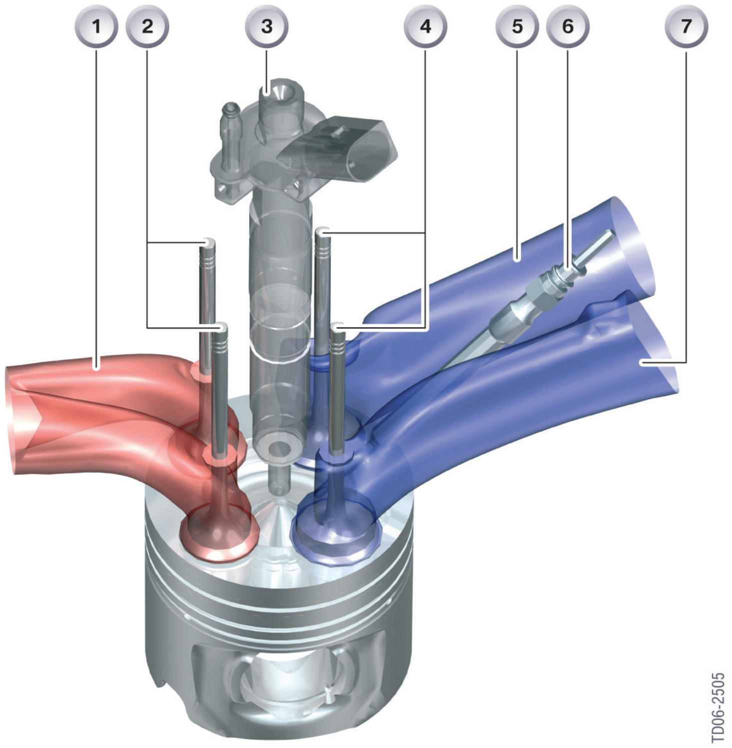
Number of valves

The N47 engine has four valves per cylinder. Ever since the M47 engine, BMW diesel engines have been equipped exclusively with this valve layout because it promotes a better charge cycle and increased efficiency of the combustion chambers by comparison with two-valve engines.

The reason being a greater overall valve surface area and thus a better flow cross section than is the case with two valves. The four-valve cylinder head also makes it possible to have the injector located centrally. This combination is necessary to ensure high specific output with low exhaust emissions.

Gas exchange ducts

With the four-valve concept, the engine has two inlet and two exhaust ducts in the cylinder head.



12 - Gas exchange ducts in the cylinder head of the N47 engine

Index	Explanation	Index	Explanation
1	Exhaust ducts	5	Swirl duct
2	Exhaust valves	6	Glow plug
3	Fuel injector	7	Tangential duct
4	Inlet ducts		

The inlet ducts can be distinguished as being the swirl duct and the tangential duct, which are designed to provide optimum mixture preparation and cylinder charging. The swirl duct and tangential duct branch off before they exit the intake manifold and pass through the cylinder head as separate ducts.

The exhaust ducts join together before they exit the cylinder head so that only one exhaust duct flows into the exhaust manifold.

Cooling method

The cooling topic is described in a separate section. However, cylinder heads are distinguished according the method of cooling adopted as there are a variety of different design concepts.

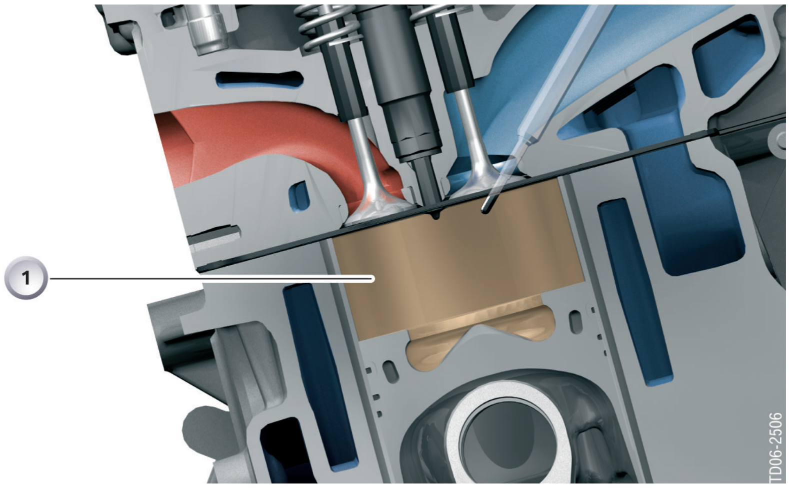
- Crossflow cooling
- Longitudinal flow cooling
- Combination of the two

The N47 engine, like all current BMW diesel engines, has a cylinder head with crossflow cooling.

With crossflow cooling, the coolant flows from the hot exhaust side of the cylinder head to the cooler inlet side. This offers the advantage of even heat distribution throughout the cylinder head. This prevents additional pressure losses in the coolant circuit.

Combustion chamber ceiling

As the ceiling of the combustion chamber, the cylinder head forms the upper boundary of the cylinder. Together with the piston geometry, it determines the shape of the combustion chamber. The combustion chamber is the space bounded by the cylinder head, the piston and the sides of the cylinder. The shape of the combustion chamber is crucial to mixture preparation.



13 - Shape of the combustion chamber in the N47 engine

Index	Explanation	Index	Explanation
1	Combustion chamber		

The N47 engine has a flat combustion chamber ceiling. Unlike on current BMW diesel engines, the inlet and exhaust valves are arranged in parallel.

Cylinder head cover

The cylinder head cover is often also called the valve cover, rocker cover or rocker box (even though, strictly speaking, there may not be any rockers!). It forms the upper seal of the engine casing.

The cylinder head cover of the N47 engine performs the following tasks:

- Sealing the top of the cylinder head from the outside
- Sound insulation
- Retention of the blow-by gas exhaust line from the crankcase, of the oil separation system and of the pressure regulating valve of the crankcase breather
- Retention of the fuel system rails
- Retention of the camshaft sensor
- Retention of the oil filler neck
- Retention of line feed-throughs.

To achieve good sound insulation, the cylinder head cover is partially isolated from the cylinder head. This is achieved by elastomer seals.

The cylinder head cover of the N47 engine is made of plastic.

The use of plastic as the material for the manufacture of cylinder head covers helps to save weight over aluminium versions. In addition, it is a material that has outstanding sound insulation properties and can be formed into very complex geometrical shapes.

Cylinder head seal

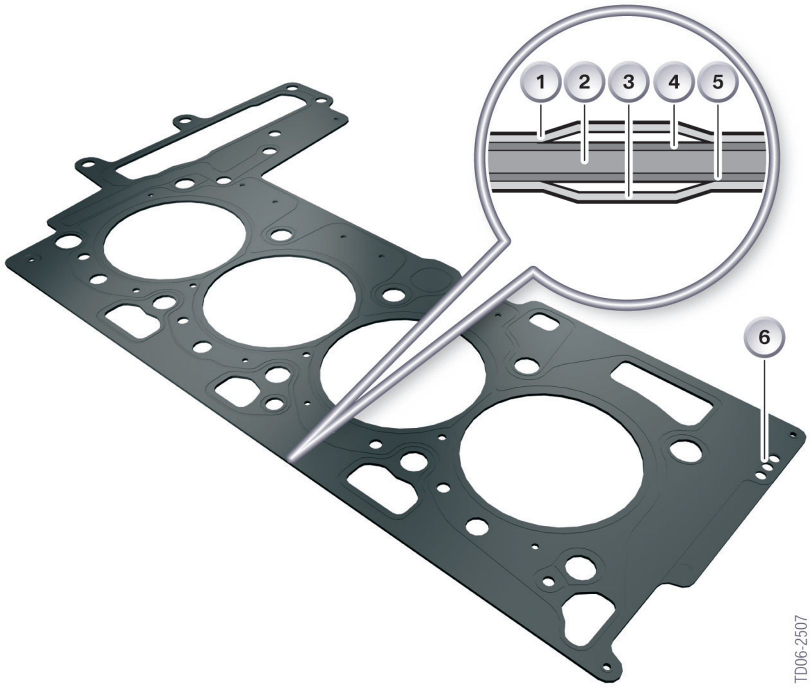
The cylinder head gasket (ZKD) is a very important component in any combustion engine. It is subjected to enormous thermal and mechanical loads.

The ZKD must be able to seal off four zones from each other. These are:

- Combustion chamber
- Atmosphere
- Engine oil ducts
- Coolant ducts.

Cylinder head gaskets can generally be distinguished as being soft-material gaskets or metal gaskets.

A three-layer metal gasket is used in the N47 engine.



14 - N47 engine cylinder head gasket

Index	Explanation	Index	Explanation
1	Outer spring steel layer	4	Inner spring steel layer
2	Intermediate layer with stopper seat welded on	5	Inner spring steel layer
3	Outer spring steel layer	6	Marking of ZKD thickness

Metal gaskets are used in engines subjected to high loads. These gaskets today consist of multiple layers of sheet steel inlays. The main feature of a metal gasket is that the effectiveness of the seal is essentially determined by integrated bead and stopper layers in the spring steel inlays. The deformation characteristics of the metal ZKD are such that it adapts ideally to match components around the cylinder head on the one hand and, to a large degree, absorb the springback that compensates for component deformation on the other hand. This springback occurs as a result of thermal and mechanical loads.

The four spring steel layers (functional layers) of the ZKD are made from a spring band. The stopper seat is welded onto the intermediate layer (spacer layer). All layers are made of rustproof steel. Additional, partial coatings optimize the function of the ZKD.

The cylinder head gasket is available to order in three different thicknesses, which depend on the piston projection concerned. The thickness is marked in the cylinder head gasket by holes, where one hole means the thinnest and three holes the thickest.

Sump

General information

The sump forms the lower extremity of the engine casing. In the N47 engine, the sump flange is located underneath the centre of the crankshaft as it is on all BMW engines.

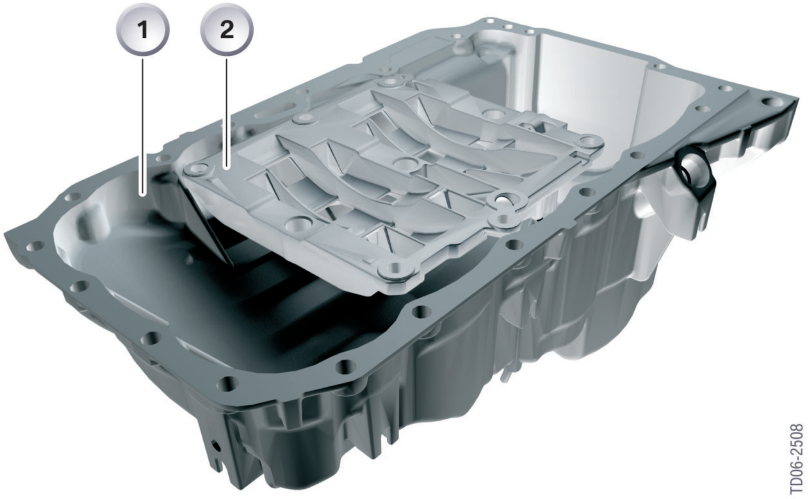
The sump of the N47 engine performs the following tasks:

- Reservoir for holding engine oil
- Return flow reservoir for engine oil
- Bottom cover for crankcase
- Reinforcement of the engine and transmission
- Retention of the thermal oil level sensor
- Attachment of oil dipstick tube
- Accommodation of oil drain plug
- Sound insulation

Sumps are made either of die-cast aluminium or double-walled steel sheet.

The sump is made of die-cast aluminium.

The oil deflector in the N47 engine is not integrated in the sump but in the reinforcement shell of the crankcase. With the use of an oil deflector, oil is removed from the crankshaft more efficiently. The oil baffle plates additionally prevent excessive foaming of the oil spray.



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Index	Explanation	Index	Explanation
1	Sump	2	Reinforcement shell with oil deflector

A girder-type seal with an elastomer strip is used for the sump. The girder material is aluminium. The cork gaskets that were used in the past had a tendency to compress which could cause the bolts to loosen.

⚠ To ensure that the seal functions correctly, no oil is permitted to come into contact with the rubber coating during assembly. There would be a risk of the seal sliding off the sealing surface. Therefore, the flange surfaces must be cleaned immediately prior to assembly. In addition, it must be ensured that all oil has been allowed to fully drain out of the engine so that it neither drips onto the flange surfaces nor the seal during assembly. ◄

Crankcase breather system

General information

When the engine is running, blow-by gases escape from the cylinder into the crankshaft cavity.

The blow-by gases contain unburned fuel and all the constituents of the exhaust gas. In the crankshaft cavity, they mix with the engine oil that is present in the form of oil vapour.

The volume of blow-by gas depends on the load. Pressure is created inside the crankshaft cavity and, due to the motion of the pistons, is also dependent on engine speed. This overpressure is also present in all spaces that connect to the crankshaft cavity (e.g. oil return, chain cavity, etc.) and if not released would force oil out through the sealed joints.

The crankcase breather system is designed to prevent this. It channels blow-by gases that are largely free of engine oil into the purified air pipe upstream of the turbocharger, and the drops of engine oil into the sump through an oil return pipe. The crankcase breather system also ensures that no overpressure builds up in the crankcase.

The N47 engine is equipped with a crankcase breather system with negative pressure regulation and has three cyclone filters to separate engine oil from the blow-by gas.

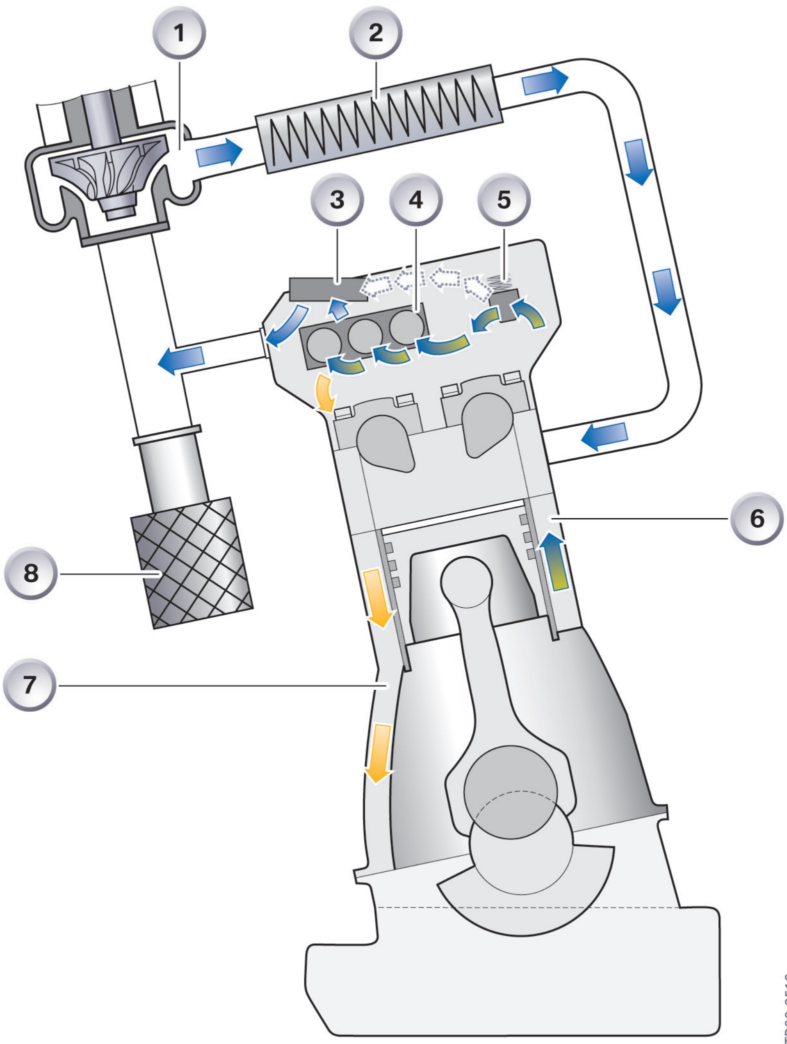
Crankcase breather system with negative pressure regulation

The crankcase breather system with negative pressure regulation was introduced to BMW diesel engines with the M51TU engine and has since become standard.

In the crankcase breather system with negative pressure regulation, a pressure regulating valve limits the negative pressure in the crankcase to a defined value. Excessive negative pressure in the crankcase could result in failure of the crankshaft seals. Fresh air would be drawn into the crankshaft cavity and create an oil sludge. With large volumes of blow-by gases, it may not be possible for the oil separator to separate all of the oil. This would be exhibited in the form of blue smoke in the exhaust gas.

In the crankcase breather system of the N47 engine, the crankshaft cavity is connected to the purified air pipe downstream of the air cleaner by the following components.

- Breather duct
- Plenum chamber
- Blow-by duct
- Cyclone oil separator
- Pressure regulating valve



16 - N47 engine crankcase breather system with negative pressure regulation

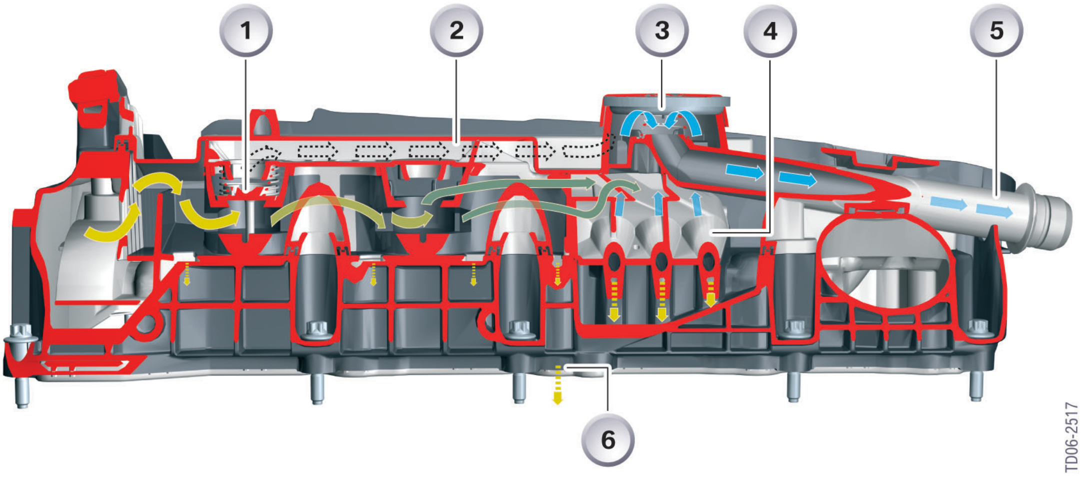
Index	Explanation	Index	Explanation
1	Exhaust turbocharger	5	Overflow valve
2	Charge-air cooler	6	Blow-by duct
3	Pressure regulating valve	7	Oil return channel
4	Cyclone filter	8	Air cleaner

A negative pressure is created in the purified air pipe due to the suction of the exhaust turbocharger.

As a result of the pressure difference relative to the crankcase, the blow-by gas is drawn into the cylinder head.

In the cylinder head, the blow-by gas enters the plenum chamber first. The purpose of the plenum chamber is to ensure that no oil spray, e.g. from the camshafts, enters the crankcase breather system. This is why an oil baffle plate is secured to the underside of the cylinder head cover of the N47 engine. An initial preliminary separation therefore takes place in the plenum chamber. The oil that deposits on the wall here flows back into the cylinder head.

The blow-by gas flows from the plenum chamber to the cyclone filters where the engine oil is separated from it. The separated oil returns to the sump. The cyclone filter also damps out gas vibrations. This prevents actuation of the diaphragm in the pressure regulating valve. The cleaned blow-by gas flows through the pressure regulating valve and into the purified air pipe upstream of the exhaust turbocharger.



17 - Oil separation in the cylinder head cover of the N47 engine

Index	Explanation	Index	Explanation
1	Overflow valve	4	Cyclone filter
2	Bypass duct as a safeguard against collapse	5	Blow-by in-feed line to the air intake system
3	Pressure regulating valve	6	Oil return to the sump

Pressure regulating valve

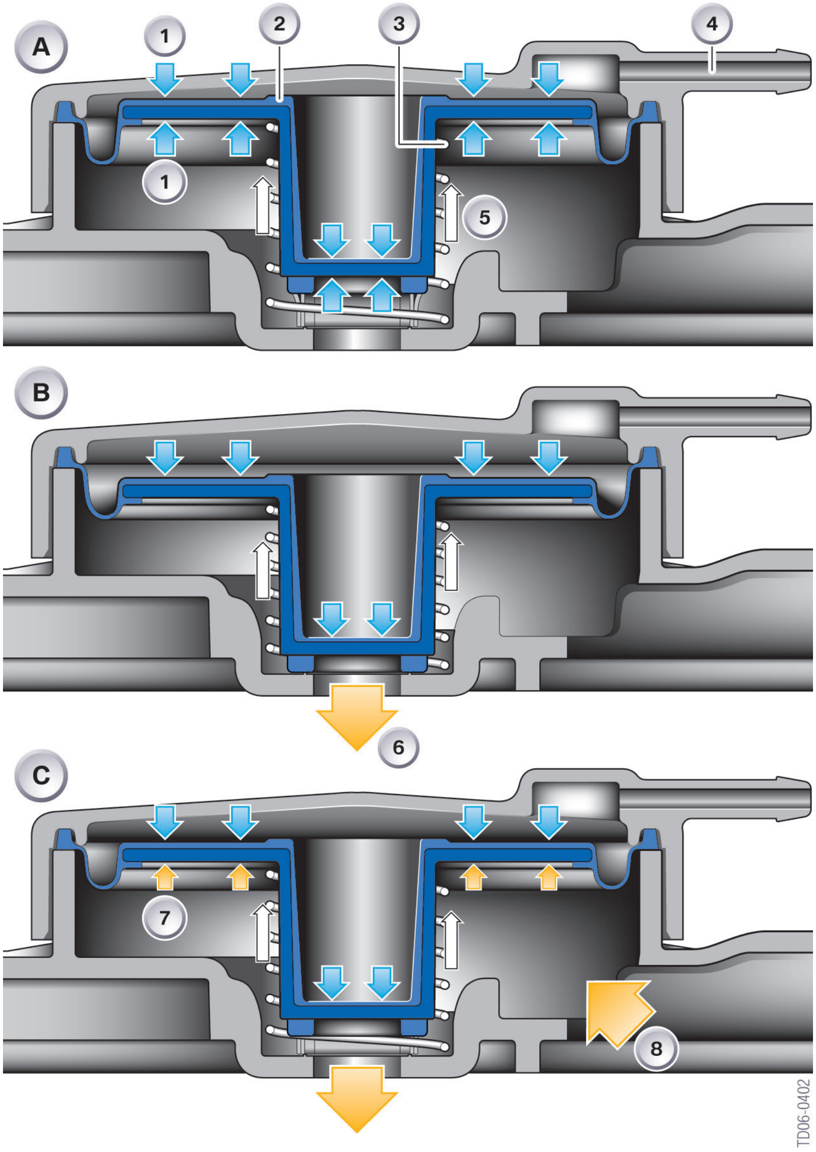
The pressure regulating valve has the job of maintaining a constant level of negative pressure inside the crankcase.

The following diagram shows the pressure regulating valve in three different operating modes.

In regulating mode, the force of the return spring (3) is in equilibrium with the moulded diaphragm (2) on which the crankcase negative pressure is acting.

The back of the diaphragm is exposed to atmospheric pressure by way of a hole in the valve body (4). If the crankcase pressure rises, then the aperture cross-sectional area in the pressure regulating valve increases. The negative pressure in the purified air pipe causes blow-by gases to be drawn off until the pressure in the crankcase drops so far that the diaphragm closes the opening cross section.

The strong negative pressure closes the pressure regulating valve in the event of a blocked air cleaner or snow in the intake snorkel, for example. This prevents oil from being sucked into the intake manifold.



18 - Regulating cycle of pressure regulating valve

Index	Explanation	Index	Explanation
A	Pressure regulating valve open when engine is not running	4	Connection to ambient pressure
B	Pressure regulating valve closed when engine is idling or overrunning	5	Force of return spring
C	Pressure regulating valve in regulating mode under load	6	Intake system depression
1	Ambient pressure	7	Effective depression in crankcase
2	Moulded diaphragm	8	Blow-by gas from crankcase
3	Return spring		

Regulating cycle

When the engine is not running, the pressure regulator is open (condition A). Ambient pressure is acting on both sides of the diaphragm, i.e. the force of the spring holds the diaphragm in the fully open position.

When the engine is started, the negative pressure in the intake pipe increases and the pressure regulating valve closes (condition B). The valve is always in this condition when the engine is idling or in overrun mode because there are no blow-by gases flowing. In other words a significantly low pressure (relative to the ambient pressure) is acting on the inside of the moulded diaphragm. As a result the ambient pressure, which is acting on the outside of the moulded diaphragm, closes the valve against the force of the spring.

Blow-by gas is produced with the engine under load and revving. Blow-by gas (8) reduces the relative negative pressure that is acting on the moulded diaphragm. Consequently, the return spring is able to open the valve and blow-by gas is drawn through. The valve opens to the point at which there is equilibrium between the ambient pressure and crankcase negative pressure plus spring force (C).

The more blow-by gas that enters the crankcase, the lower the relative negative pressure that acts on the inside of the diaphragm and thus the wider the pressure regulating valve opens. In this way, it is possible for a defined negative pressure (approximately 38 mbar) to be maintained in the crankcase.

Negative pressure in crankcase	Diaphragm response
> 38 mbar	Diaphragm moves towards fully closed position
< 38 mbar	Diaphragm moves towards fully open position

Safeguard against collapse

The N47 engine sees the first ever use of what we refer to as being a safeguard against collapse.

By collapse, we mean an event whereby blow-by gases cause such a high overpressure in the cylinder head that oil is forced into the intake port. This combusts uncontrollably. This causes the engine speed to increase and with it the blow-by gases and the pressure in the cylinder head - an unstoppable cycle begins. This can only end with total engine damage.

A pressure build-up would most likely take place at the cyclone filters because these are the narrow points in the system.

For this reason, the N47 engine has an overflow valve in the plenum chamber that acts as a bypass around the cyclone filters. It opens above a defined overpressure and allows the blow-by gases to flow directly to the pressure regulating valve. While no fine separation takes place with this solution, engine damage at least is prevented.

This system intervenes only in this emergency situation and has no bearing in normal operation.

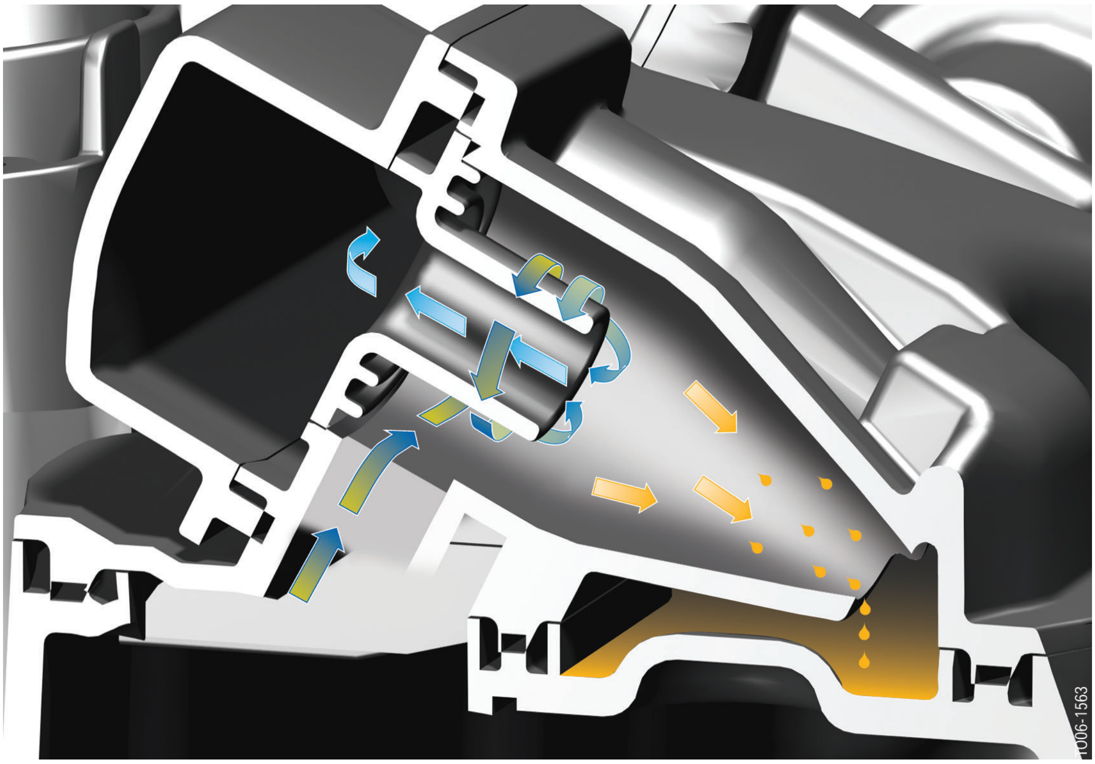
An overrevving of the engine is also prevented by an overrevving function of the DDE, which partially closes the throttle valve to a defined point.

Oil separation

The engine is equipped with various separators to free the blow-by gas of engine oil. These include:

- Cyclone filters
- Labyrinth separators
- Yarn helix separators.

The N47 engine has three cyclone filters arranged in parallel. The first two are operated at the same time, while the third is operated by a further blow-by gas flow.



19 - Function of a cyclone filter

With a cyclone filter, the blow-by gas is fed into a cylindrical body in such a way that the gas is made to rotate. The centrifugal force throws the oil outwards against the walls of the cylinder because it is heavier than the gas.

From there it can flow back down an oil return pipe and into the sump. A cyclone filter has very good separation qualities.

Crankshaft and bearings

General information

The crankshaft converts the linear (oscillatory) motion of the pistons into a turning motion (rotational). The force is applied to the crankshaft by the connecting rods and converted into torque. The crankshaft is mounted on and supported by the main bearings.

The crankshaft in the N47 engine additionally has the following tasks:

- Driving ancillary components by drive belts
- Driving the valvegear
- Driving the oil/vacuum pump
- Driving the high-pressure pump
- Driving the balancing shafts.

Overview table

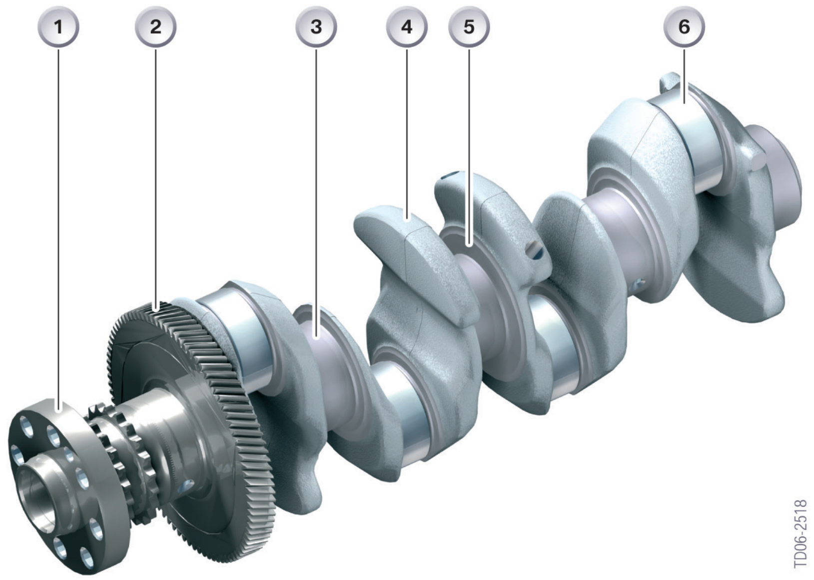
		M47TU2	**N47**
Material		37Cr4 BY	37Cr4 BY
Manufacture		Forged	Forged
Diameter of the main bearing journal	[mm]	60	55
Diameter of the big-end bearing journal	[mm]	45	50
Crank pin offset		180°	180°
Number of counterweights		4	5
Number of main bearing points		5	5
Position of thrust bearing		4	3

Design

The crankshaft is a one-piece component which, however, can be subdivided into a number of different parts. The main bearing journals locate in the crankcase main bearings to fix and support the crankshaft.

The connecting rod journals or crank pins are connected to the crankshaft by crank webs. The crank pins and crank webs are also sometimes called the crankshaft throws.

The N47 engine has crankshaft bearings in addition to each connecting rod journal - a connected rod is bearing-mounted on each connecting rod journal. This means that the crankshaft of the 4-cylinder in-line engine has five main bearing journals. The main bearings are numbered consecutively from front to back.



20 - N47 engine crankshaft

Index	Explanation	Index	Explanation
1	Output flange	4	Counterweight
2	Balancing shafts drive gear	5	Axial bearing thrust surface
3	Main bearing journal		Big-end bearing journal

The distance between the big-end bearing journals and the crankshaft axis produces a stroke of 90 mm on the N47 engine. The angle between the big-end journals determines the firing interval between cylinders. After two complete revolutions of the crankshaft, or 720° of rotation, each cylinder has fired once.

The angle between the big-end journals is known as the crank pin offset or crank angle and is calculated according to the number of cylinders, the engine design (in-line or V) and firing order. The aim is to obtain as smooth and even running of the engine as possible. For a 4-cylinder engine, this means that 720° is divided by 4, the number of cylinders. This produces a crank pin offset or firing interval of 180°.

There are oil holes in the crankshaft. They supply the big-end bearings with oil. They lead from the main bearing journals to the big-end bearing journals and are connected to the engine's oil circulation system through the bearing pedestals.

Counterweights create a balance of inertial forces around the crankshaft so as to produce even rotation of the shaft. They are designed in such a way as to also compensate for some of the oscillatory (vibrating) inertial forces in addition to the rotational (revolving) inertial forces.

The crankshaft of the N47 engine is equipped with five counterweights. An odd number of counterweights is unconventional and this is because the drive gear for the balancing shafts is located at the crank web of the last counterweight. This counterweight is therefore made smaller than the others and the crank web before it is fitted with an additional, smaller counterweight.

Production and properties

Crankshafts are either cast or forged High-torque engines in particular are fitted with forged crankshafts.

The N47 engine has a forged crankshaft made of 37Cr4 BY. BY stands for controlled cooling from the forging heat in the air and makes for uniform joints. The material specifications correspond to those of the M47 engine.

The surface treatment of the crankshaft is the same as on the M47 engine. To achieve the hardness required, a heat treatment method called nitrocarburizing is used. This forms an especially hard surface layer approximately 1/100 mm thick. After a regrinding of the crankshaft, (machining level 1 and 2), the nitrocarburizing must be carried out again.

Advantages of forged crankshafts compared to cast:

- Forged crankshafts are more rigid and have better vibrational properties
- Especially when combined with an aluminium crankcase, the crankshaft drive system must be as rigid as possible because the crankcase itself is made of material with a lower rigidity
- Forged crankshafts have better wearing characteristics at the bearing journals

In summary: The strength of a forged crankshaft is significantly greater than that of a cast one. A cast crankshaft would not be able to cope with the loads demanded on the N47 engine.

Bearings

As previously mentioned, a crankshaft in the N47 engine is bearing-mounted on each side of a big-end bearing journal. Those main bearings fix and support the crankshaft in the crankcase. The side subjected to load is in the bearing cap. The force that occurs as the result of the combustion pressure is taken up at this point.

Reliable operation of the engine requires the main bearings to be of a hard-wearing design. For this reason, bearing shells are used with sliding surfaces made from a special bearing material. The sliding surface of each bearing is on the inside, i.e. the bearing shells do not rotate together with the shaft but rather they are fixed in the crankcase.

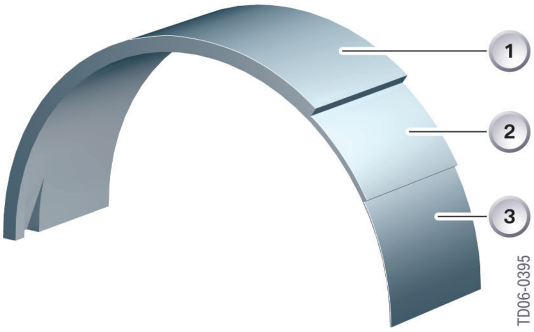
Resistance to wear is ensured if the surface of the bearing shell and the journal are separated by a film of oil. That means that an adequate supply of oil must be guaranteed. This takes place on the unladen side, i.e. from the bearing pedestal. The bearing shells are supplied with lubricating engine oil through oil bores.

There are two oil bores in the bearing shells. This is because the position of the oil bore in the main bearing block alternates between the left and right-hand side but the bearing shell should be an identical component.

An annular groove in the upper shell improves the distribution of the oil. However, such a groove reduces the contact area of the bearing and therefore the effective pressure on it. In effect, the bearing is divided into two halves each with a smaller capacity. For this reason, the oil grooves are generally located in the unladen area only. The lubricating oil also helps to cool the bearing.

Trimetal bearings

The highly stressed crankshaft main bearings are designed as trimetal bearings. The steel support shell, the unleaded bronze and the bearing metal layer made of a tin-copper alloy form the basis for a wear-resistant main bearing able to bear high loads.



21 - N47 engine trimetal bearing

Index	Designation
1	Steel supporting shell
2	Aluminium bronze
3	White metal layer

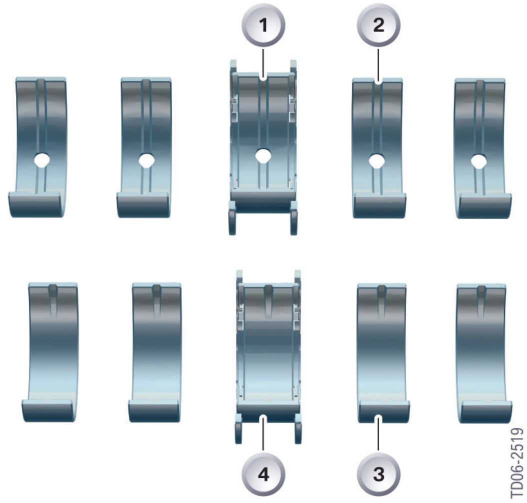
⚠ Careful handling of bearing shells is extremely important because the ultra-thin bearing metal layer is very easy to damage. ◄

Thrust bearing

The crankshaft has only one thrust bearing, also commonly referred to as a guide or axial bearing. The bearing secures the crankshaft in an axial direction and has to absorb forces in the longitudinal direction. These are generally created by:

- a gear with helically cut splines for driving the balancing shafts
- clutch operation
- axial forces that are produced in the converter on vehicles with automatic transmission.

A composite bearing is used in the N47 engine.



22 - N47 engine crankshaft bearings

Index	Designation
1	Thrust bearing shell in the main bearing pedestal
2	Bearing shell in the main bearing pedestal
3	Bearing shell in the main bearing cap
4	Thrust bearing shell in the main bearing cap

Composite bearings are made up of a number of separate components. In conjunction with this technology, a thrust washer is fitted on both sides. This makes it possible to create a dimensionally stable, loose connection with the crankshaft bearing and makes for easy assembly. The thrust washers are able to move and therefore find even contact, and wear is reduced. In the N47 engine, two composite bearing halves are fitted to locate the crankshaft. The crankshaft is therefore given a 360° thrust bearing and thus very good stability against axial displacement.

⚠ It is important that lubrication with engine oil is ensured. When thrust bearings fail, overheating is generally the cause.

A worn thrust bearing causes noise to be produced, mainly in the area of the vibration damper. Another symptom can be faulty readings from the crankshaft sensor, which on vehicles with automatic transmission is exhibited in the form of harsh gearshifts. ◄

The thrust bearing on the N47 engine is located at the point of the third main bearing, i.e. in the centre of the crankshaft. This has the benefit of promoting uniform thermal expansion. The steel of the crankshaft and the aluminium of the crankcase have different thermal expansion coefficients, i.e. their thermal expansion differs with differences between their temperature. If the thrust bearing were at the end of the crankshaft, the difference in expansion relative to the crankcase across the entire length of the crankshaft would be very big. However, since the thrust bearing is in the centre, thermal expansion is distributed symmetrically in both directions. The difference in expansion at either end of the crankshaft is then only half as big.

Connecting rods and bearings

General information

Within the crankshaft drive system, the connecting rods ("con rods") form the link between the pistons and the crankshaft. Through them, the linear motion of the pistons is converted into a rotary motion on the part of the crankshaft. They also transmit the forces generated by combustion pressure from the pistons to the crankshaft.

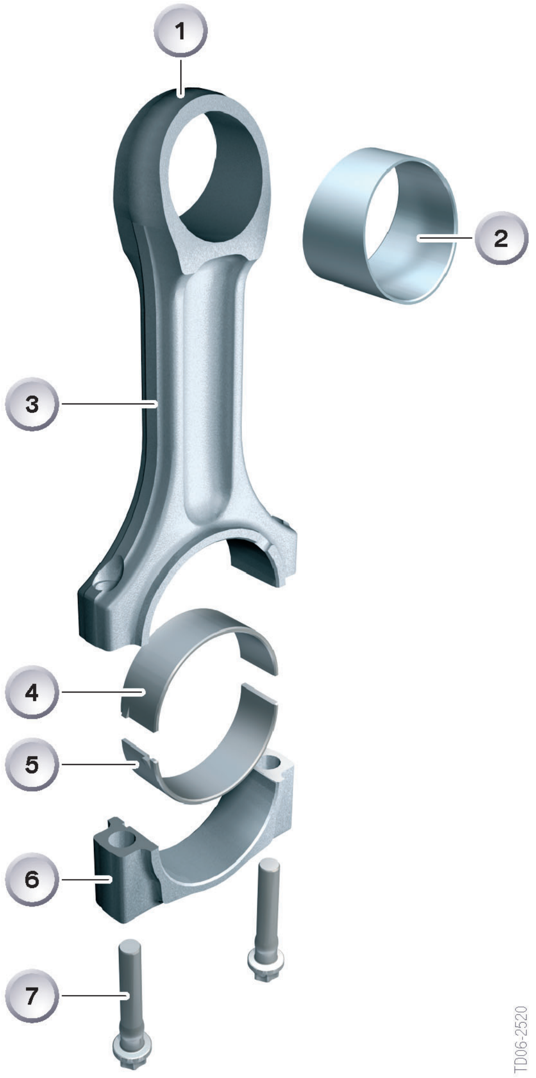
As connecting rods are subjected to very high rates of acceleration, their weight has a direct effect on the dynamics of the engine. In respect of the response of the engine, utmost importance is therefore assigned to optimizing the weight of the connecting rods.

Some special features of the N47 connecting rods are:

- rod-side big-end bearing half designed as sputter bearing.
- cracked connecting rod made of forged steel C70
- Trapezoidal connecting rods

Design

The connecting rod has two ends. The small end provides the connection to the piston by way of the gudgeon pin. Because of the lateral deflection of the con rod in the course of a crankshaft revolution, it has to be attached to the piston by a pivoting joint. This is achieved with the aid of a plain bearing. To that end, a bearing bush is press-fitted in the small end of the con rod.



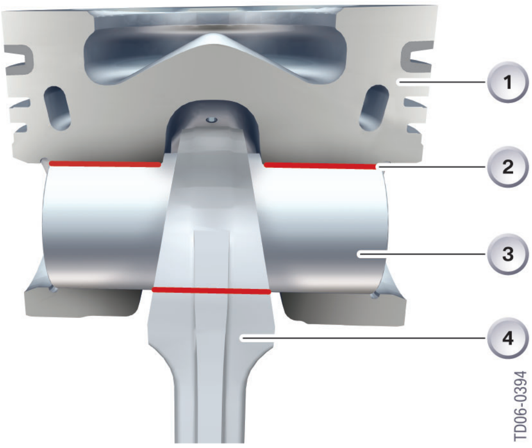
23 - N47 engine connecting rod

Index	Explanation
1	Small end connecting rod eye
2	Plain bearing
3	Con rod shaft
4	Con-rod bearing shell
5	Bearing shell in the big-end bearing cap
6	Big-end bearing cap
7	Big-end bearing bolts

There is no longer an oil bore at the end of the connecting rod (piston-end) that would have supplied the bearing with spray oil. At the crankshaft end is the split big end. The big end of the con rod has to be split so that it can be fitted around the bearing journal on the crankshaft. The big-end bearing is in the form of a plain bearing. The plain bearing consists of two bearing shells. The bearing is supplied with oil for lubrication through an oil hole in the crankshaft.

Trapezoidal connecting rods

A trapezoid con rod has a small end with a trapezium-shaped cross-section. That means the con rod narrows across small end from the junction with the shaft towards the top of the small end. Firstly, this enables a further weight reduction because material is removed on the "unstressed" side of the small end, while the side that bears the majority of the force retains its full width or is even wider. Secondly, it allows the gudgeon pin boss spacing to be reduced, which means there is less flexing of the gudgeon pin. Strictly speaking, there is an undercut of the force transmitting surface, as shown in the following graphic.



24 - Trapezoidal connecting rods

Index	Explanation
1	Piston
2	Force transmitting surface
3	Gudgeon pin
4	Con rod shaft

Another advantage is that the oil hole in the small end can be dispensed with because the slanted edge of the plain bearing bush allows oil intrusion. By doing away with the oil hole, its negative effect on the strength of that side of the bearing is also removed. This in turn makes it possible for the connecting rod to be made even narrower at this point. As a result both weight and space inside the piston are saved.

Production and properties

The con rod blank can be manufactured in a number of ways. The following options are available:

- Casting
- Sintering
- Drop forging.

The connecting rods of the N47 engine are manufactured using the drop forging technique and then cracked.

Drop forging

The original material from which the blanks are made are steel bars, which are heated to around 1,250 °C to 1,300 °C. The con rods are roughly pre-formed by rolling into the basic shape. The main forming process involves forging in the course of which excess material produces a burr that is removed in the next stage. The big-end eye is also made at this time. Depending on the steel alloy used, the component properties may be enhanced by further treatment after forging.

Cracking

As the name suggests, a cracked connecting rod has its big end split by being broken in half. The line of the fracture is scribed by laser cutting. Afterwards the big end is clamped to a two-part cracking mandrel and split by having a wedge driven into it.

This requires the use of a material that will fracture without first distorting to any significant degree (distortion < 30 µm). Blowing the split halves clean with compressed air ensures that no splinters are left on the fracture faces.

When the big-end bearing cap of a steel connecting rod is cracked, the fracture faces gain a very finely ridged surface. This surface structure centres the big-end bearing cap on the connecting rod with a perfect fit during assembly.

Cracking offers the advantage that the joint surfaces do not require any further machining. The two halves fit each other perfectly. The use of aligning bushes or bolts is not necessary.

⚠ If a big-end bearing cap were to be fitted the wrong way round or on the wrong connecting rod, the fracture face pattern of both parts would be destroyed and the bearing cap would not be centred. In that case the complete con rod set has to be replaced with entirely new parts. ◄

Con rod bolts

The con rod bolts are given special attention at this point because they are subject to very high stresses.

Due to the speed at which the engine runs, the con rod bolts are subjected to very rapidly pulsating loads. Since the con rods and their bolts are moving components of the engine, their mass must be kept as low as possible. In addition, the limited space available means that the fixings have to be as compactly dimensioned as possible.

As a result, the con rod bolts are very highly stressed and must consequently be handled very carefully.

⚠ You will find detailed information on connecting rod connections, such as tightening specifications, in the TIS. ◄

If a **new set of con rods** is being fitted:

When fitting the con rods, the con rod bolts must only be tightened once to check the bearing play and then once again for final assembly. Since the con rod bolts have already been tightened three times in the course of the machining processes during production, they have already reached their maximum tensile strength.

If the existing con rods are being re-used and **only the con rod bolts** are being replaced:

The con rod bolts must be tightened once again after checking the bearing play, loosened again and then tightened a third time to obtain maximum tensile strength.

⚠ If the con rod bolts are not tightened at least three times, or are tightened more than five times, engine damage will result. ◄

Stresses

The con rod bolts are under greatest stress when the engine is running at maximum revs but is not under load, e.g. during overrun. The higher the engine speed, the greater are the effective inertial forces. When the engine is overrunning, no fuel is injected, in other words no combustion takes place. That means that during the ignition stroke, instead of the piston driving the crankshaft, the opposite is the case. The crankshaft drags the piston downwards against the resistance of the piston's inertia, which results in tensile stress on the con rod. It is precisely that tensile stress that is exerted on the con rod bolts.

Even under those conditions, there must be no separation of the joint between con rod and big-end bearing cap. For that reason, the con rod bolts are tightened to their elongation limit when the engine is assembled at the factory. The elongation limit is the point at which the bolt begins to suffer plastic deformation. Further tightening does not increase the clamping force any further. In servicing operations, this is achieved by applying a specified jointing torque and tightening angle.

Weight classification

The connecting rods are some of the moving masses in the engine and therefore have an effect on engine operation. This effect is a particularly complex one because the big end moves in a circular motion while the small end moves back and forth in a straight line.

To ensure the engine runs evenly, the con rods must match a specified weight to within very tight tolerances. In the past, an extra machining allowance was provided and then milled away as required. With modern manufacturing processes, the production parameters can be so precisely controlled that the components can be produced within a satisfactory weight tolerance.

To gain even further control over the influence of the connecting rods on engine operation, the connecting rods are classified into weight categories.

These weight categories are classified separately according to the weight of the big and small end and then combined (see the following table).

		Weight of the small end				
Weight of the big end	Class A	A1	A2	A3	A4	A5
	Class B	B1	B2	B3	B4	B5
	Class C	C1	C2	C3	C4	C5
	Class D	D1	D2	D3	D4	D5
	Class E	E1	E2	E3	E4	E5

The combination provides the weight class (e.g. A1, C2, etc.). A weight class has a tolerance of ±4 g. This divides into ±2 g for the big end and ±2 g for the small end.

⚠ In the same engine, only connecting rods of the same weight class may be fitted. ◄

Pistons, piston rings and gudgeon

General information

The piston is the first link in the chain of the power transmitting components of an engine. The task of the piston is to take up the pressure forces that occur during the combustion process and to transfer them via the gudgeon and connecting rod to the crankshaft. This therefore means the thermal energy of the combustion process is converted into mechanical energy. An additional task of the piston is to guide the small end of the con rod.

Together with the piston rings, the piston must reliably seal off the combustion chamber to prevent the escape of gas and penetration of lubricating oil under all load conditions. The lubricating oil at the contact surfaces assists the sealing effect.

The piston of the N47 engine is made of an aluminium-silicon alloy like all pistons in BMW diesel engines. Full-skirt Autothermatik pistons are used; these are cast with steel inlays for reducing installation play and serve to regulate heat retention. As a consequence of the material pairing with the cylinder wall made of grey cast iron, the surface of the piston skirt is coated with graphite (Graphal method), which reduces friction and improves noise characteristics.

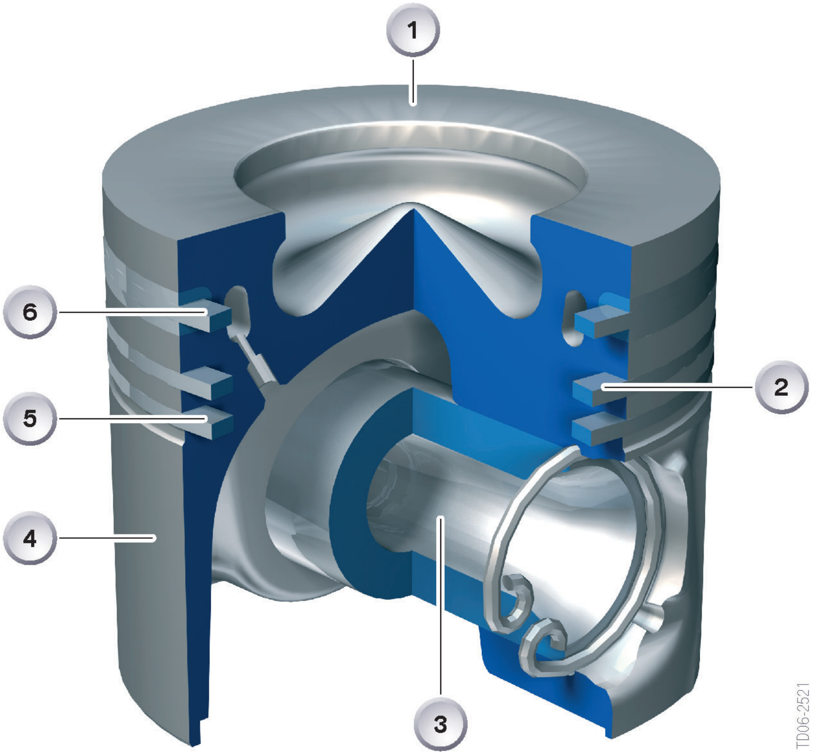
Design

Like all BMW diesel engines, the N47 engine has a solid skirt piston, which is very similar in design to that of the M47 engine.

