Reference Manual

2007 NG6 ENGINES

Technical Training

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2007 Engine Introduction

Initial Print Date: 09/06 Revision Date:

2007 Engine Introduction

Model: All with 6-Cylinder for 2007

Production: from 9/2006

OBJECTIVES

After completion of this module you will be able to:

- Describe the additions to the NG6 engine family
- Understand the new engine designations

New 6-Cylinder Engines for 2007

Previously in 2005, BMW introduced the beginning of a new generation of six cylinder engines with the N52. Now, for the 2007 model year, BMW has 3 new variations of the NG6 engine family.

The first of the new engines is the N54, which will debut in the new 3-series coupe in September 2006. The N54 is turbocharged and uses the second generation of direct injection (DI 2). This engine will power the new 335i coupe in the fall of 2006.

The N52 will eventually be replaced by the new N52KP. The N52 KP engine is an improved and cost optimized version of the N52. The N52 KP will be available in the 328i and xi coupe from September and will replace the N52 in various models.

Finally, the N51 which is a SULEV II compatible engine, will be phased into selected production models from 9/06. The N51 features many of the same features of the previous SULEV engine (M56) including a “Zero Evap” system.

New Engine Designations

A new engine numbering system has been introduced to to enable fast and distinct identification.

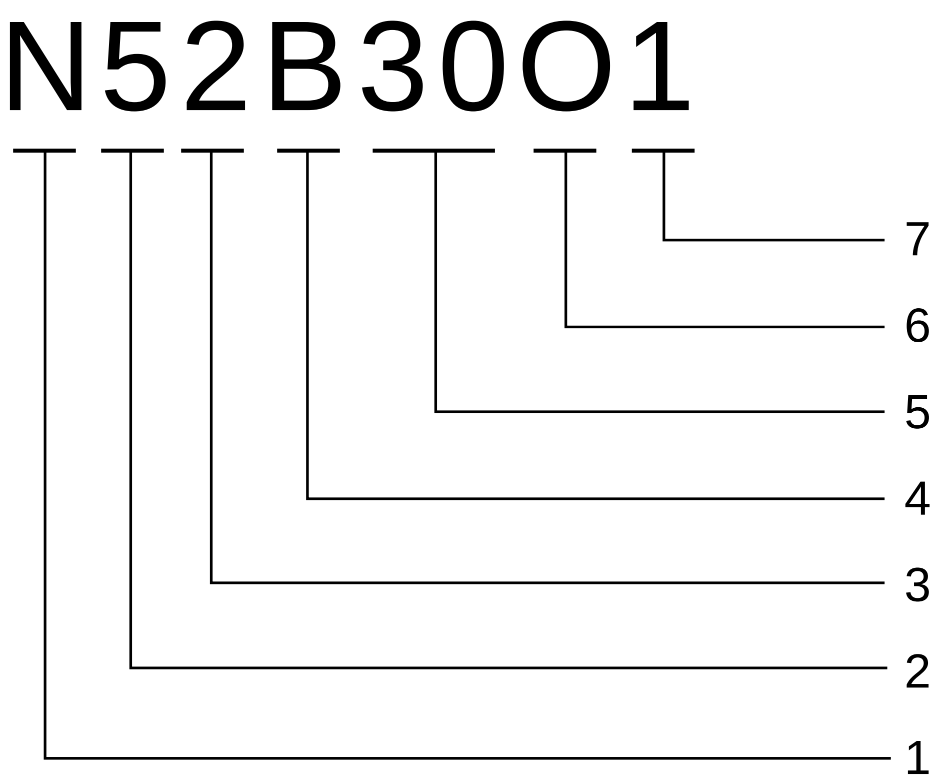
The “TU” designation has been dropped together with the associated version number which is now replaced by a simple count number at the end of the engine designation.

The codes T through K are also new for the various power stages instead of the previous “OL” or “UL” designations.

For example, the new N52KP engine which is a variant of the original N52 engine will now be known as the N52B30O1. This would be instead of the traditional “TU” suffix as in - N52B30TU.

The block stamping (above) is located in the same place as the previous N52 engine.

The chart on the opposing page shows the breakdown of the new engine designations.



Index	Designation	Code	Description
1	Engine Generation	M	BMW Engines up to 2001
		N	BMW Engines from 2001 (New Generation)
		S	BMW M GmbH
		W	External Engines (i.e. Tritec MINI)
2	Engine Type	4	4-cylinder in-line engine
		5	6-cylinder in-line engine
		6	8-cylinder “V” engine
		7	12-cylinder “V” engine
		8	10-cylinder “V” engine
3	Engine System	0	Basic engine
		1	SULEV or PZEV
		2	Valvetronic
		3	Gasoline direct injection
		4	Gasoline direct injection with turbocharger
		5	Double VANOS with Valvetronic
		7	Diesel direct injection with turbocharger
4	Fuel type/ operating mode	B	Gasoline
		D	Diesel
		E	Electric
		G	Gas (natural)
		H	Hydrogen
5	Displacement in 1/10 liter	25	2.5 liter (example)
6	Power output class	T	Top
		O	Upper output class (standard)
		M	Medium output class
		U	Lower output class
		K	Lowest output class
		0	New development
7	Version	1-9	Redesign/facelift version (TU etc.)

N54 Overview

The first new member of the NG6 family is the N54 which will be initially available in the new 335i coupe (E92). The N54 continues the tradition of “efficient dynamics” by meeting the customer demand for high performance and the necessary requirements of low fuel consumption and emissions.