The basic areas of the piston are:

- Piston crown
- Ring belt with fire land and cooling duct
- Gudgeon boss
- Skirt.

While the diameter of the piston is the same as the one used on the M47TU2 engine, the total height is greater and compression height has also been increased.



25 - N47 engine piston

Index	Explanation	Index	Explanation
1	Piston crown	4	Piston skirt
2	2nd piston ring	5	3rd piston ring
3	Gudgeon pin	6	1st piston ring

Piston crown

In the N47 engine, too, there is a combustion chamber recess in the piston crown. The shape of the combustion chamber recess is determined by the combustion process and the valve arrangement. It is similar in design to the one in the M47TU2 engine, but somewhat deeper overall. Another difference is that there are no valve pockets because the valves are arranged vertically in relation to the piston crown.

This deals with what we refer to as dead space reduction. Since the piston crown has no valve pockets, air flows out of the gap between the piston crown and the cylinder better during compression.

The shape of the piston crown and the combustion chamber recess help to determine the mixture flow characteristics inside the combustion chamber and not least the compression ratio.

The piston ring belt area is divided into what is known as the fire land, between the piston crown and the first piston ring, and the ring land, between the 2nd piston ring and the oil scraper ring.

Ring belt

The ring belt is also commonly referred to as the piston ring zone. It includes the grooves for accepting the piston rings, the fire land and the piston cooling duct.

The ring belt has three ring grooves. Between the ring grooves are the lands. The land above the first piston ring is referred to as the fire land.

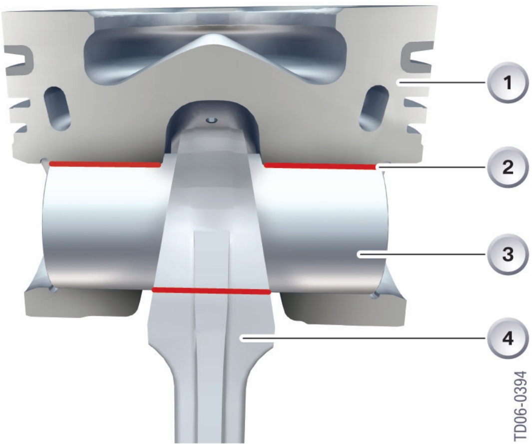
Both the fire land height and the ring land widths have been increased by comparison with the M47TU2 engine.

The first piston ring groove is a ring carrier. This is made of cast iron and is much more resistant to the friction and impact wear promoted by the high combustion pressures than the aluminium-silicon alloy of the piston. The ring carrier is cast into the piston and forms a metal connection with it, which prevents it from coming loose on impact and promotes the transfer of heat.

On the inside of the piston, the cooling duct runs directly behind the first piston ring groove. This is supplied with spray oil through a bore; the oil is then able to flow away through a second bore.

Gudgeon boss

Combustion pressure is transferred to the connecting rod by the gudgeon boss and then to the crankshaft. This makes them the part of the piston that is subjected to the heaviest loads. The loads are reduced by an increase in the area of the gudgeon seat. This is made possible by a trapezoidal connecting rod as shown in the following graphic.



26 - Trapezoidal connecting rods

Index	Explanation
1	Piston
2	Force transmitting surface
3	Gudgeon pin
4	Con rod shaft

Piston skirt

The piston skirt is responsible for guiding the piston in a straight line inside the cylinder.

Full-skirt pistons are used due to the high loads that occur on the diesel engine. This design promotes straighter travel of the piston inside the cylinder thanks to the long, continuous contact surface.

It can only do so provided there is sufficient clearance inside the cylinder bore. However, this degree of clearance in conjunction with the con rod deflection produces secondary piston motion involving a rocking action and the piston pressing alternately against opposite sides of the cylinder.

That secondary motion is also significant with regard to the sealing effect of the piston rings and oil consumption, and also has an effect on piston noise. A longer piston skirt promotes straighter travel of the piston inside the cylinder.

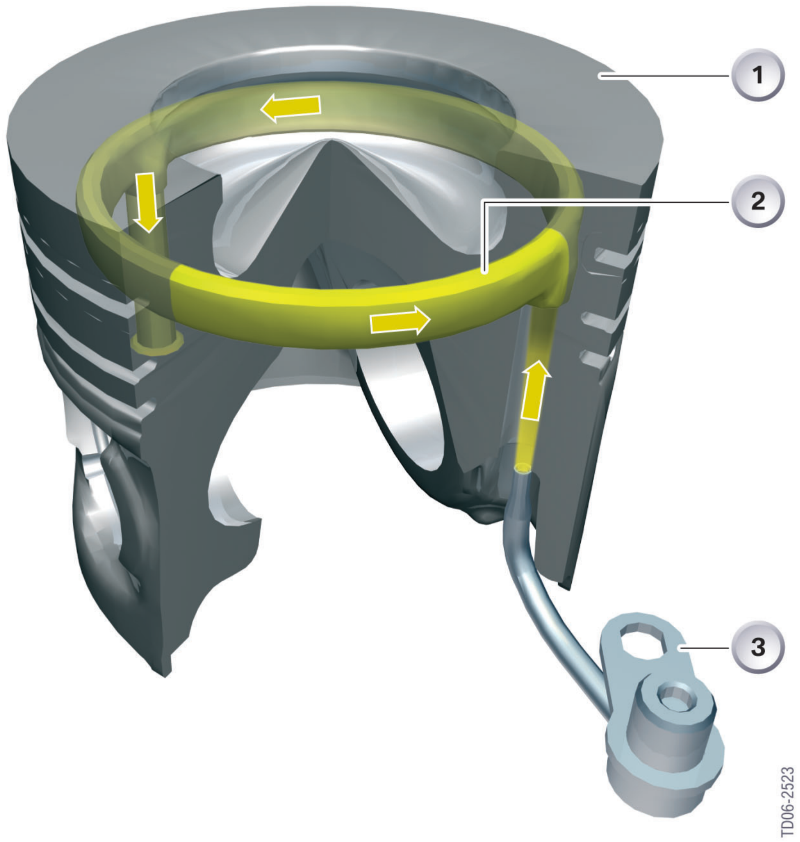
The full-skirt piston, which is also known as a solid skirt piston, has a closed skirt that is only broken by the gudgeon pin bore.

The piston skirt is a slide or friction partner of the cylinder wall. A specific material pairing must be observed here. Since the N47 engine has grey cast-iron cylinder bushes, the piston is coated with graphite.

Cooling

There is a cooling duct (annular channel) in the piston ring zone to carry heat away from the piston crown effectively.

An oil spray nozzle supplies the underside of the piston with cooling oil. It is precisely joined with a bore hole in the piston that leads to the cooling duct. The movement of the piston causes the oil to circulate and has a "shaker effect". The oil in the channel oscillates and thereby improves the cooling effect because more heat can be transferred to the oil. The oil flows back into the crankcase cavity through a drain hole.



27 - Cooling duct in the piston of the N47 engine

Index	Explanation	Index	Explanation
1	Piston crown	3	Oil spray nozzle
2	Cooling duct		

Piston rings

Piston rings are metal seals that have the following tasks:

- To seal the combustion chamber from the crankcase
- To conduct heat from the piston to the cylinder wall
- To control the amount of oil on the cylinder liner

In order for the piston rings to effectively fulfil their tasks it is necessary that they rest on the cylinder wall and on the edge of the piston ring groove. Contact with the cylinder wall is ensured by the radial spring force of the piston ring. The oil scraper ring is assisted further by an additional spring.

The piston rings turn in the grooves during engine operation and thus alter the position of the impact. This is due to the lateral force that is exerted on the piston rings as the contact point is changed. This frees the ring grooves of deposits. It also prevents the joint of the piston ring wearing into the cylinder barrel.

Types of design

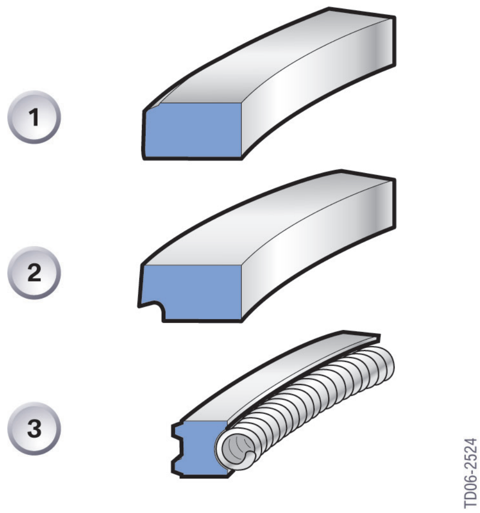
Piston rings are classified into different types according to their function.

- Compression rings
- Oil scraper rings.

Compression rings ensure that as little as possible of the combustion gases escape - between the cylinder wall and the piston - from the combustion chamber into the crankcase. Only by doing so can they ensure that sufficient pressure is produced in the combustion chamber during combustion for the engine to generate the required power. And without the piston rings it would not be possible during the compression stroke to produce the compression that is required for ignition.

Oil control rings control the oil film on the inside of the cylinder wall. They wipe away surplus lubricating oil from the cylinder wall and prevent the oil from combusting. They are thus also responsible for the rate at which the engine consumes oil.

Like all BMW diesel engines, the N47 engine has two compression rings and an oil scraper ring. The following graphic shows the piston ring set.



28 - N47 engine piston ring set

Index	Explanation
1	Plain compression ring with sharp lower edge
2	Taper-faced ring
3	Bevelled ring with hose spring

The **plain compression ring** is seated in the first position and is used only for its compression qualities. Its upper outer edge has a small chamfer. The outside surface is polished and slightly crowned.

The **taper-faced ring** is also a compression ring. The taper causes the piston ring to change from being flat to form a conical contact face, which also lends it an oil scraping effect. Even when removed, the taper-faced ring can be seen to have a minimally conical contact face. This results in a shorter run-in time. The backing-off of the tab enables the oil scraped off the running edge to be carried away and thereby prevents the formation of an oil build-up, which would otherwise diminish the scraping effect.

⚠ Taper-faced rings must not be fitted the wrong way round. The rebate must be at the bottom. Incorrect installation leads to engine damage ◄

The **bevelled ring with hose spring** is purely an oil scraper ring. A high surface contact pressure, which arises as a consequence of the two slide lands and of the chamfer in particular, promotes the oil scraping effect. Small bores around the circumference make it easier for the scraped up oil to be carried away into the annular groove of the piston. This contains four small bores for the return of the oil. The hose spring (cylindrical spring) amplifies the surface contact pressure and mould filling capacity. The spring, which is seated in a rounded groove in the cast ring, acts evenly around the entire circumference, which, among other benefits, helps to achieve the high levels of flexibility afforded by this design. The contact face of the ring is coated with chrome.

⚠ A damaged or broken oil control ring cannot be identified once fitted. The effects only come to light after a certain period of use. ◄

Gudgeon pin

The gudgeon connects the piston to the connecting rod. Due to its rapid to-and-fro movements with the piston, the gudgeon should only have a low mass otherwise high acceleration forces would be required. The alternating loads, unfavourable lubrication conditions and the low play of the gudgeon boss or in the connecting rod eye are particularly demanding.

A tubular, floating bearing design has become an accepted standard for the gudgeon. The gudgeon of the N47 engine is made of hardened steel 16MnCr5.

Appropriate gudgeon security measures prevent lateral deflection. These consist of radially-sprung steel rings (circlips), which are fitted in the associated grooves in the gudgeon eyes.

Balancing shafts

General information

Inertial forces are produced by the crankshaft drive during engine operation. The inertial forces can be distinguished as being rotational forces (turning motion) and oscillatory forces (to-and-fro motion). Rotational forces in the crankshaft drive are compensated for by counterweights and counterbalancing. Oscillatory forces, however, can only be compensated for to a certain extent. With the 4-cylinder in-line engine in particular, inertial forces are generated that cannot produce the smooth engine operation desired by means of counterweights. The use of balancing shafts minimizes this disadvantage inherent in the operating principle of 4-cylinder in-line engines.

Of all BMW diesel engines, balancing shafts have only been used on M47TU engines and now the N47. While their operating principle has remained the same, the installation of balancing shafts in the N47 engine differs entirely from their installation in the M47TU engines.

The balancing shafts in the M47TU and M47TU2 engines form a single unit with the oil pump, which is bolted onto the crankcase from underneath. In the N47 engine, the balancing shafts are individual parts that are accommodated inside the crankcase.

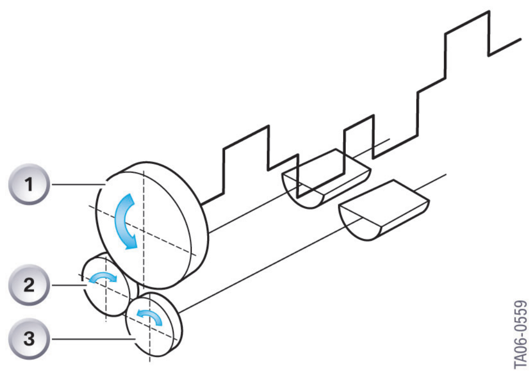
Operating principle

Mass balancing is the equalization of imbalances inherent in structural designs. The equalization of imbalances inherent in manufacture is known as counterbalancing.

The inertial forces are classified by "orders". An order is the frequency with which an event occurs in relation to the crankshaft speed. The 1st order force of inertia changes amplitude with crankshaft frequency - hence 1st order - and direction twice during one revolution.

The 2nd order force of inertia changes amplitude with twice the crankshaft frequency and direction four times during one revolution.

The task of the balancing shafts is to improve the smoothness and noise characteristics of the engine. This is achieved by two counter-rotational shafts that turn at twice the speed of the crankshaft. The shafts are fitted with imbalance masses, which counteract the imbalanced inertial forces of the crankshaft.



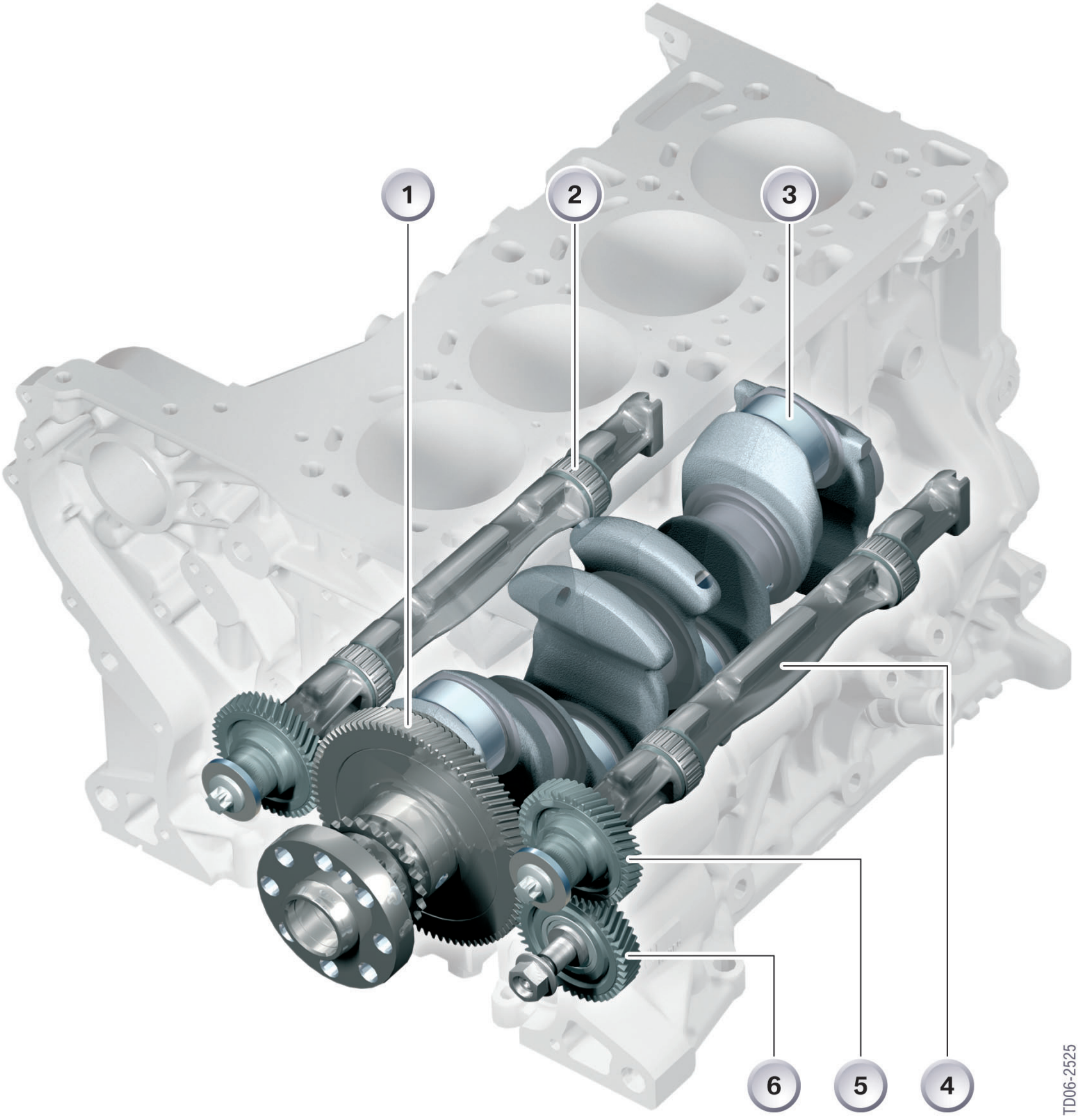
29 - Principle of the 2nd order balancing shafts

Index	Explanation
1	Drive gear
2	Balancing shaft drive gear
3	Balancing shaft drive gear

Design

As previously mentioned, the balancing shafts of the N47 engine are located inside the crankcase. They are inserted from the front.

This means that it is also possible to fit the N47 engine with balancing shafts into xDrive vehicles.



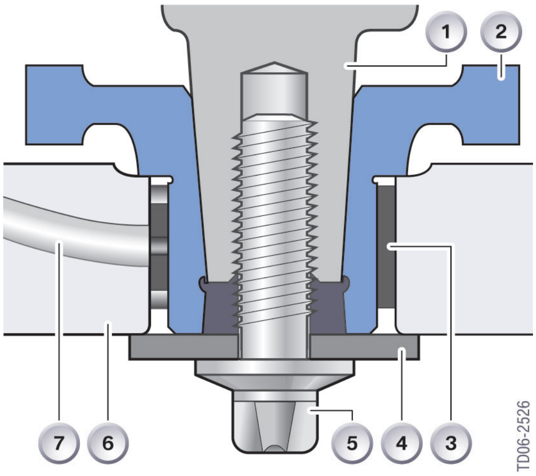
30 - N47 engine balancing shafts

Index	Explanation	Index	Explanation
1	Crankshaft drive gear	4	Balancing shaft
2	Needle bearing	5	Balancing shaft drive gear
3	Crankshaft	6	Idler gear

The graphic shows the crankcase from the force transmitting side (rear).

The balancing shafts are driven by a helically cut gear ring on the final crank web. On the right-hand side of the engine (exhaust side), an idler gear is fitted in front of the balancing shaft to reverse the direction of rotation.

The drive gears of the balancing shafts are each connected to the balancing shaft by a tapered connection.



31 - Connection of the balancing shaft to the drive gear

Index	Explanation
1	Balancing shaft
2	Drive gear
3	Bush
4	Thrust washer
5	Screw
6	Crankcase
7	Oil gallery

The tapered connection is pressed together by a screw connection. The thrust washer that is used for the connection and a thrust surface on the drive gear form the thrust bearing for the balancing shafts.

Two needle bearings for each balancing shaft form the radial bearing. These are not supplied with extra oil. The thrust bearing is supplied with lubricating engine oil through an oil duct. The bore in the bush assumes the role of a throttle. The oil reaches the axial thrust surfaces through a gap in the bush.

For the balancing shaft to turn at twice the speed of the crankshaft, the drive gears of the balancing shafts are half the size (44 teeth) of the toothed ring on the crankshaft (88 teeth).

Idler gear

The idler gear reverses the direction of rotation of the balancing shaft on the exhaust side of the engine. To keep the rotation speed the same, it is the same size as the drive gears of the balancing shafts.

It is mounted on its shaft by an angular-contact ball bearing. This shaft is fitted and screwed in by a steel bush pressed into the crankcase.

A sleeve is used because manufacturing tolerances are better maintained than if the shaft were fitted directly into the aluminium crankcase.

The tooth flanks of the idler gear are coated to make circumferential backlash adjustment possible as it is on the M47TU2.

Rotational vibration damping

General information

The energy that is transmitted to the crankshaft in a reciprocating piston engine does not follow an even pattern in reality. Firstly, there is the periodic nature of the combustion cycle, and secondly the power transmission by way of a connecting rod whose angle relative to the crankshaft is constantly changing.

That unevenness of power delivery is overlaid by the pulsating gas pressures produced by combustion.

The result is very uneven rotation. Construction of engines with multiple cylinders significantly reduces that unevenness of rotation because the forces can be transmitted to the crankshaft sequentially.

The firing order and firing intervals are therefore tuned to each other. However, there is always a certain degree of unevenness of rotation that remains.

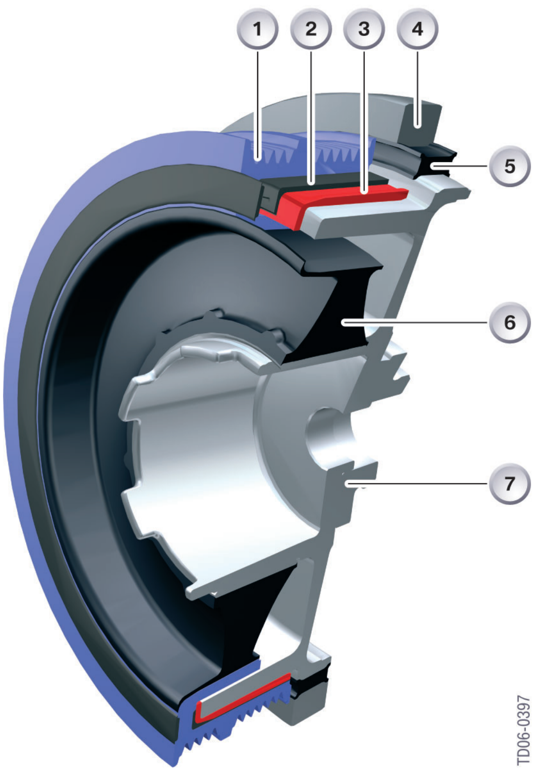
That uneven rotation pattern results in fluctuations in engine speed. The crankshaft drive system is accelerated when there is a surplus of power and decelerated when there is a shortfall. A flywheel helps to reduce the fluctuations in engine speed.

It forms an additional mass within the crankshaft drive system and therefore increases its mass moment of inertia. It acts as an energy store which stores up the energy when there is a power surplus and releases it when there is a power shortfall.

Damper systems, where the flywheel is "spring-mounted" on the crankshaft, have an even better effect at reducing rotational vibrations.

With the N47 engine, this is a rotational vibration damper on the belt drive, and a dual-mass flywheel if a manual transmission is fitted.

Rotational vibration damper



32 - Rotational vibration damper

Index	Explanation
1	Belt pulley
2	Vulcanization layer
3	Plain bearing
4	Flywheel
5	Damping rubber
6	Decoupling rubber
7	Hub

The rotational vibration damper consists of a hub (7) and a flywheel (4). They are both connected by a (vulcanized) damping rubber (5) and are therefore able to withstand a few degrees of relative twist. The hub is bolted to the front end face of the crankshaft.

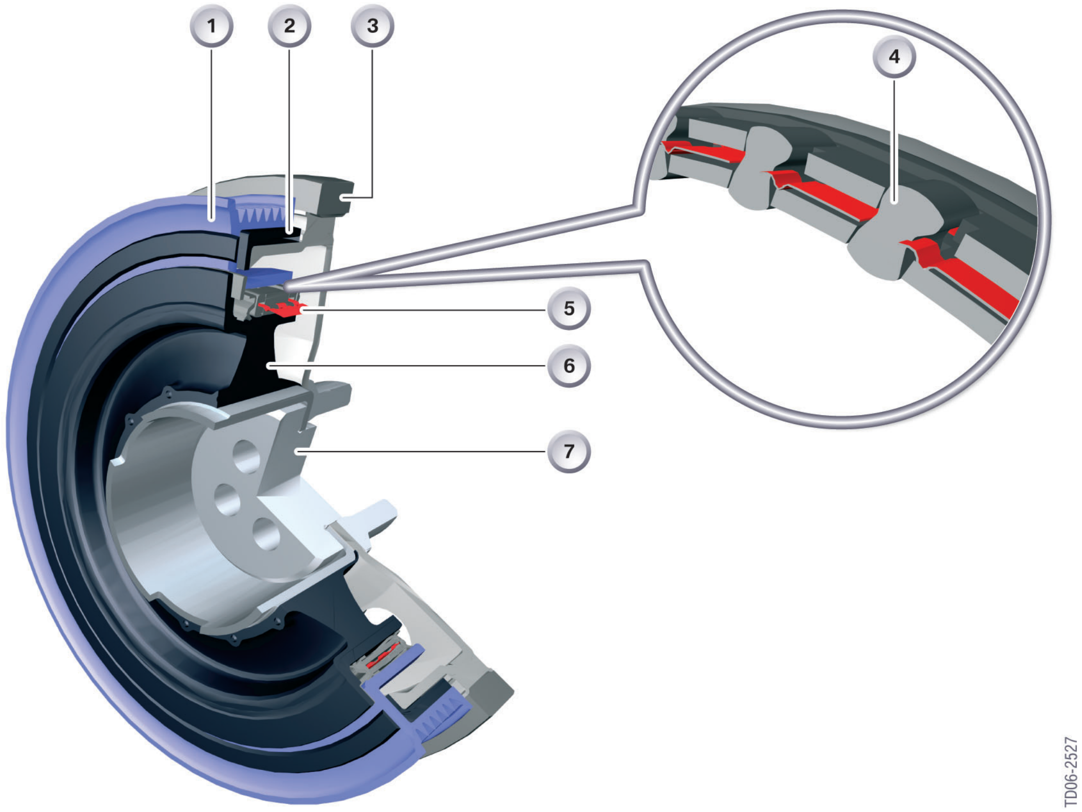
The rotational vibration damper reduces rotational vibrations of the crankshaft. This reduces the load on the crankshaft and the driven auxiliary equipment.

The rotational vibration damper is important not only for the smooth running of the engine but also for an even and low-wear camshaft drive.

Belt pulley (1) is decoupled from hub (7) by decoupling rubber (6). The decoupling rubber allows for more powerful twist and reduces residual irregular rotation and thus the load on the belt drive. The belt pulley is mounted by plain bearing (3).

Freewheel

On vehicles with manual transmission, the rotational vibration damper in the N47 engine is equipped with a freewheel.



33 - Rotational vibration damper with freewheel

Index	Explanation	Index	Explanation
1	Belt pulley	5	Freewheel
2	Vulcanization layer and plain bearing	6	Damping rubber
3	Flywheel	7	Hub
4	Clamping part		

A freewheel is a unidirectional clutch. It only allows torque to be transferred in one direction of rotation. In this direction, the drive component (e.g. hub) is coupled with the output component (e.g. belt pulley) (engaged condition). This is made possible by clamping wedges that fold up and spread between the two parts. In the opposite direction, the wheel is decoupled (freewheeling condition) - no torque is transferred.

With the rotational vibration damper of the N47 engine, the freewheel engages when it turns in the direction of the engine. The force is transferred from the engine to the belt drive.

In the presence of considerable irregular rotations (at the time the engine is switched on and off), the assemblies in the belt drive are subjected to very powerful acceleration or deceleration. To reduce the load on the belt and belt tensioner, the crankshaft may "overtake" while the belt drive is freewheeling. This reduces the load.

Dual-mass flywheel (ZMS)

On vehicles with manual transmission, the irregular rotations arising from the engine's combustion process are converted into vibrations in the drive train. That results in gearbox rattle and body vibration, which are not compatible with the standards of comfort expected from a BMW.

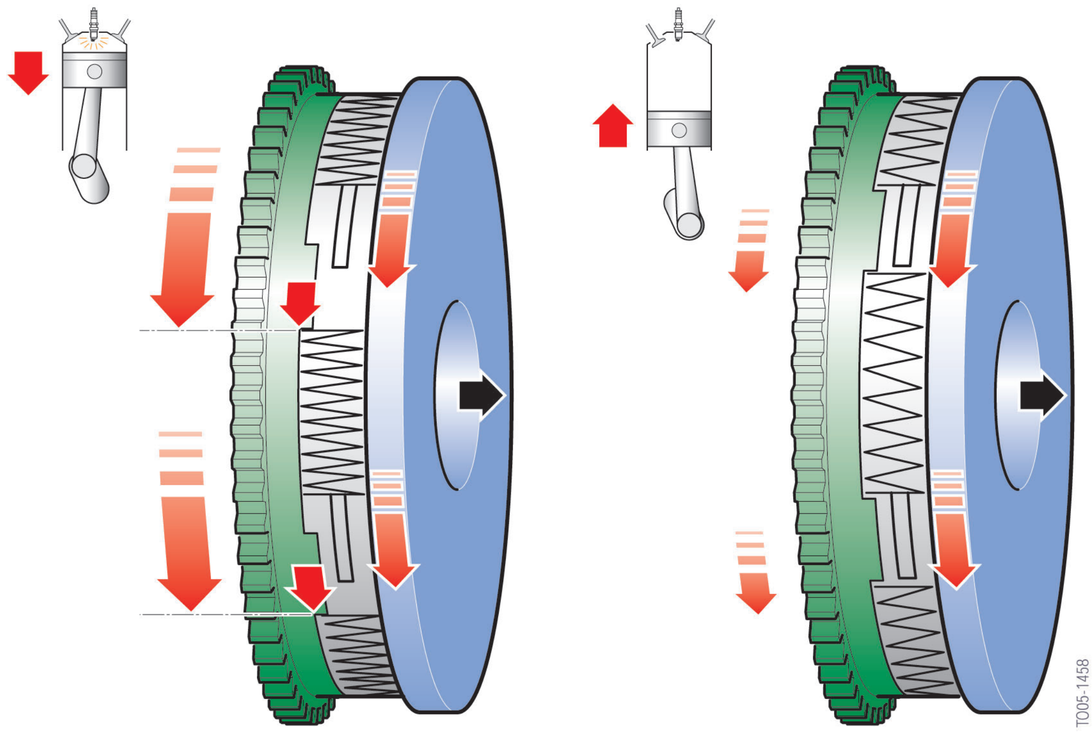
To eliminate such annoyances, BMW introduced the dual-mass flywheel.

It is not required on vehicles with automatic transmission due to the torque converter.

Function

On a dual-mass flywheel, the single mass of a conventional flywheel is split. One part contributes as before to the inertia of the engine. But the other part increases the inertia of the gearbox. As a result, the resonance band is shifted well below the normal running speeds (from approx. 1300 rpm to approx. 300 rpm).

These speeds are well below the idling speed and therefore have no influence on the smooth running of the engine. Speeds of 300 rpm are only encountered during the starting and stopping of the engine.



34 - Function of dual-mass flywheel

The two isolated masses are interconnected by a spring damper system. A clutch plate without torsional-vibration damper between the secondary mass and the gearbox performs the task of disengagement and engagement.

While the flywheel plate that is connected to the engine follows the uneven rotational pattern of the engine, the flywheel mass connected to the transmission rotates at a constant rate while engine speed remains the same.

That isolation of the two rotating masses eliminates gearbox rattle in the critical engine speed ranges.

Camshaft drive system (timing gear)

General information

Like all current BMW engines, the N47 engine is a head-controlled engine. This means that the valvegear and thus the engine control system is located in the cylinder head. The purpose of the camshafts is to fulfil this control function, i.e. to open and close the valves. The camshafts are driven by means of a traction mechanism, in this case a timing chain.

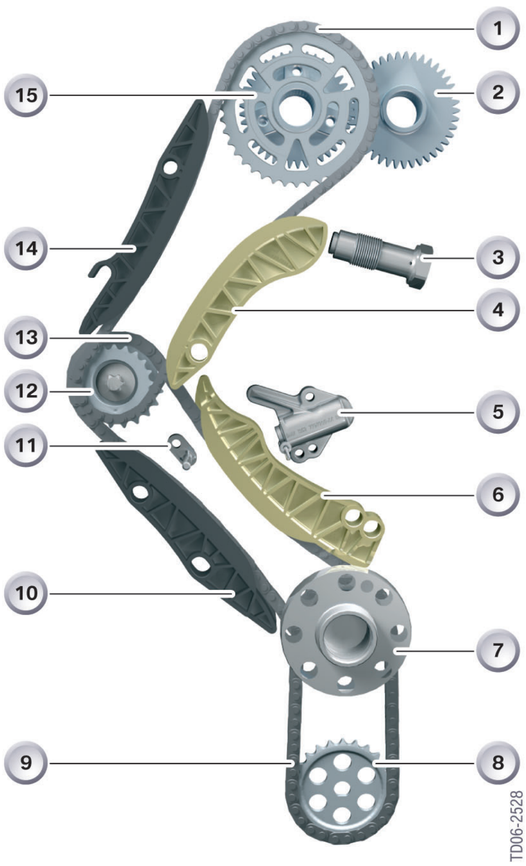
The chain drive creates the connection between the crankshaft and the camshaft. The gear ratio is a fixed ratio of 2:1 (two revolutions of the crankshaft to one revolution of the camshaft). That transmission ratio is brought about by having a chain sprocket on the camshaft that has twice as many teeth as the one on the crankshaft.

The following special features and key data apply to the chain drive of the N47 engine:

- Chain drive on the force transmitting side of the engine
- Two-piece chain drive for driving the high-pressure pump and camshafts
- Use of simplex sleeve-type chains
- Oil/vacuum pump driven by another chain
- Plastic tensioning and guide rails
- Hydraulic chain tensioners

Design

The chain drive comprises a sprocket on the crankshaft, chain guides, chain tensioners with tensioning rails, an oil supply, one sprocket on the high-pressure pump and one on the camshaft and, finally, the chain itself.



35 - N47 engine chain drive

Index	Explanation
1	Upper chain
2	Exhaust camshaft gear
3	Upper chain tensioner
4	Upper tensioning rail
5	Lower chain tensioner
6	Lower tensioning rail
7	Crankshaft
8	Oil/vacuum pump sprocket
9	Oil/vacuum pump chain
10	Lower guide rail
11	Oil spray nozzle
12	High-pressure pump sprocket
13	Lower chain
14	Upper guide rail
15	Inlet camshaft sprocket

In general, the aim is to keep the unguided length of the chain as short as possible. The part of the chain that is not under tension is called the slack side. The chain is always tensioned on the slack side. This is done by means of a tensioning rail that is operated by a chain tensioner.

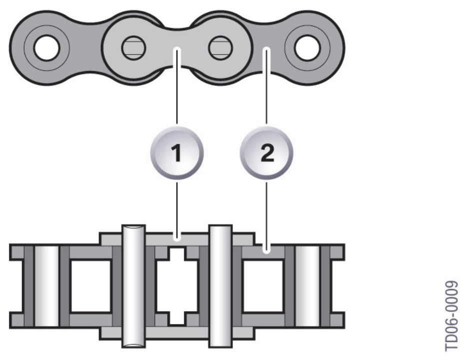
Oil is supplied by an oil spray nozzle, which sprays engine oil onto the chain.

In the N47 engine, the oil/vacuum pump is also chain-driven by the crankshaft.

Chain design

Timing chains may be of the roller type or the bushed type. In addition, there are single (simplex) and double (duplex) chains.

In the N47 engine, all the chains are simplex sleeve-type chains.



36 - Bush chain

Index	Explanation
1	Outer link with pin
2	Inner link with press-fitted pins

With a **bush chain** the teeth of the sprocket always make contact with the fixed bushes in the same place. Therefore, correct lubrication of timing gear systems that use this type of chain is essential. Bush chains have a larger pivot surface area than a roller chain with the same pitch and breaking strain. A larger pivot surface area means a lower pivot surface pressure and therefore less wear on the pivots.

Chain sprockets

The sprockets transfer the drive torque from the crankshaft to the chain and from the chain to the high-pressure pump, the camshaft and the oil/vacuum pump. The tooth profile of the sprockets has been standardized for sleeve-type chains. The correct tooth profile is of major significance in ensuring safe operation of the timing gear. The sprockets used have low-profile teeth and a wide tooth spacing. This facilitates smooth chain infeed and outfeed even at high chain velocities.

Chain tensioner and guide

The chain is subject to stretching for a variety of reasons. It results either from the operating conditions (heat expansion) or is due to wear.

If the timing chain is to last as long as the engine, the tensioning element and the guide must be matched to the engine. The chain tensioner makes sure that the slack side of the chain is preloaded with a specific tension in all engine operating modes. In addition, it performs a damping action and reduces vibrations to a permissible level.

As with all BMW diesel engines, hydraulic chain tensioners are also used in the N47 engine. The tensioner guide is held against the chain by the piston of the chain tensioner. The oil in the chain tensioner provides directional damping by virtue of a non-return valve. In conjunction with hydraulic chain tensioners and tensioning rails with plastic anti-friction covering, the chain drive remains maintenance-free throughout the entire service life of the engine.

Providing the function of a guide are plastic rails that are either straight or curved, depending on the chain path. Tensioning rails are guides that are pressed against the chain by the chain tensioner. For that purpose, they are pivoted at one end.

Layout

For the first time on a BMW engine, the chain drive is located on the force transmitting side, i.e. the rear side of the engine.

Since the gears of the camshafts are located at the rear, the front of the engine can be built lower. This is beneficial for the passive safety of pedestrians. There is more space for the bonnet to give into to absorb an impact.

Another benefit is that rotational vibrations are significantly reduced due to the inertial mass of the transmission at this end. This results in an enormous relief of load on the chain drive.

One of the consequences of this arrangement is that various components are installed in unconventional locations or positions, e.g. oil pump, camshaft sensor, etc.

Belt drive and auxiliary equipment

General information

The belt drive is responsible for driving auxiliary equipment without slip in all load conditions.

In the N47 engine, these are:

- Alternator
- Coolant pump
- Air-conditioning compressor
- Power steering pump.

A maximum torque of approximately 41 Nm and a maximum of output 21 kW are transferred to the belt drive (under full load and maximum equipment electrical load).

Particular value is placed on noise-free running and a long service life. To achieve the latter, different systems are used to relieve the belt drive of load arising from rotational vibrations and violent load reversals (see the "Rotational vibration damping" section).

The layout of the system selected must be such that noises, particularly "V-belt squeal", caused by slippage between belt and pulley, are avoided.

⚠ It is essential that auxiliary equipment be fitted in the correct position during assembly. A belt pulley alignment error would result in belt noise and ultimately belt damage.

Observe the procedure in the repair instructions ◄

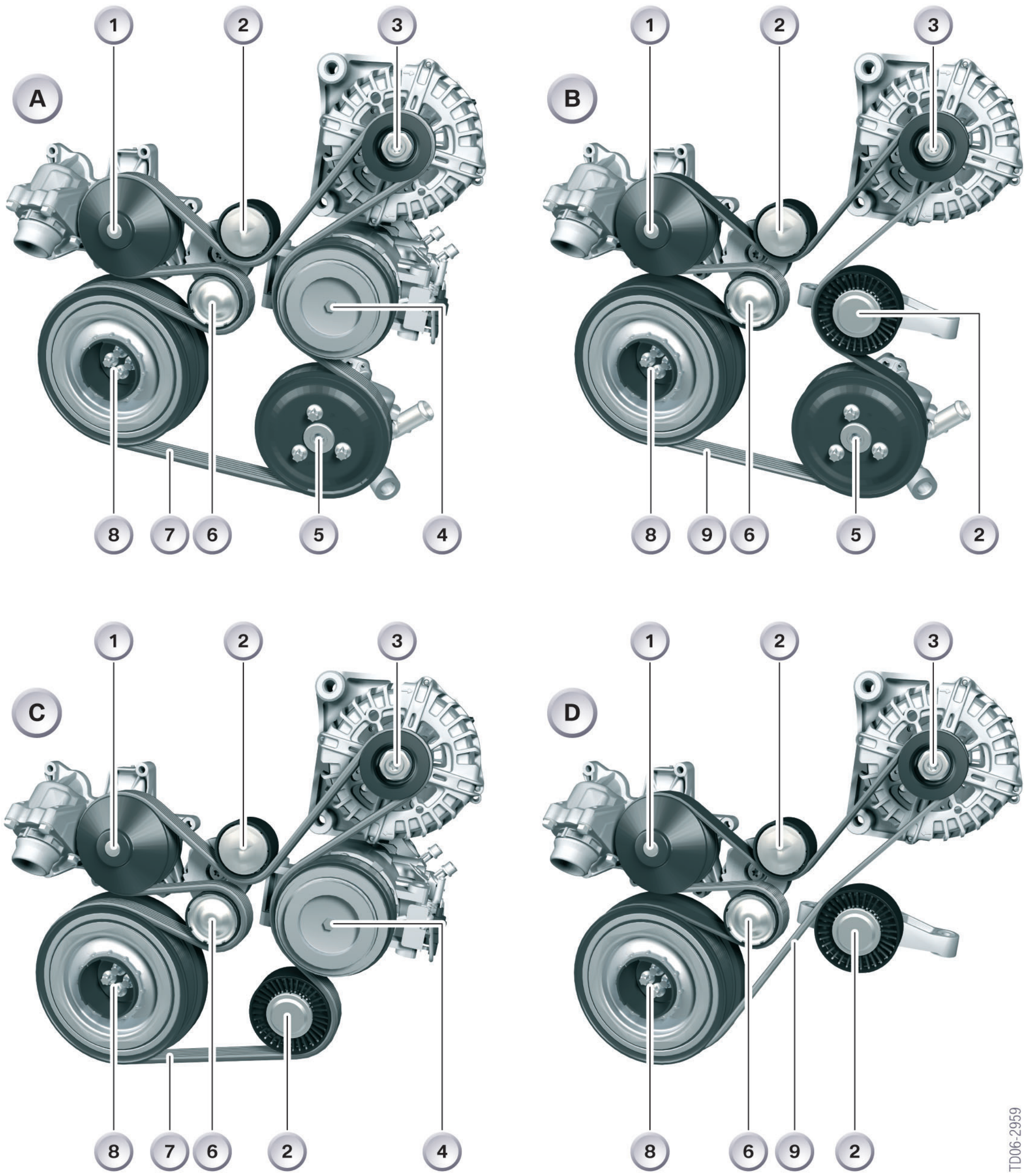
Design

In N47 engines, the design of the belt drive may differ. This depends on the following equipment:

- Air-conditioning system or automatic air-conditioning system
- Electromechanical power steering (EPS).

In either case, the belt drive is a single belt drive whereby all auxiliary equipment is driven by a single belt.

The belt drive also includes the rotational vibration damper (see the relevant section), the belt pulleys for the auxiliary equipment and the tensioning and guide pulleys.



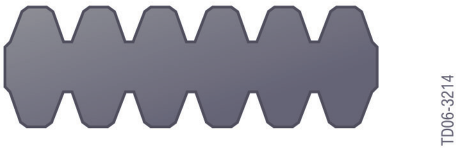
37 - Belt drive variants of the N47 engine

Index	Explanation	Index	Explanation
A	With KA* and power steering	4	Air-conditioning compressor
B	Without KA* with power steering	5	Power steering pump
C	With KA* and EPS	6	Tensioning pulley
D	Without KA* with EPS	7	Double-sided drive belt
1	Coolant pump	8	Rotational vibration damper
2	Deflection pulley	9	Single-sided drive belt
3	Alternator		

*) KA = Air-conditioning system or automatic air-conditioning system

Ribbed drive belt (poly-V-belt)

A new feature of the belt drive of the N47 engine is that the belt is double-sided if an air-conditioning compressor is fitted. The inside of the belt is therefore no longer the only side used to drive the auxiliary equipment; the outside of the belt is used too. In this case, it is the air-conditioning compressor that is driven by the outside.



38 - Cross section of a double-sided poly-V-belt

This is a poly-V-belt with six ribs on the inside and on the outside.

The benefit of using a double-sided belt is that an additional deflection pulley is no longer required. In addition, the belt drive can have a more flexible and compact design. This also makes it possible to realize a belt drive layout in which all of the auxiliary equipment is located on the left-hand side of the engine.

If no air-conditioning compressor is fitted, a conventional poly-V-belt with six ribs is used (no profile on the outside).

Tensioning pulley

Even the poly-V-belt is subjected to elongation stresses as a consequence of thermal expansion and expansion over the course of its service life.

To ensure that the poly-V-belt can transfer the correct amount of torque throughout its service life, it must be held in constant contact with the belt pulleys by a specific amount of force. To this end, the belt tension is strengthened by an automatic tensioning pulley, which compensates for belt elongation over the course of its service life.

In the N47 engine, a Z-type tensioning pulley is used and provides an initial tension of 350 N.

With the Z-type tensioner, the tensioning housing drops into the area behind the belt drive. The initial tension is created by a leg spring. At the same time, the tensioner is friction damped.

The tensioning pulley is located on the unladen side of the belt before the rotational vibration damper in the conventional way.

Deflection pulleys

The deflection pulleys ensure that the necessary arc of belt contact is achieved at all items of auxiliary equipment. This is the only way to achieve non-slip operation.

Every N47 engine variant has a deflection pulley between the coolant pump and the alternator.

A special feature of the N47 engine is that, if an air-conditioning compressor is fitted, this more or less assumes the function of a deflection pulley because it is driven by the outside of the poly-V-belt.

On vehicles without an air-conditioning system or automatic air-conditioning system, an additional deflection pulley is fitted in place of the air-conditioning compressor.

Camshafts

General information

The camshafts control the gas exchange cycle and, therefore, combustion. Their main function is to open and close the inlet and exhaust valves. They are driven by the crankshaft. The ratio between speed of rotation of the camshaft to that of the crankshaft is 1:2. In other words, the camshaft rotates at only half the speed of the crankshaft. This is brought about by the transmission ratio of the timing-chain sprockets. The position of the camshaft relative to the crankshaft is also precisely defined.

To make the valvegear as rigid as possible, in other words to keep the linkage between the camshaft and the valves as short as possible, the N47 engine has overhead camshafts like all current BMW engines. As an engine with four valves per cylinder, the N47 engine has a camshaft for both the inlet and exhaust valves.

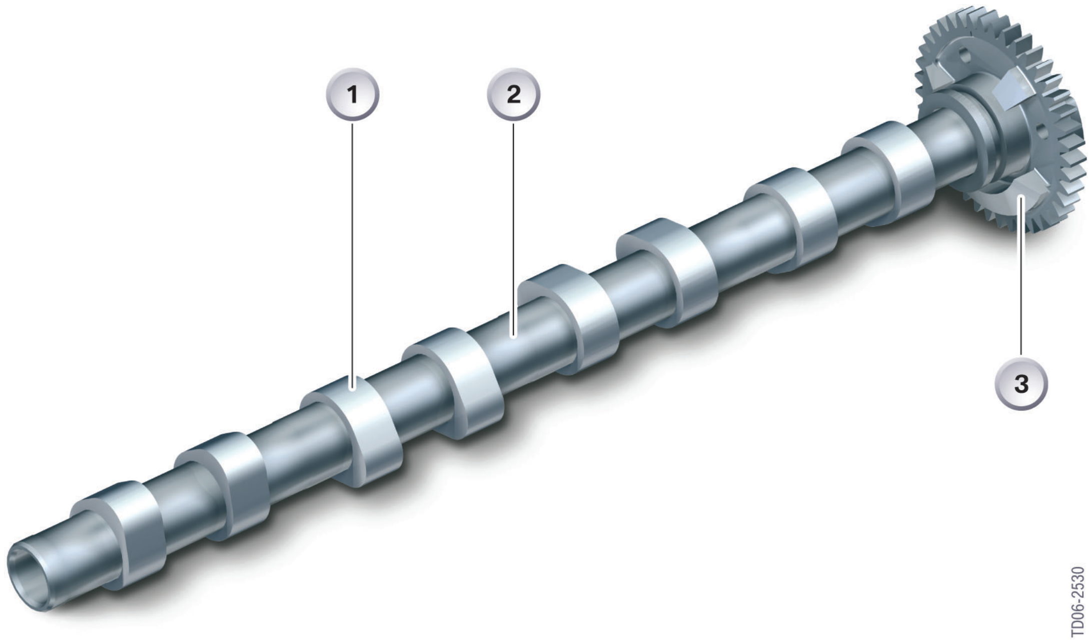
As the valves open, a force is transmitted from the cam to the valve by one or more actuating elements (the element in direct contact with the cam is called a cam follower). The valve is opened against the force of the valve spring. The valve is closed and held in the closed position against the valve seat by the force of the valve spring.

The special features of the N47 camshafts are listed below:

- Composite camshafts built in accordance with the Presta method
- Camshaft sensor wheel integrated into the gear of the inlet camshaft
- Double-flatted neck for the special tool integrated into the gear of the exhaust camshaft
- Now only one double-flatted neck for the special tool
- Connection of the sprocket arranged in such a way that all three bolts can be loosened/tightened with the engine pinned in position.

Design

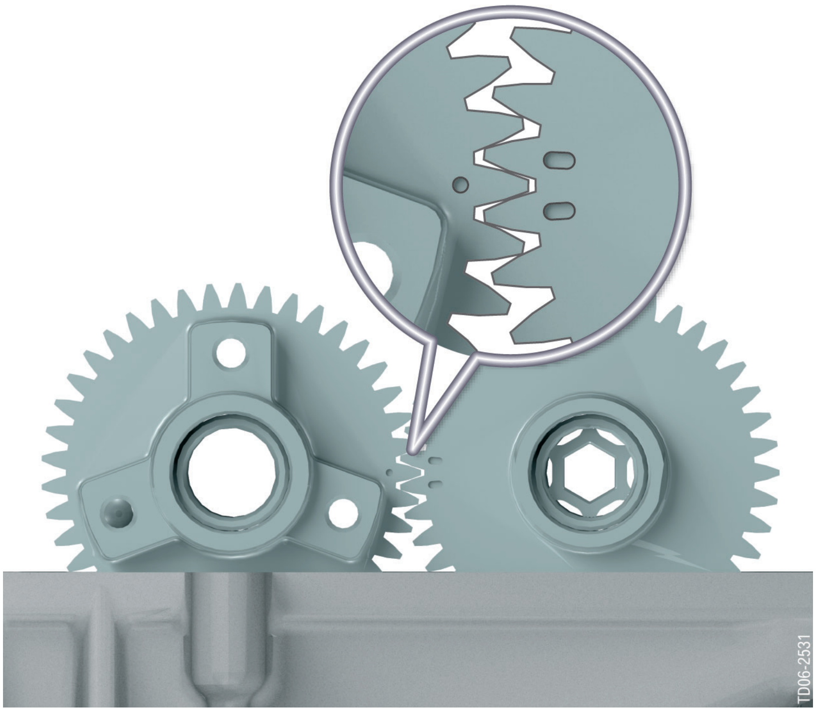
The main component of the camshaft is the cylindrical, hollow shaft. Arranged along and around it are the cams. The actuation forces are braced by the camshaft bearings. As with all BMW diesel engines, the cams in the N47 engine are bearing-mounted directly on the camshaft tube. The surface is ground at those points. An oil bore in the bearing point in the camshaft carrier provides the necessary lubrication. There is also a thrust bearing to limit axial float.



39 - N47 engine camshaft

Index	Explanation	Index	Explanation
1	Cam	3	Tooth and camshaft sensor wheel
2	Shaft		

The inlet camshaft is driven by the crankshaft by means of a chain on a sprocket. Additional gears transmit the drive force from the inlet camshaft to the exhaust camshaft. These gears are permanently connected to the camshafts. Markings on the gears help the installer to position the camshafts correctly during assembly.



40 - Marking on the gears of the camshafts of the N47 engine

The camshaft sensor wheel for the camshaft sensor is built directly into the gear for the inlet camshaft.

The double-flatted neck for the special tool used to ensure correct positioning during installation is part of the gear of the exhaust camshaft. In the N47 engine, the special tool is now only positioned on one camshaft.

The sprocket is screwed onto the inlet camshaft. Elongated holes make it possible to adjust valve timing. What is new here is that the bolt connection is arranged in such a way that it is not necessary to turn the camshafts to be able to tighten all the bolts. This is why the three bolts are not evenly spaced at a 120° angle.

An open-jawed spanner is no longer used as a countering aid during assembly. Instead, there is a hexagon socket in the shaft tube at the end where the gear is located.

Composite camshafts

The N47 engine is fitted with composite camshafts, which were first used in the M57TU2 engine. Composite means that the shaft tube, the cams and other functional elements such as the drive gear are manufactured separately and then joined together afterwards.

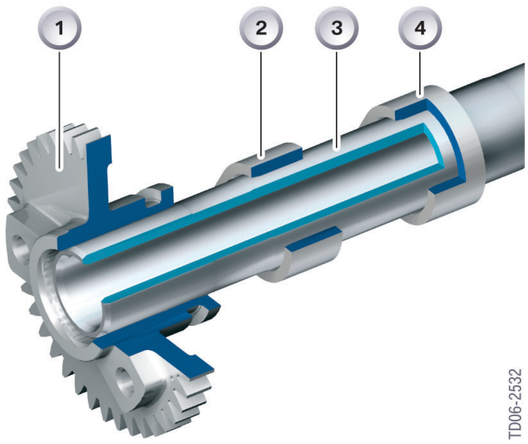
This offers the following advantages:

- Weight savings of up to 40 %. This in turn produces:
  - Lower fuel consumption
  - Improved vibrational characteristics
  - Improved noise characteristics
  - Possibility of weight savings on other system components
- Possibility of combining different materials
- New possibilities in terms of cam materials and shapes
- More economical production.

There are many different methods by which composite camshafts can be made. Firstly, there is the classic positively interlocking or frictional shaft and collar joint by which the individual components are attached to the shaft. Components can also be fixed by thermal shrink-fitting, or the shaft widened to obtain a frictional joint. The various parts may also be fixed to the shaft by welding or soldering.

The Presta method, with which all camshafts for BMW diesel engines are manufactured, is also used for the N47 engine.

Presta method



41 - N47 engine composite camshaft

Index	Explanation
1	Drive gear
2	Cam
3	Shaft tube

With the Presta method, the tube is widened by rolling and given a radial profile (pitchless thread) at the relevant position intended for the seat of a cam or another component. The appropriate part is then pressed on at the desired angle.

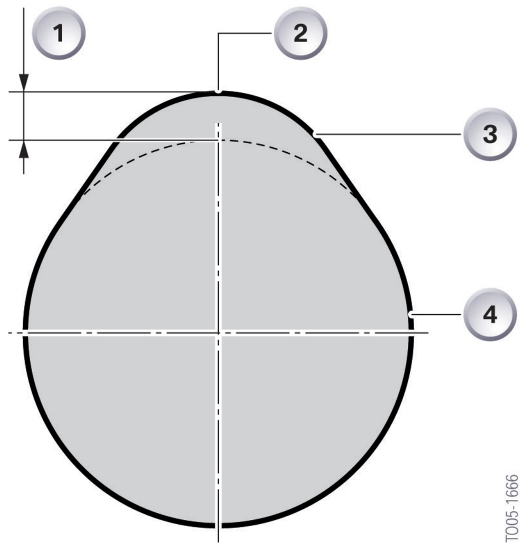
The bore of the part being pressed on has a longitudinal profile. This creates a positive and non-positive connection between the shaft and the component that was pressed on.

Since the drive gear is also fitted in this manner, it is connected to the shaft and cannot come loose.

Cam profile

The cam profile, in other words the shape of the cam cross-section, determines the valve lift pattern. The latter is usually a compromise in terms of obtaining the best possible cylinder charge at all engine speeds.

The illustration below shows the cross-section of a cam and identifies its various elements.



42 - Cam cross-section

Index	Explanation
1	Cam lift
2	Cam tip
3	Cam shoulder
4	Base circle

The cam profile is described by those four fundamental components. The cam follower, which follows the action of the cam and transmits it to the valve, traces the contour of that profile.

While the cam follower is in contact with the base circle, the valve is closed. As the cam shoulder comes into contact with the cam follower, the valve opens and then closes again as the closing shoulder runs over the follower. The steeper the shoulders, the faster the valve opens and closes.

When used in conjunction with roller cam followers, the cam shoulders may be hollowed (concave).

The cam peak represents the maximum valve opening. The broader the cam tip, the longer the valve stays open. The distance from the base circle to the cam tip is the cam lift.

In the N47 engine, the cam lift of the exhaust camshaft is somewhat greater than that of the inlet camshaft, which produces greater valve lift.

The transfer of cam movement to the valve by the roller cam follower depends on the ratio of the lever lengths.

Lever tappets

General information

The lever tappet is responsible for transferring cam movement to the valve. Because such components follow the movement of the cam, they are also called cam followers. The cam follower traces the contour of the cam profile and transmits this movement indirectly (with a transmission ratio).

Particular importance is placed on rigid transmission and light weight.

Rigid transmission ensures that the valve lift pattern follows the desired progression. Only in that way can optimum cylinder charging be accurately controlled.

Light weight is necessary to keep the inertial forces low. This is why the lever tappets of the N47 engine are made from sheet metal and not cast, which has now been the convention for BMW engines for some time.

To keep the internal friction of the engine as low as possible, the N47 engine is equipped with roller cam followers.

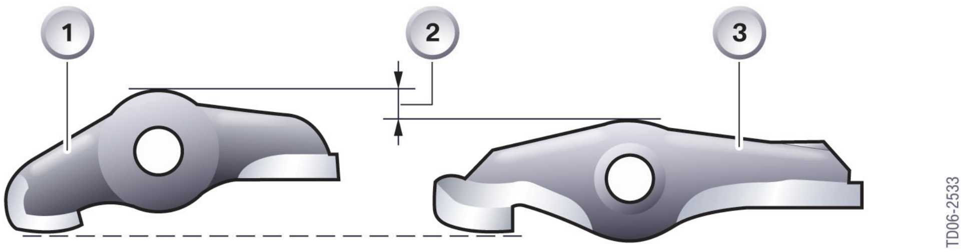
A new design has realized a significant reduction in height and a weight saving of approximately 14 %.

Design

Lever tappets are not bearing-mounted on a shaft. They rest at one end directly against the HVA element. The other end rests on the valve stem. The camshaft cam presses on the centre of the lever tappet from above.

The inertia and rigidity of the lever tappet depend heavily on its design. Short levers make for low mass moments of inertia.

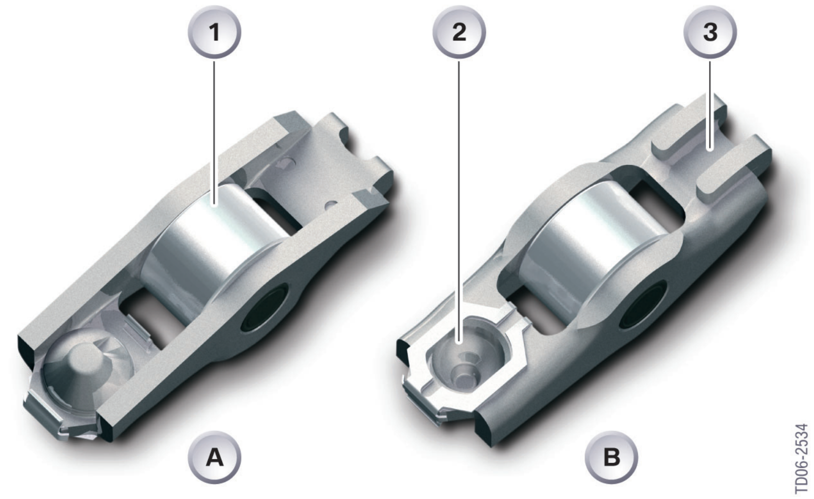
The shape of the lever tappet in the N47 engine is considerably flatter than that of its predecessor.



43 - Comparison between lever tappets in the M47TU2 engine and N47 engine

Index	Explanation	Index	Explanation
1	Lever tappet of M47TU2 engine	3	Lever tappet of N47 engine
2	Difference in height		

Roller cam follower



44 - N47 engine roller cam follower

Index	Explanation	Index	Explanation
A	Roller lever tappet, top view	2	Hemispherical recess for resting on HVA adjuster
B	Roller lever tappet, bottom view	3	Actuating face that presses on the valve
1	Needle-bearing roller for following cam		

With roller cam followers, the action of the cam is not followed by a sliding face but a roller running on needle roller bearings. In comparison with non-roller lever tappets or bucket tappets, this results in lower frictional losses especially in the lower rev band that is of significance for lowering fuel consumption. A reduction in friction, however, also results in a reduction in the damping effect at the cams.

Hydraulic valve clearance adjustment

General information

The valves must be able to close properly under all engine operating conditions so as

- to prevent loss of power by loss of compression and combustion pressure, as well as to
- dissipate the heat generated through the cylinder head and the coolant.

Valves that do not close properly do not provide a perfect seal. This firstly interrupts the flow of heat from the valve heads to the cylinder head. Secondly, the hot combustion gases flow through the narrow gap at a high velocity and may heat the heads of the exhaust valves to extreme temperatures. This can cause pre-ignition that leads to piston damage. The exhaust valves can also be burned away so that they become entirely ineffective and cause sudden major power loss.

The N47 engine is therefore equipped with hydraulic valve clearance adjustment like all current BMW diesel engines. This is identical to that which is used in the M47TU2 engine.

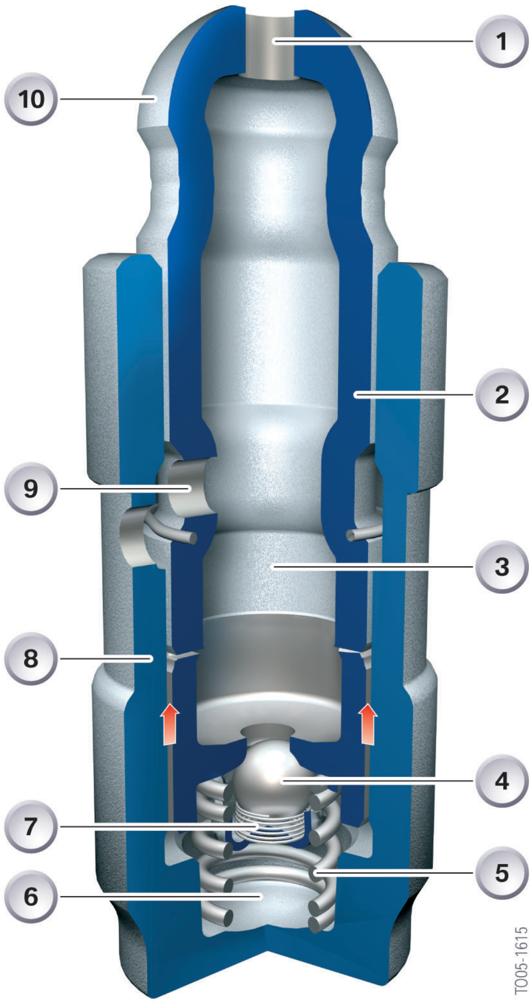
Hydraulic valve-clearance adjuster

Hydraulic valve clearance adjustment (HVA) has the following functions:

- To maintain the valve clearance at zero under all operating conditions.
- To make manual valve clearance adjustment superfluous even after the engine has completed a substantial period of service.

This is achieved by means of an HVA adjuster. With the use of a lever tappet, this is a separate component on which the lever tappet rests.

Function



45 - Hydraulic valve-clearance adjuster

Index	Explanation
1	Vent hole
2	Piston
3	Oil reservoir chamber
4	Valve ball
5	Piston spring
6	Pressure chamber
7	Valve-ball spring
8	Pressure cylinder
9	Oil supply port
10	Ball end

When the cam opens the valve by means of the lever tappet, a force is also applied to the ball end (10) of the piston (2) in the HVA adjuster. The piston is cushioned by the oil in the pressure chamber (6) in the fixed pressure cylinder (8). In the process, a very small quantity of oil escapes upwards between the piston and the cylinder (indicated on the diagram by arrows).

The expulsion of oil from the pressure chamber during the valve opening stroke would leave a degree of play between the cam and the lever tappet after the valve has closed. However, this is prevented by the spring (5) which forces the piston (2) and its ball end upwards so that the lever tappet is always in contact with the cam. This produces a vacuum effect in the pressure chamber by the increase in volume. Valve ball (4) lifts off its seat against its spring (7). The pressure chamber fills with oil from oil reservoir (3). Once the pressure chamber is full, the valve ball seals off the pressure chamber again.

The next time the valve is opened, the complete sequence repeats itself. Technically speaking, there is a mini oil circulation system within the HVA adjuster.

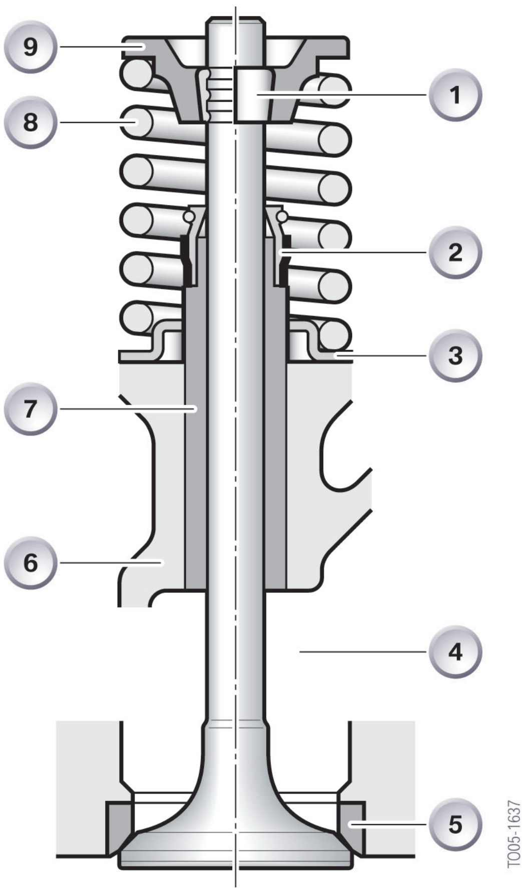
Valves, valve guides and valve springs

General information

As with all BMW diesel engines, lifting valves are used in the N47 engine as locking mechanisms for the gas exchange ducts. The inlet and exhaust valves are high-precision engine components that are subject to extreme stresses.

They have the following functions:

- To close off the inlet and exhaust ducts
- To control the gas exchange cycle
- To seal the combustion chamber



46 - Valve in fitted position

The valve performs its sealing function in conjunction with the valve seat insert.

Together with the valve guides and valve springs, the valves form an assembly that is described below as a unit. The following diagram illustrates the assembly in its fitted arrangement.

Index	Explanation
1	Collet
2	Valve stem seal
3	Lower valve spring retainer
4	Inlet/exhaust port
5	Valve seat insert
6	Cylinder head
7	Valve guide
8	Valve spring
9	Upper valve spring retainer

In the N47 engine, valve stem seal (2) forms a unit with lower valve spring retainer (3).

Design

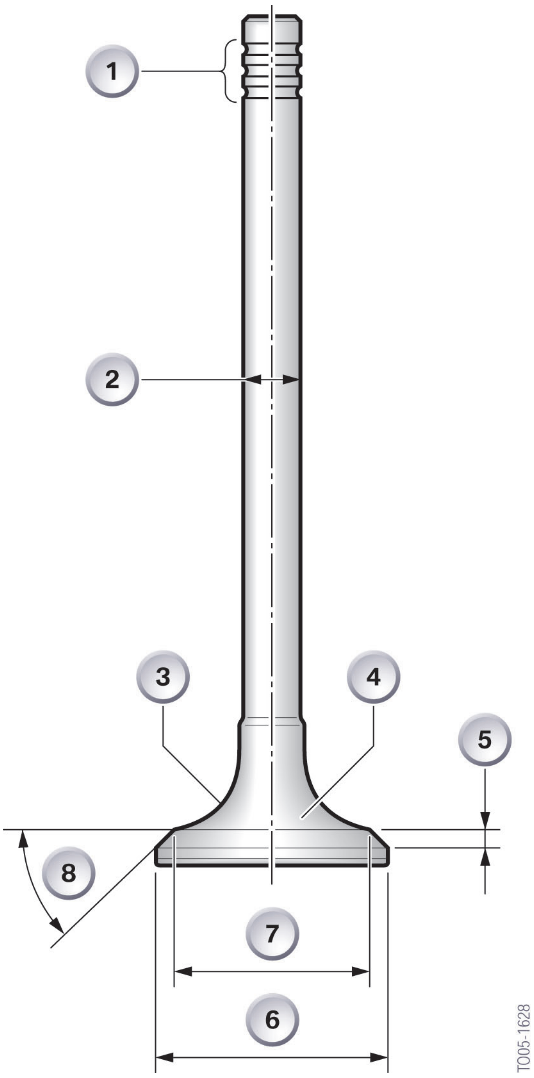
Valves can be distinguished as being monometal valves or bimetal valves. Both types are used in the N47 engine. Monometal valves are used as inlet valves, while bimetal valves are used as exhaust valves due to the much higher thermal load to which they are subjected.

Single-metal valves are made of one material and formed into the desired shape by forging.

With bimetal valves, the valve shaft and valve head are manufactured separately and subsequently joined by friction welding. This has the advantage that the most suitable material can be chosen in each case for the stem and head. Bimetal valves are used for exhaust valves because that advantage is of particular benefit on the exhaust valves. The valve head can then be made of a material that is suited to extreme temperatures, while the stem can be made of a very hard-wearing material. The valve head in the N47 engine is made of a special steel (nickel alloy) also known as Nimonic (NiCr20TiAl).

Depending on whether the valves are made of one or more materials, they will generally have the same design.

A valve can be divided into the three sections: valve head, valve face and valve stem (see diagram). The valve face forms a functional unit together with the valve seat insert. For that reason the valve seat insert is also described in conjunction with the valve face.



47 - Design of a valve

Index	Explanation
1	Groove pattern
2	Valve stem diameter
3	Fillet
4	Valve head
5	Seat height
6	Head diameter
7	Seat diameter
8	Seat angle

Valve guide

The valve guide ensures that the valve is centred on the valve seat and that heat can be conducted away from the valve head through the stem to the cylinder head. An optimum amount of play between the guide bore and the valve stem is required. It the play is too small, the valve will tend to stick. Too much play impairs heat dissipation. The aim is to achieve the smallest possible degree of valve play under those considerations.

The valve guides are press-fitted in the cylinder head. The valve guide must not protrude into the exhaust port because of the risk of it widening due to the high temperatures. Combustion residues could then enter the guide.

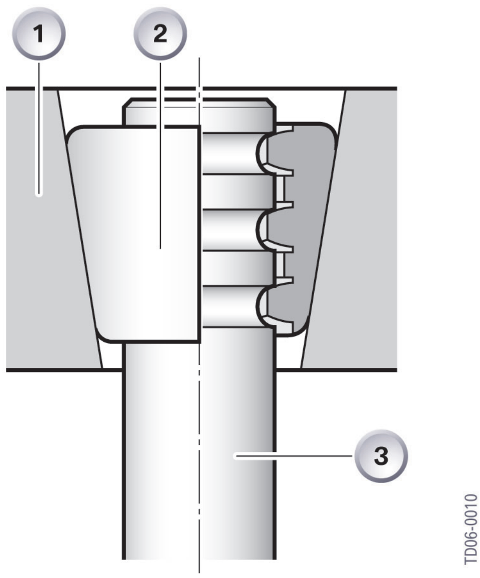
For correct functioning of the valve, it is essential that the centre misalignment between valve guide and valve seat insert be within the specified tolerance. Too great a centre misalignment causes the valve head to bend on the stem. This can result in premature failure. Other consequences may be valve leakage, poor heat transfer and high oil consumption.

Valve collets

The job of the valve collet is to attach the valve spring retainer to the valve stem. A distinction is made between compression and non-compression joints. In the N47 engine, as with all BMW diesel engines, non-compression connections are used.

With a non-compression joint, the halves of the valve collet (2) rest against each other as support when fitted. They thus allow a degree of play between the collet and the valve stem, which enables the valve to rotate. That rotation benefits the bedding in of the valve and cleaning of the valve seat.

The axial forces are transmitted through the three collet beads that engage in the valve-stem grooves. For that reason the valve collets are hardened.



48 - Non-compression valve collets

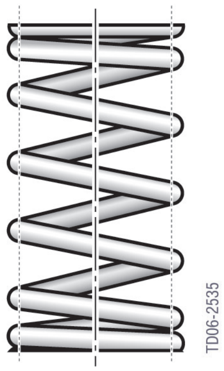
Index	Explanation
1	Valve spring retainer
2	non-compression valve collet
3	Valve stem

Valve springs

The function of the valve spring is to close the valve in a controlled manner, i.e. to make the valve follow the cam action so that it closes at precisely the right time even at maximum engine speed. In addition, its force must be sufficient to prevent vibration of the valve immediately after closing (called valve bounce). When the valve opens, the spring must prevent it from losing contact with the cam (follower).

Design

The N47 engine is fitted with the standard design of valve springs: symmetrical, cylindrical springs with round wire cross section. With this type of spring the coil spacing is symmetrical at both ends of the spring and the coil diameter is constant. The progression of the spring characteristic (the spring force increases the more the spring is compressed) is achieved by the partial contact between spring coils over the spring travel.



49 - N47 engine valve spring

Overview of the oil supply

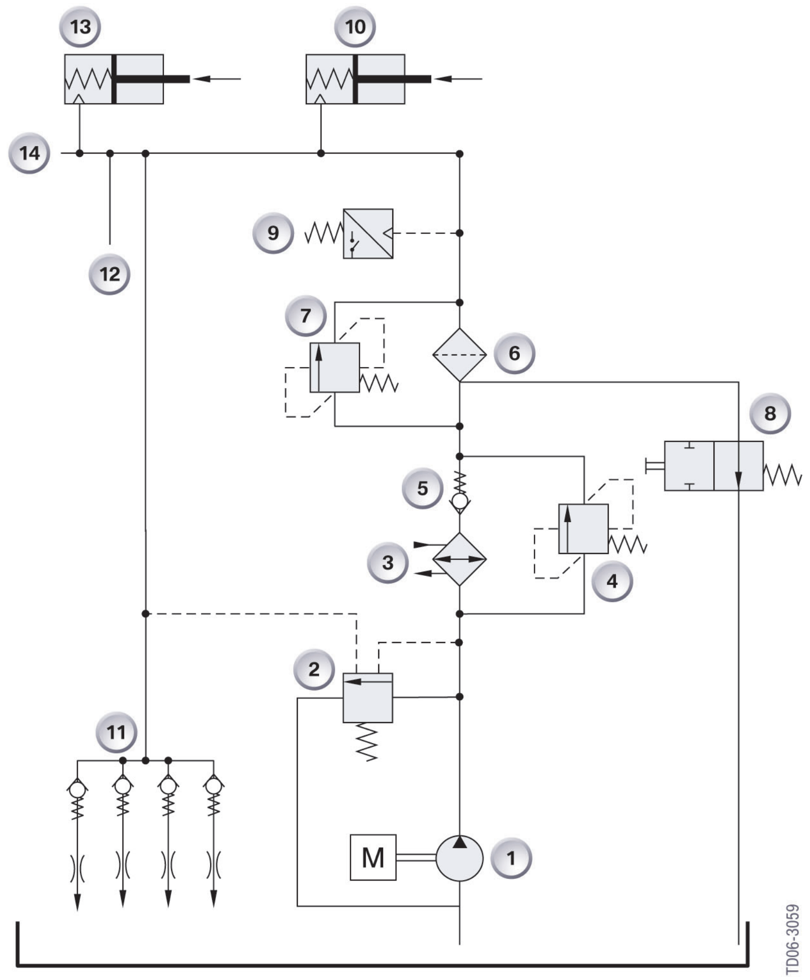
General information

The oil system serves the purpose of supplying with oil all points in the engine requiring lubrication and cooling. The N47 engine is equipped with a forced-feed lubrication system for this purpose.

Forced-feed or pressure circulating lubrication

In a forced-feed lubrication system, the oil pump takes in oil from the sump through an intake pipe and pumps it onwards into the circuit. The oil flows through the full-flow oil filter and then passes into the main oil channel, which runs parallel to the crankshaft in the engine block. Branch galleries lead to the main bearings of the crankshaft. The crankshaft has corresponding holes to feed oil from the main bearings to the crankpins and connecting rod journals. Part of the oil is branched off from the main oil gallery and fed to the corresponding lubrication points in the cylinder head. The oil ultimately returns to the sump. Either it passes through return channels or it simply drips back there freely.

Oil circuit



50 - N47 engine oil circuit

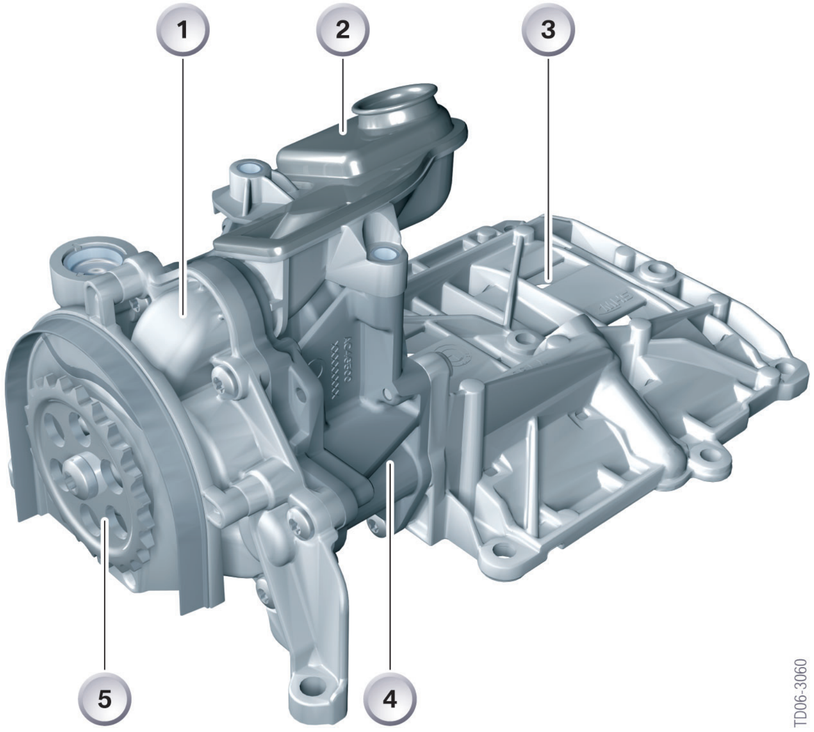
Index	Explanation	Index	Explanation
1	Oil pump	8	Oil filter outlet valve
2	Pressure limiting valve	9	Oil pressure switch
3	Engine oil/coolant heat exchanger	10	Lower chain tensioner
4	Heat exchanger bypass valve	11	Oil spray nozzles with piston cooling valves
5	Non-return valve	12	Lubrication points in the crankcase
6	Oil filter	13	Upper chain tensioner
7	Filter bypass valve	14	Lubrication points in the cylinder head

From the sump to the oil filter

Intake pipe

The oil pump takes the oil from the oil pan via the intake pipe or oil pickup pipe. The intake pipe is positioned such that the intake opening is above the oil level under all operating conditions. The intake pipe is fitted with an oil screen that keeps coarse dirt particles away from the oil pump.

The intake pipe in the N47 engine is a separate component and is screwed onto the oil pump.



51 - Oil/vacuum pump with intake pipe in the N47 engine

Index	Explanation	Index	Explanation
1	Oil pump	4	Vacuum pump
2	Intake pipe	5	Oil/vacuum pump sprocket
3	Reinforcement shell		

Oil pump

The oil pump plays a central role in the N47 engine as it does in all modern combustion engines. The high output and the enormous torque produced at even low engine speeds demand that a high rate of oil throughput be guaranteed. This is necessary for reasons of high component temperatures and bearings being subjected to high loads.

On the other side, a demand-oriented oil pump is required in order to achieve low fuel consumption.

There are different types of oil pumps to meet these requirements. A spur-gear oil pump is being used in the N47 for the first time since the M21 engine. All subsequent diesel engines, including the M47TU2, had rotor oil pumps.

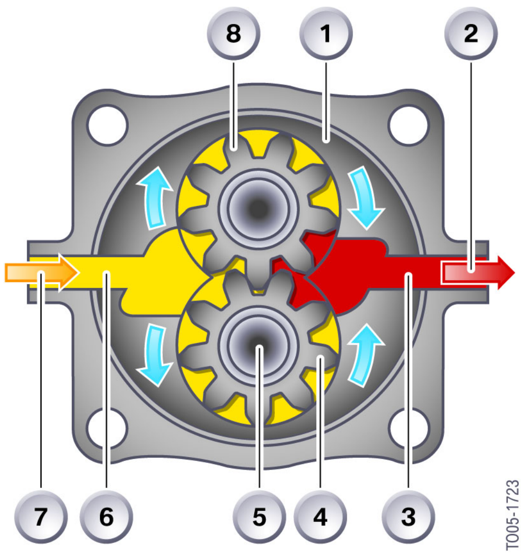
The oil pump in the N47 engine is chain-driven by the crankshaft (ratio i = 21:24 (crankshaft:oil pump); the theoretical delivery rate is 16 cm^3 per revolution of the oil pump.

In the N47 engine, the oil pump and the vacuum pump form one component. They share the drive of the crankshaft, but they are separate in their function.

Spur-gear oil pump

In this type of oil pump, two externally splined gearwheels, of which one is driven, mesh with each other. The tips of the teeth that are not engaged pass along the pump housing and convey oil from the intake into the pressure chamber.

The quantity of residual oil that remains in the base of the tooth poses a problem. This squeezed oil can build up to very high pressures, making it necessary to have pressure relief grooves in the pump housing and cover that drain the oil into the pressure chamber.



52 - Spur-gear oil pump

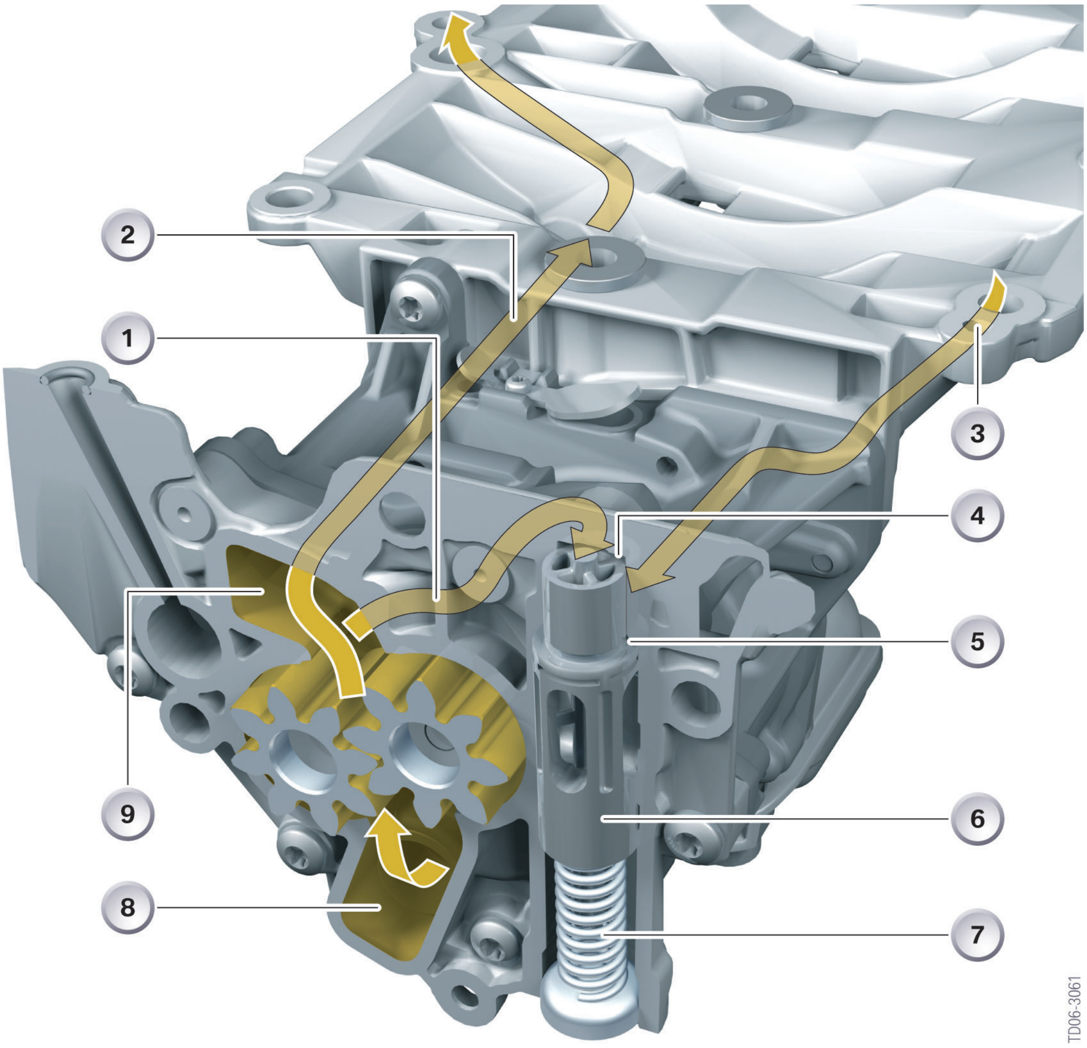
Index	Explanation
1	Oil pump housing
2	Pressurized oil
3	Pressure chamber
4	Gearwheel (oil pump gear)
5	Drive shaft
6	Intake chamber
7	Oil intake
8	Gearwheel (oil pump gear)

Pressure limiting valve

The pressure limiting valve protects against excessively high oil pressure, e.g. when starting the engine with the oil cold. It protects the oil pump, oil pump drive, oil filter and oil cooler.

The pressure limiting valve is located on the pressure side between the oil pump and oil filter. It is fitted as close as possible downstream of the oil pump -in the N47 engine, in the oil pump housing itself.

The opening or cutoff pressure in the N47 engine is 3.7 bar.



53 - N47 engine oil pump with pressure relief valve

Index	Explanation	Index	Explanation
1	Oil to upper control chamber	6	Control piston
2	Unfiltered oil duct to the oil filter	7	Return spring
3	Clean oil duct to the lower control chamber	8	Intake side
4	Upper control chamber	9	Pressure side
5	Lower control chamber		

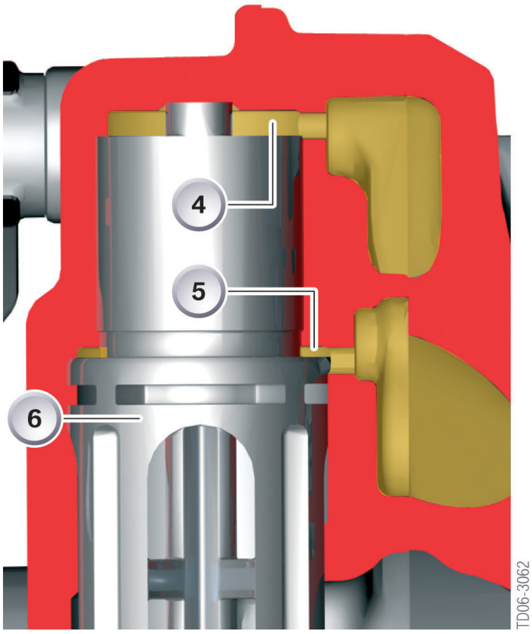
There is a special feature associated with the pressure relief valve in the N47 engine. On previous diesel engines, oil acted on the pressure limiting valve downstream of the filter. In the N47 engine, oil acts on the pressure limiting valve downstream of the filter, but also directly downstream of the pump.

Functional principle

The oil is taken in by the spur-gear oil pump and delivered to pressure side (9). A duct carries oil (1) from pressure side (9) to upper control chamber (4) of the pressure limiting valve, causing pressure to build up downstream of the oil pump and upstream of the oil filter.

The remaining oil flows through unfiltered oil duct (2) to the oil filter and finally into the main oil duct. Oil returns to the oil pump housing through clean oil duct (3) and from there supplies lower control chamber (5) of the pressure limiting valve through an oil bore. As a result, the system pressure of the oil circuit is present in the control chamber (downstream of the oil filter).

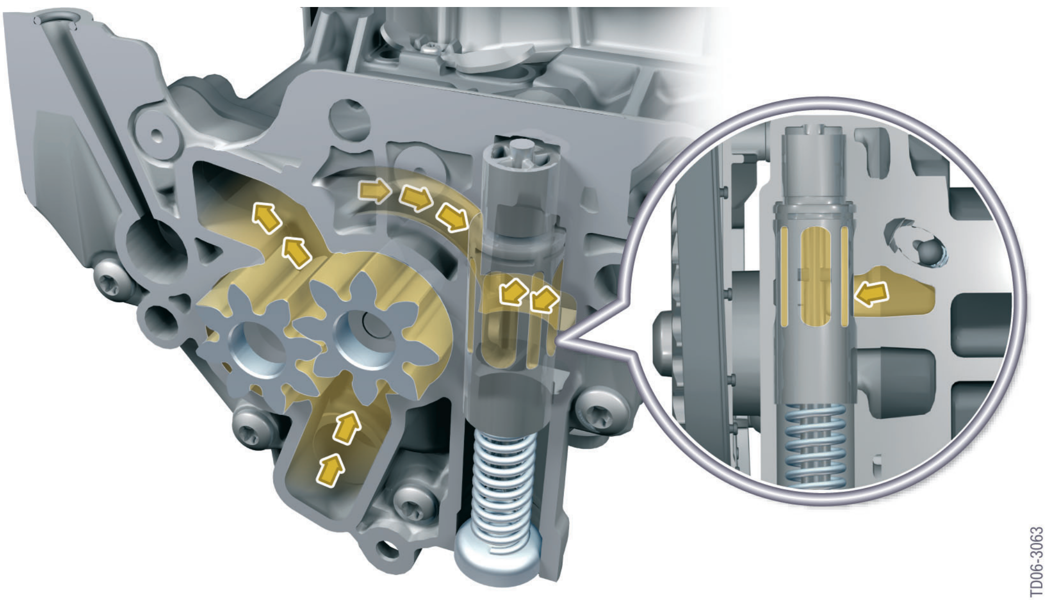
The control chambers are bordered on one side by control piston (6), which is acted on by a return spring (7).



54 - Combustion chambers in the pressure limiting valve of the N47 engine

Index	Explanation
4	Upper control chamber
5	Lower control chamber
6	Control piston

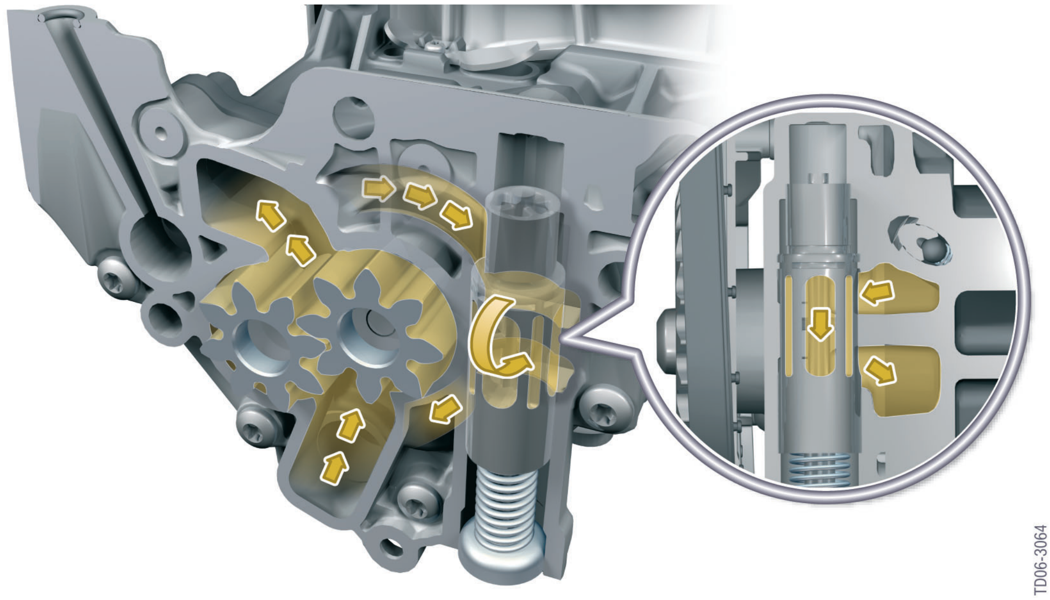
At low oil pressures, the pressure limiting valve is closed.



55 - N47 engine pressure limiting valve, closed

The spring force of the return spring determines the opening pressure of the pressure limiting valve.

If the system pressure in the oil circuit increases, and thus in the control chamber, the control piston is moved against the spring force. Due to the special shape of the control piston, a connection between the pressure side of the spur-gear oil pump and the intake section is opened.



56 - N47 engine pressure limiting valve, open

The oil circuit is for all intents and purposes closed briefly. As a consequence of the pressure ratios, a certain amount of oil flows from the pressure side and into the intake section. The more the control piston opens, the greater the volume of oil that flows away. This causes a drop of pressure in the system. Since the control piston is opened by system pressure, there is a return to equilibrium. In this way, the pressure in the system cannot exceed a desired maximum value, which is determined by the force of the return spring.

The reason why oil acts on the control piston directly downstream of the pump and also downstream of the filter is because:

- As a result of the connection with the oil circuit downstream of the filter, it is system pressure that is present and not the pressure between the oil pump and oil filter.

  A clogging of the oil filter causes a drop in downstream pressure, while the pressure upstream increases. If the pressure limiting valve were to be opened only in response to the pressure downstream of the pump, the pressure limiting valve would now open even though maximum system pressure had not been reached. In extreme cases, this could result in an undersupply of lubricating points.
- If the control piston were to be controlled only by oil downstream of the oil filter, a very high pressure would build up in the engine oil circuit during a cold start (at extremely low temperatures and thus with a correspondingly viscous oil) until the oil reached the pressure limiting valve and the pressure were regulated down.

  The high pressure could lead to damage of components and, due to the increased drive output required for the oil pump, also cause a deterioration in the starting characteristics of the engine.

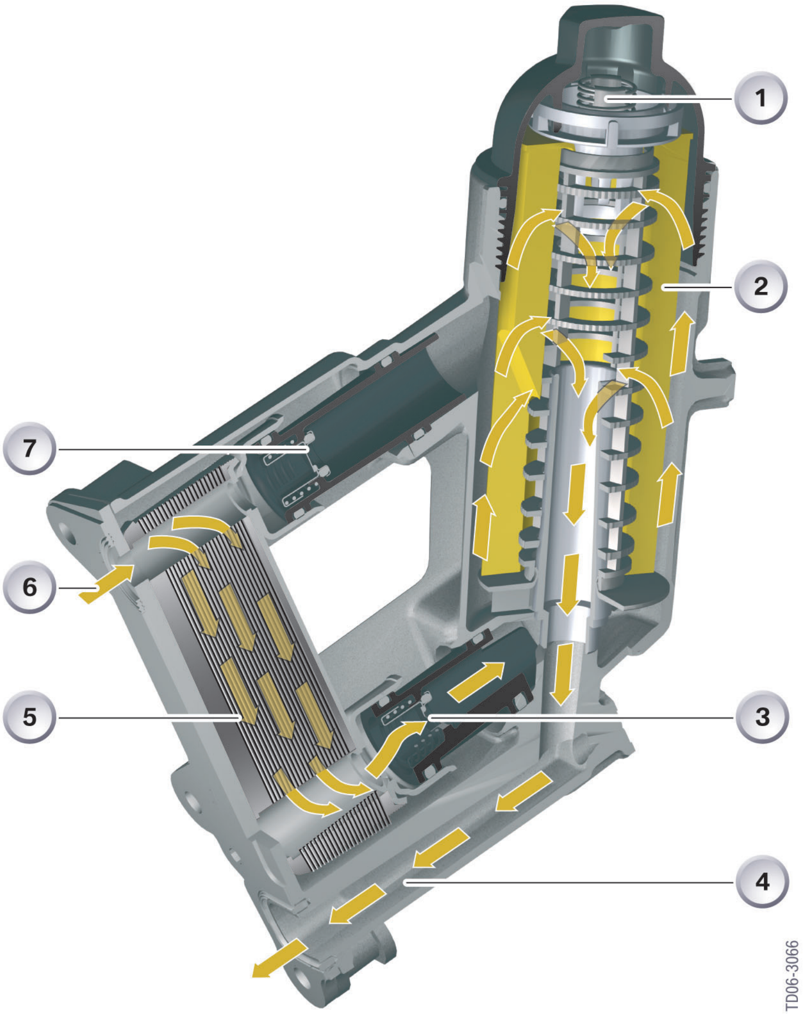
The superposition of two pressures at the pressure limiting valve helps to achieve optimum component protection and, at the same time, ensure a reliable supply of lubricating points and good cold-start characteristics.

Oil filtration and oil cooling

Oil filter

The purpose of the oil filter is to clean the oil and to prevent dirt particles from entering the oil circuit and therefore reaching the bearing points.

The N47 engine is fitted with the full-flow oil filter used on all BMW engines. All of the oil delivered by the oil pump is pumped through the full-flow oil filter.



57 - N47 engine oil filter module

Index	Explanation	Index	Explanation
1	Filter bypass valve	5	Engine oil/coolant heat exchanger
2	Oil filter	6	Unfiltered oil duct
3	Non-return valve	7	Heat exchanger bypass valve
4	Main oil duct		

Non-return valve

The oil flows through the oil pump and into the oil filter and passes through a non-return valve (3) in the process. This prevents the oil filter from running dry when the engine is switched off because the oil is only able to flow in one direction and the oil flow is blocked in the other direction.

This ensures that the lubricating points are supplied with oil when the engine is started. The oil must overcome an opening pressure of 0.2 bar in non-return valve (3). If the oil ducts have run dry, particularly after the vehicle has been parked up for a long period, there may be noises or even poor engine operation shortly after the engine has started.

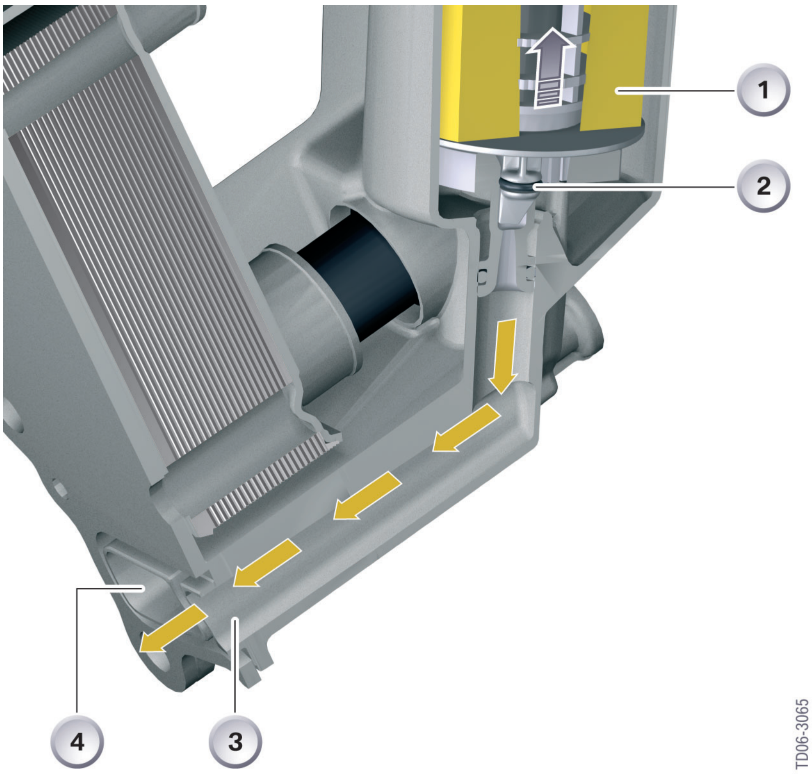
Filter bypass valve

Filter bypass valve (1) (short-circuit valve) is fitted parallel to the filter at the top side to ensure a reliable supply of oil even if oil filter (2) is clogged. If the difference in oil pressure increases to more than 2.5 bar upstream and downstream of the oil filter as a result of oil filter (2) being blocked, filter bypass valve (1) opens and oil (albeit unfiltered) is able to flow to the lubricating points.

At low outside temperatures, the cold oil may be so viscous that it could block the oil filter. In this case, too, the filter bypass valve would open.

Outlet valve

In the event of a filter replacement, the oil flows through the outlet valve, into a return duct and back to the sump. There is a piston with a seal connected to the filter cartridge that seals the return line while the filter cover is closed.



58 - Oil filter with outlet valve

Index	Explanation	Index	Explanation
1	Oil filter	3	Return duct
2	Outlet valve	4	Unfiltered oil duct

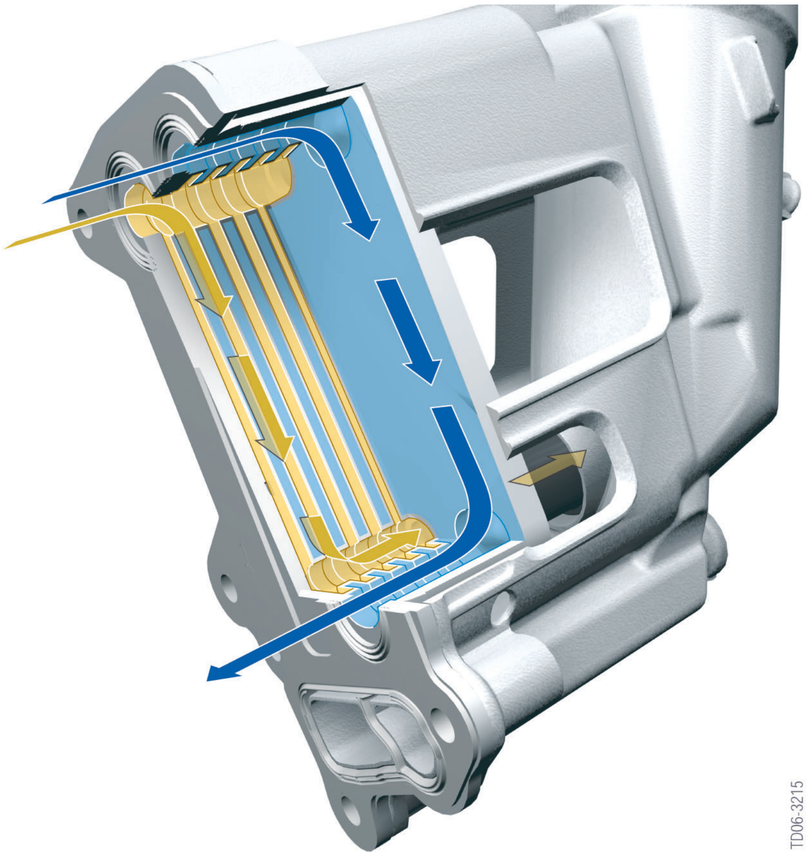
If the oil filter cover is opened for an oil change, the filter cartridge connected to the oil filter cover also moves upwards. The piston with the seal is pulled out of the return duct and oil flows to the sump.

Oil-to-coolant heat exchanger

In high-performance engines and engines subject to high thermal loads, there is a risk of the lubricating oil becoming too hot during vehicle operation. For this reason, the N47 engine has an oil/coolant heat exchanger. The oil/coolant heat exchanger heats the oil rapidly in the warm-up phase and then provides sufficient cooling.

Oil and coolant flow through the oil/coolant heat exchanger in different levels - plates - and in opposite directions. In this way, heat is transferred from one liquid to the other.

The following graphic shows the channels of the oil and coolant circuit passing through the oil filter and the oil/coolant heat exchanger.