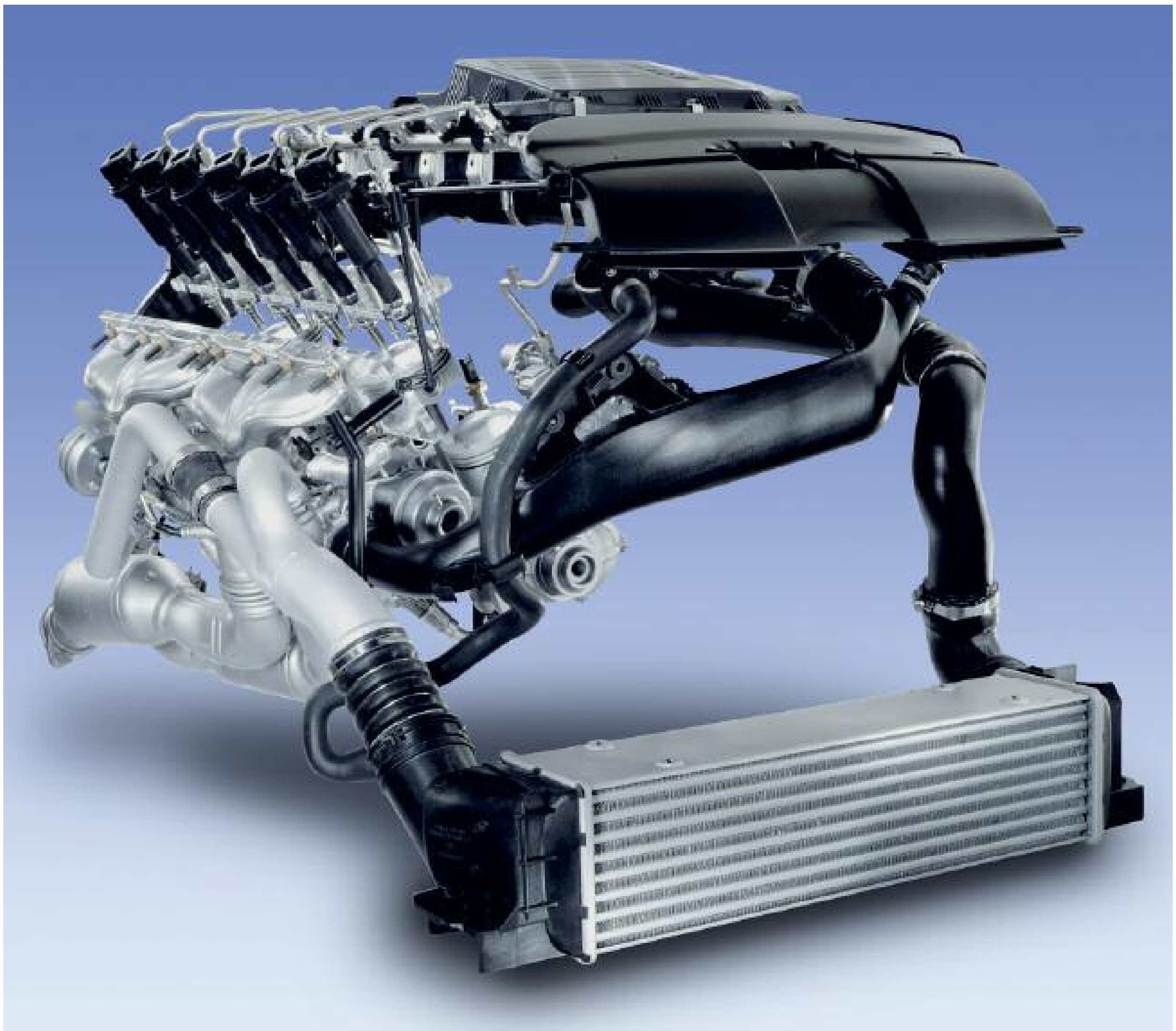
The N54 is available as a 3.0 liter engine and features the following:

- Exhaust driven turbocharger (Bi-turbo)
- Air to air Intercooler
- 2nd Generation Direct Injection (HPI) with piezo injectors
- New engine management (MSD80)
- Bi-VANOS
- All aluminum crankcase with iron cylinder liners (similar dimensions to N52)
- External oil cooler
- New high output electric water pump (400 W)
- Aluminum cylinder head with plastic valve cover
- Steel crankshaft

As per the new engine designations, the N54 will be officially referred to as the N54B30O0. The “O” designates the “upper” output range and the “0’ indicates the first generation in this series.

The N54 features the new HPI injection system which is capable of pressures of to 200 bar. This system features the new “piezo” injector technology with “outward” opening injectors.

Also, the N54 benefits from parallel bi-turbocharging with air to air intercoolers.

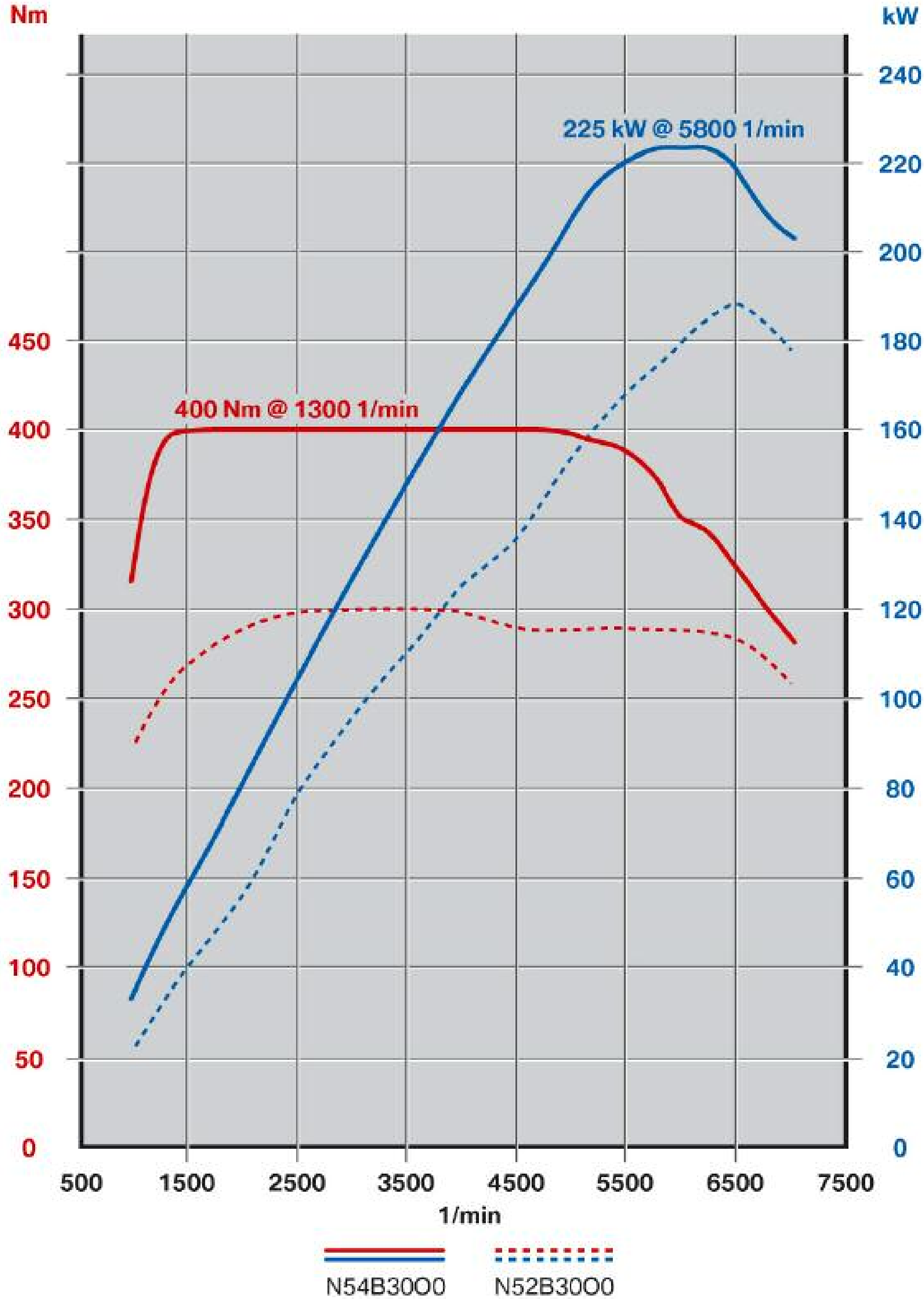


Overall, the N54 provides the driver with uncompromising response and high torque output in a package that is up to 150 pounds lighter than a V-8 engine. The new technology used in the N54, allows for maximum efficiency and the required low tailpipe emission figures to meet ULEV II guidelines.