59 - Engine oil/coolant heat exchanger

Heat exchanger bypass valve

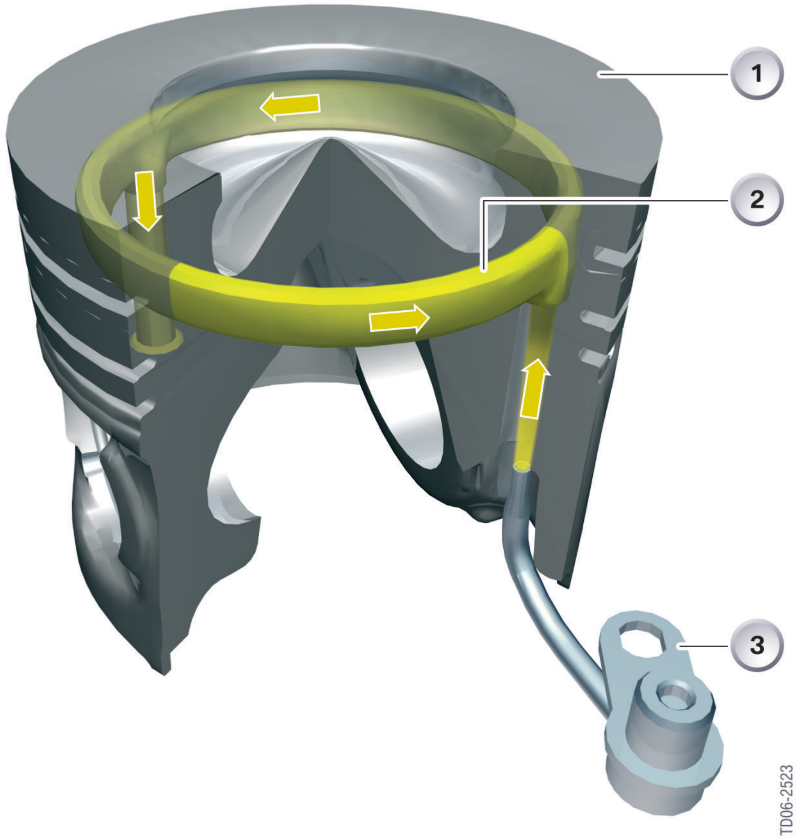
The heat exchanger bypass valve has the same function as the filter bypass valve. If the oil pressure increases as a result of a blocked oil/coolant heat exchanger, the heat exchanger bypass valve opens at a pressure of 2.0 bar and the lubricating oil (albeit not cooled) is able to flow to the lubricating points.

Oil spray nozzles and piston cooling valve

Oil spray nozzles

Oil spray nozzles are used to feed oil for lubrication or cooling purposes to defined positions of moving parts that cannot be reached via oil channels.

Oil spray nozzles for piston cooling



60 - Oil spray nozzle for piston cooling

Index	Explanation	Index	Explanation
1	Piston crown	3	Oil spray nozzle for piston cooling
2	Piston cooling duct		

The oil spray nozzle supplies the underside of the piston with oil. It sprays oil precisely into the cooling duct, where the oil collects. The movement of the piston causes the oil to circulate and has a "shaker effect". In the process, the oil vibrates in the duct and thereby improves the cooling effect. The oil returns again through further bores.

⚠ Exact positioning of the oil spray nozzles is necessary in order to achieve optimum cooling.

Bent or damaged oil spray nozzles must be replaced with new ones, otherwise there is a risk of engine damage.

The oil spray nozzles are positioned precisely with the aid of a special tool. Please observe the repair instructions. ◄

Oil spray nozzle for lubricating timing chain

The chain drive is lubricated by an oil spray nozzle. This is a plastic part that is screwed into the crankcase in the timing case. At sufficient oil pressures, oil is sprayed through three bores onto the two timing chains (timing chain between crankshaft and high-pressure pump, timing chain between high-pressure pump and camshaft).

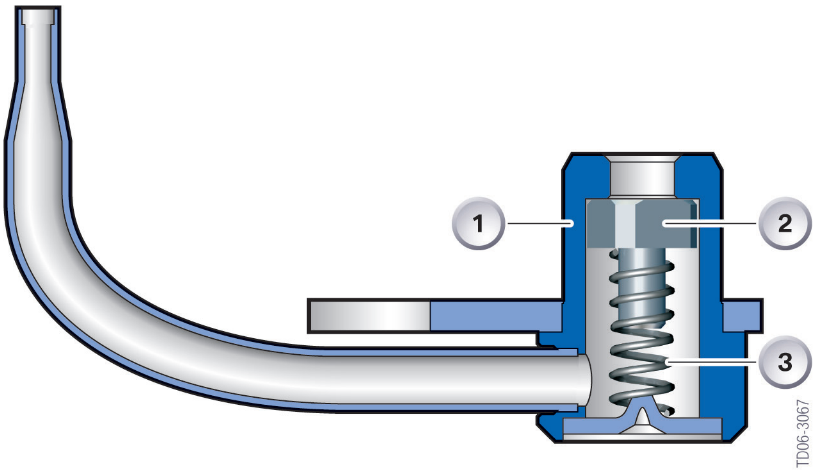
⚠ There is a risk of damage to the oil spray nozzle if the chain falls into the crankcase during assembly work. ◄

Piston cooling valve

The piston cooling valve is generally located upstream of the oil spray nozzles. In the N47 engine, each oil spray nozzle is equipped with its own piston cooling valve.

The piston cooling valves ensure that the oil spray nozzles do not begin to work until a defined pressure of 1.2 bar is reached. There are various reasons for this:

- The spray oil would not even reach the piston crown if the oil pressure were too low.
- At insufficient pressure levels, it prevents a further loss of pressure through the oil spray nozzles, which could mean oil failing to reach the lubricating points.
- With the engine switched off, it prevents the oil ducts from running dry as a consequence of oil draining from the oil spray nozzles and, during an engine start, prevents there being no oil at the lubricating points.



61 - Piston cooling valve in the oil spray nozzle for piston cooling

Index	Explanation	Index	Explanation
1	Piston cooling valve housing	3	
2			

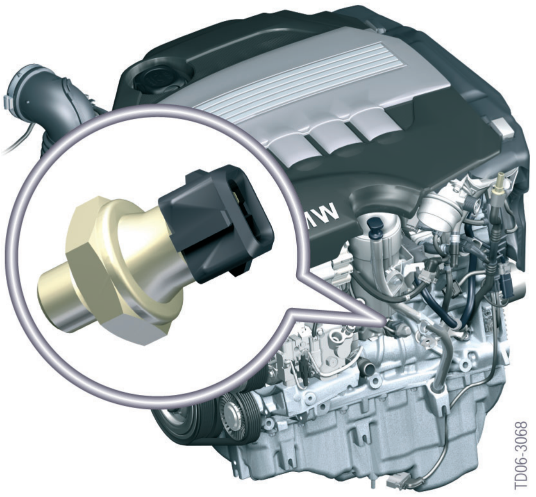
The piston cooling valve is operated by a piston, which closes the oil duct to the oil spray nozzles under spring force. Only above a defined oil pressure does the piston move against the spring force and allow the oil to reach the oil spray nozzles.

The piston has a square cross-sectional area with rounded edges, which act as the slideway in the cylinder. When the piston cooling valve is closed, the end face acts as a sealing face. When the valve opens, oil is able to flow between the cylinder wall and the flat sides of the piston.

Oil monitoring

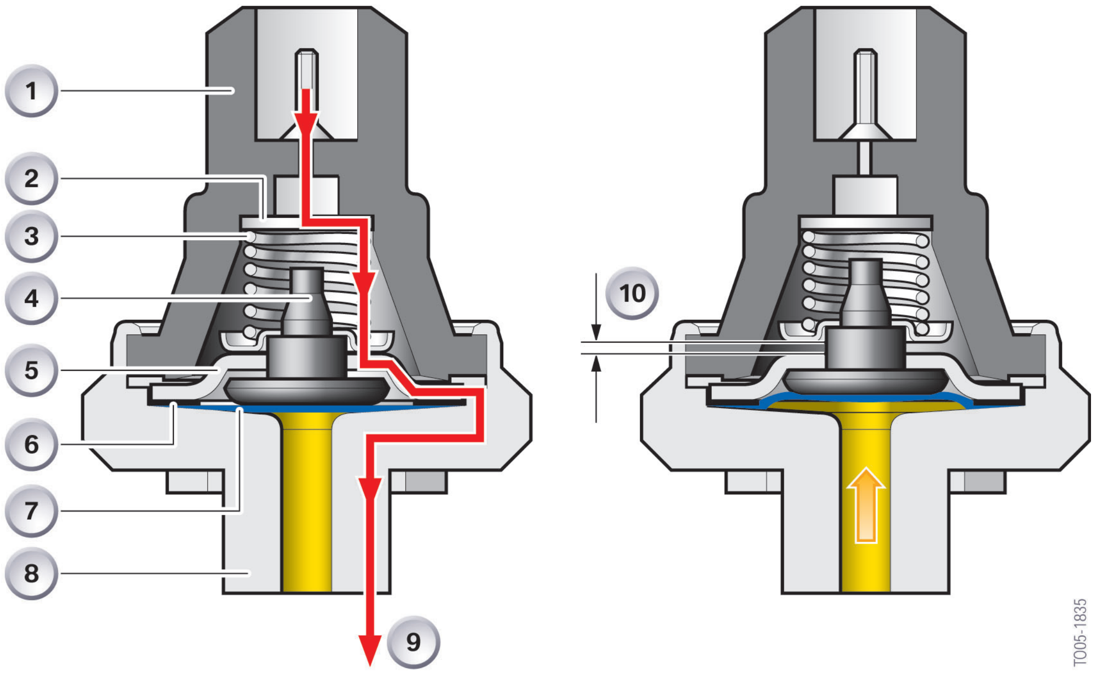
Oil pressure switch

The oil pressure switch is located under the oil filter on the oil filter housing.



62 - Oil pressure switch location in the N47 engine

The purpose of the oil pressure switch is to monitor the lubrication system. The oil pressure switch connects the oil pressure indicator light to earth. The oil pressure switch is kept closed by a spring (3) and can be opened by oil pressure. The oil pressure indicator light lights up if the oil pressure is too low to open the oil pressure switch. The spring defines the pressure value above which the oil pressure switch should open. In the N47 engine, this value is approximately 0.2 to 0.5 bar.



63 - Oil pressure switch

Index	Explanation	Index	Explanation
1	Upper section of housing made of plastic	6	Seal
2	Contact crown	7	Diaphragm
3	Spring	8	Metal housing
4	Pressure pad	9	Current flow with contact closed
5	Intermediate plate	10	Air gap with contact open

⚠ A red indicator lamp comes on and an audible signal sounds while the vehicle is in motion (e.g. engine oil pressure too low):

- Stop immediately and turn off the engine.
- Check oil level, top up oil if necessary.
- If the engine oil level is OK, contact your nearest BMW Service. ◄

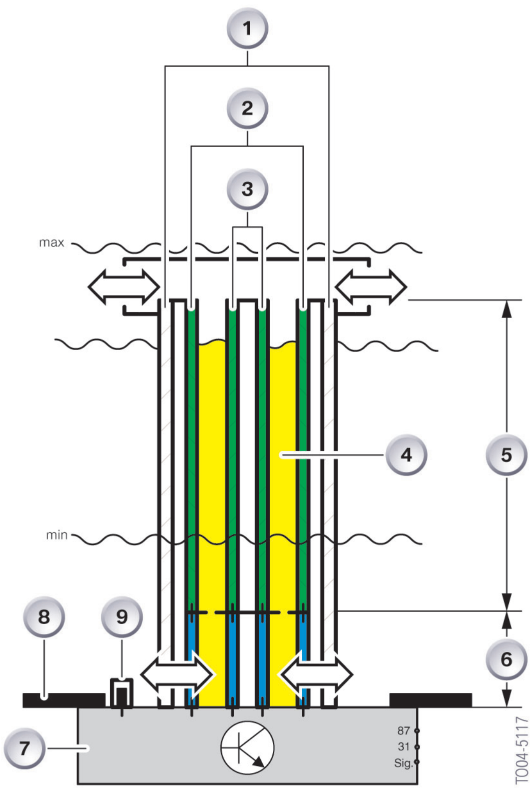
⚠ If the connector for the oil pressure switch is not connected, no oil pressure warning can be issued. ◄

Electronic oil sensors

Electronic oil sensors are fitted to record values such as the oil temperature and oil level.

In the N47 engine, a QLT oil condition sensor is used (Quality Level Temperature). The QLT is also able to determine oil quality. In the M47TU2 engine, it was a thermal oil level sensor (TÖNS) that was used.

Oil condition sensor



64 - Oil condition sensor

Index	Explanation
1	Housing
2	Outer metal tube
3	Inner metal tube
4	Oil
5	Oil level sensor
6	Oil condition sensor
7	Sensor electronics
8	Sump
9	Oil temperature sensor

The sensor consists of two cylindrical capacitors arranged one above the other.

The oil quality is determined by the lower, smaller capacitor (6).

Two metal tubes (2 + 3), arranged one inside the other, serve as the capacitor electrodes. Oil (4) serving as the dielectric flows between the electrodes. The electrical property of the oil changes with increased wear and decomposition of the additives.

In the upper cylindrical capacitors, only a part of the surface area is wetted with oil corresponding to the oil level. Therefore, the capacitance of the cylindrical capacitor changes as a function of the oil level. The DME can calculate the oil level from the values of the lower and upper cylindrical capacitor.

Dielectric: non-conductive substance in an electric field. The electric field passes through an insulator (oil). The charge of the capacitor plates is influenced by the insulator (oil).

The capacitance of the capacitor (oil condition sensor) changes in line with the change in the electrical properties of the oil (dielectric). This means that this capacitance value is processed in the evaluator electronics integrated in the sensor to form a digital signal.

However, no use is made of this sensor signal in the N47 engine. The oil quality is not taken into account in the CBS data.

The oil level and oil temperature are recorded continuously while terminal 15 is energized. The oil condition sensor is powered via terminal 87.

The electronic circuitry of the oil condition sensor has a self-diagnostics function. If a fault is detected in the component, a corresponding fault message is sent to the DDE.

Oil level measurement

Warnings

⚠ Yellow indicator lamp comes on and a gong sounds:

- Comes on while driving:
  The oil level is at the absolute minimum - top up engine oil as soon as possible. Until then, do not drive more than approx. 50 km.
- Comes on after switching off the engine:
  Top up engine oil at the next opportunity, e.g. refuelling stop.
- Comes on immediately after turning on the ignition and before starting the engine:
  There is a problem in the electrical oil level measuring system. Have checked by your BMW dealer. ◄

⚠ You will find the procedure for measuring the oil level in the Owner's Handbook.

The oil consumption depends on the driving profile and operating conditions. ◄

A possible oil consumption complaint can often be attributed to the measurement being carried out incorrectly. The exact oil consumption measurement procedure can be found in the TIS.

⚠ An oil consumption measurement should not be carried out until at least 7,500 km have been covered because it is only after this distance that the engine run-in process is more or less complete and the oil consumption has stabilized. ◄

Checking the oil level with the dipstick

On vehicles with diesel engines, a dipstick is provided in addition to the electronic oil level measurement.

The handle of the dipstick is located directly next to the oil filter housing cover.

Since the vehicle is equipped with electronic oil level measurement, the dipstick only has a black, inconspicuous handle. The following procedure must be observed if the correct oil level is to be read from the dipstick:

1. Park vehicle on flat and even ground with the engine at operating temperature, i.e. after uninterrupted driving for at least 10 km.
2. Turn off the engine.
3. After waiting approx. 5 minutes, pull out the dipstick and wipe with a lint-free cloth, paper tissue or similar.
4. Carefully insert the dipstick as far as it will go into the dipstick tube and pull out again.
5. The oil level must be between the two marks on the dipstick.

The volume of oil between the two marks on the dipstick is approximately 1 litre.

⚠ Do not exceed the upper mark on the dipstick otherwise the engine may be damaged by overfilling with oil. ◄

Electronic oil level measurement.

⚠ The dipstick has an inconspicuous black handle because it is only intended for use by the after-sales service organization. ◄

The prerequisites for a precise reading of the oil level are shown in the following graphic.

To display the oil level in the Central Information Display (CID), call up the oil level check item in the "On-board data" menu. The message texts that may be displayed are listed in the Owner's Handbook. The measured engine oil level can also be shown on the Control Display (CD). The DDE calculates the engine oil level with the help of the oil condition sensor.

There are three types of electronic oil level measurement:

- Oil level check measurement (oil level measurement)

  This measurement takes place at terminal 15 before the engine is started. Its sole purpose is to check whether there is sufficient oil for the engine start procedure. A threshold is defined for this purpose that is below minimum. If the oil level is above this threshold, this ensures the engine can run long enough without being damaged until the orientation measurement phase has been completed.

- Orientation measurement

  The orientation measurement takes place immediately after the engine has been started. It serves the purpose of providing a value after a relatively short period of time. For this measurement it is decisive whether the measurement is performed with the vehicle stationary or while driving.

- Dynamic oil level measurement

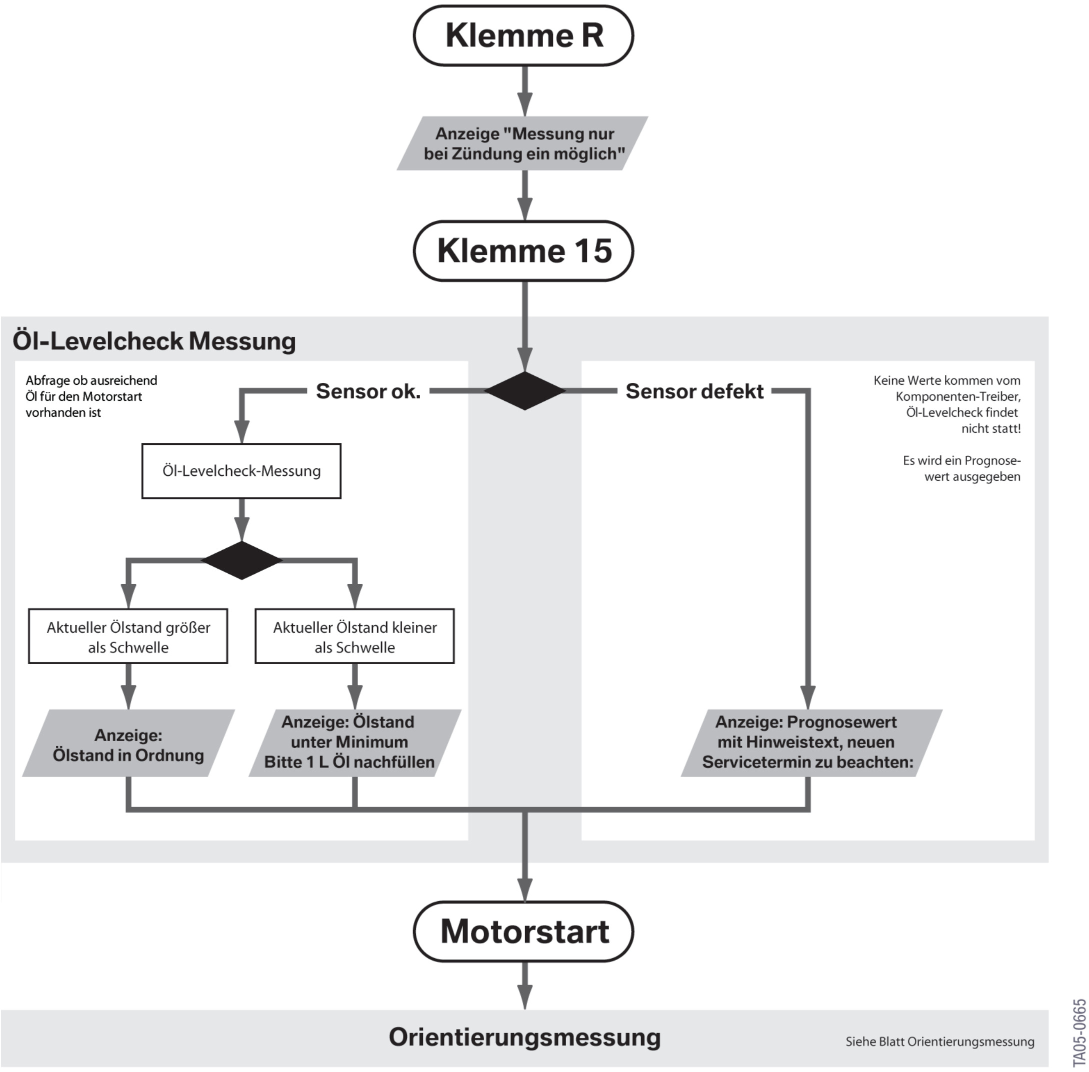
  This measurement provides the exact value relating to the oil level. This measurement can also determine the oil consumption or possible oil loss. Dynamic oil level measurement initially determines a short-term mean value and, after a longer period of driving a long-term mean value that is also stored in the engine electronics.

The oil condition sensor or the thermal oil level sensor measures at one second intervals. These individual measurements are combined in so-called packages for the purpose of determining the oil level (e.g. packages of 10 with the vehicle stationary and engine running, i.e. 10 second measurement with 10 individual values).

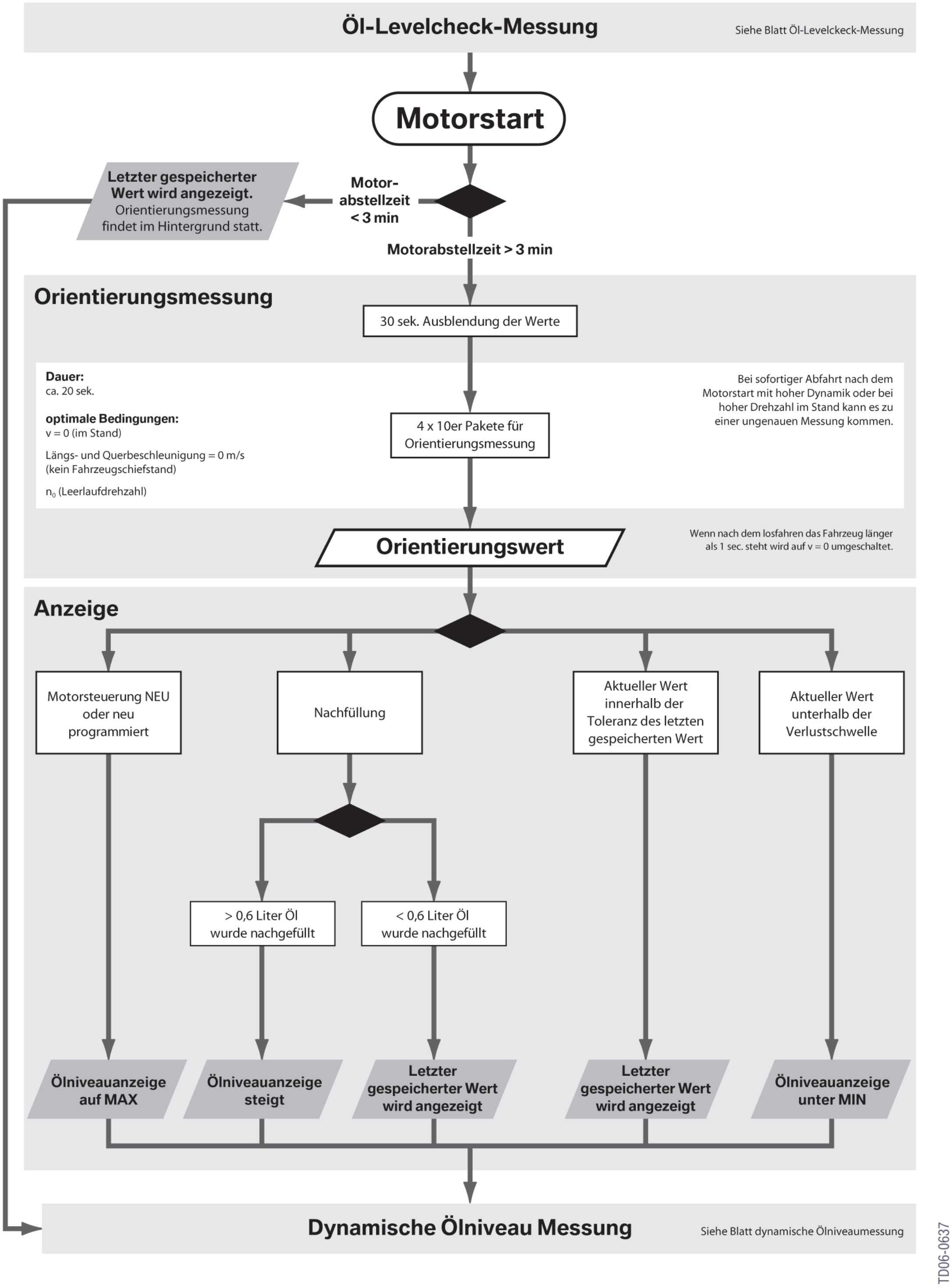
The oil level is calculated from these packages together with a correction factor. This correction factor takes into account the engine speed, longitudinal acceleration and transverse acceleration etc. as these factors have a direct influence on the actual level of the oil in the oil pan.

⚠ Initially, after replacing or reprogramming the engine control unit, no oil level is stored in the unit - "Oil level below minimum" is therefore displayed. The correct oil level is indicated after running the engine for approx. 5 minutes. ◄

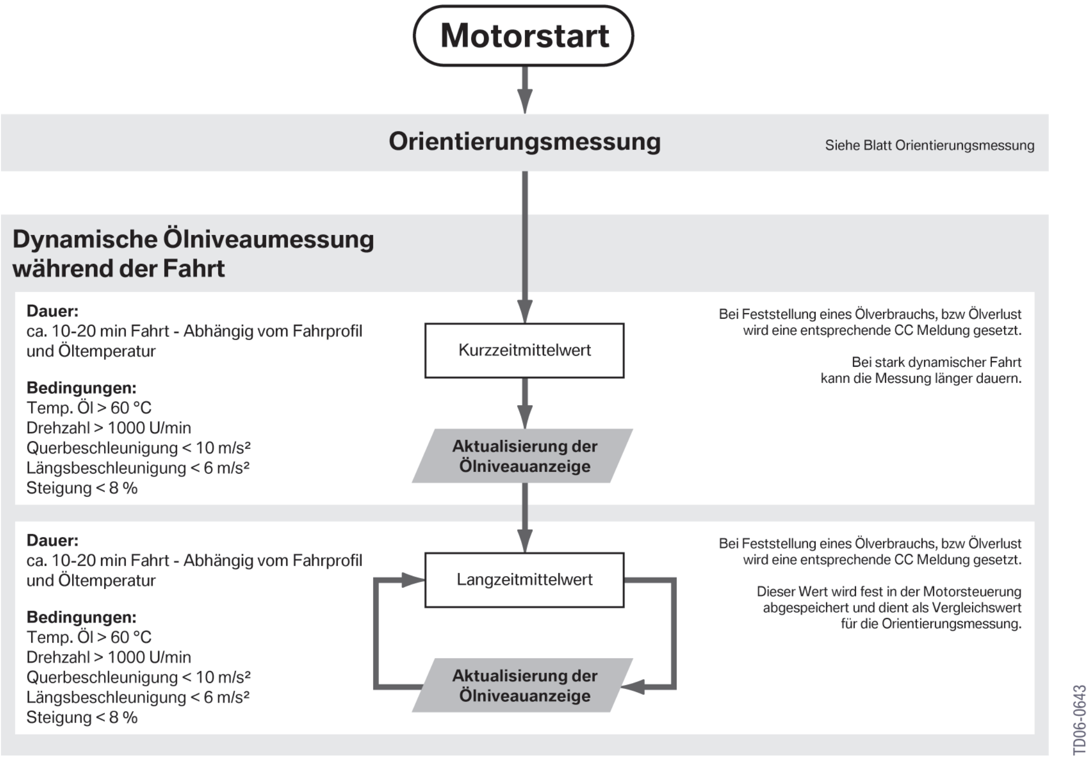
The following diagrams are shown in German and English. Other languages are not available.



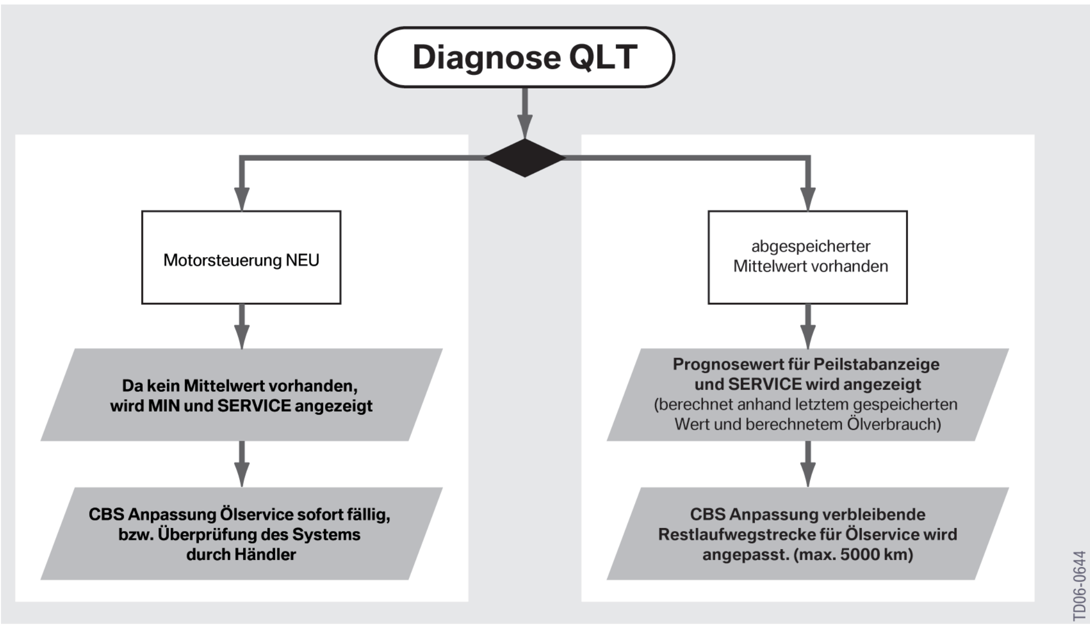
65 - Oil level check measurement



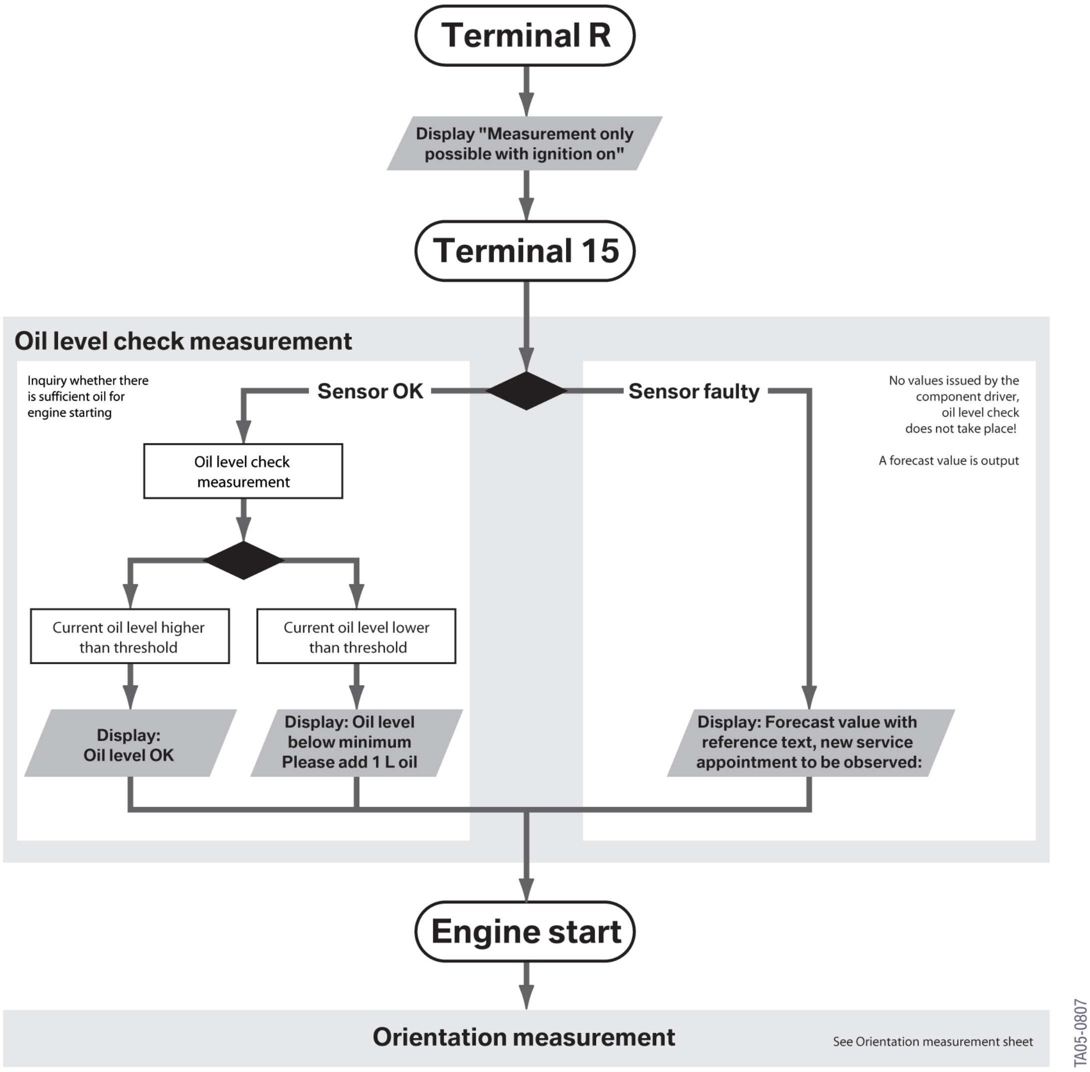
66 - Orientation measurement



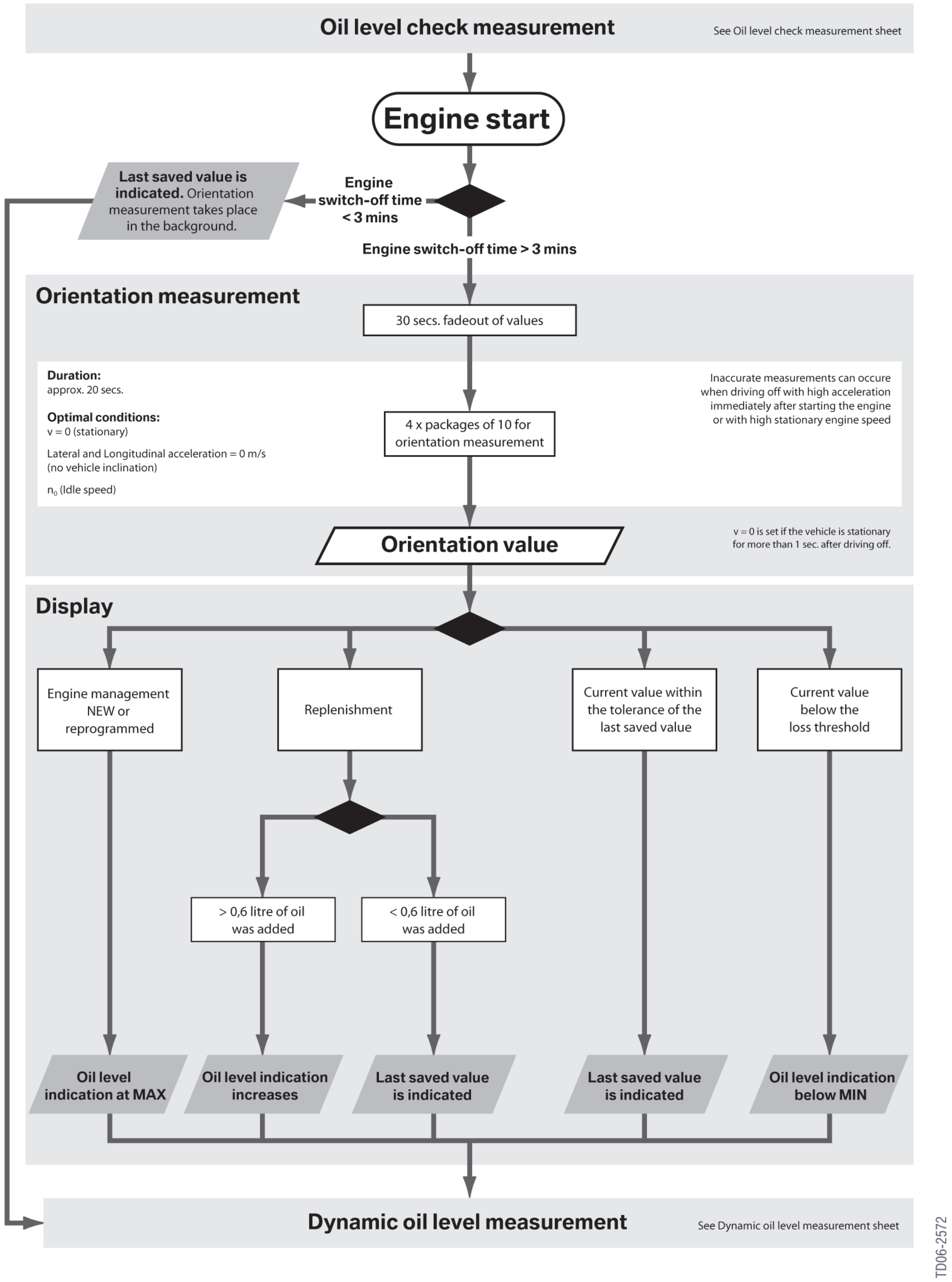
67 - Oil level measurement



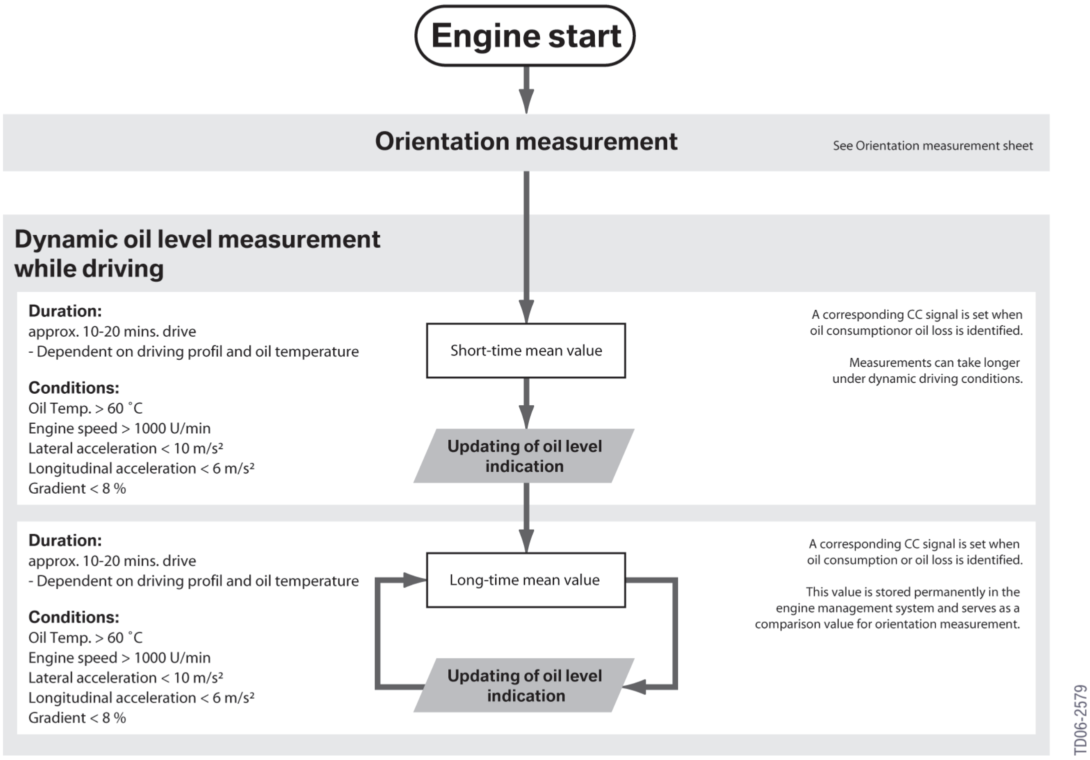
68 - QLT diagnostics



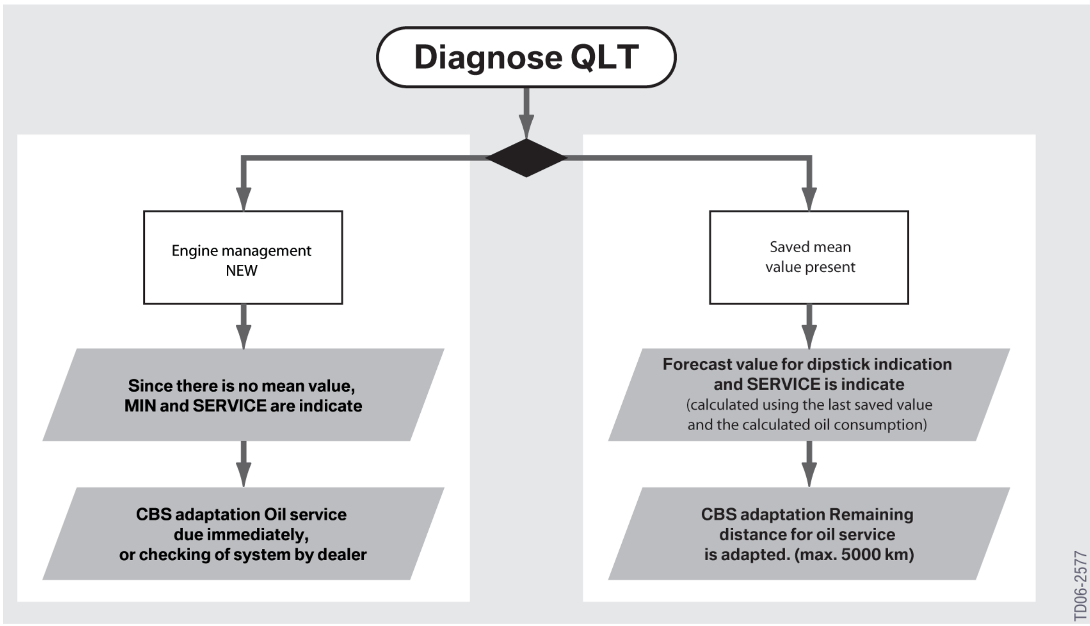
69 - Oil level check measurement



70 - Orientation measurement



71 - Oil level measurement



72 - QLT diagnostics

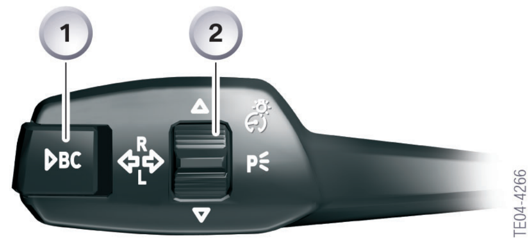
The oil level is measured by the oil condition sensor and shown in the instrument cluster and/or in the Central Information Display (CID).

The signal from the thermal oil level sensor or oil condition sensor is evaluated in the DDE. The evaluated signal is then sent via the corresponding vehicle-specific bus systems to the CID.

By determining the oil level, the engine is protected against excessively low oil level and the associated engine damage. Overfilling the engine with oil can cause leaks - a corresponding warning is therefore given.

The precondition for the most accurate indication of the oil level is that the measurement is conducted with the engine at operating temperature, e.g. after driving uninterruptedly over a minimum distance of 10 km (oil temperature > 70 °C). The oil level can be indicated while driving or with the vehicle stationary on flat and even ground with the engine running.

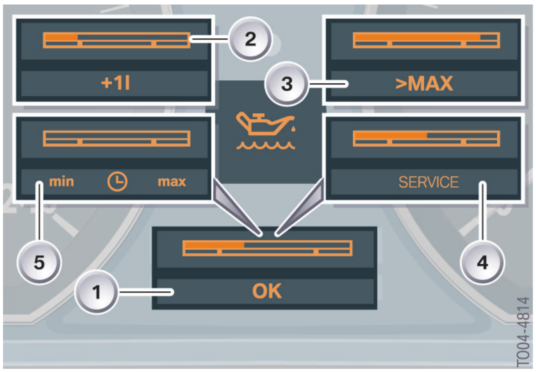
Electronic oil level indication without CID



73 - Steering column lever for turn signals

Index	Explanation
1	BC button
2	Menu rocker switch

1. Press button 2 on the direction indicator stalk up or down until the corresponding symbol and "OIL" are shown in the display.
2. Press button 1 on direction indicator stalk. The oil level is checked and displayed.



74 - Display options in the instrument cluster

Index	Explanation
1	Oil level OK
2	Oil level at minimum
3	Oil level too high
4	Oil level sensor failed
5	Determining oil level

1. Oil level OK.
2. Oil level at minimum.

   Top up max. 1 litre of oil at the next opportunity. If the oil is not topped up, this request will be repeatedly displayed until the minimum oil level is exceeded.
3. Oil level too high

   ⚠ Overfilling the engine with oil is harmful for the engine. Have the vehicle checked immediately. ◄

   A BMW dealer must extract the excess oil down to the maximum level. If the oil is not drained off, this request will be displayed repeatedly until the oil level drops below the maximum level.
4. Oil level sensor failed.

   Do not top up oil. The trip can be continued. Observe the recalculated remaining distance up to the next oil change. Have the system checked as soon as possible.

   The oil level is estimated from the oil consumption last measured and shown in the display. In the event of failure of the instrument cluster, the oil level can also be read out with the BMW diagnostic system.
5. Determining oil level.

   This procedure can take approx. 3 minutes with the vehicle parked on flat and even ground and approx. 5 minutes while driving.

Electronic oil level display with CID

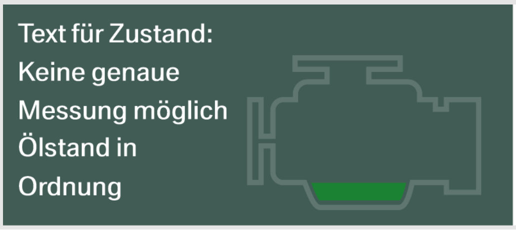
1. Press "MENU" button.

   The start menu is selected.
2. Press controller to select menu "i".
3. Select "Service" and press controller.
4. If necessary go to topmost field. Turn controller until "Service requirement" is selected and press controller.
5. If necessary go to second field from top. Turn controller until "Oil level" is selected and press controller. The oil level is indicated.

Possible messages:

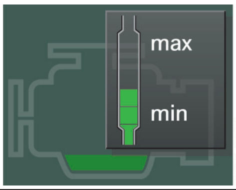
Oil level OK

With the ignition switched on, the static oil level measurement enables the driver to check whether there is sufficient oil available for a safe engine start.

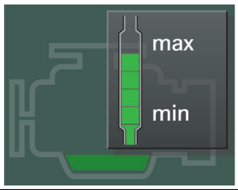


T004-5121

The dipstick symbol shows the level when the oil level is OK with the engine running.



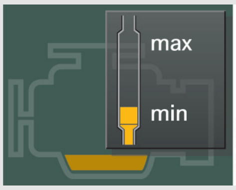
T004-5122



T004-5123

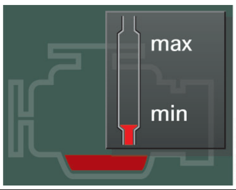
Oil level at minimum! Top up with 1 litre of oil.

If the oil level is close to minimum, the graphic with a yellow oil sump appears and an oil dipstick that indicates the low oil level in yellow.



T004-5124

If the oil level is below minimum, the graphic with a red oil sump appears and an oil dipstick which indicates the low oil level in red.

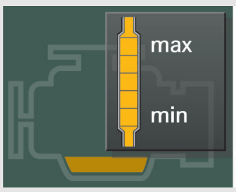


T004-5119

Oil level too high

⚠ Overfilling the engine with oil is harmful for the engine. Have the vehicle checked immediately. ◄

The graphic appears until a BMW dealer has extracted the excess oil down to the maximum limit.

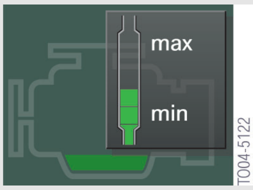


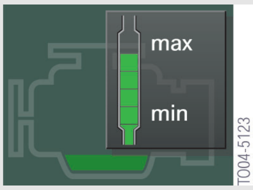
T004-5125

Please observe new oil service interval calculation.

This message in the display indicates that the measuring system is faulty. In this case, the oil level is predicted from the oil consumption last measured and shown in the display.

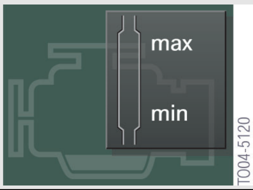
Do not top up oil. The trip can be continued. Observe the recalculated remaining distance up to the next oil change. Have the system checked as soon as possible.



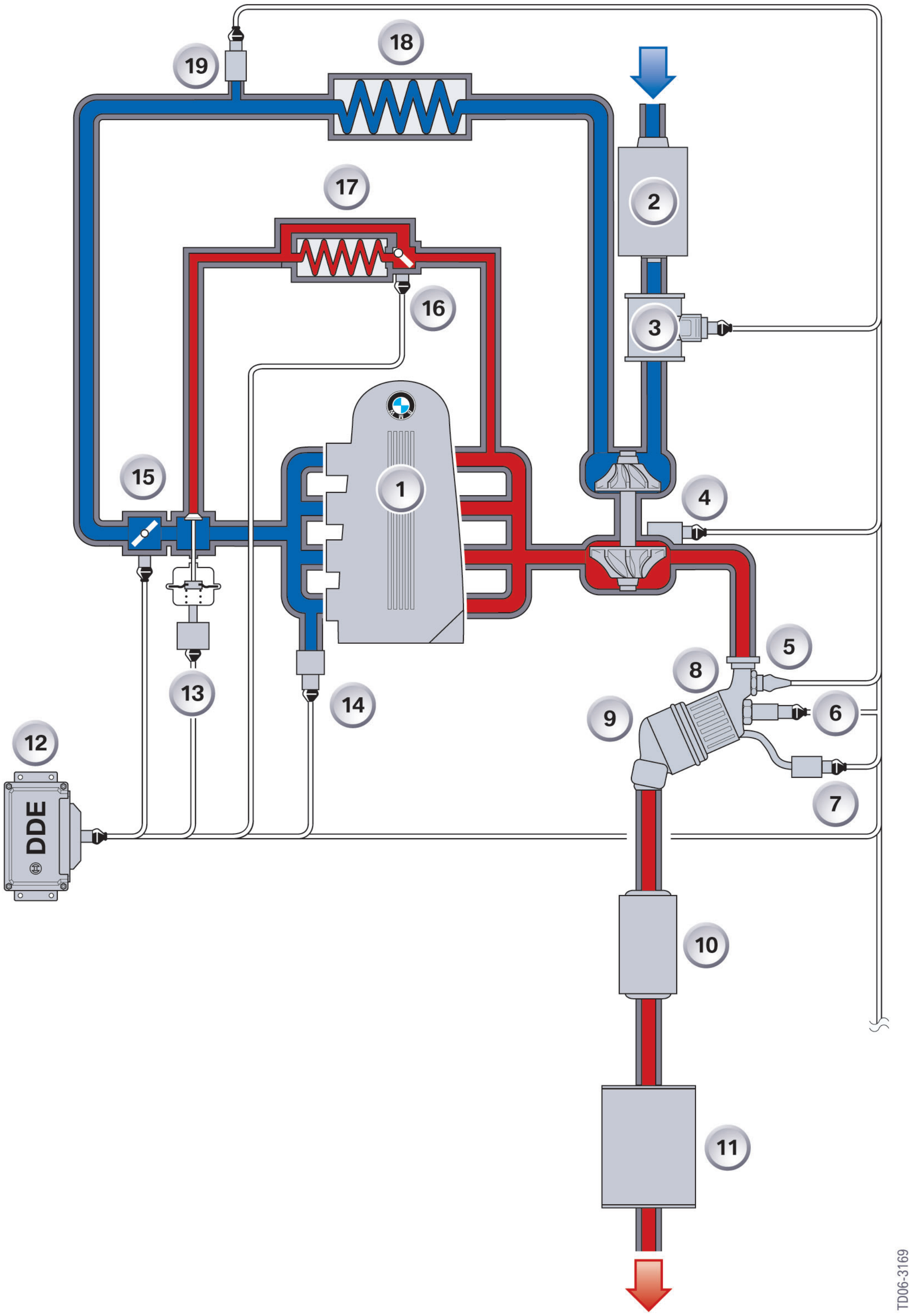


No measured value: Measuring oil level

This procedure can take approx. 3 minutes with the vehicle parked on flat and even ground and the engine running and approx. 5 minutes while driving.



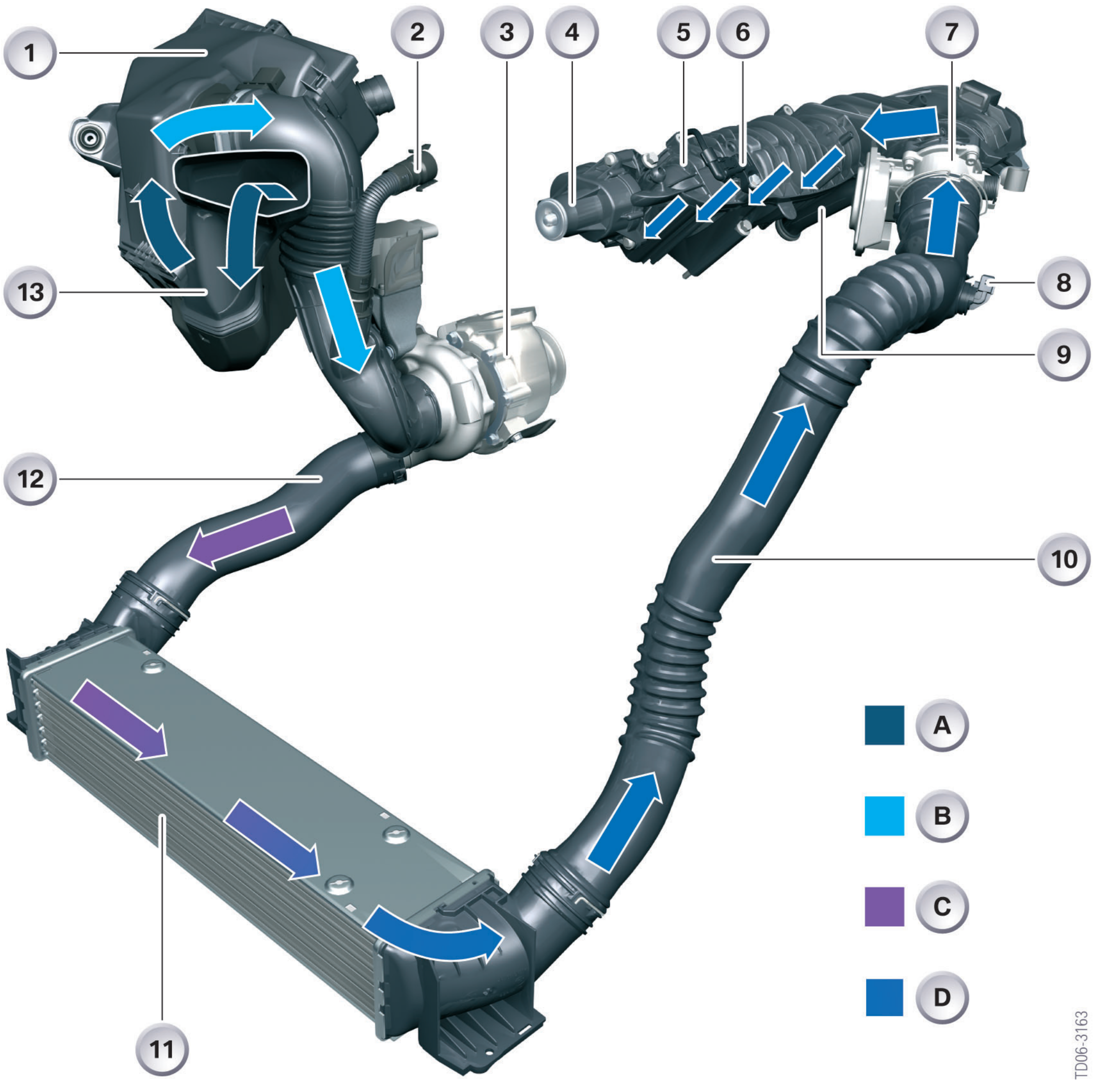
Overview of the intake and exhaust system



75 - N47 engine intake and exhaust system

Index	Explanation	Index	Explanation
1	N47 engine	11	Rear silencer
2	Intake silencer (air cleaner)	12	Digital Diesel Electronics
3	Hot-film air-mass sensor (HFM)	13	EGR valve and path sensor
4	Exhaust turbocharger with VNT	14	Boost-pressure sensor
5	Exhaust temperature sensor	15	Throttle valve
6	Oxygen sensor	16	EGR bypass valve (only upper power class with manual transmission)
7	Exhaust back pressure sensor	17	EGR cooler
8	Oxidation catalytic converter (oxi-cat)	18	Charge-air cooler
9	Diesel particulate filter (DPF)	16	Charge-air temperature sensor
10	Centre silencer		

Intake system



76 - N47 engine intake system

Index	Explanation	Index	Explanation
A	Unfiltered air	6	Boost-pressure sensor
B	Purified air	7	Throttle valve
C	Heated charge air	8	Charge-air temperature sensor
D	Cooled charge air	9	EGR in-feed line
1	Intake silencer (air cleaner)	10	Charge-air pipe
2	Blow-by gas connection	11	Charge-air cooler
3	Exhaust turbocharger	12	Charge-air pipe
4	Swirl flap regulator	13	Unfiltered air pipe
5	Intake air manifold		

Unfiltered air (A) drawn in reaches air cleaner (1) through the intake snorkel (not shown) and unfiltered air pipe (13). In the air cleaner, the unfiltered air is filtered to become purified air (B). From the air cleaner, the purified air passes by the hot-film air mass meter, through the purified air pipe and into exhaust turbocharger (3). At the same time, blow-by gases are fed into the purified air pipe through blow-by gas connection (2). In the exhaust turbocharger, the purified air is compressed and thereby heated. The compressed, heated charge air (C) is fed on in charge-air pipe (12) to charge-air cooler (11).

Cooled charge air (D) now flows away from the charge-air cooler and to throttle valve (7). Depending on the position of the throttle valve, cooled charge air (D) flows into intake manifold (5). The recirculated exhaust gas also flows into intake manifold (5).

⚠ If the purified air pipe downstream of the blow-by gas connection is heavily oiled, this could imply increased blow-by gas levels. The cause of this is usually a leak in the engine (e.g. crankshaft seal) or surplus air taken in through the vacuum lines. A consequential symptom would then be an oily exhaust turbocharger, which does not mean that there is a fault with the exhaust turbocharger itself. ◄

Unfiltered air duct

The unfiltered air duct comprises the unfiltered air snorkel and the unfiltered air pipe. Both are designed with the crash safety of pedestrians in mind. This entails the use of especially soft materials and yielding connections.

The unfiltered air snorkel in the N47 engine is what we refer to as an unfiltered air intake shroud. This has a large surface area, but is exceptionally flat. The air is drawn in by the cooling module.

Intake silencer

For the first time in a BMW diesel engine, the intake silencer is a permanent fixture of the vehicle. The housing is designed in such a way that it can collapse in the event of an impact from above (pedestrian impact). This means that it compresses by several centimetres.

Hot-film air mass meter (HFM)

The hot-film air mass meter is located directly downstream of the intake silencer. It is secured to its housing. The digital HFM6 already used in other engines is fitted.

The signal from the HFM is used as a basis for fuel flow measurement and for determining the EGR rate.

Exhaust turbocharger

The exhaust turbocharger compresses the intake air. In this way, significantly more oxygen can be delivered to the combustion chamber.

The operation of the exhaust turbocharger is described in the Exhaust system section.

Charge-air cooler

The temperature of the air increases as the air is compressed in the exhaust turbocharger. This causes the air to expand. This effect undermines the benefits of the exhaust turbocharger because less oxygen can be delivered to the combustion chamber. The charge-air cooler cools the compressed air, the air's density increases and thus more oxygen can be delivered to the combustion chamber.

The charge-air cooler is located at the bottom end of the cooling module.

Charge-air temperature sensor

The charge-air temperature sensor records the temperature of the compressed fresh air. It is located in the boost-pressure pipe, directly upstream of the throttle valve.

The charge-air temperature is used as a substitute value for calculating the air mass.

This is used to check the plausibility of the value of the HFM. If the HFM fails, the substitute value is used to calculate the fuel flow measurement and the EGR rate.

The electrical function is described in the Engine electrical system section.

Throttle valve

A throttle valve is required in all diesel engines equipped with a particulate filter system. By throttling the intake air, the throttle valve ensures that the elevated exhaust gas temperatures required for particulate filter regeneration are achieved.

The throttle valve is closed while the engine is stopping to prevent the engine from shaking during the stopping process. After the engine has stopped, the throttle valve is reopened.

The throttle valve is located directly upstream of the intake manifold.

Intake manifold

The intake manifold is made of plastic. Inside it, the air is branched off the individual cylinders. In addition, the ducts to each individual cylinder branch off further into swirl ducts and tangential ducts. In the N47 engine, both ducts are routed along the side of the cylinder head.

The swirl duct ensures reliable swirl in the combustion chamber, and the tangential duct ensures optimum cylinder charge, which is why the tangential duct is also referred to as a charge duct. The swirl flaps are located in the tangential ducts.

The swirl duct is identifiable by its almost rectangular cross section, while the tangential duct is round.

Swirl flaps

The swirl flaps close the tangential ducts so that, at low engine speeds, a more powerful swirl of air is generated in the combustion chamber. With increasing engine speed, they open to ensure cylinder charging through the tangential ducts.

The swirl flaps are adjusted by a linkage driven by a DC motor. The control of the DC motor and the control parameters are described in the Engine electrical system section.

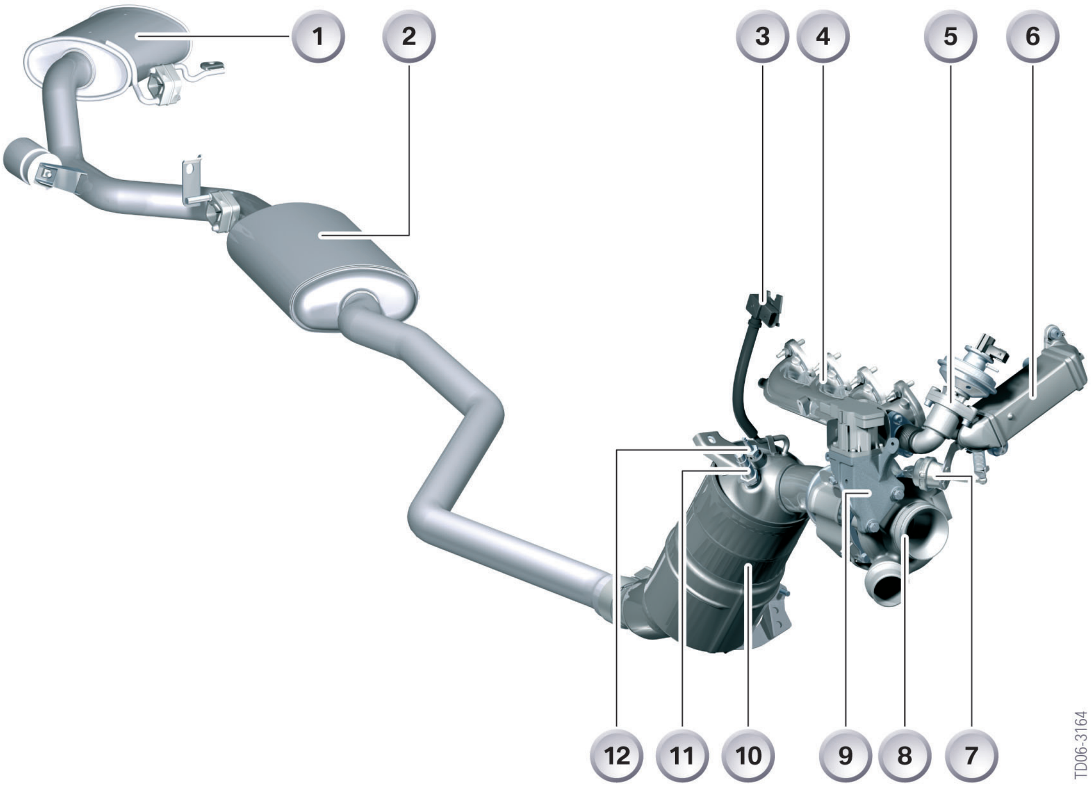
Exhaust system

The exhaust gas aftertreatment is identical in function to that of the M47TU2 engine with diesel particulate filter. However, there is a difference in the exhaust gas recirculation (EGR).

In the upper power class, a bypass valve makes it possible to bypass the EGR cooler.

The N47 engine, too, has an exhaust turbocharger with variable nozzle turbine geometry (VNT) and electrical regulator.

The oxidation catalytic converter and the diesel particulate filter are located in one housing close to the engine.



77 - N47 engine exhaust system (in the E81/87)

Index	Explanation	Index	Explanation
1	Rear silencer	7	EGR bypass regulator
2	Centre silencer	8	Exhaust turbocharger
3	Exhaust back pressure sensor	9	VNT regulator
4	Exhaust manifold	10	Oxi-cat and DPF
5	EGR valve	11	Oxygen sensor
6	EGR cooler	12	Exhaust temperature sensor

Exhaust manifold

The N47 engine has a cast four-in-one exhaust manifold. At the front end is the outlet for the exhaust gas recirculation.

Exhaust turbocharger

The turbocharger is driven by the engine's exhaust gases. The hot, pressurized exhaust gases are directed through the turbine of the exhaust turbocharger, thus producing the drive force for the compressor.

The intake air is precompressed so that a higher air mass enters the combustion chamber in the engine. In this way, it is possible to inject and combust a greater quantity of fuel, which increases the engine's power output and torque.

The speeds of the turbine are between 100,000 rpm and 200,000 rpm. The exhaust inlet temperature may be anywhere up to approximately 850 °C.

The performance of a turbocharged engine can reach the levels achieved by a naturally aspirated engine with significantly more capacity. However, the boost effect can also be used in a small engine to achieve a certain output with comparatively reduced consumption.

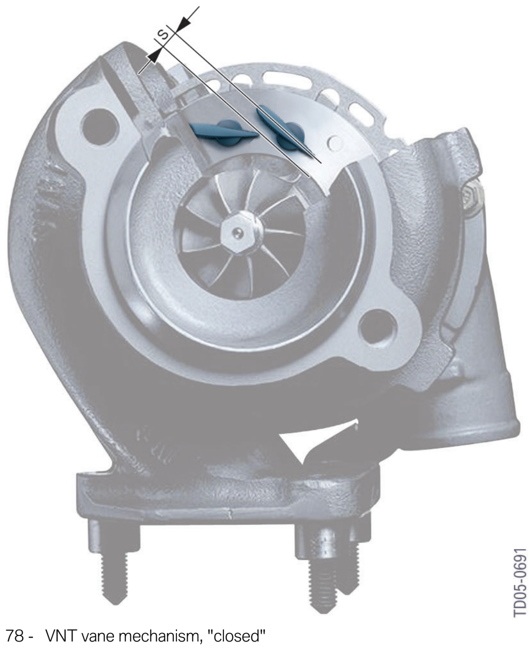
Variable nozzle turbine geometry (VNT)

The N47 engine is equipped with VNT control with a boost pressure of up to 2.5 bar absolute pressure.

The variable turbine geometry makes it possible to alter the flow conditions for the turbine wheel in relation to the engine operating point.

The turbine vanes are adjusted by the boost-pressure regulator (electrical regulator). The adjustment of the vanes reduces the flow cross section ("s", see following graphic). The flow rate of the exhaust gas and thus the exhaust gas pressure acting on the turbine wheel increases.

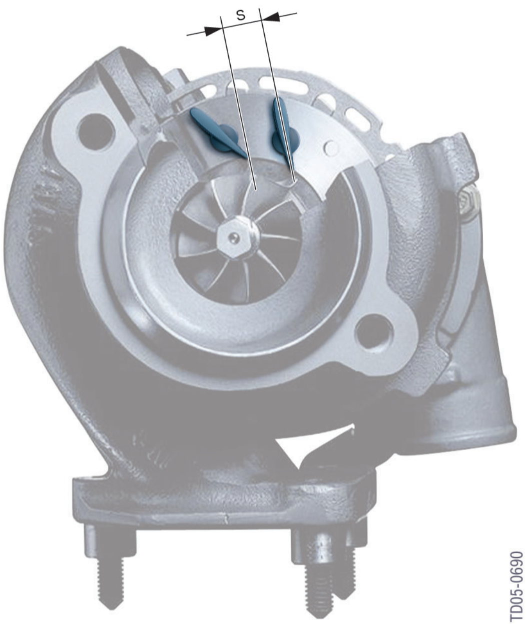
The transfer of energy (efficiency improvement) to the turbine wheel and compressor is therefore increased, particularly at low engine speeds. The boost pressure increases and a higher injection rate can be authorized by the DDE.



78 - VNT vane mechanism, "closed"

As the engine speed increases, the vanes are gradually opened so that the energy transfer always remains in equilibrium at the desired boost-pressure speed and required boost-pressure level.

The variable turbine geometry promotes more efficient use of the exhaust gas energy, making it possible to further improve the efficiency of the exhaust turbocharger and thus of the engine by comparison with the "wastegate control".



79 - VNT vane mechanism, "open"

The boost-pressure regulator is controlled by the DDE by means of a pulse-width-modulated signal.

A control rod turns the adjustment ring, which in turn moves the turbine vanes. The position of the vanes affects the size of the flow cross section to the turbine wheel.

This means that there is an additional degree of freedom in the optimization of thermodynamic behaviour by comparison with a conventional exhaust turbocharger (ATL), which has a permanently constant flow cross section. Furthermore, the exhaust turbocharger with VNT does not need a wastegate valve.

The control of the boost-pressure regulator is described in more detail in the Engine electrical system section.

Exhaust gas aftertreatment

The N47 engine has an exhaust gas aftertreatment system in the form of an oxidation catalytic converter and a diesel particulate filter (DPF). Both are fitted in the same housing. The oxi-cat is upstream of the DPF as usual.

Catalytic converter

The engine-side oxidation catalytic converter ensures the conversion of the following exhaust gas constituents across the entire operating range:

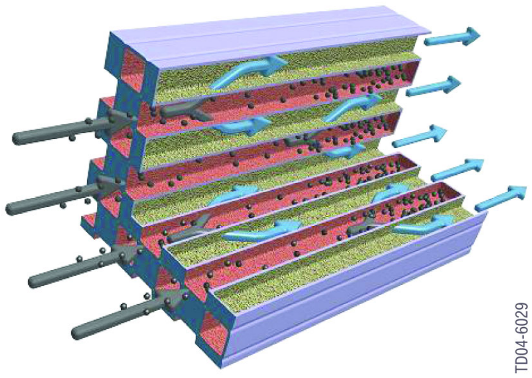
- $2NO + O_2 \Rightarrow 2NO_2$
- $2CO + O_2 \Rightarrow 2CO_2$
- $C_xH_y + (x+y/4)O_2 \Rightarrow yCO_2 + {}^x/_2\,H_2O$

Soot particles flow through the oxidation catalytic converter unimpeded. Due to the high oxygen content of the exhaust gas, the oxidation catalytic converter starts to work at approximately 170 °C. Above around 350 °C, the particle emissions begin to increase again. Sulphates form due to the sulphur content of the fuel (sulphur-oxygen compounds). A reduction in the sulphur content of the fuel contributes to a reduction in particle formation.

Diesel particle filter

The diesel particulate filter ensures the conversion of the following exhaust gas constituents:

- $C + 2NO_2 \Rightarrow CO_2 + 2NO$
- $C + O_2 \Rightarrow CO_2$
- $2CO + O_2 \Rightarrow 2CO_2$



80 - Cross section of the diesel particulate filter

The filter element of the diesel particulate filter consists of a ceramic honeycomb made of heat-resistant silicon carbide. It is up to 50 % porous and has a platinum-based, catalytic coating. This coating helps to achieve a reduction in the soot ignition temperature and thus to guarantee good regeneration characteristics of the diesel particulate filter.

The exhaust gases flow out of the oxidation catalytic converter and into the inlet ducts of the diesel particulate filter. These are closed at their ends. Each inlet duct is surrounded by four exhaust ducts.

The soot particles deposit on the platinum coating of the inlet ducts and remain there until they are combusted as a result of an increase in the exhaust temperature. The cleaned exhaust gas flows out of the exhaust ducts through the platinum-coated, porous filter walls.

The soot particles (carbon particles) that are deposited on the filter walls would eventually cause damage to the diesel particulate filter. The soot particles therefore need to be burnt off. This happens when the exhaust temperature rises above the soot ignition temperature. This process is known as filter regeneration. The carbon particles are converted to gaseous carbon dioxide (CO_2).

Soot particles have a relatively high ignition temperature. These temperatures are achievable during permanent full load operation. It complements the natural regeneration supported by the upstream oxidation catalytic converter through the formation of NO_2.

The exhaust temperature required is not usually achieved if a diesel engine runs permanently in the partial load range. The particles retained in the diesel particulate filter increase the exhaust back pressure.

A pressure sensor records the increase in pressure upstream of the diesel particulate filter, a regeneration can be initiated.

To this end, the intake air is throttled by the throttle valve so that less cool air flows into the cylinder, which would otherwise draw heat away from the exhaust gas. A delayed injection start and a secondary injection also increase the exhaust temperature.

The conversion of nitrogen monoxide to nitrogen dioxide in the oxidation catalytic converter brings about a reduction in the ignition temperature of the soot particles, thereby promoting the regeneration of soot particles in the diesel particulate filter.

The diesel particulate filter retains all particles. These include non-regenerative particles, such as oil ash, swarf and additive residues. The non-regenerative particles gradually lead to a blockage of the diesel particulate filter over time.

The diesel particulate filter is therefore subject to a replacement interval. CBS displays when a diesel particulate filter replacement is due. The replacement interval can be anywhere between 160,000 km and 220,000 km.

⚠ If the sulphur content in the diesel fuel is > 50 - 100 ppm, there is a possibility of heavy white smoke development and a sulphur odour from the exhaust tailpipe. ◄

Exhaust gas recirculation (EGR)

The exhaust gas recirculation is a measure for reducing the emission of nitrogen oxide (NO_x). Nitrogen oxides are produced in large amounts if combustion takes placed with an air surplus and at very high temperatures. Oxygen combines with the nitrogen in the combustion air to form nitrogen monoxide (NO) and nitrogen dioxide (NO_2).

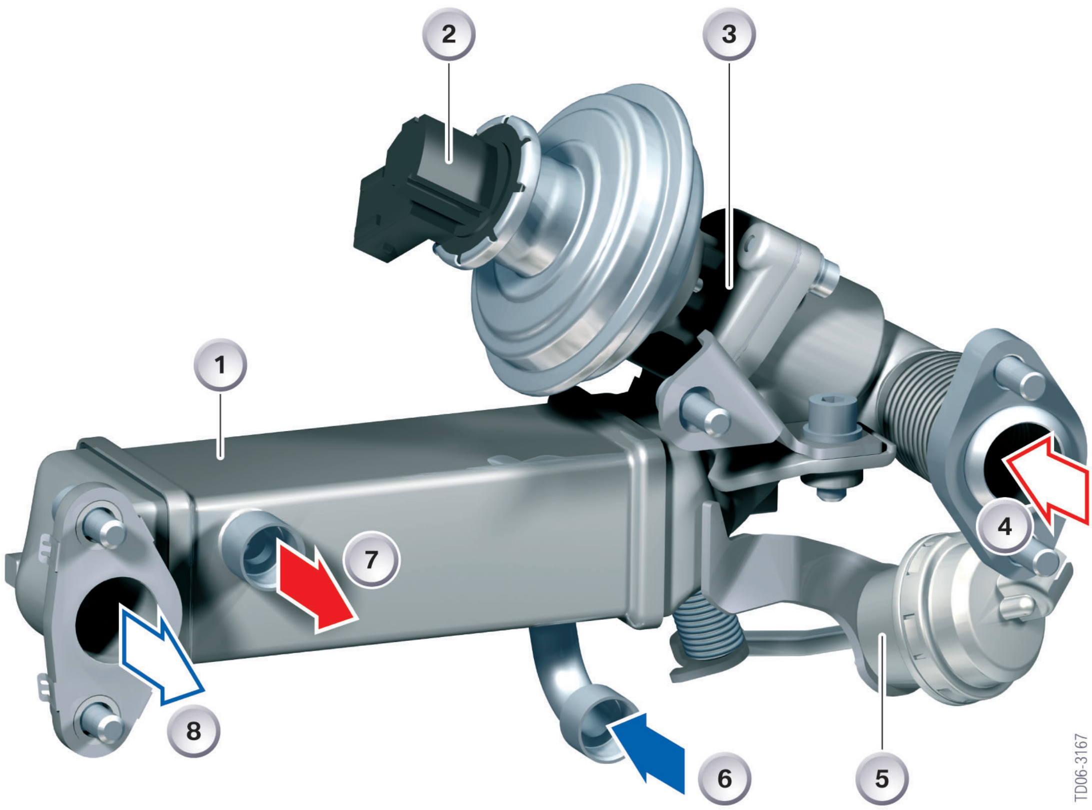
The exhaust gas recirculation is occasionally required at idling speed but always in the partial load range because this is where the engine works with a particularly high air surplus.

The recirculated exhaust gas, which is mixed with the fresh air and acts as an inert gas, serves to achieve the following:

- a lower oxygen and nitrogen concentration in the cylinder,
- a reduction in the maximum combustion temperature of up to 500 °C. This effect is increased still further if the recirculated exhaust gases are cooled.

The EGR in the N47 engine begins at the exhaust manifold. There is a connection at the forward end for this purpose. Connected here is the EGR valve, which controls the volume of recirculated exhaust gas.

Located downstream of the EGR valve is the EGR cooler. Its design differs depending on the power class and equipment. The EGR valve and the EGR cooler are contained in the EGR module.



81 - N47 engine EGR module

Index	Explanation	Index	Explanation
1	EGR cooler	5	EGR bypass regulator
2	EGR path sensor	6	Coolant supply
3	EGR valve	7	Coolant return
4	Hot exhaust gas	8	Cooled exhaust gas

The EGR duct from the EGR cooler to the intake manifold is cast into the cylinder head. At the intake manifold, the exhaust gas is ultimately mixed with the fresh air.

EGR valve

The EGR valve controls the return of exhaust gas to the air intake system. It is located upstream of the EGR cooler and therefore subjected to high thermal loads. However, the component itself is not cooled. This is not essential because it is controlled by a vacuum canister. Electrical EGR valves are much more sensitive to thermal load.

As previously mentioned, the EGR valve is opened in response to negative pressure. An electropneumatic pressure converter (EPDW) is controlled by the DDE by means of a pulse-width-modulated signal (PWM signal). The EPDW then places a corresponding negative pressure on the vacuum canister of the EGR valve. This causes the EGR valve to open against the force of a spring.

The PWM signal determines the negative pressure, and the negative pressure determines the opening dimension of the valve. In this way, it is possible to have a defined volume of exhaust gas recirculated.

With a pulse width of 10 %, the EGR valve is fully closed and, at 90 %, it is fully open.

If there is no pressure present, the EGR valve is closed due to the force of the spring. As a consequence, no exhaust gas can be recirculated in the event of an electrical or pneumatic system failure.

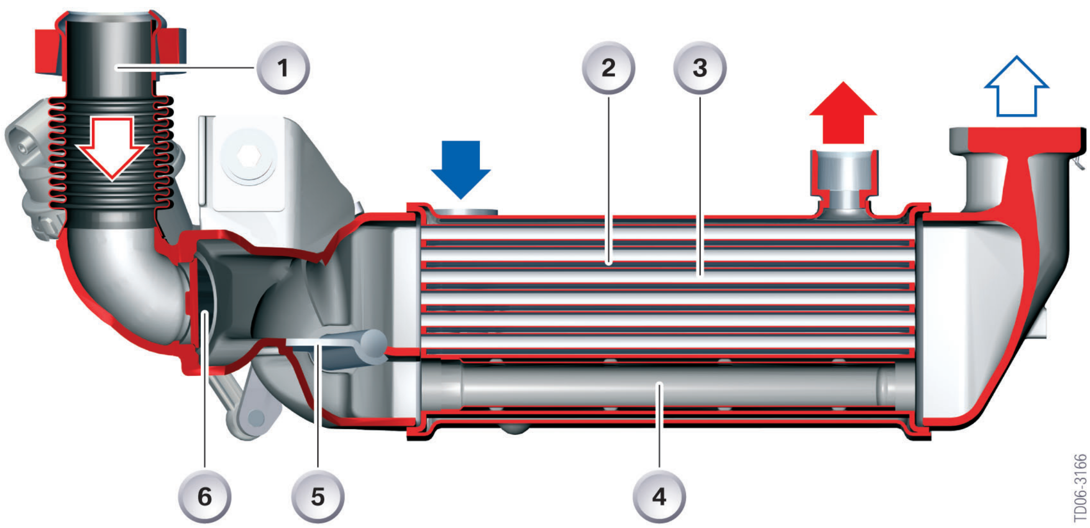
A new feature is the sensor on the EGR valve that records the opening dimension. This sensor is a potentiometer. Recording the opening dimension makes it possible to regulate the EGR rate much more accurately.

EGR cooler

The use of an EGR cooler increases the efficiency of exhaust gas recirculation. The cooled exhaust gas is able to draw off more thermal energy from the combustion and thus reduce the maximum combustion temperature.

The EGR cooler in the N47 engine is located downstream of the EGR valve. The engine's coolant flows through it. The exhaust gas is fed through this coolant flow in several flat pipes (almost rectangular cross section). In the process, its thermal energy is transferred to the coolant.

Different EGR coolers are used for the upper and lower power class. In addition, different EGR coolers are available to the upper power class depending on whether the vehicle concerned has a manual or automatic transmission.



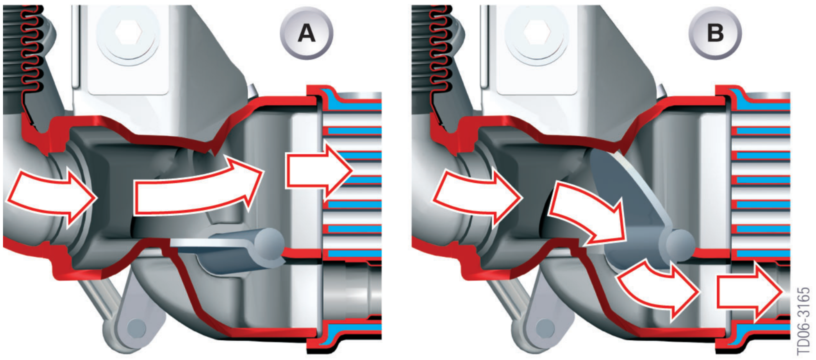
82 - EGR cooler with bypass

Index	Explanation	Index	Explanation
1	EGR supply from the exhaust manifold	4	Bypass
2	Cooling jacket	5	Bypass valve
3	EGR pipe	6	EGR valve

The EGR cooler for vehicles with manual transmission offers a new feature. It is equipped with a bypass valve, which allows the exhaust gas to bypass the EGR cooler when required.

This is useful in the engine warm-up phase for bringing the catalytic converter up to its operating temperature more rapidly.

The bypass valve is adjusted by a vacuum canister. There are two states only: open and closed. The vacuum canister is controlled by an electropneumatic changeover valve, which in turn is controlled by the DDE.



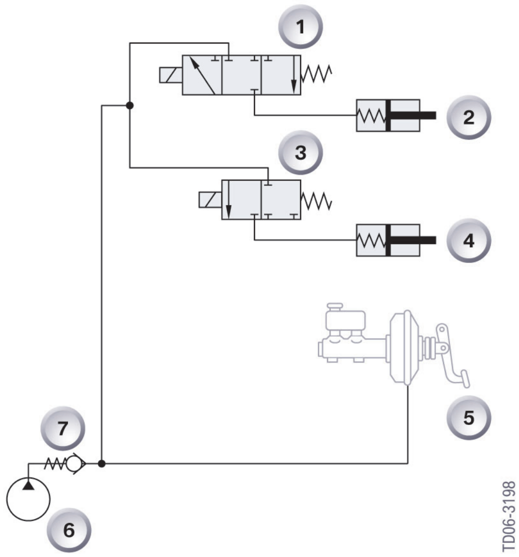
83 - Bypass valve closed and open

Index	Explanation	Index	Explanation
A	Bypass valve closed	B	Bypass valve open

With no negative pressure, the bypass valve is closed, i.e. the exhaust gas flows through the EGR cooler. If no negative pressure is present, the bypass valve opens the bypass (located inside the housing of the EGR cooler) and at the same time closes the supply to the EGR cooler.

Negative pressure system

The negative pressure system is another system in addition to the electrical system for activating various components.



84 - N47 engine negative pressure system

A vacuum pump creates the negative pressure and makes it available to the system.

The negative pressure is circuited to a vacuum canister for the control of components. The vacuum canister converts the negative pressure into motion.

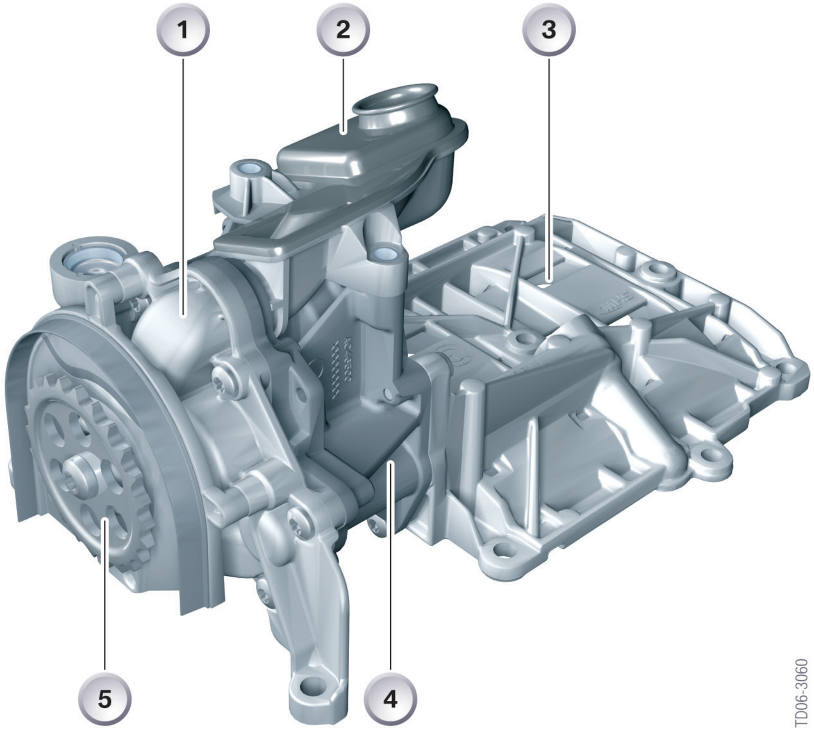
Index	Explanation
1	Electropneumatic pressure converter
2	EGR valve vacuum canister
3	Electropneumatic changeover valve
4	EGR bypass valve vacuum canister
5	Brake force amplifier
6	Vacuum pump
7	Non-return valve

To circuit the negative pressure to the vacuum canister, either electropneumatic changeover valves or pressure converters are used. These ones are controlled electrically.

A non-return valve prevents the negative pressure collapsing through the vacuum pump while the engine is switched off.

Vacuum pump

The vacuum pump of the N47 engine is fitted inside the sump and forms a single unit together with the oil pump and the reinforcement shell.



85 - Oil/vacuum pump with intake pipe in the N47 engine

Index	Explanation	Index	Explanation
1	Oil pump	4	Vacuum pump
2	Intake pipe	5	Oil/vacuum pump sprocket
3	Reinforcement shell		

The reason for the unusual installation location is to reduce the engine height dimension. It was designed in this manner with passive pedestrian safety in mind.

The pump is a vane-type pump with aluminium housing (AlSi9Cu3) with a steel rotor and a plastic vane. It is chain-driven together with the oil pump by the crankshaft.

The vacuum pump evacuates down to a negative pressure of 500 mbar (absolute) in fewer than 5 s.

The negative pressure duct passes through the oil pump housing and the crankcase. At the outlet of the crankcases, the main negative pressure line is connected to the brake force amplifier and the other consumers. The non-return valve is located at this very connection.

Electropneumatic pressure converter

An electropneumatic pressure converter (EPDW) is used for the control of the EGR valve.

Negative pressure and atmospheric pressure are present at the EPDW. This results in a "pressure blend" (control pressure) that acts on the vacuum canister. It is controlled electrically by the DDE and the control pressure is adjusted in line with this signal.

In this way, the EGR is adjustable with infinite variability.

Electropneumatic changeover valve

The electropneumatic changeover valve operates in a similar way to the EPDW.

The difference being that it does not set a pressure but merely forwards on the negative pressure in the system to the vacuum canister. As a result, there is no infinitely variable regulation possible, but rather a "black/white" or open/closed control.

In the N47 engine, the bypass valve around the EGR cooler is switched by an electropneumatic changeover valve.

Fuel system

The N47 engine is equipped with a common rail injection system. The upper and lower power class differ as illustrated in the following table.

Engine	Fuel system	Fuel injectors	Maximum pressure
N47D20U0	Common rail 2nd generation	Solenoid valve	1,600 bar
N47D20O0	Common rail 3rd generation	PIEZO	1,800 bar

Fuel supply system

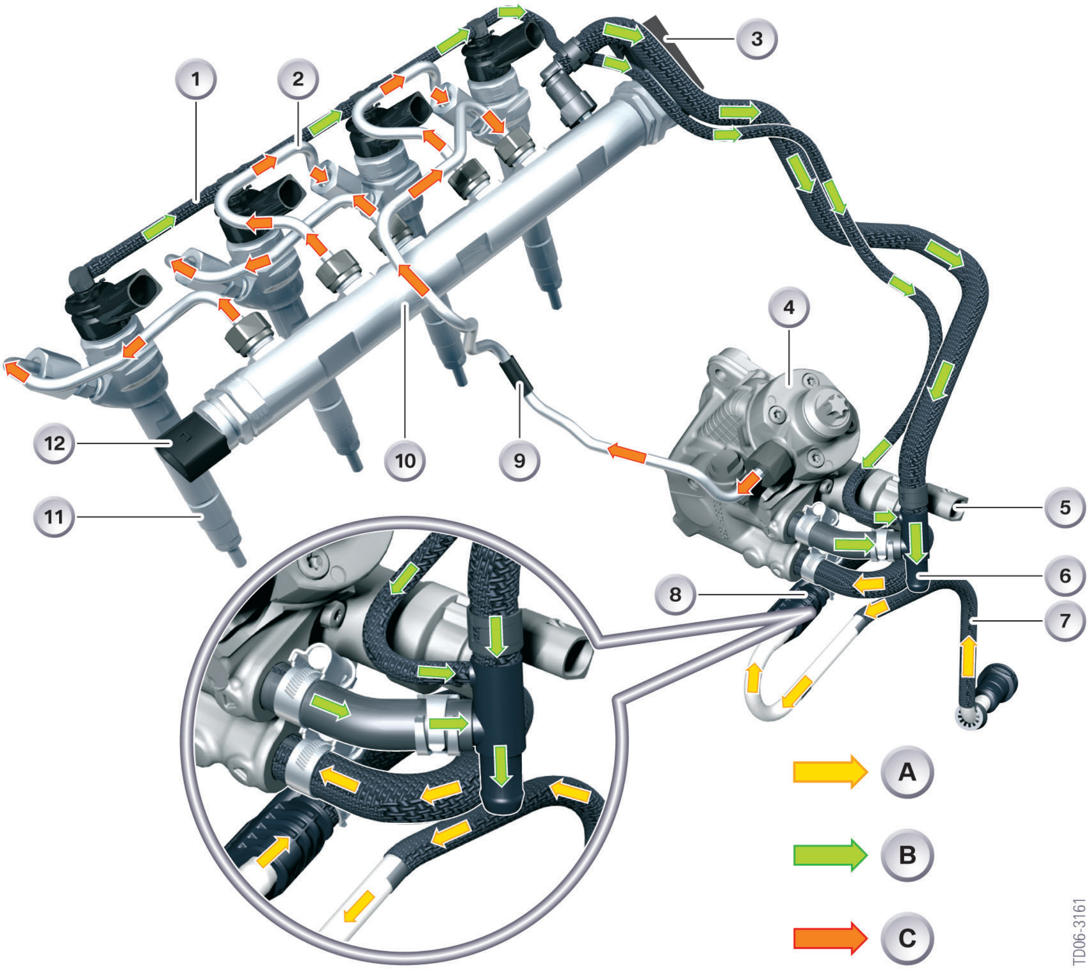
The fuel supply system is vehicle-specific and corresponds to the existing E87 diesel variant. It comprises the complete fuel tank with pump and all tank internal and external lines. This system has hardly changed for the N47 engine. Only the control of the electric fuel pump is different.

The electric fuel pump (EKP) is controlled by the EKP module by means of a PWM signal. The EKP module in turn receives a request from the DDE.

This request used to be based on engine load and engine speed. Now the regulation is pressure-sensitive.

For this purpose, a combined pressure/ temperature sensor is fitted to the fuel line directly upstream of the high-pressure pump. This allows the electric fuel pump to be controlled on demand. This reduces the energy consumption of the fuel pump, which improves fuel economy.

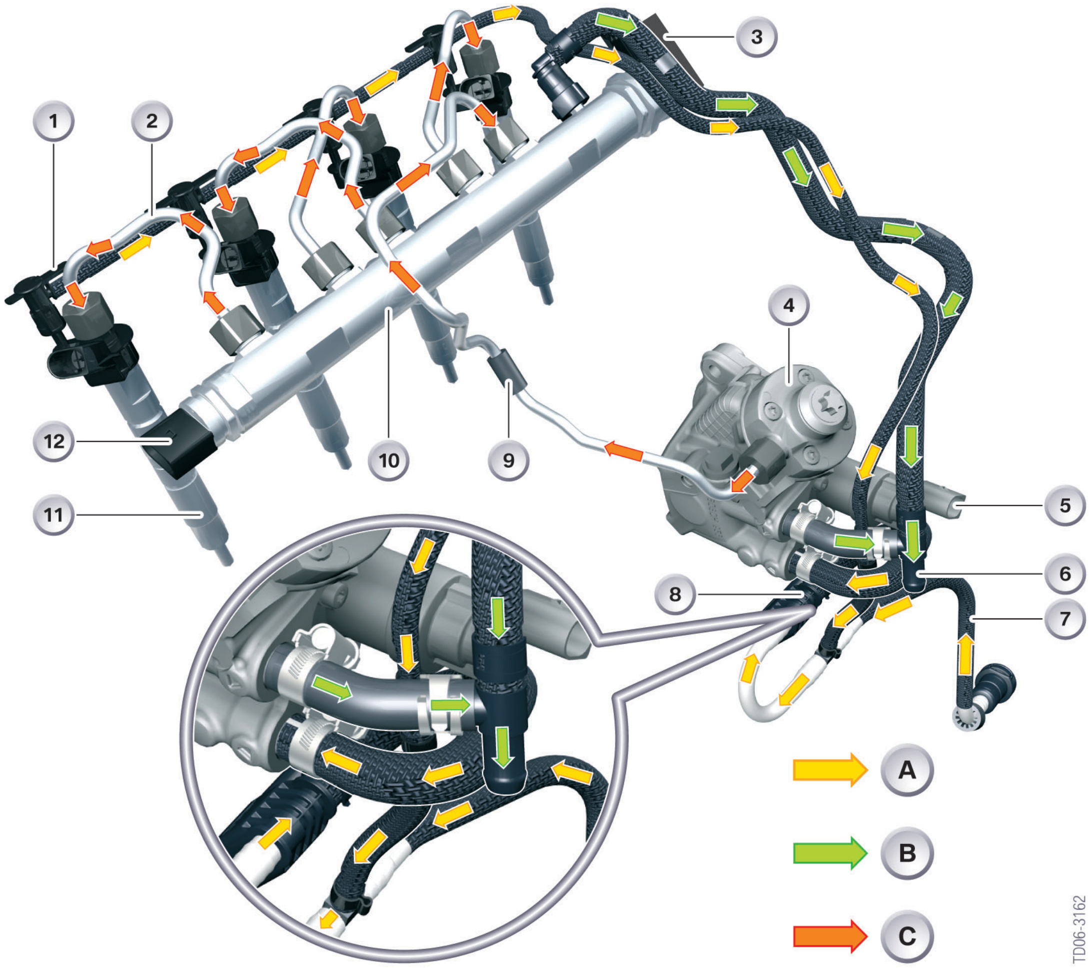
System overview of lower power class



86 - Common rail system with solenoid valve injectors

Index	Explanation	Index	Explanation
A	Fuel feed (low pressure)	6	Fuel return to the tank
B	Fuel return	7	Fuel feed from the fuel tank
C	Fuel high pressure	8	Combined pressure/temperature sensor
1	Leakage oil rail	9	High-pressure line from the high-pressure pump to the rail
2	High-pressure line from the rail to the injector	10	Rail (high-pressure accumulator)
3	Rail-pressure regulating valve	11	Solenoid valve injector
4	High-pressure pump	12	Rail pressure sensor
5	Volume control valve		

System overview of upper power class



87 - Common rail system with PIEZO injectors

Index	Explanation	Index	Explanation
A	Fuel feed (low pressure)	6	Fuel return to the tank
B	Fuel return	7	Fuel feed from the fuel tank
C	Fuel high pressure	8	Combined pressure/temperature sensor
1	Leakage oil rail	9	High-pressure line from the high-pressure pump to the rail
2	High-pressure line from the rail to the injector	10	Rail (high-pressure accumulator)
3	Rail-pressure regulating valve	11	Solenoid valve injector
4	High-pressure pump	12	Rail pressure sensor
5	Volume control valve		

High-pressure pump

The N47 engine is fitted with a new high-pressure pump. It is a single-piston pump with the designation CP4.1. The same one is used for the lower and upper power class of N47 engine.

The high-pressure pump is located on the force transmitting side and is driven by the timing chain of the crankshaft.

It is capable of generating a pressure of 1,800 bar.

Volume control valve

The volume control valve (metering unit) is also integrated in the CP4.1 high-pressure pump. It is a solenoid valve that controls the volume of fuel supplied by the high-pressure pump by characteristic mapping. Surplus fuel is directed into the return line back to the fuel tank.

The volume control valve thereby determines the pressure generated by the pump and made available in the rail.

In this way, the high-pressure pump does not generate unnecessarily high levels of pressure in partial load mode that would then be relieved by the rail-pressure regulating valve. This reduces the drive output of the high-pressure pump and thus the consumption of the engine.

The control of the volume control valve is described in the Engine electrical system section.

Rail (high-pressure accumulator)

The purpose of the rail is to provide fuel under high pressure for injection at all cylinders.

It is designed in such a way that, even when large volumes of fuel are drawn, the pressure inside is kept at a virtually constant value. This ensures that the injection pressure remains virtually constant when the injector is opened.

The spring effect of the fuel produced by the high pressure is utilized to conserve the accumulator effect.

This also helps to damp out pressure pulsations arising from pumping.

The N47 engine has a welded rail that is seated in the cylinder head cover.

It is essentially a thick-walled pipe that provides means of retention for high-pressure lines, the rail-pressure sensor and the rail-pressure regulating valve.

Rail-pressure sensor

The rail-pressure sensor is located at the forward end of the rail. It has the purpose of measuring the pressure in the rail and delivering a corresponding signal to the DDE.

The rail-pressure sensor works with a sensor diaphragm, which is deformed by the pressure that is present. This diaphragm converts the deformation into an electrical signal that is sent to an evaluator circuit. From there, the processed signal is sent to the DDE.

Rail-pressure regulating valve

The rail-pressure regulating valve is able to adjust the pressure in the rail to the correct level. To do so, it opens if the pressure is excessive and allows fuel into the return line until the desired pressure is present.

If the pressure is too low, it closes and seals the high-pressure section.

In new-generation common rail systems, the rail-pressure regulating valve no longer has to be responsible for this task in normal operation. The pressure in the rail is adjusted by the volume control valve in the meantime, thanks to which it was possible for the pumping work of the high-pressure pump to be reduced, especially in the partial load range.

In this case, the rail-pressure regulating valve is used if the driver spontaneously releases the accelerator pedal and, consequently, too much pressure is present in the rail.

It is also used during a cold start. In this case, the volume control valve allows the maximum volume of fuel into the high-pressure pump so that the fuel is heated by the pumping action. The excess pressure is then relieved by the rail-pressure regulating valve.

Fuel injectors

The injectors are high-precision components that are able to inject the finest and precisely defined fuel volumes into the combustion chamber at precisely determined times.

Different injectors are used for the upper and lower power class.

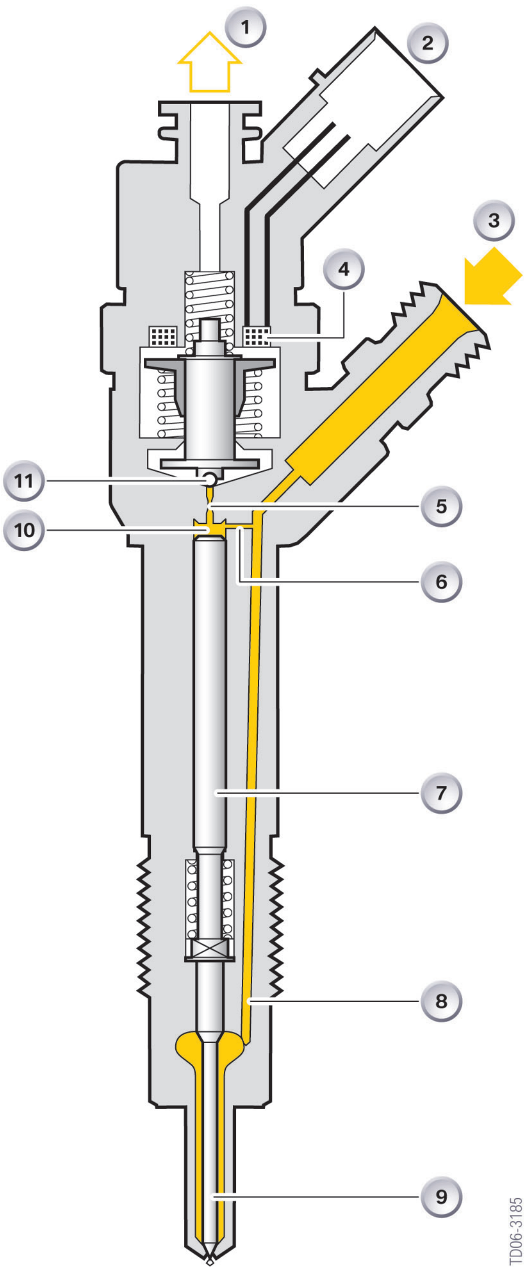
The lower power class uses the solenoid valve injectors that have been used since BMW introduced the common rail system.

The upper power class is equipped with the PIEZO injectors that have been used in the M67TU/M57TU2 since 2005.

With either type of injector, injection takes place when the nozzle needle lifts away from the hole nozzle and thereby releases the fuel that is present there under high pressure.

The nozzle needles are opened hydraulically in both types of injector. The PIEZO injector differs from the solenoid valve injector by how the switch valve that controls the hydraulics in the injector is activated. The operating principle of the solenoid valve injector will now be described.

Solenoid valve injector



88 - Sectional view of the solenoid valve injector

Fuel flows from high-pressure connection (3) through a supply duct and into nozzle (8), and through inlet restrictor (6) and into control chamber (10).

Index	Explanation
1	Fuel return
2	Electrical connection
3	High-pressure connection
4	Solenoid valve control unit
5	Outlet restrictor
6	Inlet restrictor
7	Valve control piston
8	Supply duct to the nozzle
9	Nozzle needle
10	Control chamber
11	Valve ball

The control chamber is connected to fuel return (1) by outlet restrictor (5), which can be opened by a solenoid valve. With the valve closed, the hydraulic force acting on the valve control piston outweighs that which acts on the pressure stage of nozzle needle (9). Consequently, the nozzle needle is pressed into its seat and forms a tight seal between the high-pressure duct and the combustion chamber.