Technical Data N54

Description	Value
Engine type	Inline 6 cylinder
Displacement (cm^3)	2979
Stroke/bore (mm)	84/89.6
Cylinder spacing (mm)	91
Crankshaft main bearing diameter (mm)	65
Crankshaft rod journal diameter (mm)	50
Firing order	1-5-3-6-2-4
Power output(kw/bhp) @ RPM	225/300 @ 5800 RPM
Torque (Nm) @RPM	400 @ 1300 - 5000
Maximum engine speed	7000
Power to weight ratio (kg/kW)	0.83
Power output per liter (kW/l)	75.5
Compression ratio	10.2
Valves/cyl	4
Inlet valve diameter (mm)	31.44
Exhaust valve diameter (mm)	28
Engine weight (kg)	187
Knock control	Yes
Engine management	MSD80
Emission compliancy (US)	ULEV 2
Injection system type	HPI (DI 2)

Power Output Comparison (N52 to N54)



N52KP Overview

The enhanced and improved version of the original N52 is referred to as the N52KP or more accurately the N52B30O1. This engine includes cost saving measures as well as various technical improvements. The N52KP will eventually replace the N52 in all vehicle applications. One of the first vehicles to use the N52KP will be the 328i coupe (E92) in September.

The technical highlights of the N52KP include:

- New engine management (MSV80)
- New HFM (digital)
- New throttle - EGAS8 with magnetoresistive position feedback
- Plastic valve cover with integrated crankcase vent valve and oil separation
- Stronger connecting rods
- Exhaust valve stem increased to 6mm
- New electric water pump (2nd generation)
- Lightweight camshafts (hydroformed)

The N52KP will be available in three versions as follows:

- N52B30O1 - High Output version with 260hp
- N52B30M1 - Medium Output version with 230hp
- N52B30U1 - Possible future application with 215hp

Each of the above engines will have a different specific output for installation into various models. For example, the new E83 LCI (X3 3.0si) will receive the "O" version which has a power output of 260 horsepower at 6600 RPM.

Technical Data (N52B30M1)

Description	Value
Engine type	Inline 6 cylinder
Displacement (cm^3)	2996
Stroke/bore (mm)	88/85
Cylinder spacing (mm)	91
Firing order	1-5-3-6-2-4
Power output(kw/bhp) @ RPM	172/230 @ 6250 RPM
Torque (Nm) @RPM	270 @ 3000
Maximum engine speed	7000
Compression ratio	10.7
Valves/cyl	4
Knock control	Yes
Engine management	MSV80
Emission compliancy (US)	ULEV 2
Injection system type	Manifold injection

N51 Overview

In order to comply with SULEV requirements, the N51 is another variant of the N52 engine. There are various measures to meet the EPA/CARB standards, some of which are familiar from the previous SULEV (M56) engine.

Some of the SULEV measures for the N51 include:

- Near engine catalyst with additional underbody catalyst
- Secondary air system
- Optimized combustion chamber geometry in cylinder head
- Modified piston crown for lower compression
- Plastic valve cover with integrated crankcase vent valve and separator (from N52KP)
- Stainless steel fuel lines with threaded connections
- Radiator with “Prem-air” coating
- Throttle system - EGAS08 carried over from N52KP
- Airbox with Activated carbon filter for EVAP control
- Purge system pipes are made from “optimized” plastic

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2007 Engine Technology

Initial Print Date: 09/06 Revision Date:

2007 Engine Technology

Model: All with 6-cylinder for 2007

Production: from 9/2006

OBJECTIVES

After completion of this module you will be able to:

- Understand the technology changes to the NG6 family
- Understand basic turbocharging principles
- Understand the basics of second generation of direct injection (HPI)

New Technology for 6-Cylinder Engines

In 2005, the first of the new generation 6-cylinder engines was introduced as the N52. The engine featured such innovations as a composite magnesium/aluminum engine block, electric coolant pump and Valvetronic for the first time on a 6-cylinder.

To further increase the power and efficiency of this design, three new engines have been introduced for the 2007 model year. These engines are designated the N54 and the N52 K. The third engine, the N51, will be also be brought to the market to meet the SULEV II requirements in the required states.

The N54 engine is the first turbocharged powerplant in the US market. In addition to turbocharging, the N54 features second generation direct injection and Bi-VANOS.

The N52K (N52KP) engine is the naturally aspirated version of the new 6-cylinder engines. The "K" designation indicates that there are various efficiency and cost optimization measures. This engine can also be referred to as the "KP" engine.

The measures include new optimized components such as the consolidation of various items such as the crankcase ventilation system into the cylinder head cover.

The N51 engine is introduced to comply with SULEV II requirements. The N51 features much of the same measures and technology as the previous SULEV engine, the M56.

This training module discusses the latest 6-cylinder technology including Direct Injection and turbocharging.

Turbocharging

As far as gasoline engines are concerned, turbocharging has not been in widespread use at BMW. As a matter of fact, the last turbocharged BMW production vehicle was the E23 (745) which was not officially imported into the US. The previous “turbo” model before that was the legendary 2002 tii turbo in the early 1970’s. This 2002 tii turbo was also not officially imported into the US.

Until now, BMW has built a reputation for building high performance engines which are naturally aspirated. Much research has gone into the development of an efficient engine design which meets not only the expectations of the customer, but complies with all of the current emissions legislation.

Currently, the global focus has been centered around the use of alternative fuels and various hybrid designs. While BMW recognizes these concerns, there is still much development to be done on the internal combustion engine. Therefore, at least for the time being, BMW will continue to build the some of best internal combustion engines in the world.

Turbocharging Terminology

An engine which does not use any form of “forced induction” is referred to as a “naturally aspirated” engine. This means that the air which is entering the engine is at atmospheric pressure. Atmospheric air enters the engine due to the low pressure created during the intake stroke.

An engine which uses “forced induction” is referred to as supercharged. This means that the air entering the engine is under pressure (above atmospheric). As far as terminology is concerned, supercharging is the broad term for this type of technology.

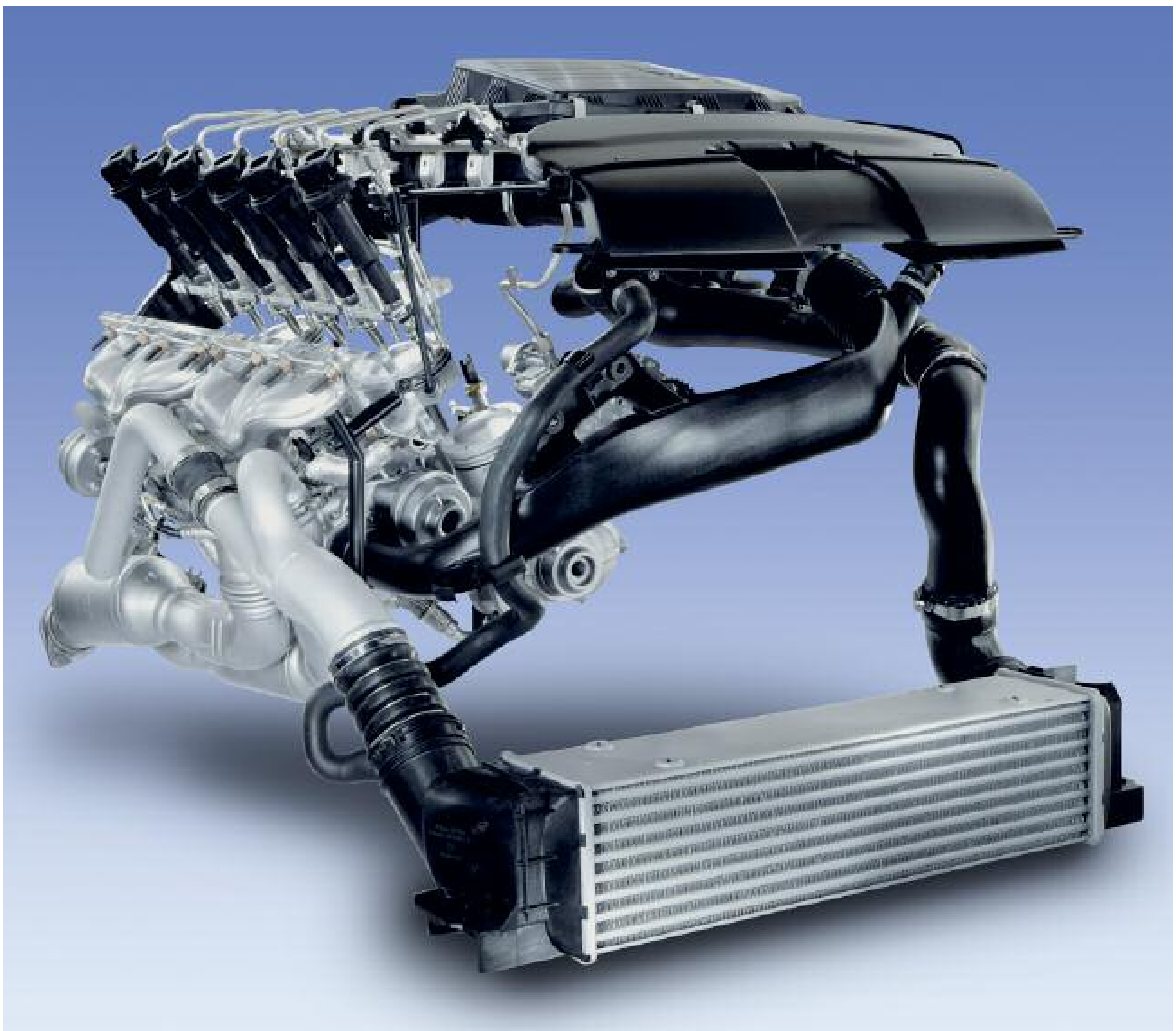
Supercharging can be broken down into two categories, those engines which use a mechanical supercharger and those which use an exhaust driven supercharger. Today, BMW is only using turbochargers, which are exhaust driven.

Basic Principles of Turbocharging

In order to make an engine more efficient. it is necessary to ensure an adequate supply of air and fuel on the intake stroke. This mixture can then be compressed and ignited to create the desired engine power output. A normally aspirated engine relies on the basic principle of gas exchange without the use of forced induction.

The volumetric efficiency refers to the ratio between the theoretical cylinder volume and the actual amount of air (and fuel) filling the cylinder during the intake stroke. A naturally aspirated engine has a volumetric efficiency of between .6 and .9 (60-90%). With the turbocharged engine, volumetric efficiency can peak at over 100%.

A turbocharger is driven by waste (exhaust) gasses and in turn drives a compressor which forces air into the engine above atmospheric pressure. This increase pressure allows for an air charge with a greater density. The result is increased torque and horsepower.



The turbocharger consists of a turbine and compressor assembly (1) on a common shaft inside of the turbocharger housing. The turbine wheel is driven by waste exhaust gases and in turn drives the compressor wheel.

The compressor forces air into the intake manifold of the engine. The air entering the engine from the compressor is above atmospheric pressure. The increased atmospheric pressure allows for an air-charge that is more dense and therefore contains more oxygen.

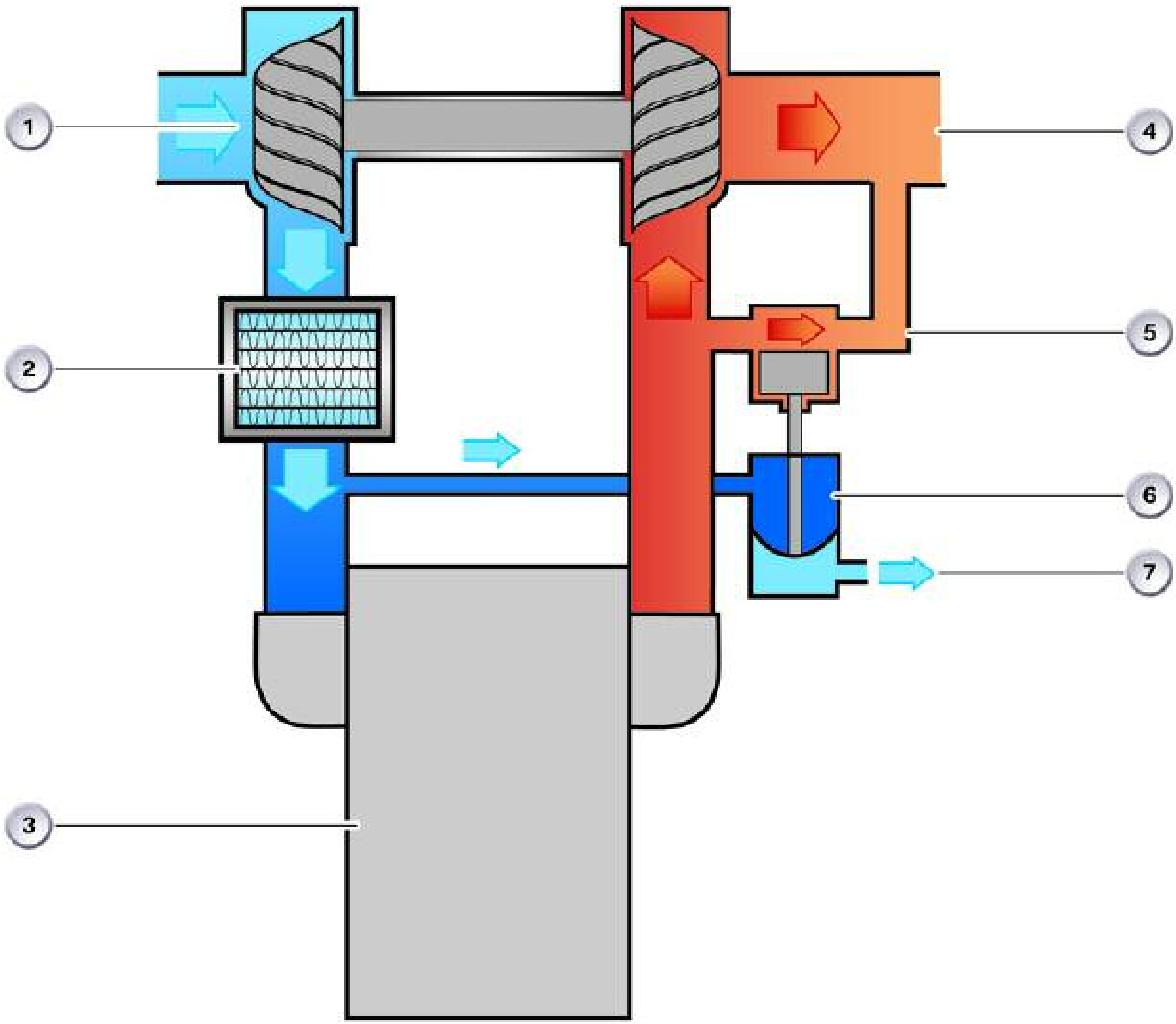
This increased density during the intake stroke ultimately adds up to the creation of more engine output torque. Of course, this increased density much be accompanied by additional fuel to create the desired power. This is accomplished by engine management system programming to increase injector “on-time” and enhance associated maps.