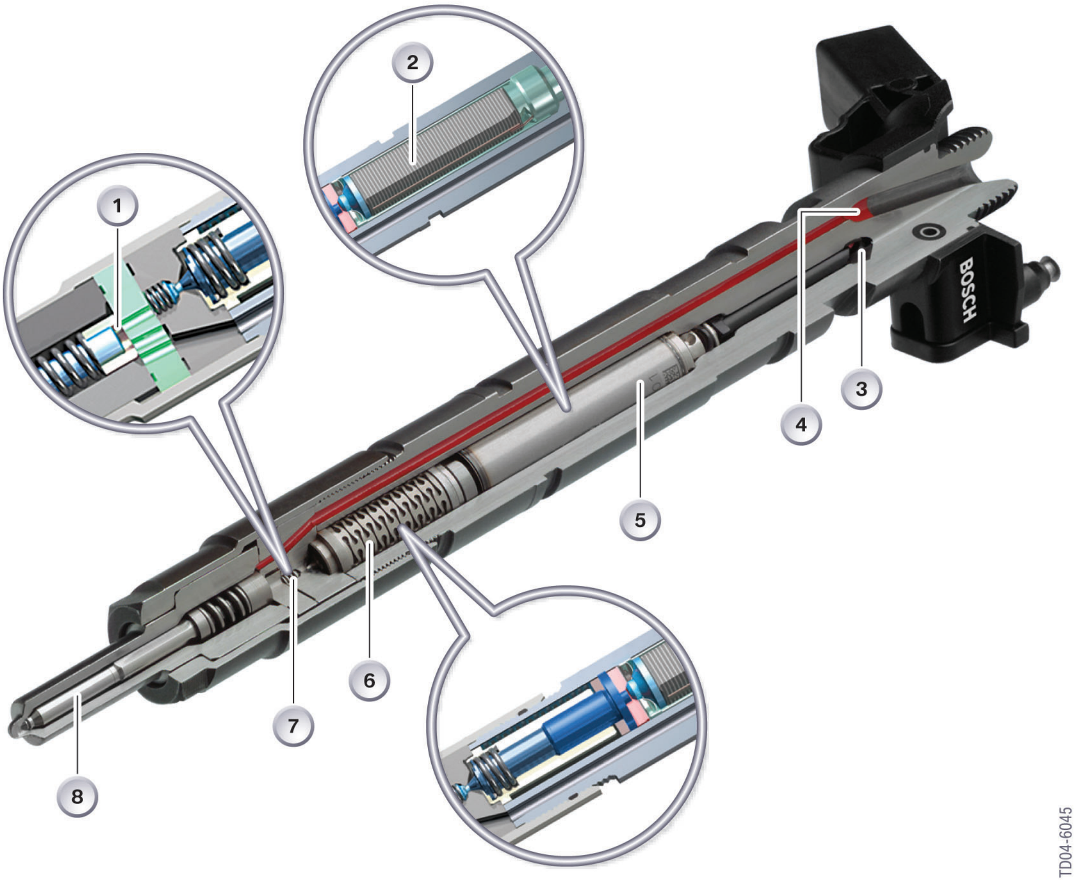
When the solenoid valve is controlled, the connection to the fuel return line through the outlet restrictor is opened. This causes a reduction in pressure inside the control chamber and therefore in the hydraulic force acting on the valve control piston.

As soon as the hydraulic force acting on the valve control piston is less than that which acts on the pressure stage of the nozzle needle, the nozzle needle opens and fuel is thereby able to flow into the combustion chamber through the holes in the nozzle.

This indirect control of the nozzle needle by means of a hydraulic fuel booster system is used because the forces required to open the nozzle needle rapidly cannot be generated directly by the solenoid valve. The amount of fuel, known as the control volume, required in addition to the injected volume of fuel flows through the leakage oil line and into the fuel return line.

PIEZO injector

The hydraulic operation of the PIEZO injector is the same in principle. The only difference is that the valve that releases the fuel return line is not a solenoid valve. It is controlled by a PIEZO element and is known as a switch valve.



89 - Sectional view of the PIEZO injector

Index	Explanation	Index	Explanation
1	Control chamber	5	Actor module
2	PIEZO element	6	Coupler module
3	High-pressure supply	7	Switch valve
4	Leakage oil return	8	Nozzle needle

The PIEZO element is located inside the actor module. When controlled, it produces the movement necessary to open the switch valve.

Circuited between the two elements is the coupler module, which functions as a hydraulic compensating element, e.g. to compensate for temperature-related length expansions.

When the injector is controlled, the actor module expands. This movement is transferred to the switch valve by the coupler module. When the switch valve opens, the pressure in the control chamber drops and the nozzle needle opens in exactly the same way as with the solenoid valve injector.

The benefits of the PIEZO injector are that they offer a considerably faster control response, which results in greater metering accuracy.

In addition, the PIEZO injector is smaller, lighter and has a lower power consumption.

The N47 engine is equipped with PIEZO injectors that have been developed further still and are even more compact and lighter.

Leakage oil

A certain amount of leakage oil occurs in the injectors due to the design of the system. On the one hand, this is fuel that flows away as a control volume when the switch valve or outlet restrictor opens. On the other hand, a certain amount of fuel is always forced past the switch valve or outlet restrictor as a result of the pressure in the injector.

This volume flows into the leakage oil line that is connected to each injector. At this point, the systems in the upper and lower power class differ.

In the lower power class, this leakage oil is directed into the return line back to the fuel tank.

In the upper power class, the leakage oil is directed into the supply line to the high-pressure pump. The reason for this is that the switch valve in the PIEZO injector needs a certain back pressure to work correctly.

Overview of the cooling system

The entire cooling system in the vehicle is as complex as it is important. The systems that draw heat away from the transmission and the steering are in part functionally, or locally very closely, linked to the engine cooling system.

In the engine itself, there are different types of cooling:

- Coolant cooling
- Engine-oil cooling
- EGR cooling (exhaust gas recirculation)
- Charge-air cooling.

The engine's central cooling system is the coolant circuit. Coolant circulates around thermally laden components and carries away their heat. Since the coolant heats up in the process, it is cooled back down in a coolant radiator. The coolant radiator is a heat exchanger whereby the heat of the coolant is dissipated into the air. An electric fan supports the output of the coolant radiator. Both components are located in the cooling module.

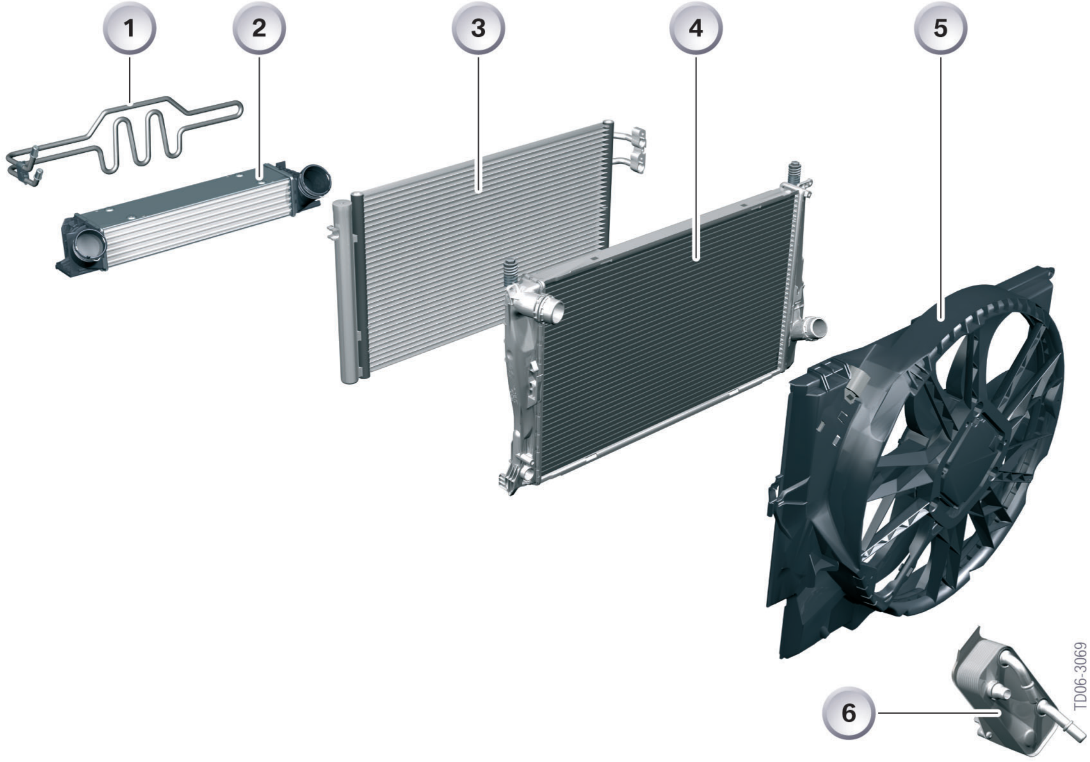
Since engine oil also carries away heat from components, this oil also needs to be cooled. In the N47 engine, the oil is cooled by a heat exchanger that transfers the heat of the engine oil to the coolant.

If the vehicle is equipped with an automatic transmission, the same happens with the transmission oil.

Recirculated exhaust gas is also cooled to reduce pollutant emissions. This, too, is channelled through a heat exchanger that transfers the heat of the exhaust gas to the coolant.

The charge-air cooler and, if hydraulic power steering is fitted, the power steering cooler are fitted directly in the cooling module. These heat exchangers transfer heat directly to the air.

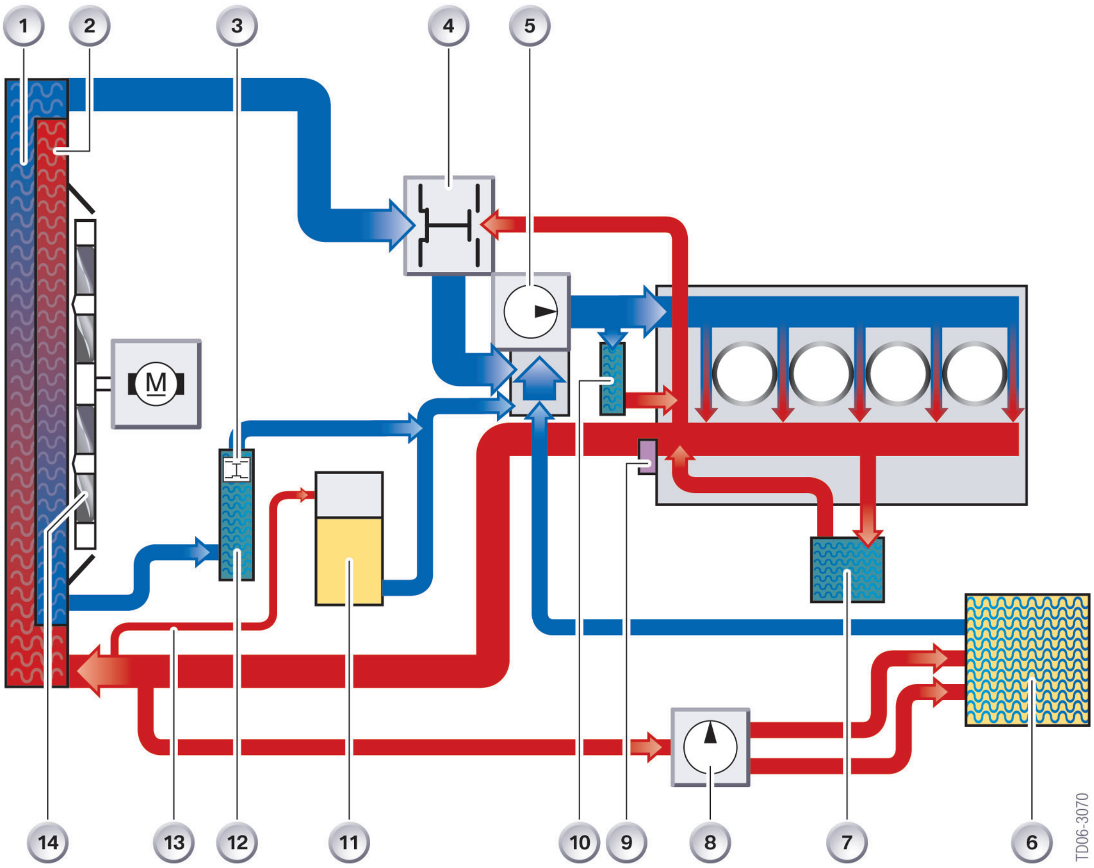
Cooling module



90 - N47 engine cooling module

Index	Explanation	Index	Explanation
1	Power steering cooler	4	Coolant radiator
2	Charge-air cooler	5	Electric fan
3	Air-conditioning condenser	6	Transmission oil cooler

Coolant circuit



91 - N47 engine coolant circuit

Index	Explanation	Index	Explanation
1	Coolant radiator Coolant/air heat exchanger	8	Auxiliary coolant pump
2	Transmission radiator Coolant/air heat exchanger	9	Coolant-temperature sensor at engine outlet
3	Thermostat in the transmission oil cooler	10	EGR cooler
4	Thermostat	11	Expansion tank
5	Coolant pump	12	Transmission oil cooler Transmission oil/coolant heat exchanger
6	Heat exchanger for heating system	13	Vent line
7	Engine oil cooler Engine oil/coolant heat exchanger	14	Electric fan

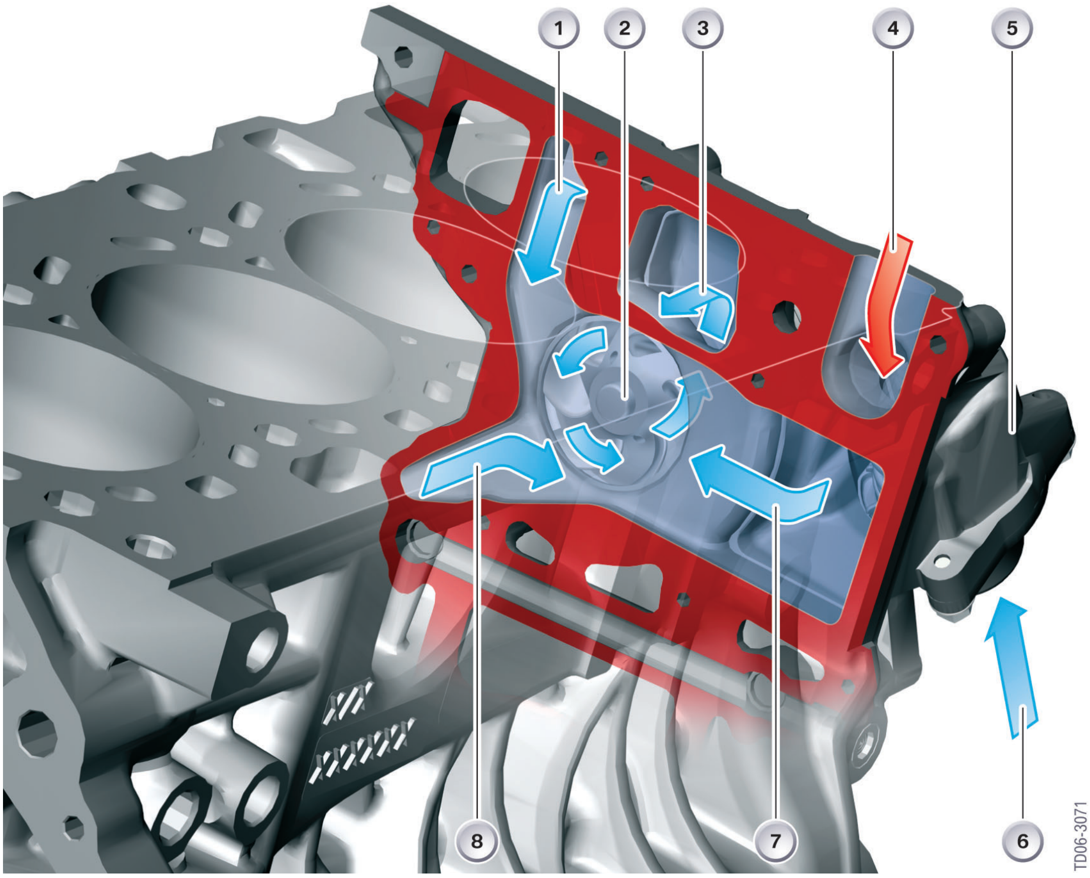
Components in the coolant circuit

The purpose of the coolant circuit is to carry heat away from thermally laden components or other media, e.g. engine oil, and transfer it to the ambient air.

The following pages describe the components that belong to the coolant circuit.

Coolant pump

The coolant pump circulates the coolant in the coolant circuit using an impeller. The turning motion of the impeller draws in coolant on the front side and pumps it out into the pressure chamber.



92 - N47 engine coolant pump

Index	Explanation	Index	Explanation
1	Supply of expansion tank (and transmission oil cooler with automatic transmission)	5	Thermostat
2	Coolant pump	6	Radiator return
3	Supply to crankcase	7	Supply of thermostat
4	Return from the cylinder head	8	Heating return

In the N47 engine, the coolant pump forms one unit with the thermostat. The housing of the coolant pump is made of aluminium alloy AlSi9Cu3; the impeller and the thermostat cover are made of plastic.

Coolant leakage

The impeller, which is located in the water jacket, is bearing-mounted on a shaft. The water jacket is sealed off from the outside by a slide ring on the shaft. For this to work correctly, there must be some leakage between the shaft and the slide ring. This improves the sliding properties. This is known as the functional leakage of the slide ring seal.

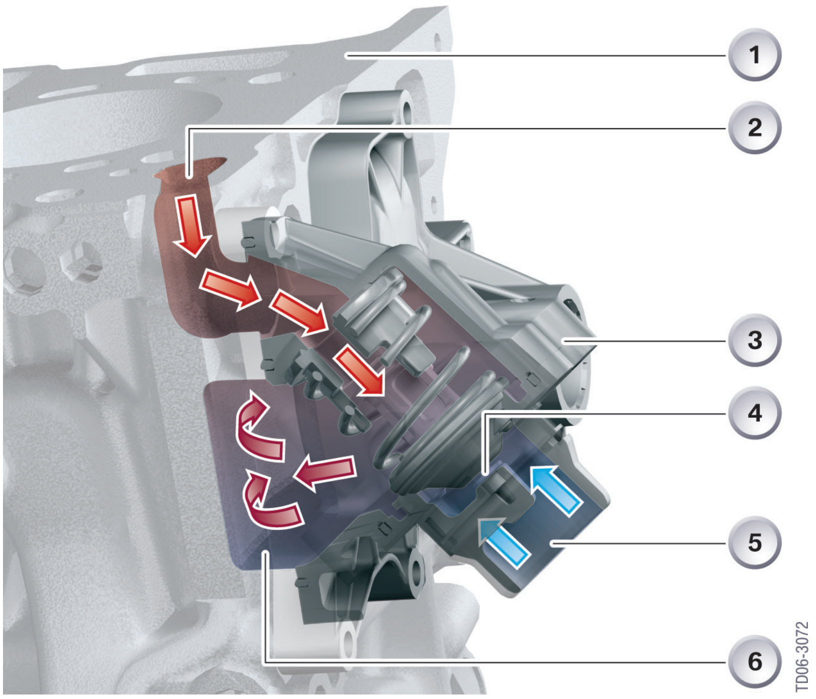
In the N47 engine, as in the M47TU2, the leakage is directed into the belt pulley, which may give rise to minor traces of coolant.

⚠ In the past, coolant pumps would often be replaced due to the presence of coolant traces. However, minor traces of coolant are acceptable due to the functional leakage of the slide ring seal.

The maximum permissible coolant leakage is 800 mg/h, which corresponds to one drop with a diameter of a little over 1 cm per hour. ◄

Thermostat

In the N47 engine, the engine temperature is regulated by a conventional thermostat. This means that only the coolant temperature determines regulation of engine temperature.



93 - N47 engine thermostat

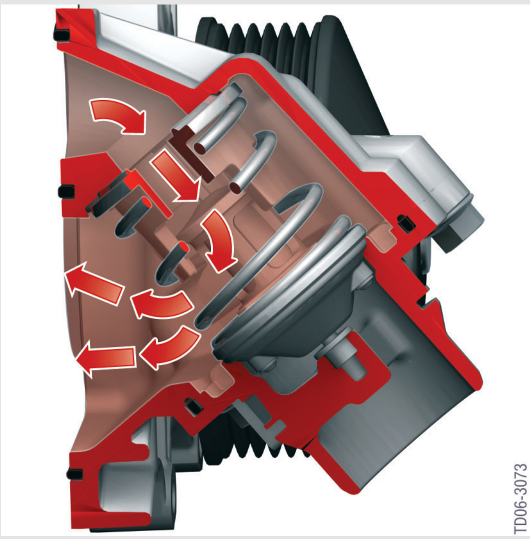
Index	Explanation	Index	Explanation
1	Crankcase	4	Wax element
2	Hot coolant from the cylinder head	5	Radiator return
3	Thermostat housing	6	Supply to the coolant pump

This is done by a wax element that assumes the temperature of the coolant that flows around it. The wax is an expanding substance that expands on heating and opens the thermostat.

The thermostat divides the coolant flowing through the cooling radiator or past it through a short-circuit line.

Regulation can be broken down into three operating ranges.

Operating ranges of the thermostat

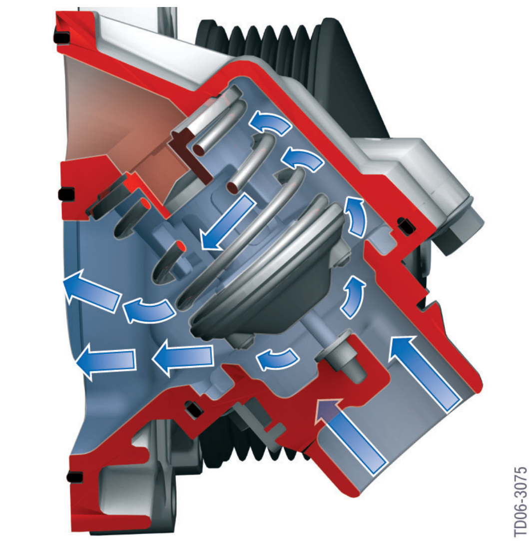


Thermostat closed

The coolant temperature is below the opening temperature of the thermostat.

The coolant circuit is short-circuited. The coolant only flows inside the engine and not through the coolant radiator.

Opening point: approximately 88 °C

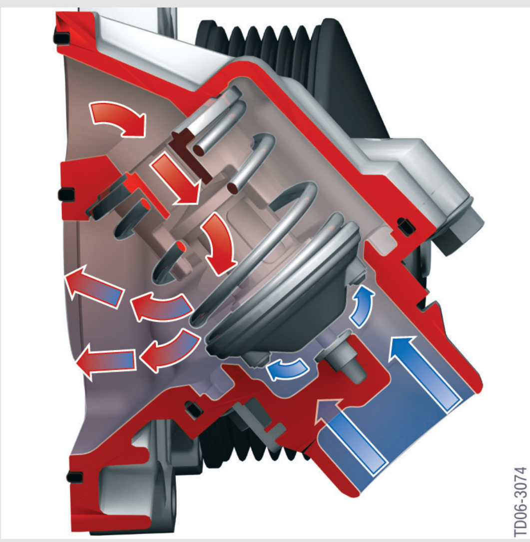


Thermostat open

The coolant temperature is above the full opening temperature of the thermostat.

All the coolant flows through the coolant radiator. This makes use of the maximum cooling output.

Full opening temperature: 100 °C



Thermostat regulation range

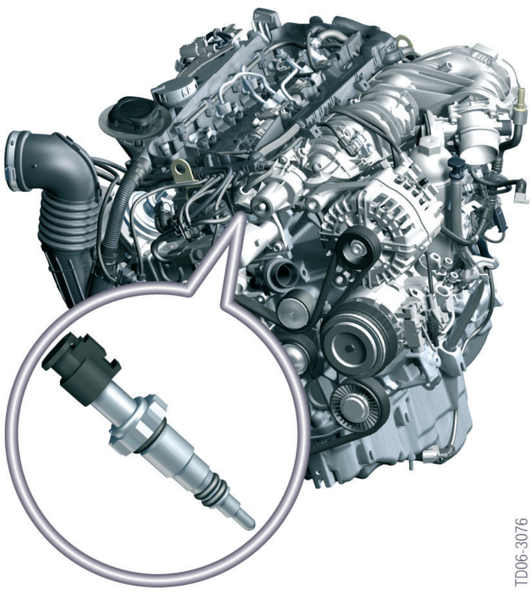
The coolant temperature is between the opening point and the full opening temperature.

The extent to which the coolant is divided depends on the coolant temperature. One part flows through the coolant radiator, the rest remains in the engine.

Thanks to this regulating principle, maximum cooling output can be achieved at high temperatures, while cooling can largely be avoided at very low temperatures.

Additionally, the engine can be brought up to normal operating temperature more rapidly following a cold start.

Coolant-temperature sensor (at engine outlet)



94 - Location of the coolant-temperature sensor in the N47 engine

The coolant-temperature sensor is located in the coolant outlet of the engine, i.e. at the hottest part of the coolant circuit.

It reports the coolant temperature to the Digital Diesel Electronics (DDE), which uses this value as the basis for a variety of measures, e.g. fan control, engine emergency operation, displays (Check Control message), etc.

Electrical function

The coolant temperature sensor is connected to earth by the DDE. The second connection is connected to a voltage divider circuit in the DDE.

The resistor has a negative temperature coefficient (NTC). This means that the resistance decreases as temperature increases.

The resistor is part of a voltage divider circuit that receives a 5 V voltage from the DDE. The electrical voltage at the resistor is dependent on the coolant temperature. There is a table stored in the DDE that specifies the corresponding temperature for each voltage value; the table is therefore a solution to compensate for the non-linear relationship between voltage and temperature.

The resistance changes in relation to temperature from 76 kΩ to 42 Ω, corresponding to a temperature of -40 °C to 150 °C.

Coolant radiator

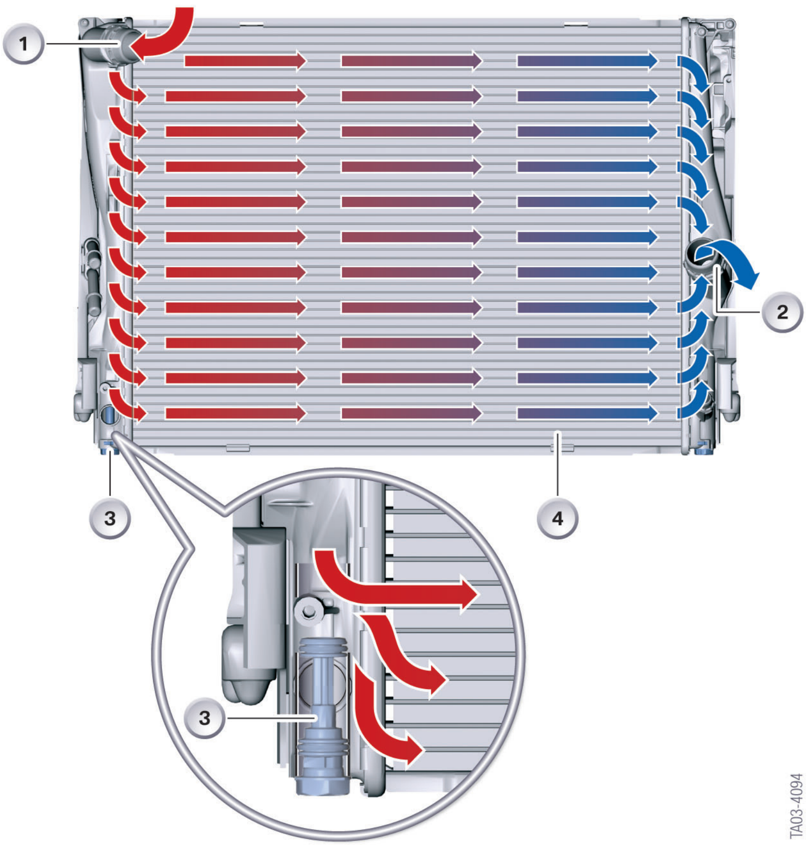
The coolant radiator dissipates the heat of the coolant into the ambient air. To this end, the coolant flows through the coolant radiator at various points. A large surface area makes for efficient heat transport.

The coolant radiator is designed in such a way that it can transfer the heat given off in the engine to the ambient air reliably under all possible operating and environmental conditions. Accordingly, the size of the coolant radiator is matched to the vehicle and the equipment.

The coolant radiator in the N47 engine is made of aluminium as it was in its predecessor.

Control sleeve

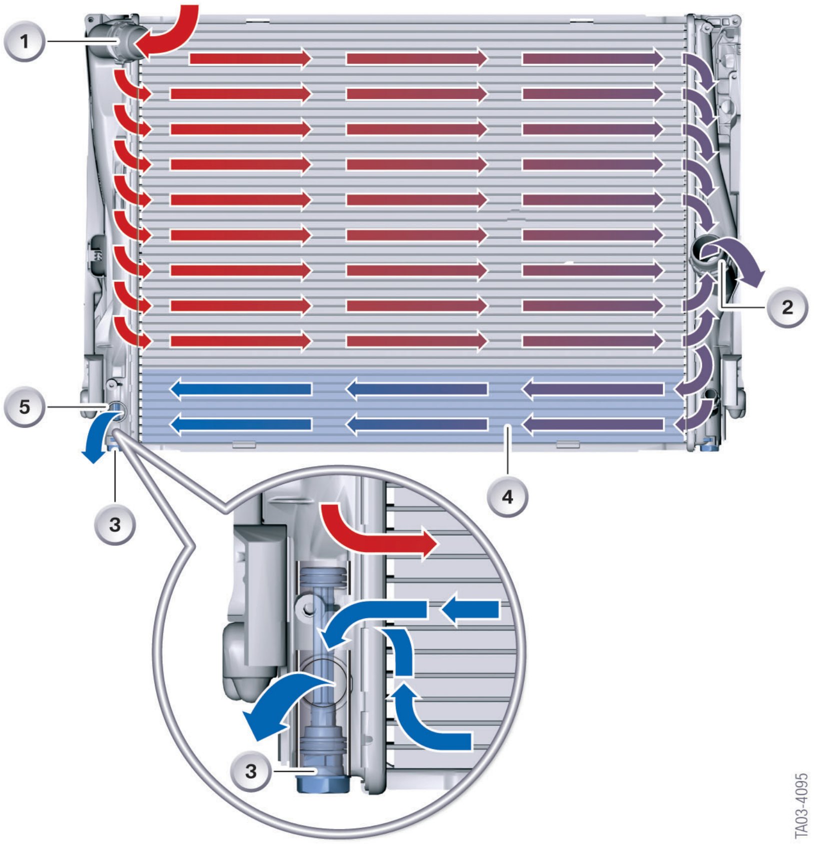
Vehicles with a manual transmission use the entire surface of the radiator for engine cooling. There is a short control sleeve fitted in the radiator for this purpose.



95 - Coolant radiator with short control sleeve for vehicles with manual transmission

Index	Explanation	Index	Explanation
1	Coolant inlet	3	Control sleeve (short)
2	Coolant outlet	4	Coolant radiator

For vehicles with automatic transmission, there is an additional low-temperature section at the bottom end of the coolant radiator. Some of the already cooled coolant flows through the coolant radiator again. This coolant flows into the transmission oil/coolant heat exchanger and is used to cool the transmission.



96 - Coolant radiator with long control sleeve for vehicles with automatic transmission

Index	Explanation	Index	Explanation
1	Coolant inlet	4	Low-temperature section
2	Coolant outlet	5	Coolant outlet to the transmission oil/coolant heat exchanger
3	Control sleeve (long)		

This low-temperature section is produced by a long control sleeve, which diverts some of the coolant flow.

Expansion tank

The expansion tank acts a supply reservoir for the coolant. It ensures that a sufficient volume of coolant is always available in the coolant circuit.

The expansion tank also permits an acceptable amount of gas separation, which, in connection with the pressure in the system, helps to prevent cavitation in the cooling system. Cavitation is the formation of cavities (vapour bubbles) in the coolant as a consequence of a localized drop in pressure below the vapour pressure with a subsequent implosion of the vapour bubbles. This causes damage to the adjacent surfaces. Cavitation would mainly occur on the intake side of the pump.

The volume of air in the expansion tank must be sufficient to promote a rapid increase in pressure during heating and expansion of the coolant, but not so great that an overpressure would be created. An increase in pressure is necessary to increase the boiling point of the coolant.

The expansion tank is divided into several chambers that are interconnected only by relatively small passages. This contributes to the stability of the expansion tank because it is subjected to high pressure during engine operation.

Cap

An overpressure function in the cap protects the coolant circuit from damage if the coolant were to overheat.

The cap on the expansion tank has the property of supporting the pressure increase and making the pressure in the coolant circuit independent of the atmospheric pressure. This prevents the coolant's boiling point from dropping to lower levels in the presence of lower air pressure (e.g. at higher altitudes).

⚠ Never open the cover on the expansion tank while the engine is hot.

The reason for this is not only a risk of scalding. In the upper sections of the coolant circuit (e.g. cylinder head), gas bubbles may form as a consequence of the loss of pressure. Sufficient heat dissipation would no longer be guaranteed at this point, which would result in overheating. ◄

Bleeding

At the highest point in the coolant circuit, a bleed hose branches off to the expansion tank from the coolant hose that leads from the engine to the radiator.

At the connection to the expansion tank, there is a bleed screw for the cooling system bleeding procedure. This makes it possible to remove any air bubbles from the coolant circuit.

During normal operation, this bleed hose carries coolant from the highest point of the circuit into the expansion tank. From there, it is fed vertically upwards through a pipe and through a very small bore, where the coolant reaches the coolant in the expansion tank.

In this way, the coolant is calmed and any gas bubbles are left behind in the downpipe where a certain amount can be absorbed.

Fill-level sensor/indicator

The expansion tank (AGB) for the N47 engine contains, as normal, a visual fill-level indicator and an electrical fill-level sensor. Both function as floats.

The visual fill-level indicator indicates the actual fill level in the expansion tank when the expansion tank cap is open. A minimum and maximum mark indicate the optimum fill level.

The electrical fill-level sensor is a reed contact. It is simply a switch that triggers an indicator lamp in the instrument cluster if the fill level in the expansion tank drops below the minimum level. However, it only switches at a value that is significantly lower than the minimum mark of the visual fill-level indicator.

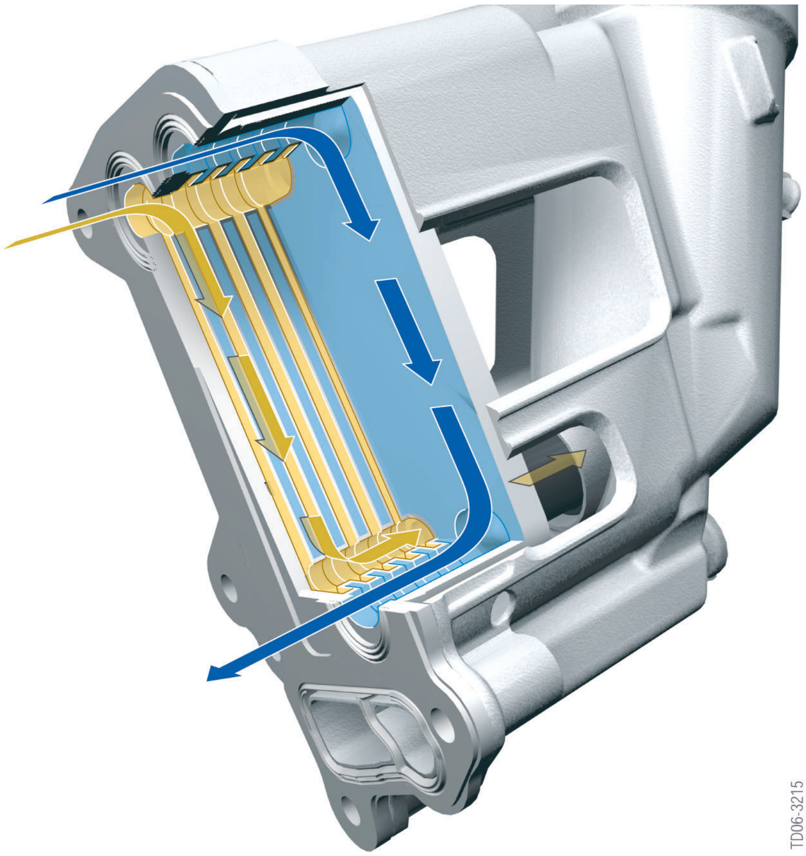
Designation	Volume
Expansion tank total volume	2.2 l
Upper limit position of visual fill-level indicator	1.7 l
Maximum mark of visual fill-level indicator	1.3 l
Minimum mark of visual fill-level indicator	1.0 l
Switch point of electrical fill-level sensor	0.4 l

Oil-to-coolant heat exchanger

In high-performance engines and engines subject to high thermal loads, there is a risk of the lubricating oil becoming too hot during vehicle operation. For this reason, the N47 engine has an oil/coolant heat exchanger. The oil/coolant heat exchanger heats the oil rapidly in the warm-up phase and then provides sufficient cooling.

Oil and coolant flow through the oil-coolant heat exchanger in different levels - plates - and in opposite directions. In this way, heat is transferred from one liquid to the other.

The following graphic shows the channels of the oil and coolant circuit passing through the oil filter and the oil/coolant heat exchanger.



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97 - Engine oil/coolant heat exchanger

Engine oil/coolant heat exchanger

The engine oil/coolant heat exchanger is fitted to the crankcase almost in the centre of the inlet side of the engine. It is located in the same housing as the oil filter.

The coolant flows from the water jacket in the crankcase into the engine oil/coolant heat exchanger. This is an area that rapidly supplies the heat exchanger with heated coolant when the engine is cold; during operation, however, it provides a uniformly well cooled coolant.

From the engine oil/coolant heat exchanger, the coolant flows back into the crankcase. Depending on the position of the thermostat, it then flows directly into the radiator or to the thermostat in the small coolant circuit.

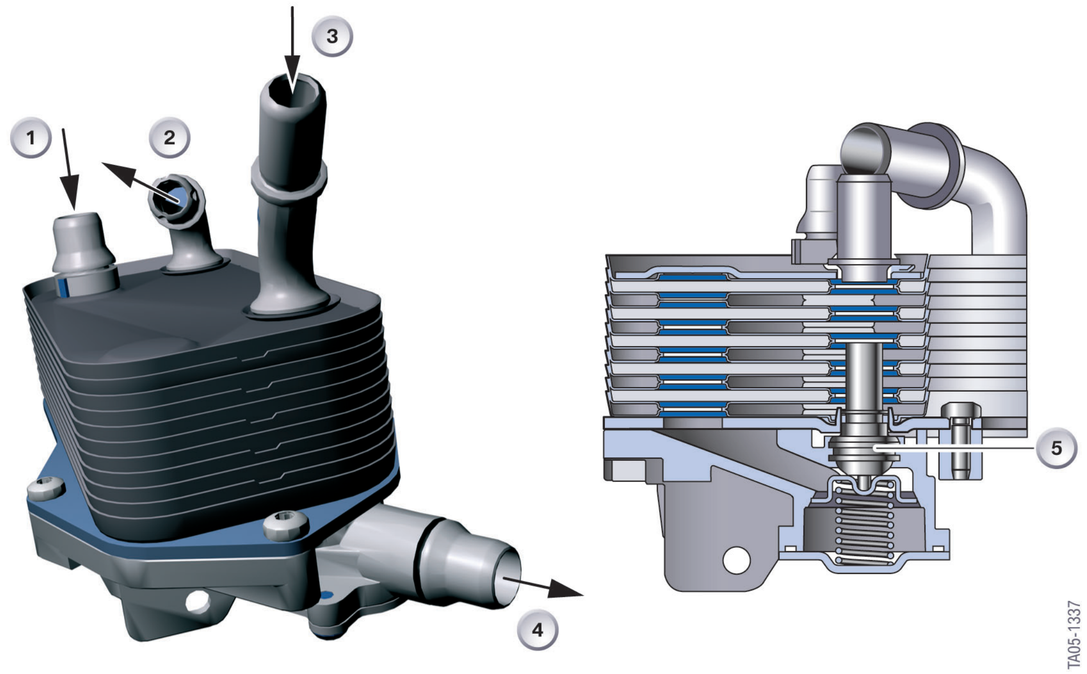
Transmission oil/coolant heat exchanger

If the vehicle is equipped with an automatic transmission, an additional oil/coolant heat exchanger is used for the purpose of cooling the transmission oil.

The transmission oil/coolant heat exchanger (also known as the transmission oil cooler) is located behind the cooling module, at the bottom on the left-hand side.

It is supplied with coolant by a specially designed low-temperature section of the coolant radiator. The coolant is channelled from the transmission oil cooler into the coolant hose leading from the expansion tank to the coolant pump.

The transmission oil cooler is fitted with a thermostat to bring the operating temperature rapidly up to normal operating temperature and to maintain an ideal temperature.



98 - Transmission oil/coolant heat exchanger

Index	Explanation	Index	Explanation
1	Coolant inlet	4	Coolant outlet
2	Transmission fluid outlet	5	Thermostat
3	Transmission fluid inlet	6	

The wax element is located in the oil circuit. The transmission oil temperature therefore regulates the thermostat.

When the transmission oil is cold, the thermostat is closed. No coolant flows through the transmission oil cooler. Since no heat is being carried away by the coolant, the transmission oil heats up rapidly.

Above a transmission oil temperature of approximately 92 °C, the thermostat begins to open and coolant flows through the transmission oil cooler.

By the time a transmission oil temperature of 104 °C has been reached, the thermostat has fully opened. The maximum volume of coolant flows through the transmission oil cooler to achieve maximum cooling of the transmission oil.

Due to hysteresis, the thermostat does not close again fully until the transmission oil temperature has dropped to 88 °C.

Exhaust gas recirculation cooler (EGR cooler)

Current BMW diesel engines are equipped with an exhaust gas recirculation system to reduce NO_x in the exhaust gas. The EGR cooler increases the efficiency of exhaust gas recirculation.

The EGR cooler is located in the forward end face of the cylinder head. It is supplied with coolant from the cooling jacket in the crankcase directly downstream of the coolant pump. The coolant flows through the EGR cooler and, in the process, around the pipes carrying the recirculated exhaust gas. Heat is transferred to the coolant. After passing through the EGR cooler, the coolant flows into the cylinder head.

Different EGR coolers are fitted for the upper and lower power class. With the upper power class, there are also differences between vehicles with a manual or automatic transmission. However, these differences concern the exhaust side of the EGR cooler and are described in the N47 intake air and exhaust system Product Information.

Cooling module

This section describes the components of the cooling module. These are:

- Electric fan
- Coolant radiator
- Air-conditioning condenser
- Charge-air cooler
- Power steering cooler.

The coolant radiator and the transmission oil cooler are no longer addressed here because they have already been described as components of the coolant circuit.

The air-conditioning condenser and power steering cooler are components of the cooling module that are not part of the engine. For this reason, they will not be described at this point.

Electric fan

The electric fan improves the cooling output of the cooling module. It ensures sufficient engine cooling event at low speeds. It is located at the rear end of the cooling module and sucks cooling air through the individual components on demand. For this reason, the electric fan is also known as a suction ventilator.

The housing and the fan itself are made of plastic as usual. This fan is a full plastic fan.

⚠ When you carry the electric fan, do not hold it in the fan ring as this could break. ◄

Sickle-shaped fan blades promote low-noise operation in exactly the same way as the uneven blade distribution on the largest fan. Balance clips on the fan blades ensure the necessary true running. Only a maximum of five of these may be fitted.

Variants

Different electric fans are fitted, depending on the vehicle, power class and equipment.

The following are used:

- 300 W; diameter 419 mm; 7 blades
- 400 W; diameter 488 mm; 6 blades
- 600 W; diameter 500 mm; 7 blades

Charge-air cooler

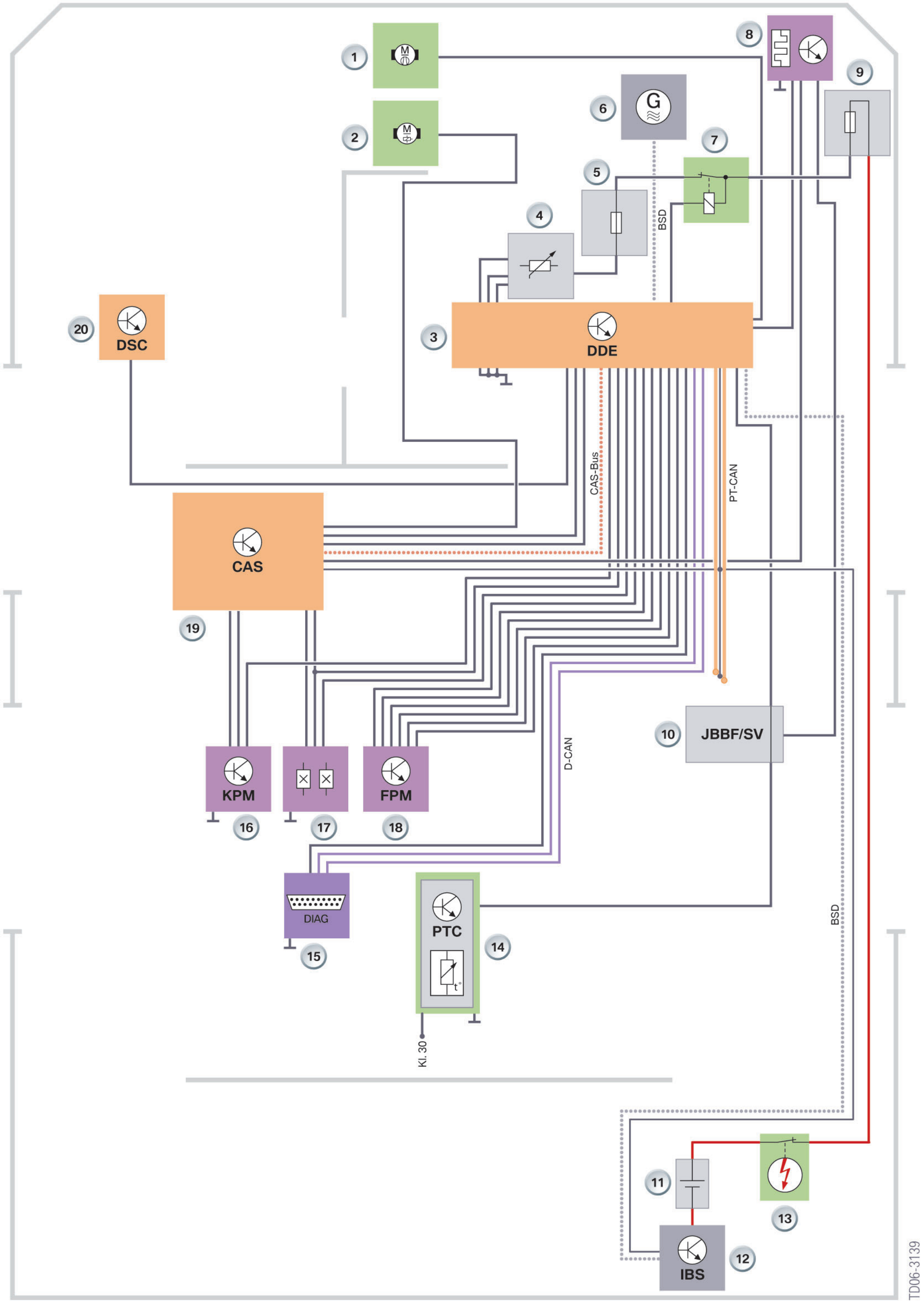
The main purpose of turbocharging in a diesel engine is to boost output. Since more air is delivered to the combustion chamber as a consequence of "forced aspiration", it is also possible to have more fuel injected, which leads to high output yields.

However, the volume of oxygen that can be delivered to the combustion chamber is reduced because the air unfortunately heats up, and thus expands, as it is compressed. The charge-air cooler counteracts this effect because the cooling process increases the density of the compressed air, i.e. so too the oxygen proportions per volume.

The charge-air cooler is located in the cooling module underneath the coolant radiator. Compressed air flows through the charge-air cooler in several plates, around which cooling air is circulated.

Overview of the engine electrical system

On-board network connection



99 - N47 engine on-board network connection

Index	Explanation	Index	Explanation
1	Electric fan	11	Battery
2	Starter	12	Intelligent battery sensor
3	Digital Diesel Electronics (DDE)	13	Safety battery terminal
4	Battery positive potential distributor	14	Auxiliary heater
5	Engine electronics fuse carrier	15	Diagnostics socket
6	Alternator	16	Clutch module (KPM)
7	DDE main relay	17	Brake light switch
8	Fuel filter heater	18	Accelerator pedal module (FPM)
9	Jump-start connection point	19	Car Access System (CAS)
10	Junction box front passenger distribution box	20	Dynamic Stability Control (DSC)

Functions of the engine electrical system

Power supply

General

The power management is the most important component in the energy management system. Power management is realized in the form of software in the engine control unit. The power management controls the alternator voltage while the engine is running.

With the aid of the intelligent battery sensor, the power requirements of the electric loads are reduced or the loads are completely switched off corresponding to requirements even while the engine is running. This electric load shutdown facility reduces the power consumption in critical situations, preventing complete discharge of the battery.

DDE

The DDE receives the terminal 15 ON signal from the CAS control unit via a separate connection. The DDE activates the DDE main relay in response. The DDE main relay then supplies voltage to different DDE inputs. The DDE main relay also ensures the supply of power to other components. For memory functions, the DDE requires a permanent power supply from terminal 30. The earth connection of the DDE is provided by several pins that are interconnected in the control unit. The battery voltage is constantly monitored in the DDE. A corresponding fault code is entered in the memory at a battery voltage of < 2.5 V or > 24 V. Diagnosis is activated 3 minutes after the engine has been started. In this way, effects of the starting procedure or a jump start on the battery voltage will not be interpreted as a fault.

Alternator

The following functions are realized in the DDE for the alternator with bit-serial data interface:

- Alternator switch-on and switch-off based on defined parameters
- Specification of maximum permissible power intake of the alternator
- Calculation of drive torque for the alternator from the power intake
- Control of alternator response during an engine start (start-load response function)
- Control of alternator response to connecting higher electric loads (load-response function)
- Diagnostics of data line between alternator and DDE control unit
- Storage of any fault codes relating to the alternator in the fault code memory of the DDE control unit
- Activation of charge indicator lamp in instrument cluster via bus connection

The main function of the alternator is maintained even in the event of an interruption in communication between the alternator and DDE control unit. The following causes of fault can be defined by corresponding entries in the fault code memory:

- Overheating protection:

  The alternator is overloaded. As a precaution, the alternator voltage is lowered until the alternator has cooled down (charge indicator lamp no longer on)
- Mechanical fault:

  The alternator is mechanically blocked, or the belt drive is defective.
- Electrical fault:

  Defect relating to exciter diode, interruption in exciter coil, overvoltage caused by defective regulator.
- Communication failure:

  Defective line between DDE control unit and alternator.

A break of short-circuit in the coils of the alternator cannot be detected.

Sole responsibility for the pre-excitation of the alternator is assumed by the controller (microcontroller) in conjunction with terminal 15. The battery charge indicator lamp is controlled by an electrical switch fitted in the controller. This switch is supplied by terminal 15. The controller internally measures the voltage difference between terminal 30 and terminal 15. In the event of a fault, the signal for lighting the charge indicator lamp is sent to the instrument cluster on the CAN. The battery charge indicator lamp then lights up.

Start-load response function

The start-load response function prevents the alternator from outputting current until the engine starting process has finished. This results in a lower mechanical resistance for the starter motor. This leads to improved starting characteristics, especially at low temperatures. During the starting operation, the engine speed is approximately 300 - 400 rpm (at
-20 °C approximately 150 rpm). The alternator has a speed of 1,200 - 1,400 rpm at this time and would begin the charging process.