To prevent the turbocharger from providing too much boost, a “wastegate” (6) is added to allow exhaust to bypass the turbine. This provides a means on control for the turbocharger system. The wastegate is actuated usually via a vacuum diaphragm (6) which is controlled via vacuum fed from solenoids. These solenoids are usually controlled via the engine management system.

Once the intake air is compressed, it is also heated which is not desirable for maximum efficiency. To combat this situation a heat exchanger (2) is added between the compressor and the engine intake. This heat exchanger is commonly referred to as an intercooler. The intercooler is usually an air-to-air heat exchanger which is installed in the air stream ahead of the radiator. The intercooler lowers the intake air charge to achieve the maximum density possible.

The use of an exhaust driven turbocharger is used to create more engine power through increased efficiency. In the case of the new N54 engine, the turbocharger is used in conjunction with direct fuel injection. This provides the best combination of efficiency and power with no compromise.

For more information on the N54 bi-turbocharging system, refer to the training module “2007 Engine Management”.



Index	Explanation	Index	Explanation
1	Compressor and turbine wheel (on common shaft)	5	Exhaust bypass from wastegate
2	Charge air cooler (intercooler)	6	Wastegate (and diaphragm)
3	Engine	7	Vacuum control for wastegate diaphragm
4	Exhaust outlet from turbine housing		

Direct Injection

The term “direct injection” refers to a fuel injection system which injects fuel directly into the combustion chamber rather than into the intake manifold. This technology has been around since the 1930’s, but has not been in widespread use until the late 20th century.

The early development of this type of injection system took place in Germany in 1937 on an aircraft engine. The first passenger car to run on direct engine was a car called the “Gutbrod” in 1952.

Due to the complexity and cost of the direct injection system, the technology did not take hold. Later, the development of more cost efficient components and the need for a more efficient internal combustion engine, the DI engine made a comeback in the late 1990’s.

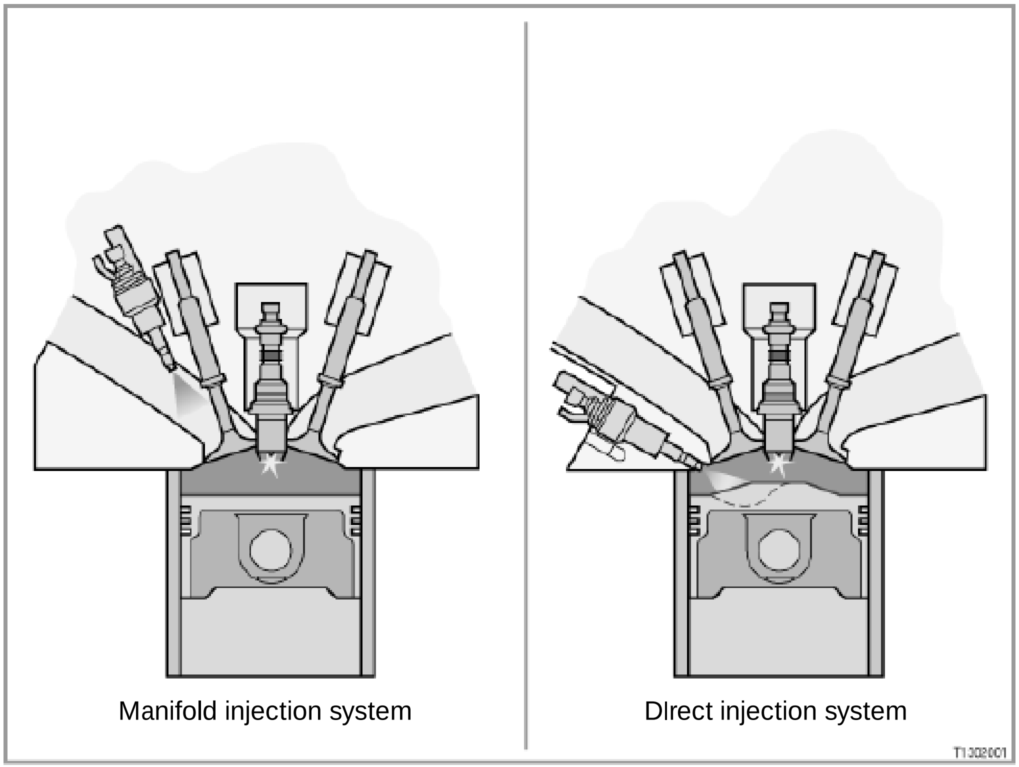
The first application of this technology on a BMW was in 2003 on the 760Li. The new N73 V-12 engine utilized direct injection with the combination of Valvetronic and the latest direct injection technology.

For the 2007 model year, BMW has introduced a new 6-cylinder engine with direct fuel injection. The N54, which is turbocharged, uses the second generation of direct injection (DI 2), which is referred to as High Precision Injection (HPI).

Direct Injection Principles

As the name suggest, the direct injection (DI) system use a fuel injector which sprays fuel directly into the combustion chamber. The fuel injection pressure (N73) is from 80 to 120 bar. The A/F mixture in a DI engine is formed inside of the combustion chamber.

In comparison, a manifold injection system sprays fuel into the intake manifold or into the intake port near the intake valve. In this case, the A/F mixture is formed outside of the combustion chamber. The injection pressure on most manifold injection systems is between 3 and 5 bar.



The DI system allows for increased engine efficiency and has several distinct advantages over manifold injection systems:

- The fuel is evaporated and atomized in the combustion chamber, which provides a “cooling effect” on combustion. A cooler combustion chamber allows an increase in air density, which allows for more available oxygen. In addition, cooler combustion allows for an increase in compression ratio which equates to improved efficiency and engine power.
- By injecting the fuel directly into the combustion chamber, there is less possibility for fuel to condense or accumulate on the manifold walls or the back of the intake valve. This results in less fuel needed to achieve the desired A/F ratio.
- The increased injection pressure causes the fuel droplet size to be reduced. This allows for improved atomization and therefore improved mixture formation.

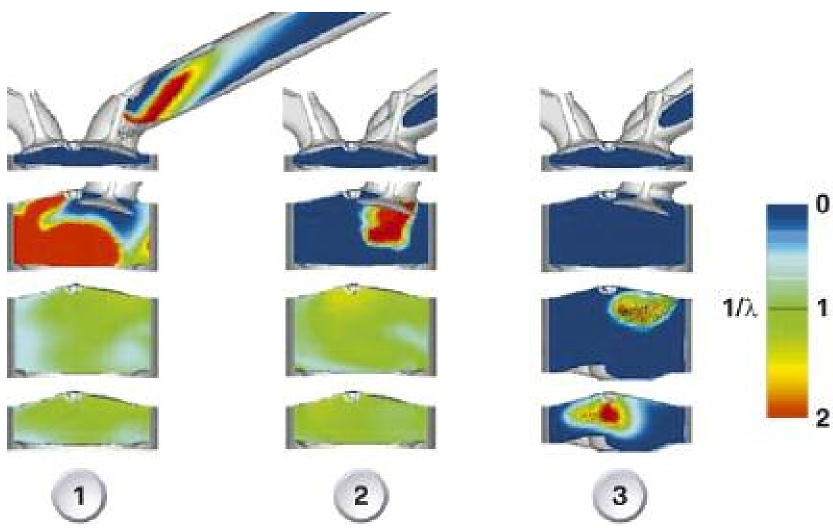
Mixture Formation

In a conventional (manifold injection) engine, the air fuel mixture is formed outside of the combustion chamber. In contrast, the mixture must be formed inside the combustion chamber in a DI engine.