The start-load response function prevents the alternator from generating current until an alternator speed of approximately 2,250 rpm is reached. Above this speed, the alternator current increases at a rate of approximately 10 amps per second up to the maximum current that the alternator is able to deliver.

⚠ Starting characteristics could be significantly affected if the start-load response function were to malfunction. ◄

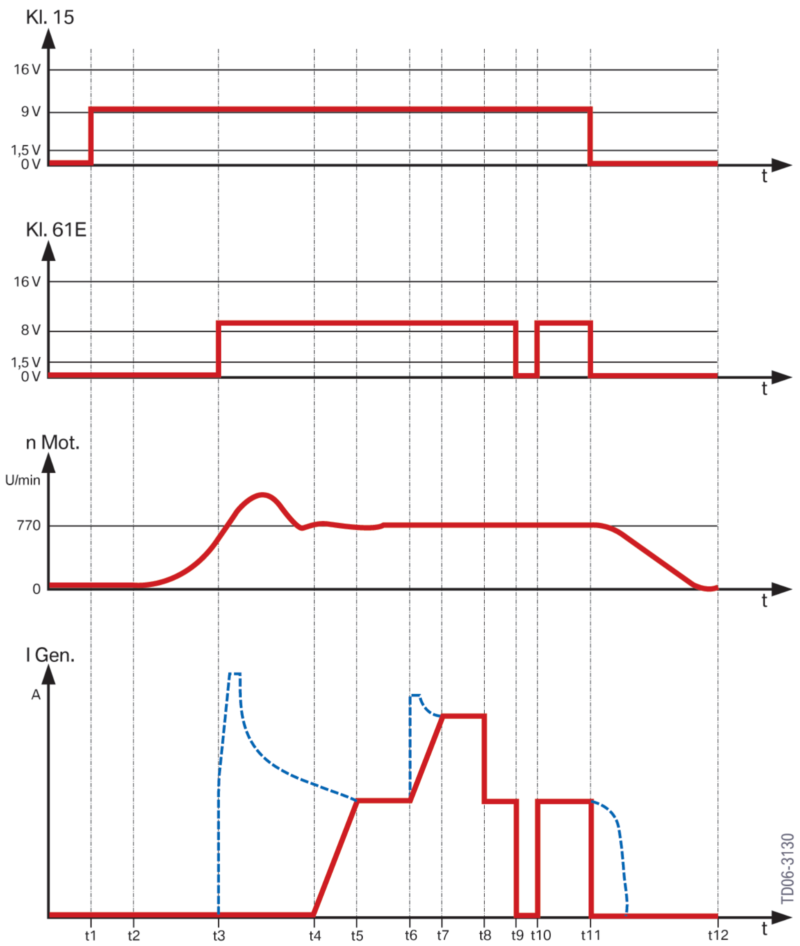
The start-load response function can also be considered as a switch-on delay and is illustrated in the following logic diagram t1 to t5.

Load response function

The load response function prevents a speed collapse during the activation of high-consumption consumers (e.g. heated rear window).

The cause of the speed collapse is the high power requirement arising from the switching load that is balanced as quickly as possible. To provide balance, the excitation coil of the alternator is energized for longer, which amplifies the magnetic field and thus makes more current available. Due to the amplified magnetic field, the input torque of the alternator increases in the process.

The load response function delays the amplification of the magnetic field. The somewhat longer current deficit due to the degraded generation of the alternator is temporarily covered by the battery. The on-board supply voltage then inevitably drops below the control voltage of the alternator. The speed collapse is hardly noticeable to the driver.



100 - Alternator regulation logic diagram (the broken blue line represents the curve without a load response function)

Index	Explanation
t1	Ignition ON, alternator pre-excitation
t2	Engine start
t3	Switch-on speed reached at the alternator
t4	End of delay period Start-load response function, start of controlled current increase
t5	End of controlled current increase, vehicle electrical system current requirement
t6	Consumers switch on, e.g. heated rear window with overshoot
t7	End of current increase
t8	Consumers switch off
t9	Fault in charging system, e.g. excitation interruption
t10	Charging system OK
t11	Engine switch off
t12	Engine off

Load-sensitive voltage regulation

The alternator is connected to the DDE by the BSD. This is a bidirectional line on which the alternator and DDE communicate. The following signals are sent for the purpose of load-sensitive voltage regulation.

- Alternator load feedback
- Control of alternator.

Alternator load feedback:

- The alternator forwards its current load to the DDE control unit by means of a square-wave signal. The load can be between 5 % and 95 %.

  This function has become all the more important with the use of the electrical instant heater (auxiliary heater).

  Since the auxiliary heater may draw up to 120 A, it would be possible for the battery to be discharged. To prevent this, the engine management must detect the alternator output and activate the auxiliary heater on the condition that the alternator's remaining capacity be sufficient.

  During constant operation, the voltage at the B+ connection on the alternator is approximately 14.5 V and there is a corresponding duty factor at the S_DF signal, depending on the alternator load.

  If the current requirement in the vehicle electrical system changes (consumers switched on), the voltage will also change within a short space of time. Alternator excitation is regulated to bring the voltage back up to approximately 14.5 V.

  The pulse duty factor of the excitation signal changes. With this change, there is an adjustment at the S_DF signal.

  The duty factor of the S_DF signal does not refer to the on-board supply voltage but to the load on the alternator. There may be various duty factors at the same voltage, depending on the load on the alternator.

  When viewed as a snapshot, the duty factor fluctuates around an average value. This is necessary to regulate the on-board supply voltage and the output.

  The frequency of the S_DF signal is variable. It is anywhere in the 20 to 300 Hz range.

Control of alternator:

- The DDE controls the alternator to reduce torque in specific circumstances. This control makes it possible to reduce the normal charge voltage of approximately 14.5 V at 25 °C to around 12.5 V. As a result, there is a reduction in the torque required to drive the alternator.

  The following conditions lead to a reduction in the charge voltage for a period of 5 s:

  – Pulling away AND coolant temperature < 100 °C
  – Powerful acceleration AND coolant temperature < 100 °C

Relationship between control value and charge voltage at 25 °C:

Control value	Charge voltage
High	approximately 14.9 V
Low	approximately 12.8 V

In extreme cases, the charge voltage may be between "High" 15.3 V and "Low" 12.5 V at -30 °C. At a temperature of 140 °C, the charge voltage may be between "High" 14.8 V and "Low" 11.6 V.

Air supply

Boost-pressure control

The N47 engine is charged by an exhaust turbocharger.

On the exhaust side, there are adjustable vanes on the outside that are bearing-mounted and able to turn about the turbine wheel. These vanes influence the drive energy that the exhaust gas exerts on the turbine so that the desired boost pressure can be set.

An adjustment lever on the turbine housing operates the adjustable vanes. The adjustment lever is operated by an electrical boost-pressure regulator (electric motor with worm gear and control electronics), which is fitted directly on the turbocharger. It is not possible to replace the boost-pressure regulator separately.

The DDE sends a pulse-width-modulated signal to the electric boost-pressure regulator. The operating range of the signal is between 10 % and 95 %, where 10 % means that the vanes are open and 95 % means that they are closed.

The electronics in the boost-pressure regulator converts the PWM signal into an adjustment angle and controls the servomotor.

The DDE only detects feedback of the adjusted position indirectly from the boost-pressure sensor. The boost-pressure regulator itself is capable of performing self-diagnostics and reports faults to the DDE.

Determining air mass

In the diesel engine, the DDE requires information about the air mass taken in so that it can control various functions.

The intake air mass is measured by the hot-film air mass meter (HFM).

The measured air mass is the basis for calculating the exhaust gas recirculation rate.

The air mass is also used in the calculation of the limit volume. The limit volume is the maximum permissible volume of fuel that may be injected under full load before smoke development would occur.

Swirl flap control

Swirl flaps provide a better air swirl effect. The result is to improve exhaust emission values.

The controllable swirl flaps are located in the tangential ducts of the intake manifold and are closed or opened depending on the operating condition. The electrically controllable swirl flaps are opened by the swirl flap regulator with increasing engine speed.

The swirl flaps are **closed** under the following conditions:

- at low engine speeds **and**
- low injection rates (map-controlled).

The swirl flaps generally remain **open** if:

- coolant temperature < 15 °C **or**
- intake air temperature < 15 °C.

The swirl flap regulator is a stepper motor that is controlled by the DDE by means of a PWM signal. The stepper motor operates the adjustment rod and the swirl flaps close.

A sensor reports the position of the swirl flaps to the DDE.

Fuel system

Fuel injection

The N47 engine is equipped with high-pressure fuel injection with common rail pressure accumulator. The common rail has the following advantages:

- Optimum fuel preparation for each individual cylinder
- Adaptation of injection time to engine operating conditions (engine speed, load, temperature)
- Cylinder-selective injection correction in response to load change (the injection time can be corrected by post-injection, extending or shortening the time during the induction stroke)
- Cylinder-selective switch-off possible
- Diagnostics of each individual injector is possible.

Common rail injection offers these advantages due to the fact that all cylinders are supplied with fuel independently of each other.

High-pressure control

The volume control valve establishes the fuel feed from the low pressure side to the high pressure side of the high-pressure pump, thus achieving the required rail pressure. The volume control valve is forced open hydraulically as from a defined pressure on the high pressure side of the high-pressure pump. The less fuel that the volume control valve allows into the high-pressure side, the less the radial cylinders of the high-pressure pump will be filled. This results in a reduction in rail pressure. The signal from the rail pressure sensor is an important input signal for the DDE for the control of the volume control valve.

During a cold start, the pressure in the rail is not controlled by the volume control valve but by the rail-pressure regulating valve in the rail. The high-pressure pump therefore always generates maximum pressure, which causes the fuel to heat up.

The rail-pressure regulating valve also relieves excess pressure in the rail if the accelerator pedal is suddenly released.

In the event of the rail pressure sensor failing, the DDE controls the volume control valve in emergency mode.

Injector volume calibration (IMA)

At the end of the injector manufacturing process, measuring data is recorded for each individual injector. This is how the tolerance ranges of their hydraulic properties are determined.

A correction value is then defined for the pre-injection and main injection. This correction value is printed on the injector as a seven-digit numerical code. In the event of an injector replacement, this correction value must be programmed into the DDE using the diagnostic system.

Injector voltage calibration (ISA) (upper power class only)

PIEZO injectors not only bear the hydraulic tolerances but also information concerning the stroke characteristics of the injector. This is a separate classification for the injector voltage calibration.

This information is necessary due to the individual voltage requirement of each injector. The injector is assigned to a voltage requirement class. This replaces the seventh digit of the IMA numerical combination on the injector.

A PIEZO injector therefore has only six digits for the IMA (due to a more precise manufacture of the PIEZO injectors) and a seventh digit for the ISA.

Volume-balancing control

Fluctuations in engine speed are detected by the DDE. The control duration of the injectors is corrected based on these engine speed fluctuations. The volume-balancing control equalizes the injection volume of all cylinders.

Zero-volume calibration (NMA)

The zero-volume calibration is a continual learning process. This learning process is required to enable precise pre-injection for each individual injector. Accurate metering of the very low pre-injection volume is necessary for the fulfilment of exhaust emission regulations. The NMA must be carried out on a continual basis due to the volume drift of the injectors.

At each cylinder, a small amount of fuel is injected during overrun mode. This volume continues to increase until a slight increase in engine speed is detected by the DDE. The DDE is thus able to detect when the respective cylinder begins to work. The volume of fuel injected during the zero-volume calibration is used by the DDE as a value for the characteristic map of pre-injection.

Average volume value adaptation (MMA)

The average volume value adaptation (MMA) is a learning process in which the air/fuel ratio (lambda value) is corrected by the adjustment of the air mass or exhaust gas recirculation rate. Unlike the other processes, this process affects all injectors equally rather than the individual injector.

An injection volume averaged across all cylinders is calculated from the lambda value measured by the oxygen sensor and the air mass measured by the HFM. This value is compared with the injection volume specified by the DDE.

If a discrepancy is detected, the air mass is adjusted to match the actual injection volume by an adjustment of the EGR valve. The correct lambda value is set in turn.

The MMA is not an "instantaneous" regulation but an adaptive learning process. In other words, the injection volume error is taught into an adaptive characteristic map that is permanently stored in the EEPROM of the control unit.

A replacement of the following components requires a reset (clearance) of this MMA characteristic map:

- HFM
- Injector(s)
- Rail-pressure sensor.

The characteristic map is reset by a function in the BMW diagnostic system.

Fuel heater

The fuel heater is built into the fuel filter housing.

A new feature is that the fuel heater is controlled by the DDE. It is switched on and off as a function of the temperature and the pressure in the fuel feed and of the power consumption of the electric fuel pump.

The temperature signal comes from the combined pressure/temperature sensor upstream of the high-pressure pump. The fuel heater is switched on if the fuel temperature is below a defined value and the target pressure is not reached despite the elevated power consumption of the electric fuel pump (EKP).

If the target pressure is not reached above a defined fuel temperature, the DDE control unit stores a fault code memory entry indicating a blocked filter.

The filter heater diagnostics cable is no longer fitted. Until now, it triggered the fault code memory entry concerning a blocked filter.

Cooling

Electric fan

The electric fan is informed of the necessary cooling output by a PWM signal with a pulse duty factor of between 5 and 90 % sent by the DDE. The electric fan is fitted with an output stage that controls the fan in line with this output requirement and adjusts to different speeds. The pressure sensor for the air conditioning system also has an influence on the drive of the electric fan.

Exhaust system

Lambda control

An optimum fuel-air mixture is necessary for complete and problem-free combustion.

Modern catalytic converters therefore achieve a conversion rate of 98 % up to virtually 100 %, i.e. the percentage of converted pollutants. The optimum composition of the fuel-air mixture is controlled by the Digital Diesel Electronics (DDE). The required information relating to the composition of the exhaust gas is supplied by the oxygen sensors.

The broadband oxygen sensor upstream of the catalytic converter constantly measures the residual oxygen in the exhaust gas. The fluctuating values of the residual oxygen are sent to the DDE in the form of a voltage signal.

The DDE corrects the mixture composition through fuel injection.

Both oxidation and reduction processes occur in the catalytic converter. Oxygen O_2 is required for oxidation while carbon monoxide CO is required for reduction. The pollutants CO, HC, NO_x and the reduction catalysts O_2 and CO must be present in a certain ratio in order to facilitate the highest possible conversion rate.

CO Adjustment

The emission of carbon monoxide at idle speed is defined by the BMW diagnosis system on vehicles with no lambda control, thus also specifying the adjustment values.

Lambda adaptation

Lambda adaptation (mixture adaptation) serves the purpose of adjusting component tolerances and ageing phenomena that have an influence on the fuel-air mixture. Factors such as secondary air and fuel pressure also affect lambda adaptation (partial adjustment). For these reasons, no exact control limits can be specified for a specific fault. The following distinctions are made in terms of lambda adaptation:

- Additive mixture adaptation
- Multiplicative mixture adaptation

Additive mixture adaptation is effective at idle speed or the near idle speed range. Its influence decreases as the engine speed increases. Multiplicative mixture adaptation is effective over the entire characteristic map. One of the main factors is the fuel pressure.

The adaptation values and the equipment variants can be reset to the as-delivered state with the "Adaptation value reset" service function. It will then be necessary to relearn the adaptation values. A longer period of vehicle operation between idle speed and partial load is required in order to learn the values for mixture adaptation.

Exhaust gas recirculation (EGR)

A calculated volume of exhaust gas based on the prevailing operating condition is fed back to the intake manifold by the EGR valve to reduce pollutant emissions.

The EGR valve is switched by a vacuum canister.

The vacuum canister is connected to the negative pressure supply by the pressure converter. The pressure converter subjects the vacuum canister to a variable negative pressure, the value of which depends on the control signal sent by the DDE control unit. The DDE control unit controls the pressure converter with a square-wave signal with pulse duty factors (= variable pulse widths) of between 10 % and 90 %.

The volume of the recirculated exhaust gas influences the mass of the intake fresh air: The more exhaust gas is recirculated, the less fresh air is taken in. It is known how much fresh air mass the engine takes in at any given operating point with EGR switched off. The reduction in the intake fresh air mass caused by the exhaust gas recirculation is therefore a measure of the volume of the recirculated exhaust gas. The regulation adjusts the pulse duty factor at the pressure converter during operation in such a way that the target fresh air mass defined for the operating point is taken in.

The DDE control unit calculates a target fresh air mass for each operating point from the following influencing variables:

- Engine speed
- Injected quantity
- Coolant temperature
- Atmospheric pressure
- Intake air temperature
- Reduction in the exhaust gas recirculation caused by idling for longer than 5 minutes.

Glow system

The glow system ensures reliable cold start characteristics and smooth engine operation when the engine is cold.

The glow system comprises the following components:

- Preheater control unit
- New ceramic, rapid-start glow plugs
- LIN-bus and electrical lines.

The rapid-start glow plugs are designed for operation at a voltage of 5.3 to 7.8 V. During the glow-plug start-assist stage, there may even be a voltage equivalent to the on-board supply voltage for a short time.

The preheater control unit communicates with the DDE control unit via the LIN-bus.

The DDE control unit sends the request for heating output to the preheater control unit via the LIN-bus. The preheater control unit implements the request and controls the glow plugs with a pulse-width-modulated signal. Additionally, the preheater control unit feeds back diagnostics and status information to the DDE.

The necessary heat output is determined by the DDE control unit as a function of the following operational values:

- Coolant temperature
- On-board supply voltage.

Two further operational values influence the activation and deactivation of the glow function:

- Engine speed
- Injection volume.

Each one of the four glow circuits is individually compatible with diagnostics.

Preglow

Preglow takes place for 0.5 seconds at a coolant temperature of below 25 °C. As the temperature falls, the preglow time increases to a maximum of 2.7 seconds at coolant temperatures of below -25 °C.

The glow indication in the instrument cluster is only controlled at coolant temperatures of below 0 °C.

Post-glow

To improve idling and emissions characteristics, a temperature-sensitive post-glow takes place after an engine start with the coolant temperature below 30 °C.

Start-standby glow function

A start-standby glow function is activated for approximately 10 seconds if the engine has not started by the time the preglow time has elapsed and the ignition remains switched on.

Electronic immobilizer (EWS)

The electronic vehicle immobilizer serves the purpose of preventing theft and enabling vehicle start-up.

It is equipped with a newly developed electronic vehicle immobilizer (4th generation). This new development makes use of a new and modern encryption process.

Each vehicle is assigned a 128 bit long secret code. This secret code is stored in a BMW database so that it is known only to BMW. The secret code is programmed and locked in the CAS control unit and in the DDE control unit.

Once stored in the control units, the secrete code can no longer be deleted or changed. This means each control unit is assigned to a specific vehicle. The CAS control unit and the EWS control unit mutually identify themselves with the secret code and the identical algorithm.

The CAS control unit activates the starter by means of a relay located in the control unit only if the identification data are correct. At the same time, the CAS control unit sends a coded authorization signal (variable code) to the DDE to start the engine. The DDE control unit authorizes the start request only if a correct authorization signal is received from the CAS control unit. These procedures may cause a slight delay in start-up (up to half a second).

⚠ A certain procedure must be followed in the event of a defective CAS or DDE. The required control unit must be ordered precisely for the specific vehicle. The vehicle data (vehicle identification number) are required for this purpose. EWS matching is not necessary after replacing the control units. ◄

Sensors and actuators

DDE7 control unit

The DDE is the computational and switching centre of the engine management. Sensors installed on the engine and in the vehicle provide the input signals for the DDE. Actuators execute the commands of the DDE. The DDE calculates the necessary control signals for the actuators from the input signals together with the computational models and characteristic maps stored in the DDE.

The DDE is not watertight and is therefore protected in the E-box.

DDE operation is guaranteed with a system voltage of between 6 V and 16 V.

An ambient pressure sensor and a temperature sensor are integrated in the DDE.

The ambient pressure sensor makes it possible for the density of the ambient air to be precisely determined - a variable that is used in numerous diagnostic functions. Furthermore, it is needed if the cylinder charge is being calculated from the substitute variables in the event of a hot-film air mass meter fault, example.

The temperature sensor measures the temperature inside the control unit. If the temperature there increases to excessively high levels, the multiple injection, for example, is reduced in order to cool down the output stages a little and to maintain the temperature inside the control unit within a non-critical range.

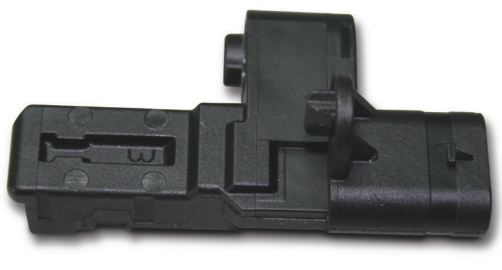
Crankshaft sensor

The crankshaft sensor informs the DDE of the position of the crankshaft. The signal from the engine speed sensor is one of the most important variables in the engine management.

In addition to this, the N47 engine is equipped with a new sensor that is able to detect reversed rotation. This is necessary for the automatic engine start-stop.

The operation of the conventional crankshaft sensor will now be described once more.

Conventional crankshaft sensor



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101 - Crankshaft sensor

A ferromagnetic increment wheel with space for 60 teeth is mounted on the crankshaft. Two teeth are omitted.

A crankshaft sensor scans this tooth sequence of 58 teeth.

The crankshaft sensor is designed in accordance with the Hall principle.

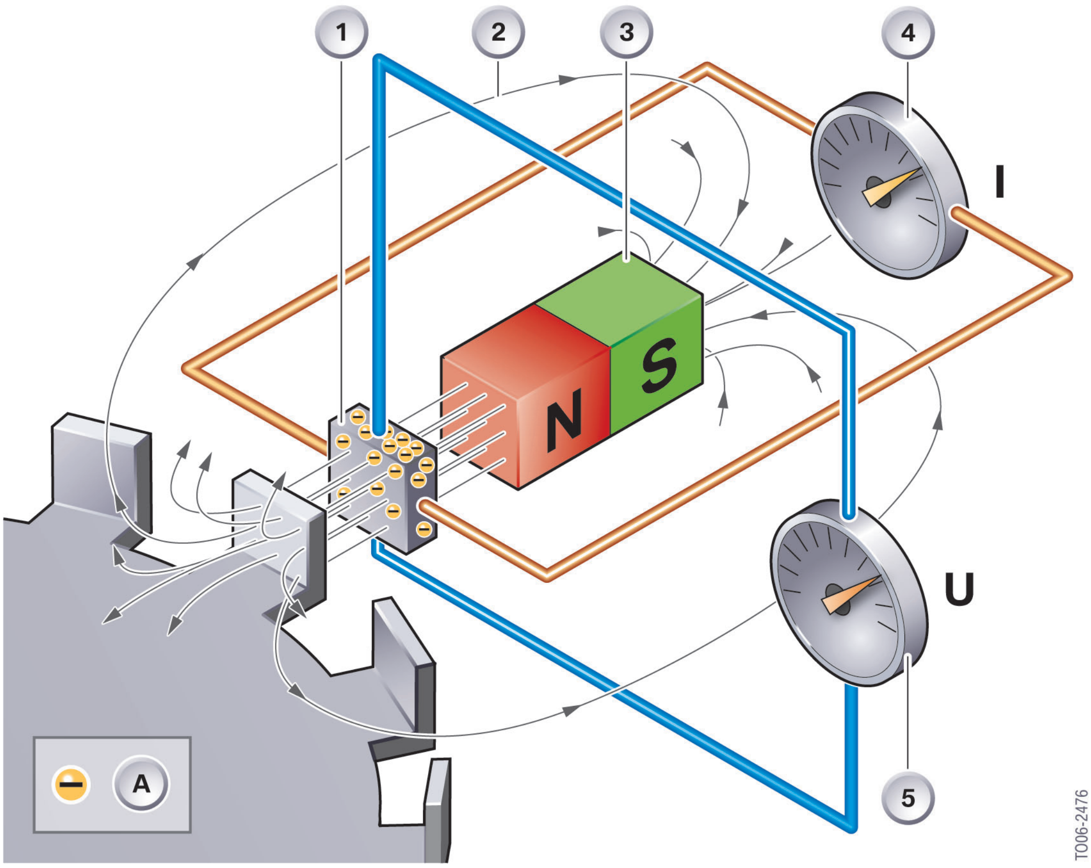
The sensor is supplied with a voltage of 5 V and connected to earth by the DDE. The sensor sends a digital signal to the DDE on the signal line.

An effective signal that can be evaluated is output as from a speed of approx. 20 rpm.

The control unit detects the tooth gap in that the measured spacing of the gaps is more than double as great as the previous or subsequent gaps. The tooth gap itself is assigned to a defined crankshaft position of cylinder number 1 (TDC). The DDE synchronizes the crankshaft position with respect to this timing point. With each subsequent low signal it increments the crankshaft position by 6°.

Exact assignment is necessary for the DDE to be able to adapt the fuel injection to specific requirements. The time interval measured between two level changes (e.g. High to Low) is therefore divided into smaller units of time.

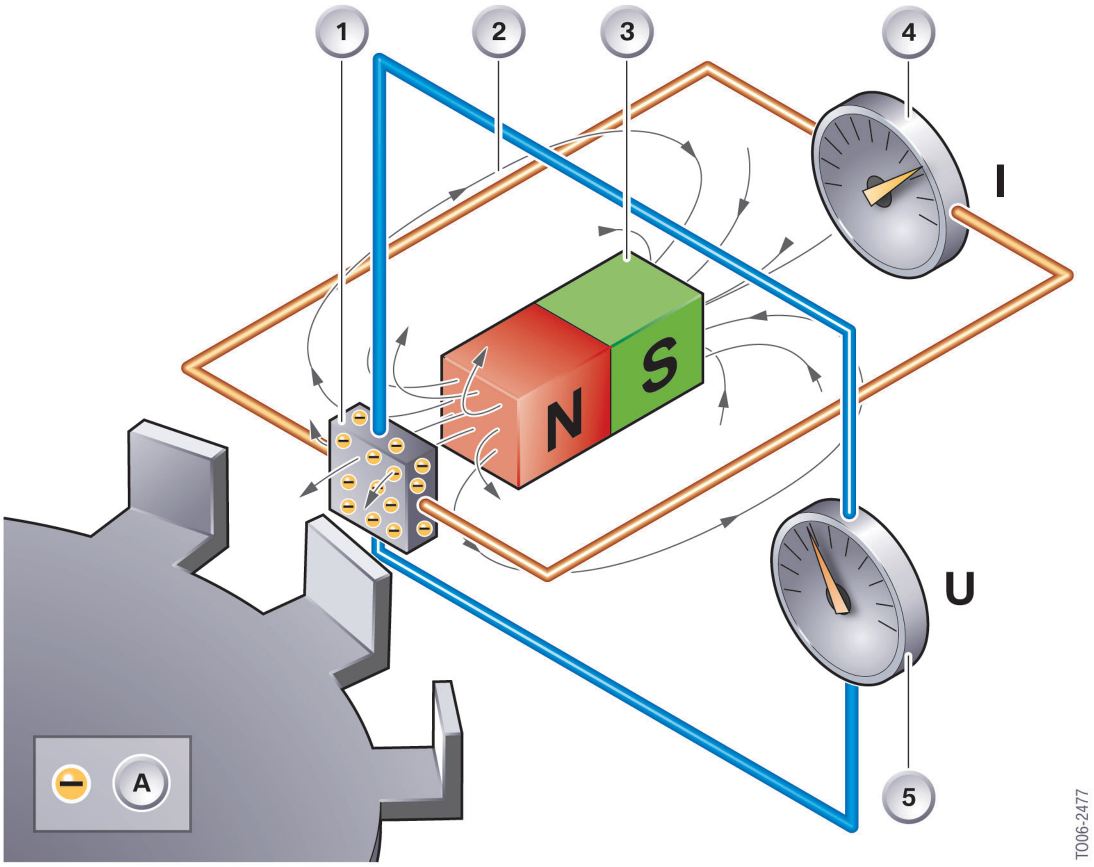
The following graphic illustrates sensor operation.



102 - Hall-effect with tooth

Index	Explanation	Index	Explanation
A	Electrons	3	Permanent magnet
1	Hall module	4	Power supply
2	Lines of magnetic force	5	Hall voltage

When electrons (A) move in a conductor (1), through which the lines of force of a magnetic field (2) pass, the electrons will be deflected vertically with respect to the direction of current flow and vertically with respect to the direction of magnetic field. An electron surplus is created on the one side and an electron deficiency on the opposite side. Consequently, the Hall voltage (5) occurs between the electron surplus and electron deficiency. This so-called Hall effect is particularly prevalent in the case of semiconductors.



103 - Hall-effect with tooth gap

Index	Explanation	Index	Explanation
A	Electrons	3	Permanent magnet
1	Hall module	4	Power supply
2	Lines of magnetic force	5	Hall voltage

As the increment wheel with its gaps and teeth moves pass the sensor (Hall module), the flux density of the lines of magnetic field (2) of the permanent magnet (3) change accordingly. This change is detected in the Hall module and a high or low signal is output on the signal line to the DDE depending on the strength of the magnetic field (see diagrams - Hall effect with tooth gap and Hall effect with tooth).

Due to the high degree of accuracy, a square-wave signal that replicates the shape of the increment wheel is sent to the DDE. This signal can be used in the control unit without the need for special processing.

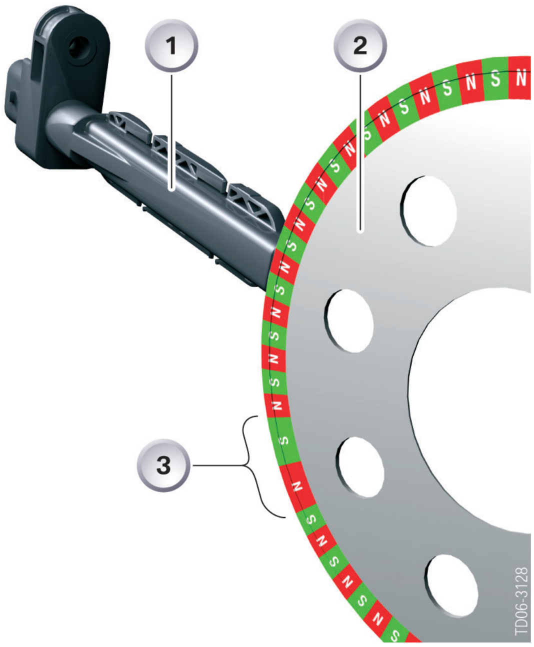
The change in the signal takes place precisely at the mid-point of the tooth/gap on the increment wheel. This is attributed to the internal circuitry and the design of the crankshaft sensor.

Crankshaft sensor in the N47 engine

The N47 engine is fitted with a new speed sensor that is also able to detect the direction of rotation.

The sensor is what is known as an active speed sensor, also functioning in accordance with the Hall principle. The sensor has its own evaluation logic.

With the speed sensor of the N47, pairs of magnetic poles assume the function of the teeth of an incremental gear. It can therefore be referred to as a multipolar sensor wheel, as already used in the M47TU2. On the multipolar sensor wheel, the tooth gap of the incremental gear is represented by a pair of poles twice as long.



104 - Active crankshaft sensor with multipolar sensor wheel in the N47 engine

Index	Explanation
1	Active crankshaft sensor
2	Multipolar sensor wheel
3	Pole pair as "tooth gap"

There are three Hall elements in the sensor, arranged next to each other in a housing. The signals of the first and third Hall element produce a differential signal for determining the signal frequency and the air gap to the sensor wheel. A clockwise or anti-clockwise direction of rotation can be detected thanks to the time offset between the signal of the centre element and the differential signal.

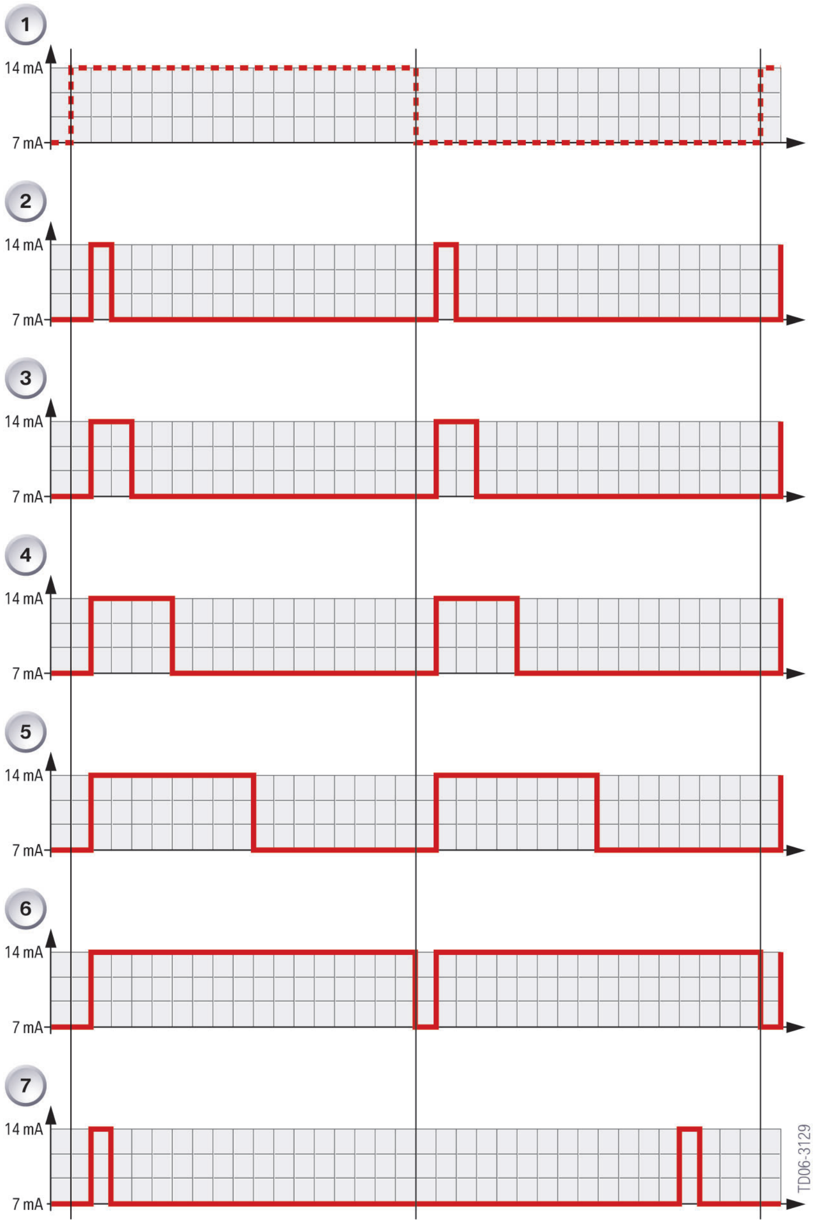
The additional signals of the air gap and the direction of rotation are output using the pulse width of the digital signal.

The signals processed in the sensor are sent to the control unit on the combined earth and data line. On the data line, it is not the voltage level that is decisive but the current flow. There is a self-repeating data telegram that uses two different currents.

The 14 mA level contains the information about the speed, direction of rotation and the air gap.

The 7 mA level acts as the evaluation current for the fault code memory.

Unlike the sensors used to date, a pulse indicating sensor availability is sent approximately every 740 ms when the vehicle is stationary.



105 - N47 engine crankshaft sensor with multipolar sensor wheel

Index	Explanation	Index	Explanation
1	Maximum signal length of the sensor	5	Speed, anti-clockwise direction of rotation + air gap width
2	Speed signal	6	Speed, clockwise direction of rotation + air gap width
3	Speed, direction of rotation: anti-clockwise	7	Basic signal when the vehicle is stationary (740 ms)
4	Speed, direction of rotation: clockwise		

Camshaft sensor

A camshaft sensor that operates in accordance with the Hall principle is used for the purpose of detecting the camshaft position.

In the N47, the camshaft sensor is located on the inlet camshaft. For this purpose, a camshaft sensor wheel is mounted directly on the drive gear on the camshaft.

With the aid of the camshaft sensor, the DDE can determine whether cylinder number 1 is in the compression stroke or intake stroke.

This deduction cannot be made from the crankshaft position. Correct assignment is necessary for the purpose of controlling the fuel injection accordingly.

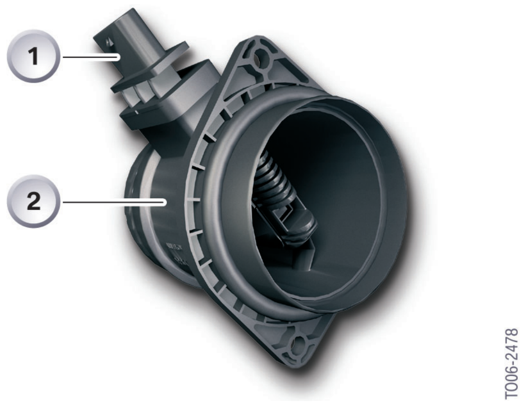
The sensor is supplied with a voltage of 5 V and connected to earth by the DDE. The sensor sends a digital signal to the DDE on the signal line.

Function

The camshaft sensor operates in accordance with the principle of the conventional crankshaft sensor (not of the active sensor). The camshaft sensor wheel however, is fundamentally different.

A special aperture pattern facilitates emergency operation in the event of the crankshaft sensor failing. The resolution of the camshaft sensor signal, however, is too inaccurate to replace the crankshaft sensor during normal operation.

Hot-film air mass meter (HFM)



106 - Hot-film air mass meter

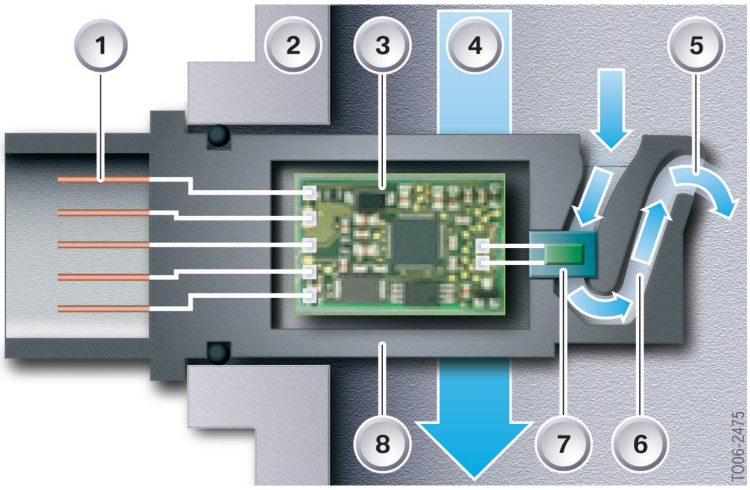
Index	Explanation
1	HFM
2	Measurement tube housing

The HFM 6 hot-film air mass meter is located downstream of the intake silencer and is fitted directly to its cover. The HFM measures the air mass taken in by the engine. This is used to record the actual air mass, which in turn is used to calculate the exhaust gas recirculation rate and the fuel limit volume.

There is also an intake air temperature sensor in the HFM. The temperature evaluated by the HFM and sent to the DDE as a PWM signal.

A pulse width of 22 % equates to a temperature of -20 °C and a pulse width of 63 % equates to a temperature of 80 °C.

Measurement method



107 - Sectional view of hot-film air mass meter

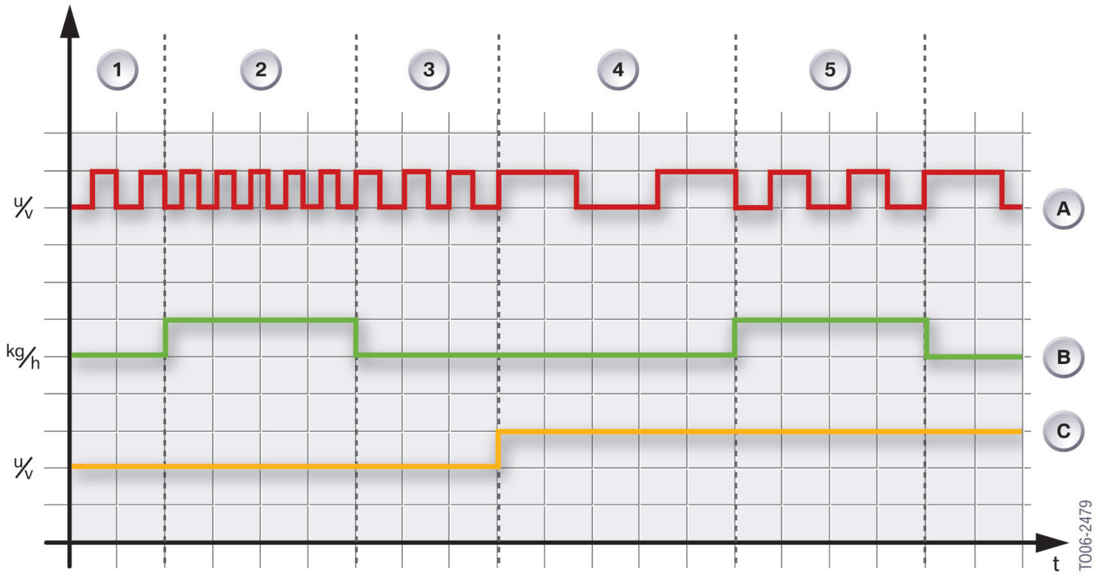
Index	Explanation	Index	Explanation
1	Electric connections	5	Partial flow for measurement, exhaust
2	Measurement tube housing	6	Labyrinth
3	Electronic evaluator	7	Sensor measuring cell
4	Mass air flow	8	Sensor housing

A labyrinth (6) makes sure that only the actual air mass is recorded. Thanks to the labyrinth, backflow and pulsation are not registered. In this way, the HFM determines the actual air mass irrespective of the air pressure and backflow.

An electrically heated sensor measuring cell (7) protrudes into the air flow (4). The sensor measuring cell is always kept at a constant temperature. The air flow absorbs air from the measuring cell. The greater the mass air flow, the more energy is required to keep the temperature of the measuring cell constant.

The evaluator electronics (3) digitizes the sensor signals. This digitized sensor signal is then transferred frequency-modulated to the DDE. In order to be able to compensate for temperature influences, the air mass signal is referred to the variable temperature signal.

The HFM is supplied with on-board voltage and connected to earth by the DDE.



108 - HFG signal progression

Index	Explanation
A	Air mass signal
B	Air mass
C	Temperature signal
1	Air mass signal (A) as a function of air mass (B) and temperature signal (C)
2	The period duration of the air mass signal (A) decreases as the air mass (B) increases
3	The period duration of the air mass signal (A) is extended as the air mass (B) reduces
4	When the temperature increases (C) and air mass (B) remains constant, the period duration of the air mass signal (A) is extended in order to compensate for temperature influences
5	When air mass (B) increases, the period duration of the air mass signal decreases while taking the temperature signal (C) into account

Boost-pressure sensor

The boost-pressure sensor is located on the intake manifold and measures the pressure (absolute) inside it. It is supplied with a 5 V voltage and connected to earth by the DDE.

The boost pressure information is sent to the DDE on a signal line.

The useful signal for the boost pressure fluctuates depending on the pressure. The measuring range of approximately 0.1 - 0.9 V corresponds to a boost pressure of 50 kPa (0.5 bar) to 300 kPa (3 bar).

The sensor serves the purpose of controlling the boost pressure.

Charge-air temperature sensor

The charge-air temperature sensor is located in the air duct downstream of the charge-air cooler, directly upstream of the throttle valve.

The DDE connects the charge-air temperature sensor to earth. A further connection is connected to a voltage divider circuit in the DDE.

The intake temperature sensor contains a temperature-dependent resistor that protrudes into the flow of intake air and assumes the temperature of the intake air.

The resistor has a negative temperature coefficient (NTC). This means that the resistance decreases as temperature increases.

The resistor is part of a voltage divider circuit that receives a 5 V voltage from the DDE. The electrical voltage at the resistor is dependent on the air temperature. There is a table stored in the DDE that specifies the corresponding temperature for each voltage value; the table is therefore a solution to compensate for the non-linear relationship between voltage and temperature.

The resistance changes in relation to temperature from 149 kΩ to 161 Ω, corresponding to a temperature of -40 °C to 130 °C.

Coolant temperature sensor

The coolant temperature sensor is located on the forward side of the cylinder head. It records the temperature of the coolant at the engine outlet. This value is used for the engine temperature.

It is connected to earth by the DDE. The second connection is connected to a voltage divider circuit in the DDE.

The functional principle of the coolant temperature sensor is identical to that of the intake temperature sensor.

The resistor has a negative temperature coefficient (NTC). This means that the resistance decreases as temperature increases.

The resistor is part of a voltage divider circuit that receives a 5 V voltage from the DDE. The electrical voltage at the resistor is dependent on the air temperature. There is a table stored in the DDE that specifies the corresponding temperature for each voltage value; the table is therefore a solution to compensate for the non-linear relationship between voltage and temperature.

The resistance changes in relation to temperature from 216 kΩ to 41.7 Ω, corresponding to a temperature of -55 °C to 150 °C.

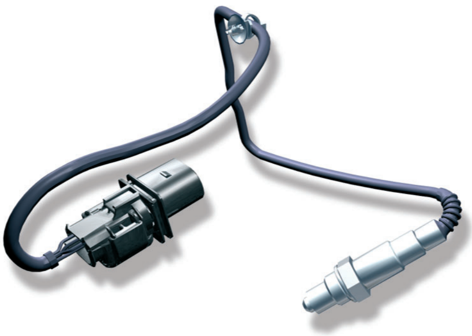
Oxygen sensor

The oxygen sensor is an indispensable component for controlling and measuring the composition of exhaust gas with the aim of conforming to legally stipulated emission values. This is achieved by measuring the residual oxygen content in the exhaust gas.

For optimum combustion, a diesel engine is operated with a fuel-air ratio of $\lambda > 1$, i.e. rich in oxygen. $\lambda = 1$ signifies a mixture of 1 kg fuel with 14.7 kg air.

The oxygen sensor is located at the inlet to the shared housing of the diesel particulate filter (DPF) and oxidation catalytic converter.

Control sensor with rising characteristic



109 - Control sensor with rising characteristic

The control sensor with rising characteristic is a type LSU 4.9 broadband oxygen sensor supplied by Bosch. This broadband oxygen sensor is installed upstream of the catalytic converter close to the engine.

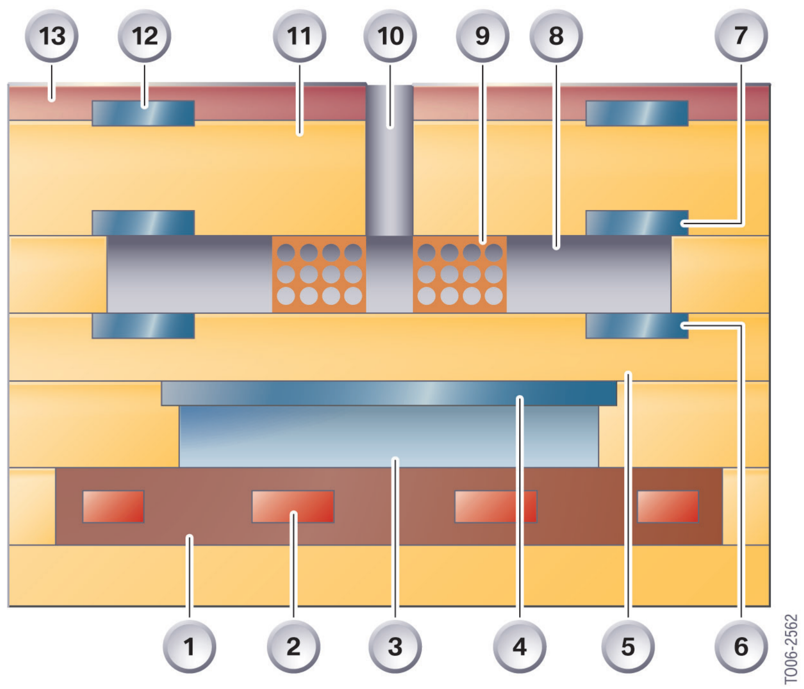
The oxygen concentration in the exhaust gas can be determined over a large range with the broadband oxygen sensor. This makes it possible to determine the fuel-air ratio in the combustion chamber.

The broadband oxygen sensor is capable of providing accurate measurements not only at $\lambda = 1$ but also at $\lambda < 1$ (rich) and $\lambda > 1$ (lean). The broadband oxygen sensor supplies a distinct, steady-state electrical signal from $\lambda = 0.7$ to $\lambda = \infty$ ($\lambda\ \infty$ = air).

The oxygen sensor is connected by 5 lines to the connector housing. The following connections lead into the housing:

- Pump current, positive
- Pump current and Nernst voltage, negative
- Heating, negative
- Heating, positive
- Nernst voltage, positive

⚠ A compensating resistor that compensates for production tolerances is integrated in the oxygen sensor connector. This resistor is connected to a free contact. ◄



110 - Design of broadband oxygen sensor

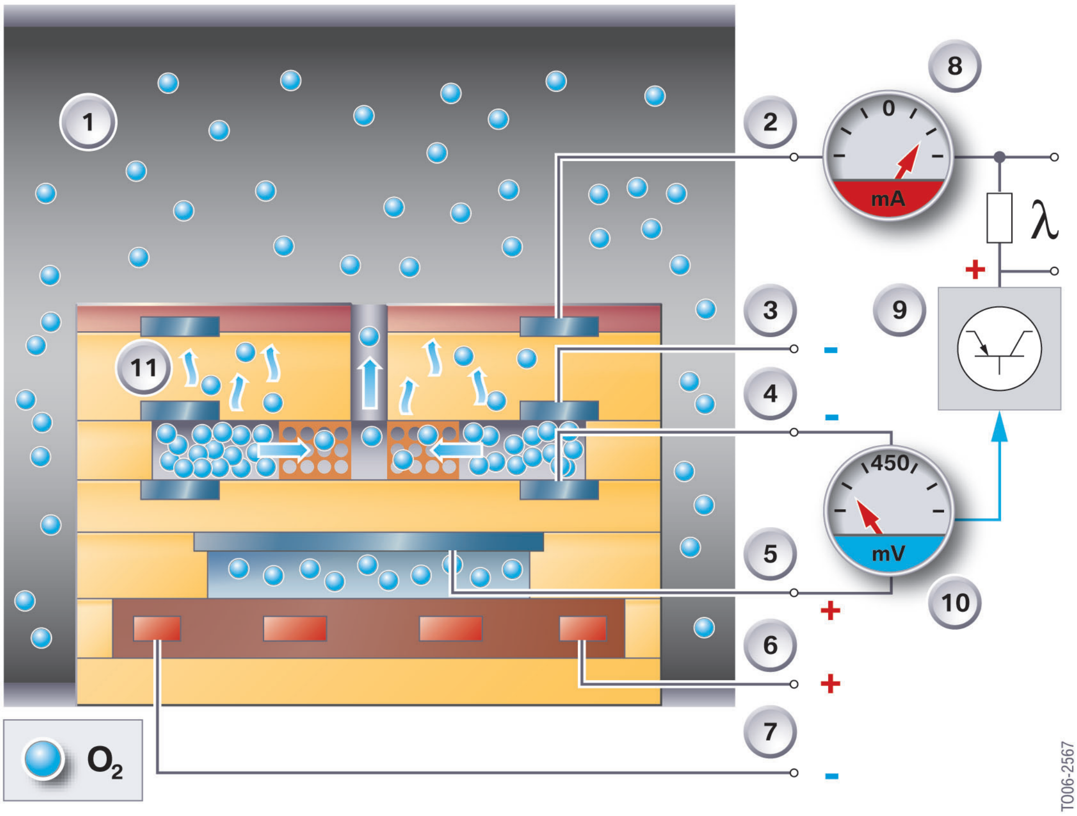
Index	Explanation	Index	Explanation
1	Insulation layer	8	Diffusion gap
2	Heating element	9	Porous diffusion barrier
3	Reference air channel	10	Exhaust inlet hole
4	Inner electrode, reference cell	11	Ceramic layer made of ZrO_2
5	Ceramic layer made of ZrO_2	12	Outer electrode, oxygen pump cell
6	Outer electrode reference cell	13	Protective layer
7	Inner electrode, oxygen pump cell		

The measuring cell of the broadband oxygen sensor is a zirconium dioxide ceramic material ZrO_2. It is designed as the combination of a Nernst concentration cell (sensor cell with the function of an oxygen sensor with erratic characteristic) and an oxygen pump cell that transports oxygen ions.