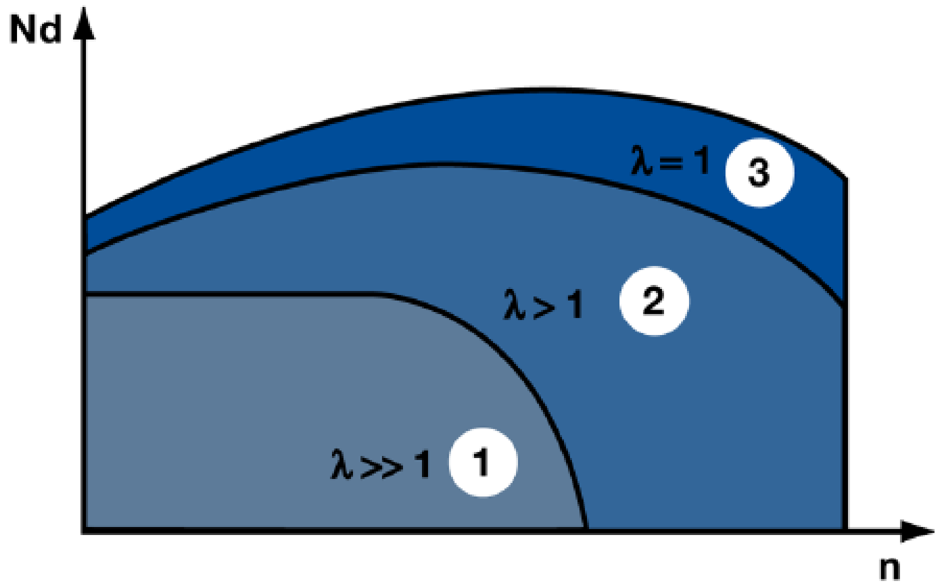
A DI fuel system has two basic operating concepts:

- Homogeneous Mixture Formation - A homogeneous mixture means that the A/F ratio is stoichiometrically controlled much in the same way as a manifold injection system. This means that the A/F mixture is evenly spread throughout the combustion chamber. One of the primary advantages of this arrangement is that a conventional three-way catalytic converter can be used. Also, the sulfur content of the fuel is not a factor which allows the engine to be used in all global markets. Currently, BMW only uses engines which operate in this mode. The N73 and N54 both operate mostly at Lambda = 1.

- Stratified Mixture Formation - In the stratified injection method, a homogeneous mixture is only created around the area of the spark plug. A lean (inhomogeneous) mixture exists in the rest on the combustion chamber. Therefore the overall A/F mixture in the combustion chamber is lean (lambda > 1). This results in increased combustion chamber temperature, and subsequently increased NO_x emissions. The increased NO_x requires the use of a $DeNO_x$ catalyst which is not effective when sulfur is present in the fuel. Therefore, sulfur free fuel must be used which is not readily available in all markets. For the time being, BMW does not have any engines which operate as “stratified charge” engines.



Index	Explanation
1	Manifold injection
2	Homogeneous direct injection
3	Stratified direct injection



Index	Explanation
1	Lean, charge stratification
2	Lean, homogeneous
3	Homogeneous
Nd	Engine torque
n	Engine speed

As the above chart shows, the use of load stratification (1) is only possible in a limited load and speed range. Over and above this load and speed range, the engines can only be operated in homogeneous mode (2-3).

Through the deployment of Valvetronic, the N73 engine in the middle torque/speed range (1) demonstrates the same consumption advantages as engines of other manufacturers with charge stratification.

Because large-capacity engines are mainly operated in the lower to middle load and speed range, it is only advisable to use load stratification in these engines.

Smaller-sized engines are mainly operated in the high load and speed range and thus in homogeneous mode.

Both the N73 and N54 engines operate mostly in the homogeneous mode with a lambda value of 1. In the US market, BMW does not use a "stratified charge" engine due to the fact that these engines emit high NO_x levels.

High Precision Injection

The new BMW High Precision Injection (HPI) is the latest development of BMW direct fuel injection. This is the second generation of of direct injection (DI 2) for BMW. The first generation was on the N73 engine in 2003.

The term “high precision” refers to the precise metering and directional control of the atomized fuel. Also, the injection process now allows for multiple injection events due to the use of piezo injectors. The HPI system represents a key function in the concept for the most economical use of fuel without compromising performance.

High precision injection allows for a more precise metering of the fuel injection process and therefore permits a higher compression ratio of 10.2 to 1. This compression ratio is quite high considering the N54 is turbocharged. However, the “spray guided” injection process cools the air charge and decreases the possibility of unwanted engine knock. The operating pressure of the HPI system is up to 200 bar.

For more information on HPI, refer to the training module “2007 Engine Management”.

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2007 Engine Mechanical

Initial Print Date: 09/06 Revision Date:

2007 Engine Mechanical

Model: All 2007 with 6-Cylinder

Production: from 9/2006

OBJECTIVES

After completion of this module you will be able to:

- Understand the basic mechanical features of the N54, N52KP and N51
- Understand the differences between the N54 and N52

Engine Construction

Of the three new 6-cylinder engines for 2007, the N54 has perhaps the most changes in comparison with the N52. Beginning with the crankcase, the N54 engine uses an all aluminum alloy block with cast cylinder liners. The aluminum crankcase is pressure cast and differs from the “insert” design of the N52. This design is in contrast to the previous composite magnesium/aluminum crankcase on the N52. The construction of the N54 crankcase is to accommodate the increased torque output of the turbocharged N54.

Dimensionally, the N54 crankcase is the same as the N52 and continues to use the 2-piece crankcase with bedplate. There are some slight differences regarding the bolt pattern for the transmission mounting. This requires a new engine mounting bracket when installing on to the engine stand.

All aluminum (AL226 alloy) crankcase - N54

The crankshaft is forged steel on the N54 engine. The crankshaft on the N52KP and N51 engines remains cast iron as on the original N52.

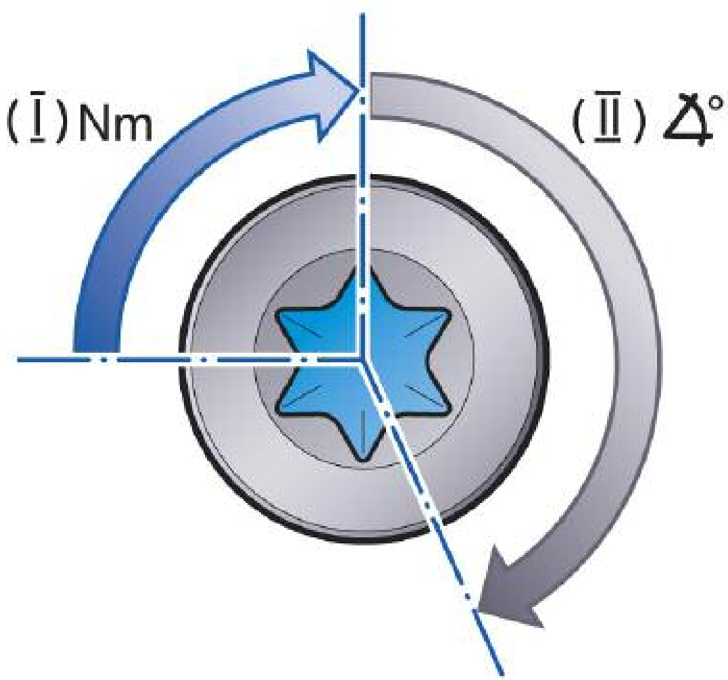
Engine Mechanical Changes

Bolts

As with the N52, the N54 continues to use the aluminum bolts for most fastening duties. Even though the N54 is an all aluminum crankcase, the aluminum bolts are used to reduce any confusion. This decreases the possibility of any incorrectly installed bolts of the wrong material (steel vs. aluminum). Of course, the N52KP and N51 still retains the use of aluminum bolts as well.

The same rules apply to the handling and installation of aluminum bolts as in the past. Strict adherence to repair instructions is required to ensure proper connections.

Be sure to use the proper torque/tightening angle sequence as indicated in the "tightening torques" section of TIS.



Cylinder Head Cover
The cylinder head covers on all of the new engines have changed. While the N52 uses a magnesium cylinder head cover, the new engines use a plastic cover. The N52KP and N51 use the same basic design to accommodate the VVT motor and new crankcase ventilation system. In comparison, the N54 uses a completely different design. This is due to the lack of Valvetronic and the modified crankcase ventilation system.

The bolts that secure the cylinder head cover are steel.

Cylinder Head

As far as the cylinder head designs are concerned, all three of the new engines use a different cylinder head. While all of the heads are made from aluminum, they differ due to the design requirements. For example, the N54 does not use Valvetronic and requires accommodation for the fuel injectors for direct injection. The N52KP engine uses a cylinder head which is mostly identical to the N52. The N51, which is a SULEV II design, uses a lower compression ratio and therefore a different cylinder head with a modified combustion chamber.

Cross-section of N54 Cylinder Head

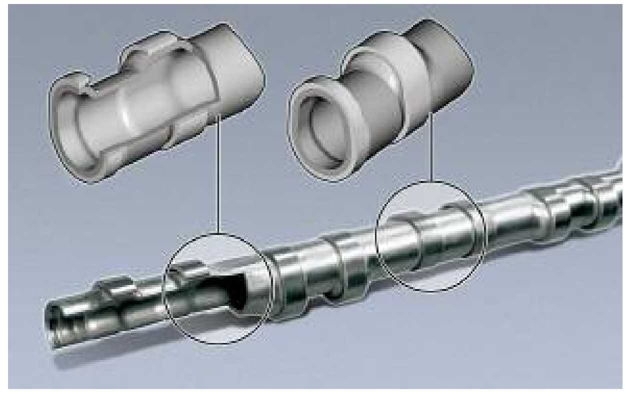
Valvetrain

With regard to the valvetrain changes, the intake valves still use the 5mm stem from the N52. However, the exhaust valves have been upgraded to a 6mm valve stem for increased durability. The 6mm exhaust stem has also been in production on the current N52 since 3/06.

The valves have solid construction and the valve head diameters are engine specific.

Camshafts

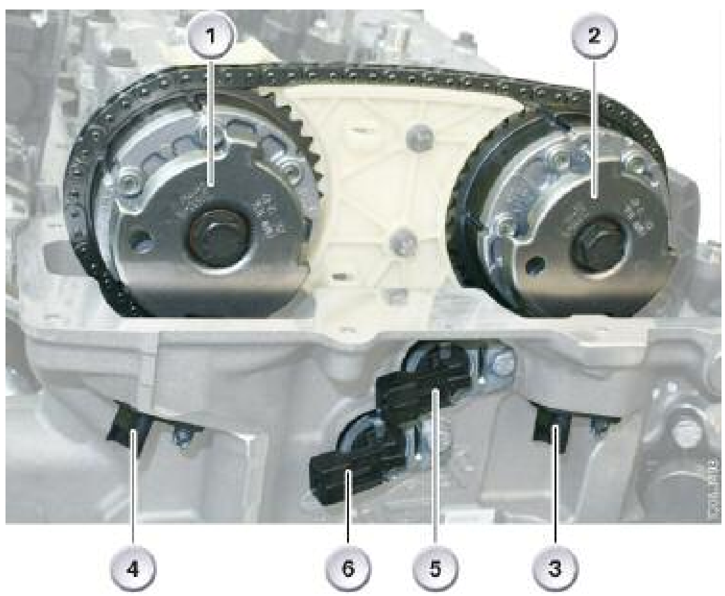
All of the new engine variants will take advantage of the lightweight, hydroformed camshafts from the N52. For supply and production reasons, it is possible that some engines may be fitted with cast camshafts.



Consequently, it is possible to interchange these camshafts with no problem. Cast camshafts and hydroformed camshafts can be fitted as replacement parts. It is even possible to have cast and hydroformed camshafts on the same engine as well.

VANOS

The infinitely variable double VANOS system is still in use on all NG6 engines. The system still retains the use of the lightweight VANOS units from the N52. The only change to the system is that the N54 uses different spread ranges as compared to the other engines (N52, N52KP and N51). As with the previous systems, the VANOS units should not be mixed up as the spread ranges for the intake and exhaust are different and engine damage could result.