The oxygen pump cell (items 7, 11 and 12) and the Nernst concentration cell (items 4, 5 and 6) are arranged such that there is a diffusion gap (8) of about 10 to 50 µm between them. The diffusion gap is connected via an exhaust inlet hole (9) to the exhaust gas. On the one side, the Nernst concentration cell is connected via a reference air channel (3) and opening to the surrounding atmosphere. On the other side, it is exposed to the exhaust gas over a diffusion gap (8).

The exhaust gas passes through the gas inlet hole and enters the diffusion gap of the Nernst concentration cell. Initially, the same oxygen concentration as in the exhaust gas is established in the diffusion gap. In order to achieve $\lambda = 1$ in the diffusion gap, the Nernst concentration cell compares the exhaust gas in the diffusion gap with the ambient air in the reference air channel.

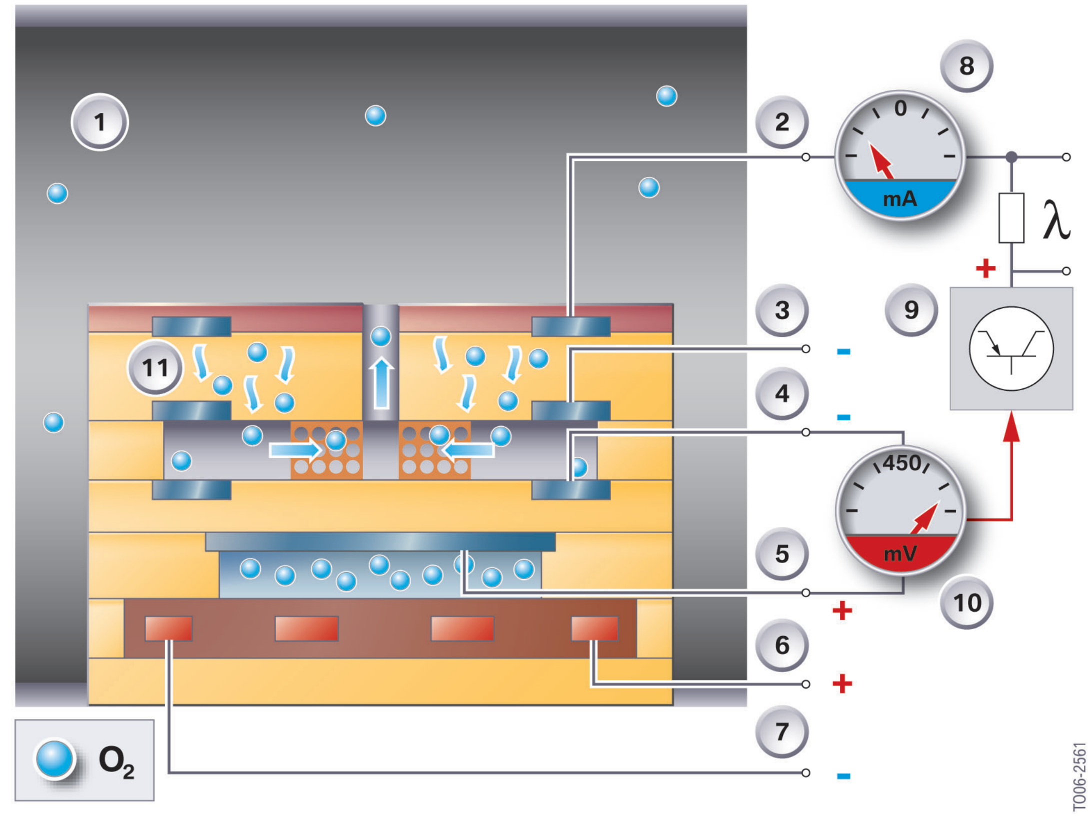
⚠ It is extremely important to ensure that the cable connection to the oxygen sensor is free of soiling so that the ambient air can enter the reference air channel. It is therefore necessary to protect the plug connection from soiling (washing agents, preservatives, etc.). ◄



111 - Broadband oxygen sensor with lean mixture

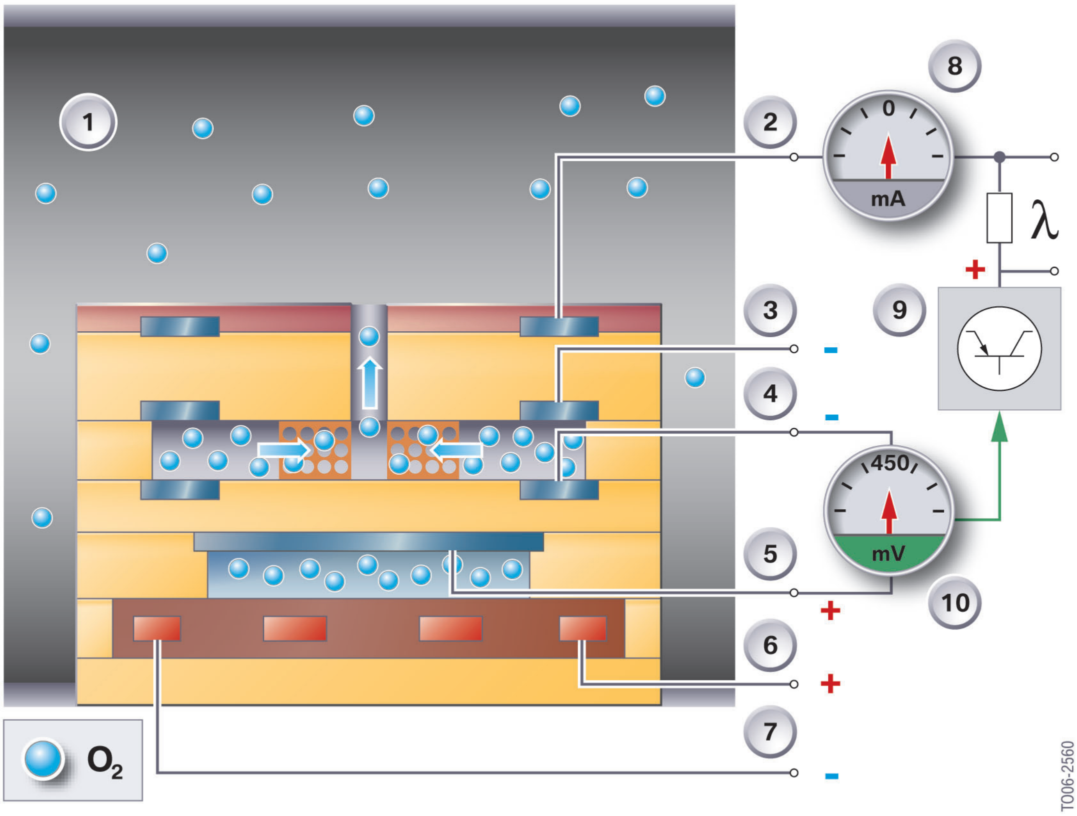
Index	Explanation	Index	Explanation
1	Exhaust pipe	7	Connection, oxygen sensor heater, negative
2	Connection, outer electrode of oxygen pump cell, positive	8	Pump current in mA (red = positive)
3	Connection, inner electrode of oxygen pump cell, negative	9	Evaluator circuit
4	Connection, outer electrode of reference cell, negative	10	Reference voltage in V (< 450 mV = blue)
5	Connection, inner electrode of reference cell, positive	11	Oxygen ion flow initiated by pump current
6	Connection, oxygen sensor heater, positive	O_2	Oxygen ions

By applying a pump voltage to the outer electrode (2) and inner electrode (3) of the oxygen pump cell, oxygen can be pumped in or out from the exhaust gas through the porous diffusion barrier into the diffusion gap. An evaluator circuit (9) in the DDE controls this voltage applied at the pump cell with the aid of the Nernst concentration cell such that the composition of the gas in the diffusion gap is always at a constant $\lambda = 1$. In the case of exhaust gas from lean combustion, the oxygen pump cell pumps the oxygen ions out of the diffusion gap. Conversely, in the case of exhaust gas from rich combustion, the oxygen ions, resulting from catalytic decomposition of CO_2 and H_2O at the outer electrode of the pump cell, are pumped out of the surrounding exhaust gas into the diffusion gap. No oxygen ions need to be transported at $\lambda = 1$. The pump current is zero. The pump current is proportional to the oxygen ion concentration in the exhaust air and therefore a measure for the fuel-air ratio λ.



112 - Broadband oxygen sensor with rich mixture

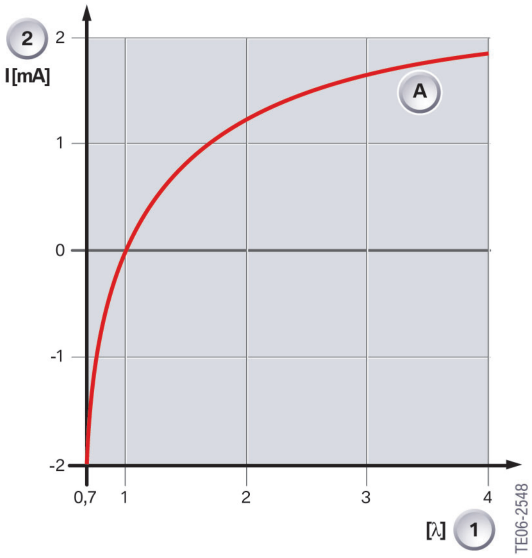
Index	Explanation	Index	Explanation
1	Exhaust pipe	7	Connection, oxygen sensor heater, negative
2	Connection, outer electrode of oxygen pump cell, positive	8	Pump current in mA (blue = negative)
3	Connection, outer electrode of oxygen pump cell, negative	9	Evaluator circuit
4	Connection, outer electrode of reference cell, negative	10	Reference voltage in V (> 450 mV = red)
5	Connection, inner electrode of reference cell, positive	11	Oxygen ion flow initiated by pump current
6	Connection, oxygen sensor heater, positive	O_2	Oxygen ions



113 - Broadband oxygen sensor, λ = 1

Index	Explanation	Index	Explanation
1	Exhaust pipe	7	Connection, oxygen sensor heater, negative
2	Connection, outer electrode of oxygen pump cell, positive	8	Pump current in mA (grey = zero)
3	Connection, outer electrode of oxygen pump cell, negative	9	Evaluator circuit
4	Connection, outer electrode of reference cell, negative	10	Reference voltage in V (450 mV = green)
5	Connection, inner electrode of reference cell, positive	11	Oxygen ion flow initiated by pump current
6	Connection, oxygen sensor heater, positive	O_2	Oxygen ions

The following diagram shows the correlation between pump current and fuel-air ratio λ.



114 - Pump current/fuel-air ratio diagram

Index	Explanation
A	Characteristic curve
1	Fuel-air ratio λ
2	Pump current

Exhaust back pressure sensor

The exhaust back pressure sensor is located on the cylinder head cover outside the exhaust system. It is connected to the exhaust pipe directly upstream of the shared housing of the oxidation catalytic converter and diesel particulate filter (DPF) by a hose and a pipeline.

The exhaust back pressure sensor measures the pressure in the exhaust system upstream of the DPF. If the exhaust back pressure rises above the permissible value of 750 mbar, the DDE initiates regeneration of the DPF.

The exhaust back pressure sensor is connected to the DDE by three pins. The DDE connects it to earth and supplies it with a voltage of 5 V. The voltage signal is delivered to the DDE through the third pin.

In the exhaust back pressure sensor, a sheet diaphragm converts the exhaust back pressure into a path dimension. This path is converted into a voltage signal by four pressure-sensitive resistors. The measuring range of the exhaust back pressure sensor is 600 to 2,000 mbar absolute, which corresponds to a voltage of 1.875 to 4.5 V.

The signal is checked for plausibility by comparison with the engine speed, injection volume, consumption and operating time.

If the sensor fails, the DDE initiates filter regeneration on a regular basis and a fault code entry is stored in the DDE.

Exhaust temperature sensor

The exhaust temperature sensor is located directly next to the oxygen sensor at the inlet to the oxi-cat/DPF. The exhaust temperature sensor is used by the DDE to regulate regeneration of the DPF.

The exhaust temperature sensor contains a temperature-sensitive resistor.

The resistor has a negative temperature coefficient (NTC). This means that the resistance decreases as temperature increases.

The resistor is part of a voltage divider circuit that receives a 5 V voltage from the DDE. The electrical voltage at the resistor is dependent on the air temperature. There is a table stored in the DDE that specifies the corresponding temperature for each voltage value; the table is therefore a solution to compensate for the non-linear relationship between voltage and temperature.

The resistance changes in relation to temperature from 96 kΩ to 32 Ω, corresponding to a temperature of -40 °C to 800 °C.

Throttle valve actuator

The throttle valve actuator is mounted on the intake manifold.

The DDE control unit calculates the position of the throttle valve from the position of the accelerator pedal and from the torque requirement of other control units. The throttle valve actuator is opened and closed electrically by the DDE control unit.

It is controlled by the DDE by means of a PWM signal with a pulse duty factor of 5 to 95 %.

The throttle valve is also used for diesel particulate filter regeneration and to counteract shaking during engine switch-off.

Position sensor

To achieve optimum control of the throttle valve, its exact position must be recorded on a continual basis. The throttle valve position is monitored contactlessly in the throttle valve actuator by 2 Hall sensors.

The position sensor is supplied with a 5 V voltage and connected to earth by the DDE. Two data lines guarantee redundant feedback of the throttle valve position to the DDE. The second signal is output as the inverse of the first. The DDE evaluates the plausibility of the signal through subtraction.

Actuator motor

The actuator motor for operating the throttle valve is designed as a DC motor. It is driven by the DDE on demand.

An H-bridge is used for activation which makes it possible to drive the motor in the opposite direction. The H-bridge in the DDE is monitored by the diagnostics system.

When no power is applied to the drive unit, the throttle valve is set, spring-loaded, to an emergency operation position.

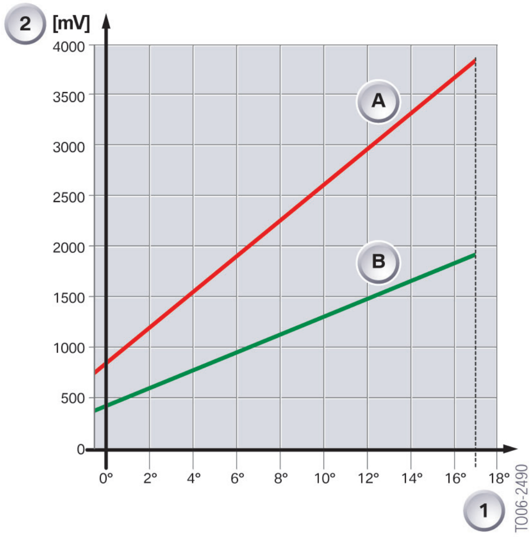
Accelerator pedal module (FPM)

The accelerator pedal module delivers the "driver's load request" signal to the DDE.

The accelerator pedal module operates in accordance with the magnetoresistive principle. Two Hall-effect angle sensors are used to facilitate monitoring and fault detection.

The two Hall-effect angle sensors are separately supplied with a 5 V voltage and connected to earth by the DDE. The sensors output a voltage signal, which is sent as an analogue signal to the DDE.

The signal of the Hall angle sensor 1 (A) is greater than the signal from Hall angle sensor 2 (B) by a factor of 2.



115 - Signal progression of accelerator pedal module

Index	Explanation
1	Operating angle in degrees
2	Pedal position voltage in mV
A	Hall angle sensor 1
B	Hall angle sensor 2

The DDE monitors the two input signals of the Hall angle sensors and compares them for plausibility.

Intelligent battery sensor

The intelligent battery sensor (IBS) assesses the current quality of the battery. The IBS is equipped with its own control unit and is a part of the battery negative terminal.

The IBS regularly (cyclically) measures the following values:

- Battery voltage
- Charging current
- Discharge current
- Battery temperature

The software in the IBS controls the functional procedure and communication with the DDE. During vehicle operation, the data from the IBS are sent via the bit-serial data interface (BSD) to the engine management.

When the vehicle is stationary, the measured values are scanned cyclically in order to save energy. The IBS is programmed in such a way that it wakes up every 40 seconds. The measuring time of the IBS is approx. 50 ms. The measured values are entered in the closed-circuit current histogram resident in the IBS. In addition, the state of charge (SoC) is also partially calculated. The DDE evaluates the histogram when the vehicle is restarted. If an off-load current problem is present, a corresponding fault code entry is stored in the DDE. The data are sent via the bit-serial data interface.

The IBS calculates the battery indicators as the basis for the state of charge and health of the battery. The battery indicators are the charging current, discharge current, voltage and temperature of the vehicle battery.

The charging/discharge current of the battery are balanced.

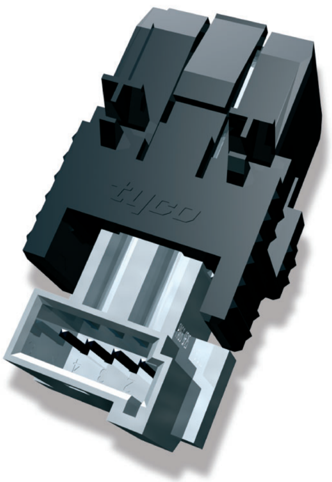
The charge status of the battery is permanently monitored and corresponding data is sent to the DDE if the charge drops to low levels.

The current progression is calculated while starting the engine in order to determine the battery's state of health.

The closed-circuit current in the vehicle is monitored.

The IBS features self-diagnosis capabilities.

Brake light switch



T006-1028

116 - Brake light switch

Two switches are integrated in the brake light switch: the brake light switch and the brake light test switch (redundancy for safety reasons). The DDE control unit uses the signals to determine whether or not the brake pedal is depressed. Data transmission takes place digitally.

The brake light switch is supplied with 12 V terminal R voltage, and connected to earth. Two signal lines lead into the DDE. The brake light switch sends a voltage of 0 V to the DDE on a signal line when the brake pedal is in the released position, and a voltage of 12 V when the brake pedal is depressed.

The brake light test switch sends a voltage of 0 V to the DDE on another signal line when the brake pedal is in the released position, and a voltage of 12 V when the brake pedal is depressed.

Clutch module

T006-1029

117 - Clutch module

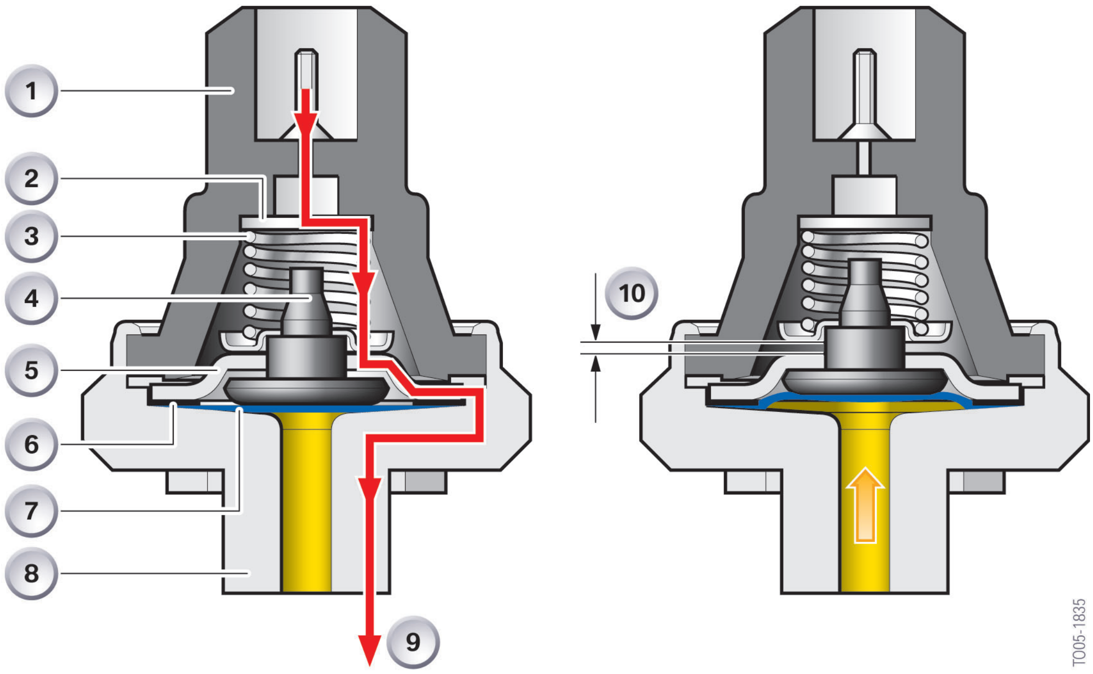
On vehicles with manual transmission, the clutch module on the clutch pedal detects the position of the clutch. The clutch module consists of a Hall sensor and evaluator electronics.

The clutch module is supplied with 12 V terminal R voltage, and connected to earth. One signal line leads into the DDE. The clutch switch sends a voltage of 0 V to the DDE when the clutch pedal is in the released position, and a voltage of 12 V when the clutch pedal is depressed.

Oil pressure switch

The oil pressure switch serves the purpose of monitoring the lubrication system. The oil pressure indicator lamp comes on when the oil pressure does not exceed a value defined by the spring (3, following diagram). This value is between 0.2 and 0.5 bar.

The oil pressure switch is connected to the DDE by means of a signal line. A 12 V voltage is applied on this line when the switch is not activated and a 0 V voltage when the switch is activated. Data transfer takes place digitally.



118 - Oil pressure switch

Index	Explanation	Index	Explanation
1	Upper section of housing made of plastic	6	Seal
2	Contact crown	7	Diaphragm
3	Spring	8	Metal housing
4	Pressure pad	9	Current flow with contact closed
5	Intermediate plate	10	Air gap with contact open

Pressure sensor for air conditioning system

The pressure sensor for the air conditioning system is located on the pressure or delivery line of the refrigerant circuit.

In cooling mode, the high pressure of the refrigerant is recorded by a pressure sensor and evaluated in the DDE.

The sensor is supplied with a 5 V voltage and connected to earth by the DDE. The information is sent to the DDE on a signal line. The evaluation signal fluctuates depending on the pressure. The measuring range from approx. 0.1 to 0.9 V corresponds to a pressure from approx. 10 kPa (0.1 bar) to 3.5 kPa (35 bar).

With the signal from the pressure sensor and the stored characteristic map, the DDE can calculate the pressure in the delivery line of the refrigerant circuit and switch the electric fan on or off corresponding to requirements. Likewise, the signal to switch the compressor clutch on or off is also sent via the PT-CAN to the junction box.

Car access system control unit

The Car Access System control unit (CAS control unit) is connected to the DDE by the PT-CAN and the junction box. The electronic immobilizer function is realized in the CAS and DDE network. In addition, the CAS control unit is connected to the DDE by the CAS bus and another line for starter control.

The CAS control unit also supplies the terminal R and terminal 15 signals.

Rail pressure sensor

The rail pressure sensor is installed in the stainless steel rail. The pressurized fuel is buffered in the rail and distributed to the high pressure fuel injectors.

The fuel pressure is transmitted through the high pressure connection to the diaphragm with sensor element. The deflection of the diaphragm is converted by the sensor element into an electrical signal. The evaluator circuit processes the signal and sends an analogue voltage signal to the DDE. The voltage signal is applied in linear form as the fuel pressure increases.

The signal from the rail pressure sensor is an important input signal to the DDE in its controlling of the volume control valve (component of the high-pressure pump).

The sensor is supplied with a 5 V voltage and connected to earth by the DDE. The information is sent to the DDE on a signal line. The evaluation signal fluctuates depending on the pressure.

In the event of the rail pressure sensor failing, the DDE controls the volume control valve in emergency mode.

Rail-pressure regulating valve

The purpose of the rail-pressure regulating valve is to relieve excess pressure in the fuel accumulator (rail). It is connected to one end of the rail.

The rail-pressure regulating valve is controlled by the DDE by means of a PWM signal.

It is only active during a cold engine start or during a release of throttle.

Relays of front power distribution box

Several relays for the engine management are integrated in the front power distribution box:

- DDE main relay
- Ignition unloader relay
- Engine ventilation-heating relay (only Cold Climate option).

DDE main relay

The DDE main relay is activated by the DDE. The DDE main relay is switched on when the DDE receives the ignition ON signal from the CAS.

Various components are supplied with power by the DDE main relay.

When the ignition is switched off, the DDE switches off the DDE main relay after a specific period has elapsed. The reason for this is that adaptations etc. are stored in the non-volatile memory in the control unit after deactivation of terminal 15 in order to make them available again after switching on the ignition.

The DDE main relay is supplied with terminal 30 on-board voltage, and connected to earth by the DDE.

Engine ventilation-heating relay (only Cold Climate option)

The engine ventilation-heating relay secures the heating system for the engine ventilation. This relay is also switched by the DDE.

The relay is supplied with terminal 87 on-board voltage, and connected to earth by the DDE.

Fuel injectors

The most important requirement of injectors is that they must be able to meter the injection volume with exact accuracy and control injection timing with precision. They are connected in the cylinder head and protrude into the centre of the combustion chamber.

The upper power class of the N47 is equipped with PIEZO injectors, while the lower power class uses solenoid valve injectors. Both systems conform to systems that have been used on previous engines.

Solenoid valve injectors (MVI)

The MVIs have two connections to the DDE. With injector control technology, it is possible to make a distinction between the "high-side" and "low-side".

Through the "high-side" control, the injectors are supplied with power.

Through the "low-side" control, the injectors are activated by the output stage - fuel is injected into the combustion chamber.

The injection time and duration for the cylinder concerned are adapted to suit the prevailing operating conditions (engine speed, load and engine temperature).

There is a coil inside the injector that creates a magnetic field when current is applied to it. The magnetic field causes a valve to open, which brings about a hydraulic lifting action of the nozzle needle and results in injection. You will find more detailed information about the injectors in the Fuel preparation section.

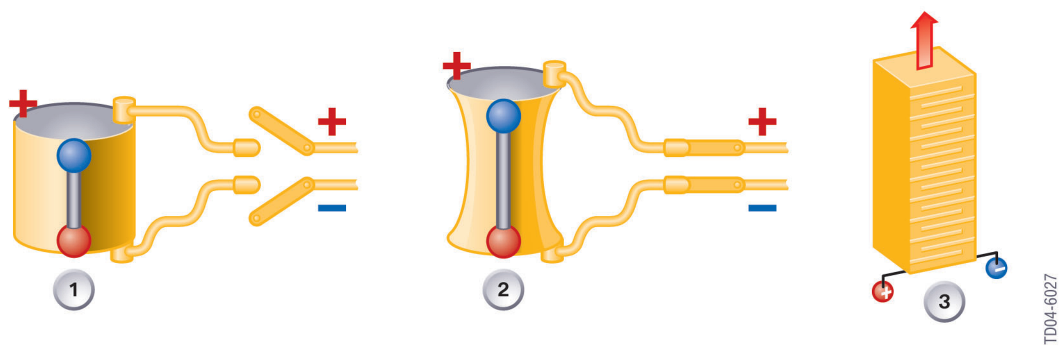
The voltage required to control the MVI is produced by an output stage for each injector.

PIEZO injectors

In the case of the PIEZO injector, the movement of the valve is not generated by a solenoid coil but rather by a PIEZO element.

A PIEZO element is an electromechanical converter, i.e. it consists of a ceramic material that converts electrical energy directly into mechanical energy (force/travel).

With the PIEZO element in the injector, a voltage is applied so that the crystal expands. To achieve greater travel, the PIEZO element is built up from 264 layers.

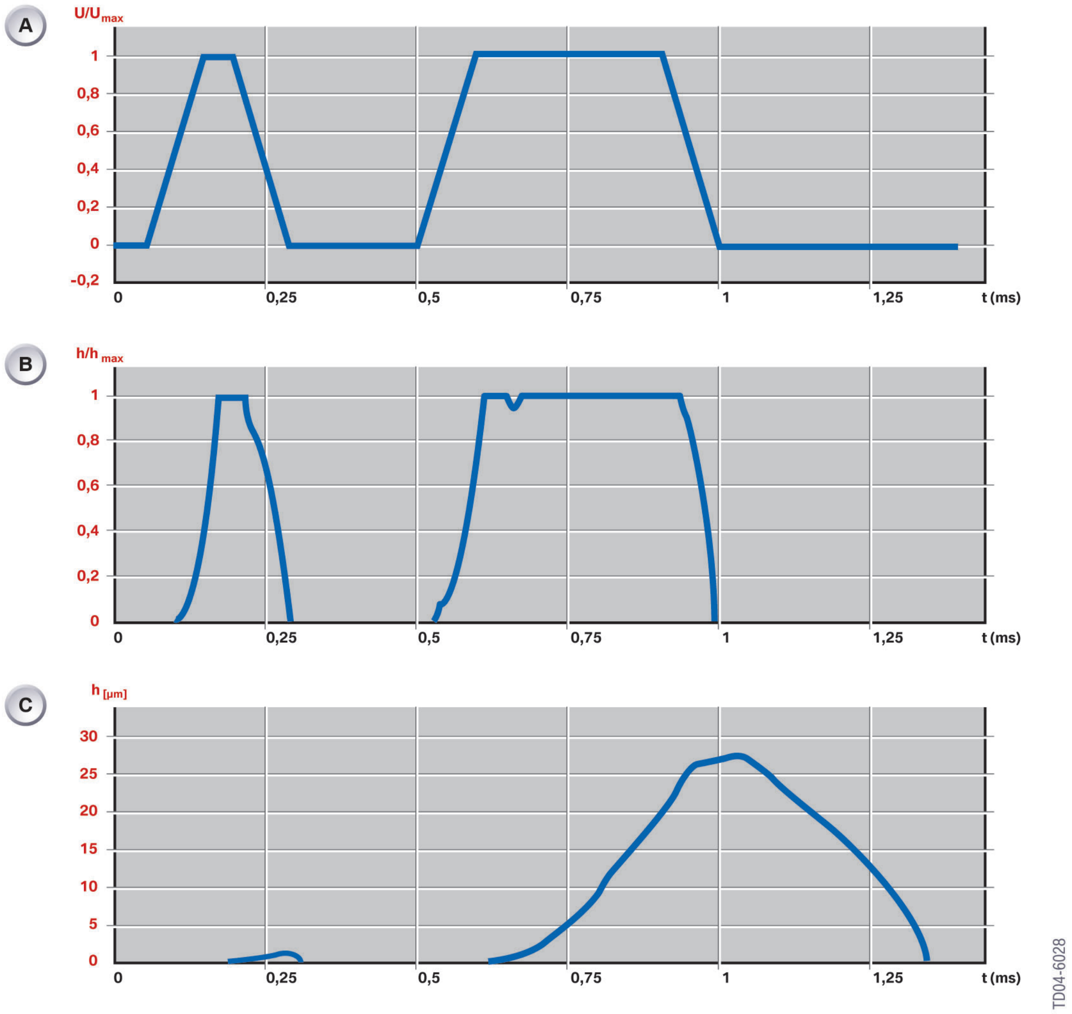


119 - Behaviour of a PIEZO element

Index	Explanation	Index	Explanation
1	PIEZO crystal de-energized	3	Layer structure of a PIEZO element
2	PIEZO crystal energized		

If a PIEZO element is isolated from the voltage source while it is charged, it will retain its charge - in a similar way to a capacitor. In other words, if the injector were to be isolated from the control unit during actuation, the PIEZO element would remain in a state of expansion and there would be continuous injection. To prevent this, the PIEZO element is connected in parallel with a resistor through which it may discharge itself in less than a second.

The following graphic is a qualitative representation of the control of PIEZO injectors.



120 - Control of PIEZO injectors

Index	Explanation	Index	Explanation
A	Control (idealized)	C	Needle lift
B	Valve lift		

Electric fan

The electric fan has its own output stage. It is controlled by the DDE by means of a PWM signal. This signal indicates the target value for the cooling output required. The controller of the electric fan converts this into a corresponding speed.

The electric fan is driven by a DC motor, the output of which depends on the vehicle and equipment fitted.

Exhaust turbocharger

The N47 engine, too, has a turbocharger with variable nozzle turbine geometry (VNT). The turbine vanes are adjusted electrically. This achieves a more accurate regulation of the boost pressure by comparison with pneumatic adjustment.

The servomotor is controlled by the DDE by means of a PWM signal. The position regulator and the diagnostics function are integrated in the servomotor.

In the event of a malfunction, the PWM signal from the internal position regulation of the servomotor is directed to earth for 0.5 to 2 seconds (depending on the fault message). From this, the DDE detects a fault with the electrical vane adjustment.

Alternator

The alternator exchanges data with the DDE control unit through a bit-serial data interface. The alternator sends information to the DDE, such as model and manufacturer. This allows the DDE control unit to adapt regulation of the alternator to match the actual alternator model installed.

The alternator is connected to the DDE by the bit-serial data interface BSD. Data exchange is bidirectional. The DDE is therefore able to detect the status of the alternator and initiate control interventions.

Volume control valve

The volume control valve (metering unit, ZME) is integrated in the fuel high-pressure pump. It limits the volume of fuel delivered to the high-pressure pump on a demand basis. This increases the efficiency of the high-pressure pump, especially in the partial load range.

The volume control valve is map-controlled by a PWM signal.

Starter

The starter is activated by the CAS. The DDE has a connecting line to the CAS for this function. The CAS detects that the DDE is requesting starter operation when the DDE outputs 12 V on-board supply voltage on this line. If the line is switched to earth, the CAS detects that the DDE wishes to end the starting operation.

Fuel temperature and pressure sensor

Fuel temperature and pressure are recorded by a combination sensor that is located in the fuel feed directly upstream of the high-pressure pump.

This component has only one connection to earth, which is then shared by the individual sensors. For the fuel-pressure sensor, there is a power supply. In addition, each sensor has one signal output. The combination sensor therefore has four connections.

Fuel temperature sensor

The fuel temperature sensor measures the fuel temperature upstream of the high-pressure pump. It is used for engine overheating protection and calculating the injection volume.

The fuel temperature sensor is connected to earth by the DDE. The second connection is connected to a voltage divider circuit in the DDE.

It contains a temperature-dependent resistor that protrudes into the fuel and assumes its temperature.

The resistor has a negative temperature coefficient (NTC). This means that the resistance decreases as temperature increases.

The resistor is part of a voltage divider circuit that receives a 5 V voltage from the DDE. The electrical voltage at the resistor is dependent on the fuel temperature. There is a table stored in the DDE that specifies the corresponding temperature for each voltage value; the table is therefore a solution to compensate for the non-linear relationship between voltage and temperature.

The resistance changes in relation to temperature from 75.5 kΩ to 87.6 Ω, corresponding to a temperature of -40 °C to 120 °C.

Fuel pressure sensor

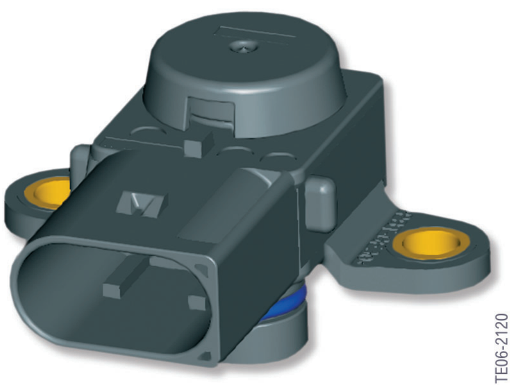
The fuel temperature sensor measures the pressure in the fuel low-pressure system upstream of the high-pressure pump. The fuel pressure is used by the DDE as a basis for the on-demand control of the electric fuel pump.

The DDE connects the fuel pressure sensor to earth and supplies with a voltage of 5 V. It delivers a voltage signal to the DDE.

A sheet diaphragm converts the fuel pressure into a path dimension. This path is converted into a voltage signal by four pressure-sensitive resistors.

Brake negative pressure sensor (MSA only)

The brake negative pressure sensor is a new component used in the operation of the automatic engine start-stop (MSA).



121 - Brake negative pressure sensor

The brake negative pressure sensor is used to ensure that there is always sufficient negative pressure available for the brake power assistance in connection with the automatic engine start-stop (MSA) function. If the pressure falls below a defined value, the engine is started by the MSA.

The brake negative pressure sensor is located next to the brake force amplifier.

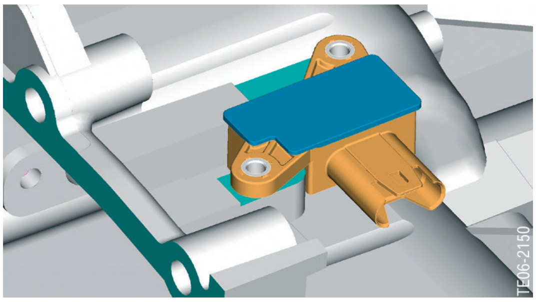
The DDE connects it to earth and supplies it with a voltage of 5 V.

Inside the sensor, a sheet diaphragm converts the negative pressure into a path dimension. This path is converted into the voltage signal by four pressure-sensitive resistors and then sent to the DDE.

Zero gear sensor (MSA only)

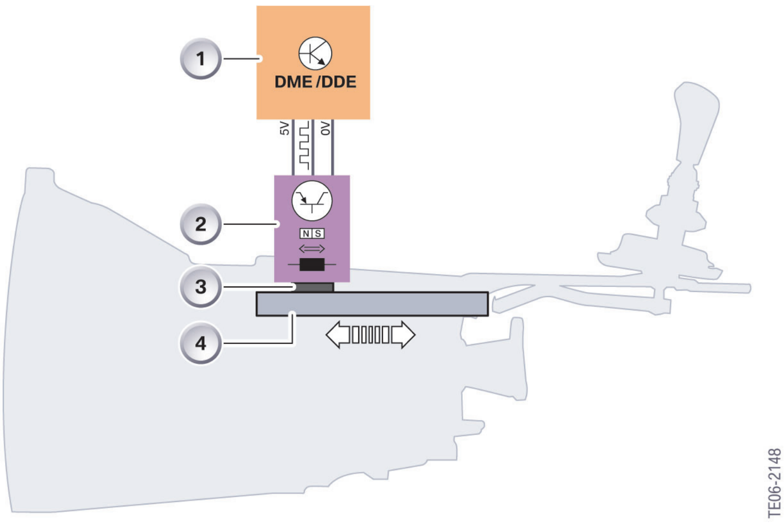
The zero gear sensor is also new and is fitted only in conjunction with the MSA.

It makes sure that the MSA only starts the engine if no gear has been engaged.



122 - Zero gear sensor

The zero gear sensor is fitted to the top of the transmission housing and has the task of detecting the neutral position of the gear lever. It is a PLCD sensor (permanent magnetic linear contactless displacement sensor).



123 - Zero-position sensor operating principle

Index	Explanation	Index	Explanation
1	Digital Diesel Electronics (DDE)	3	Magnet
2	PLCD sensor	4	Selector rod

As the gear lever moves, the selector rod is shifted and so too the magnet in the transmission. Using the PLCD sensor, the DDE is able to detect the position of the gear lever.

You will find more detailed information on the zero-position sensor in the automatic engine start-stop document.

EGR valve

The EGR valve is opened in response to negative pressure. The vacuum canister of the EGR valve is subjected to the appropriate negative pressure by an electropneumatic exhaust pressure converter (EPDW).

The EPDW is controlled by the DDE by means of a PWM signal with a pulse duty factor of 5 to 94 %. It converts the signal into a corresponding negative pressure.

At 5 %, the EGR valve is closed; at 94 % it is fully open.

EGR path sensor

The path dimension to which the EGR valve opens is recorded by the EGR path sensor. This makes it possible to meter the EGR rate more accurately.

The EGR path sensor is located on the vacuum canister of the EGR valve.

The sensor is supplied with a 5 V voltage and connected to earth by the DDE. The sensor is a potentiometer.

Inside the potentiometer, there is a resistor with a defined resistance in the circuit from the voltage supply to earth. A sliding contact picks up voltage along the length of the resistor. This sliding contact moves with the travel of the EGR valve.

The tapped voltage is thus proportional to the travel of the EGR valve.

EGR bypass valve

To enable uncooled exhaust gas to be mixed with the fresh air in specific operating situations, the N47 engine in the upper power class with manual transmission is equipped with an EGR cooler bypass for the first time.

This allows the exhaust gas to bypass the EGR cooler.

The EGR bypass valve is opened by a vacuum canister and closed by spring force. There are only two positions: open and closed. The vacuum canister is supplied with the necessary negative pressure by an electropneumatic changeover valve.

The electropneumatic changeover valve is switched by the DDE.

Swirl flap regulator

The swirl flaps are adjusted by a DC motor. This is located at the forward end of the intake manifold.

The DC motor is controlled by a PWM signal with a pulse duty factor of 5 to 95 %. At 5 %, the swirl flaps are open; at 95 %, they are closed.

With no current supplied, the swirl flaps are open.

Swirl flap sensor

The position of the swirl flaps is measured contactlessly by the swirl flap sensor located inside the housing of the swirl flap regulator.

The swirl flap sensor makes it possible to control the swirl flaps with greater precision, which in turn makes it possible to reduce pollutant emissions.

The swirl flap sensor is a Hall sensor. It is supplied with a voltage of 5 V and connected to earth by the DDE.

The sensor sends an analogue signal to the DDE.

Preheater control unit (GSG)

The preheater control unit fitted to the oil filter housing is compatible with diagnostics and communicates with the DDE control unit on the LIN bus.

It is also connected to earth by the DDE.

The preheater control unit is additionally connected to terminal 15, and to terminal 30 by an additional "high-current connection".

The preheater control unit's mechanical and electrical layout enable it to be fitted close to the engine. This reduces the length of the lines from the GSG to the glow plugs.

The heat output is determined by the DDE as a function of specific operating conditions, e.g. temperature, engine speed and engine load, and forwarded to the GSG on the LIN bus. The preheater control unit implements the request and feeds back diagnostics and status information to the DDE on request.

Control of the glow plugs

The preheater control unit receives the glow requirements for various glow functions, e.g. start-assist, operational or diagnostics, from the DDE.

The glow plugs are controlled by the GSG by means of a pulse-width-modulated signal. Each glow plug is switched on and off individually by an output stage assigned to the glow plug. Thanks to the pulse width modulation, the effective voltage (useful voltage) at the glow plugs can be varied in such a way that a constant temperature of approximately 1,200 °C is achieved across the engine's entire operating range.

Thanks to the PWM control, the voltage at the glow plugs is kept constant so that voltage fluctuations in the vehicle electrical system have no effect on the glow plugs and their temperature.

In clocked mode, the glow plugs are not all switched on and off simultaneously but in succession in order to prevent malfunctions in the vehicle electrical system caused by very high currents as a result of periodic switching on and off.

Ceramic glow plugs

New, ceramic glow plugs are used in the N47 engine. They stand out for higher temperatures, lower power consumption and a short response time.

The tip of this type of glow plug is made of a ceramic material that is able to produce a temperature of 1,200 °C (predecessor: 1,000 °C).

Ceramic glow plugs are also characterized by a long service life. However, they must be handled with care because the ceramic tip is very fragile.

System components

TE06-0645

Crankcase

Reinforcement shell

⚠ Before the reinforcement shell is fitted, it is essential that the spacer sleeves be screwed into the reinforcement shell fully, otherwise there is a risk of damage. The procedure in the repair instructions must be observed. ◄

Sump

⚠ To ensure that the seal functions correctly, no oil is permitted to come into contact with the rubber coating during assembly. There would be a risk of the seal sliding off the sealing surface. Therefore, the flange surfaces must be cleaned immediately prior to assembly. In addition, it must be ensured that all oil has been allowed to fully drain out of the engine so that it neither drips onto the flange surfaces nor the seal during assembly. ◄

Crankshaft and bearings

Three-layer bearings

⚠ Careful handling of bearing shells is extremely important because the ultra-thin bearing metal layer is not capable of adjusting to flexural distortion. ◄

Thrust bearing

⚠ It is important that lubrication with engine oil is ensured. When thrust bearings fail, overheating is generally the cause.

A worn thrust bearing causes noise to be produced, mainly in the area of the vibration damper. Another symptom can be faulty readings from the crankshaft sensor, which on vehicles with automatic transmission is exhibited in the form of harsh gearshifts. ◄

Connecting rods and bearings

Cracked connecting rod

⚠ If a big-end bearing cap were to be fitted the wrong way round or on the wrong connecting rod, the fracture face pattern of both parts would be destroyed and the bearing cap would not be centred. In that case the complete con rod set has to be replaced with entirely new parts. ◄

Con rod bolts

⚠ You will find detailed information on connecting rod connections, such as tightening specifications, in the TIS. ◄

If a **new set of con rods** is being fitted:

When fitting the con rods, the con rod bolts must only be tightened once to check the bearing play and then once again for final assembly. Since the con rod bolts have already been tightened three times in the course of the machining processes during production, they have already reached their maximum tensile strength.

If the existing con rods are being re-used and **only the con rod bolts** are being replaced:

The con rod bolts must be tightened once again after checking the bearing clearance, loosened again and then tightened a third time to obtain maximum tensile strength.

⚠ If the con rod bolts are not tightened at least three times, or are tightened more than five times, engine damage will result. ◄

Weight classification

⚠ In the same engine, only connecting rods of the same weight class may be fitted. ◄

Pistons, piston rings and gudgeon

Piston rings

⚠ Taper-faced rings must not be fitted the wrong way round. The rebate must be at the bottom. Incorrect installation leads to engine damage ◄

⚠ A damaged or broken oil control ring cannot be identified once fitted. The effects only come to light after a certain period of use. ◄

Belt drive and auxiliary equipment

⚠ It is essential that auxiliary equipment be fitted in the correct position during assembly. A belt pulley alignment error would result in belt noise and ultimately belt damage. Observe the procedure in the repair instructions ◄

Oil spray nozzles and piston cooling valve

Oil spray nozzle for piston cooling

⚠ Exact positioning of the oil spray nozzles is necessary in order to achieve optimum cooling.

Bent or damaged oil spray nozzles must be replaced with new ones, otherwise there is a risk of engine damage.

The oil spray nozzles are positioned precisely with the aid of a special tool. Please observe the repair instructions. ◄

Oil spray nozzle for lubricating timing chain

⚠ There is a risk of damage to the oil spray nozzle if the chain falls into the crankcase during assembly work. ◄

Oil monitoring

Oil pressure switch

⚠ If the connector for the oil pressure switch is not connected, no oil pressure warning can be issued. ◄

Oil level measurement

⚠ You will find the procedure for measuring the oil level in the Owner's Handbook.

The oil consumption depends on the driving profile and operating conditions. ◄

A possible oil consumption complaint can often be attributed to the measurement being carried out incorrectly. The exact oil consumption measurement procedure can be found in the TIS.

⚠ An oil consumption measurement should not be carried out until at least 7,500 km have been covered because it is only after this distance that the engine run-in process is more or less complete and the oil consumption has stabilized. ◄

⚠ Do not exceed the upper mark on the dipstick otherwise the engine may be damaged by overfilling with oil. ◄

⚠ The dipstick has an inconspicuous black handle because it is only intended for use by the after-sales service organization. ◄

Electronic oil level measurement

⚠ Initially, after replacing or reprogramming the engine control unit, no oil level is stored in the unit - "Oil level below minimum" is therefore displayed. The correct oil level is indicated after running the engine for approx. 5 minutes. ◄

⚠ Overfilling the engine with oil is harmful for the engine. Have the vehicle checked immediately. ◄

Intake system

⚠ If the purified air pipe downstream of the blow-by gas connection is heavily oiled, this could imply increased blow-by gas levels. The cause of this is usually a leak on the engine (e.g. crankshaft seal) or surplus air taken in through the vacuum lines. A consequential symptom would then be an oily exhaust turbocharger, which does not mean that there is a fault with the exhaust turbocharger itself. ◄

Exhaust system

⚠ If the sulphur content in the diesel fuel is > 50 - 100 ppm, there is a possibility of heavy white smoke development and a sulphur odour from the exhaust tailpipe. ◄

Components in the coolant circuit

Coolant pump

⚠ In the past, coolant pumps would often be replaced due to the presence of coolant traces. However, minor traces of coolant are acceptable due to the functional leakage of the slide ring seal.

The maximum permissible coolant leakage is 800 mg/h, which corresponds to one drop with a diameter of a little over 1 cm per hour. ◄

Expansion tank

⚠ Never open the cover on the expansion tank while the engine is hot.

The reason for this is not only a risk of scalding. In the upper sections of the coolant circuit (e.g. cylinder head), gas bubbles may form as a consequence of the loss of pressure. Sufficient heat dissipation would no longer be guaranteed at this point, which would result in overheating. ◄

Cooling module

Electric fan

⚠ When you carry the electric fan, do not hold it in the fan ring as this could break. ◄

Functions of the engine electrical system

Power supply

⚠ Starting characteristics could be significantly affected if the start-load response function were to malfunction. ◄

Electronic immobilizer (EWS)

⚠ A certain procedure must be followed in the event of a defective CAS or DDE. The required control unit must be ordered precisely for the specific vehicle. The vehicle data (vehicle identification number) are required for this purpose. EWS matching is not necessary after replacing the control units. ◄

Sensors and actuators

Oxygen sensor

⚠ A compensating resistor that compensates for production tolerances is integrated in the oxygen sensor connector. This resistor is connected to a free contact. ◄

⚠ It is extremely important to ensure that the cable connection to the oxygen sensor is free of soiling so that the ambient air can enter the reference air channel. It is therefore necessary to protect the plug connection from soiling (washing agents, preservatives etc.). ◄

Test questions.
N47 engine.

Questions

Consolidate and recheck what you have learned.

In this section, you have the opportunity to check what you have learned. You will be asked questions on the subject of the N47 engine presented here.

1. The crankcase of the N47 engine is made of which material?

☐ Grey cast iron

☐ Aluminium

☐ Magnesium.

2. What are the special features of the belt drive of the N47 engine?

☐ The air-conditioning compressor is now driven by an elastomer belt

☐ If an air-conditioning compressor is fitted, the poly-V-belt is double-sided

☐ Correct positioning of the alternator and air-conditioning compressor is achieved by spacer sleeves

☐ All items of auxiliary equipment (alternator, air-conditioning compressor and power steering pump) are fitted on the left-hand side of the engine.

3. Where is the first cylinder located in the N47 engine?

☐ Opposite the force transmitting side (front)

☐ As close as possible to the timing gear (rear).

4. Which designs most accurately describe the crankcase of the N47 engine?

☐ Open-deck

☐ Closed-deck

☐ Crankcase with upper and lower section

☐ Crankcase with side walls that extend downwards.

5. Which statements concerning the crankcase breather system and the oil separation are correct?

☐ In the event of excessive overpressure in the crankcase, an overflow valve ensures that no oil enters the intake duct

☐ Yarn helix separators provide fine separation

☐ A pressure regulating valve ensures the correct level of negative pressure in the crankcase

☐ A preliminary separation takes place on the walls of the plenum chamber.

6. Which of the following statements are correct in respect of the balancing shafts?

- ☐ Both balancing shafts have the same direction of rotation
- ☐ Both balancing shafts turn at the same speed
- ☐ The balancing shafts are located inside the sump
- ☐ The balancing shafts are mounted on needle bearings
- ☐ The balancing shafts are inserted into the crankcase from the front.

7. What is the special feature of the oil pump of the N47 engine?

- ☐ It is a map-regulated oil pump
- ☐ It forms a single unit with the vacuum pump
- ☐ It has flow rate regulation
- ☐ The pressure limiting valve has a stepped piston that is subjected to oil pressure upstream and downstream of the filter.

8. What is the purpose of the bypass valve in the EGR cooler?

- ☐ Thanks to the recirculation of uncooled exhaust gas, the catalytic converter is brought up to its operating temperature more rapidly
- ☐ It directs the coolant into a bypass in the EGR cooler
- ☐ It directs exhaust gas into a bypass in the EGR cooler
- ☐ Since the EGR cooler can be bypassed, the coolant temperature can be regulated more effectively.

9. Which fuel system combination is fitted in the N47 engine?

- ☐ Lower power class with solenoid valve injectors and 1,800 bar
- ☐ Upper power class with PIEZO injectors and 2,000 bar
- ☐ Lower power class with PIEZO injectors and 1,600 bar
- ☐ Lower power class with solenoid valve injectors and 1,600 bar
- ☐ Upper power class with solenoid valve injectors and 1,800 bar
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Answers to the questions

Check it!

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