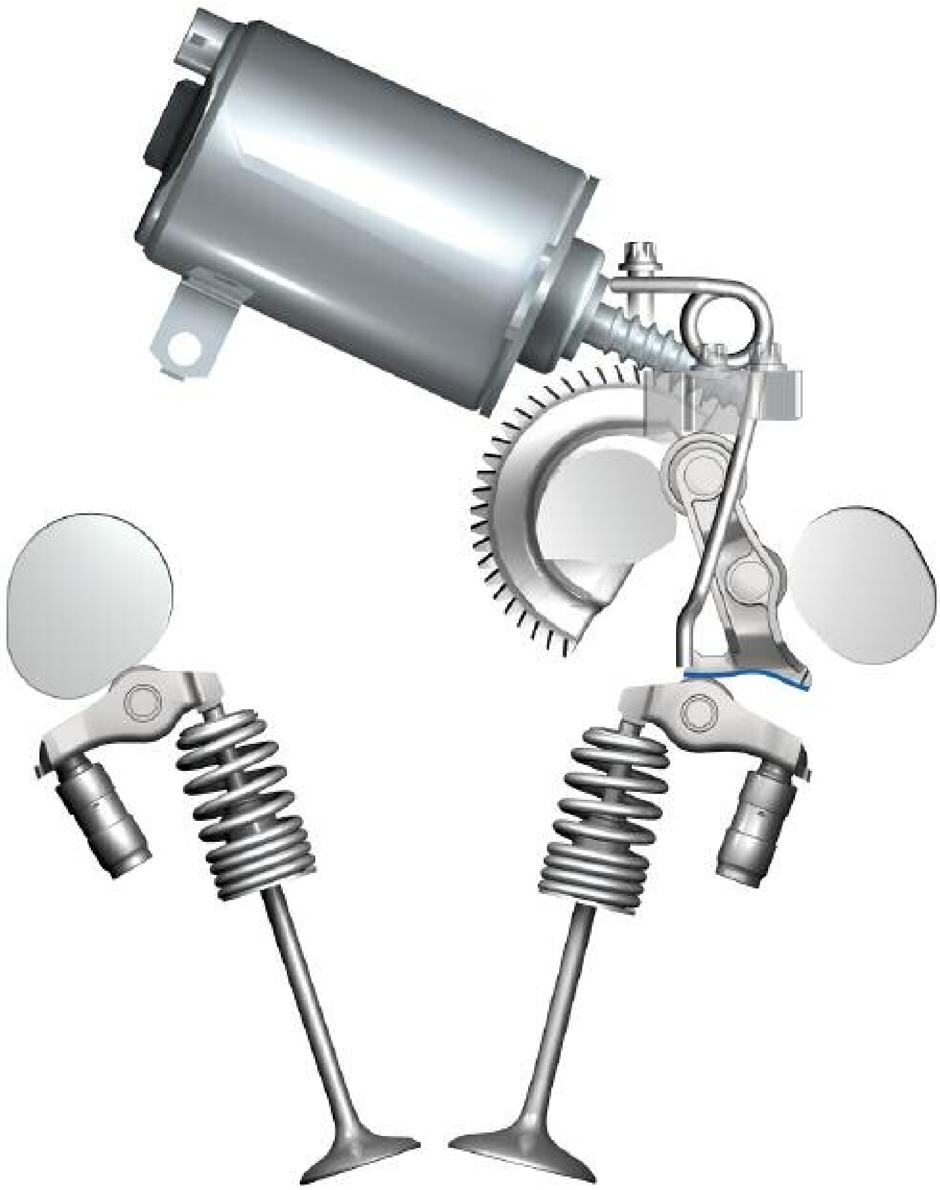
Index	Explanation	Index	Explanation
1	VANOS unit, Exhaust	4	Exhaust camshaft sensor
2	VANOS unit, intake	5	VANOS solenoid valve
3	Intake camshaft sensor	6	VANOS solenoid valve

Valvetronic

The N52KP and N51 retain the already proven Valvetronic system. The only changes to the system for 2007 is an optimized VVT motor.

On the other hand, the N54 engine does **NOT** use Valvetronic. This is due to the fact that the Valvetronic system is designed to reduce pumping losses. It is a system which improves volumetric efficiency by optimizing the air charge.

A turbocharger system is also designed to increase volumetric efficiency by reducing pumping losses. Therefore, there is no need for both of these systems to be employed on the same engine. The N54 gains maximum efficiency by the use of turbocharging and direct injection.



Gaskets and Seals

The gasket design on the new engines is mostly similar to the N52. The N54 uses a specific head gasket for use with the turbocharged application. The head gasket is a multi-layered design which does not have the protruding lip as on the N52. This lip is not needed due to the fact that the cylinder head is aluminum and contact corrosion is not an issue.

The split crankcase still uses the injected sealant carried over from the N52.

Piston and Connecting Rods

As with the cylinder head, the piston designs differ between engines. The N54 uses a special piston for compatibility with the direct injection system. The piston crown is modified to meet the mixture formation requirements.

The N51 engine uses a lower compression ratio and accordingly uses a different piston design. The N52KP uses the same design as the N52 engine.

The connecting rods on all of the NG6 engines have been stiffened with a thicker beam on the rod. This design has also been in production on the N52 since 6/06.

Crankshaft

The cast iron crankshaft is retained for the N52KP and N51. To accommodate the increased power output of the N54, the crankshaft is forged steel.

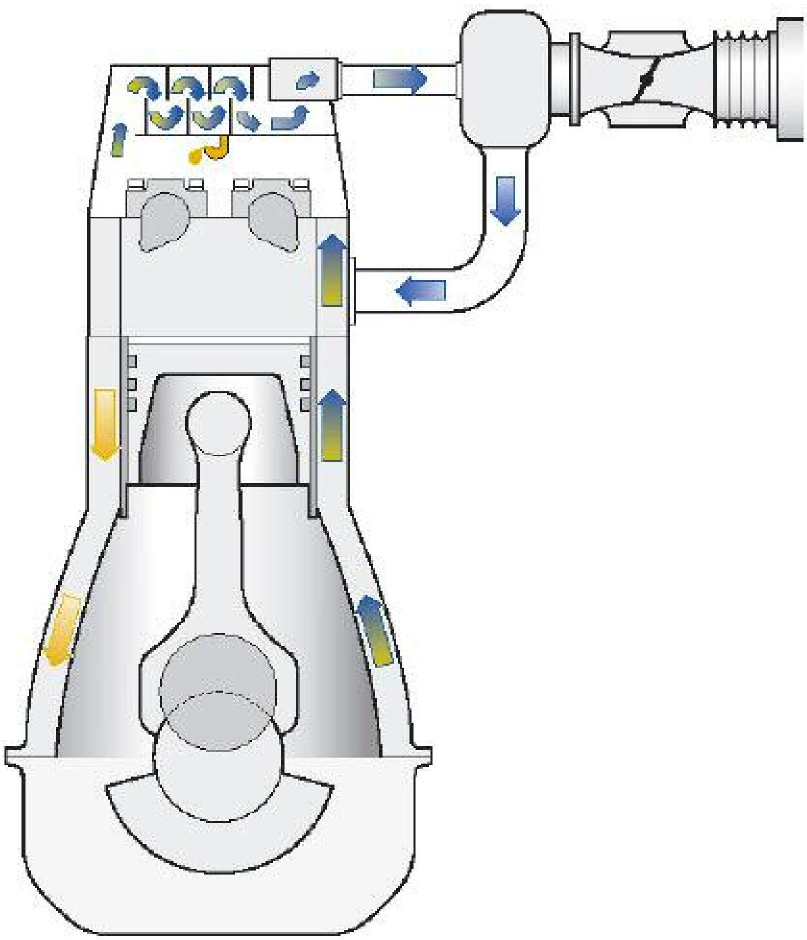
Torsional Vibration Damper

The torsional vibration damper has need optimized to improve damping of first order vibrations. The damper is secured with new bolts and the tightening procedure has been changed. These procedures should not be confused with the N52 as damage to the belt drive could result.

Crankcase Ventilation

There are two basic methods for ventilating the crankcase which have been in use a BMW engines. One of the methods uses a crankcase ventilation valve and the other does not. In either case, the crankcase vapors must be metered into the intake and the oil must be separated from the vapors.

The basic crankcase ventilation system is shown below. It features the “labyrinth” method of oil separation which uses a maze of channels to divide the crankcase vapor from the liquid oil. The vapors can enter the engine through a “calibrated” orifice, while to liquid oil returns back into the engine or oil sump.



In the case of the three new NG6 engines, there are two methods employed. The N54 engine does not use a crankcase ventilation valve and oil is separated using the “cyclonic method”.

The N52KP and N51 engines use a crankcase ventilation valve and the “labyrinth” method of oil separation.

N54 Crankcase Ventilation

The crankcase ventilation system on the N54 engine is unique due to the fact that this is a turbocharged engine. This means the the intake manifold pressure will be higher than that of a naturally aspirated engine. This presents new challenges regarding the design of the crankcase ventilation system.

The basic description of the system is as follows:

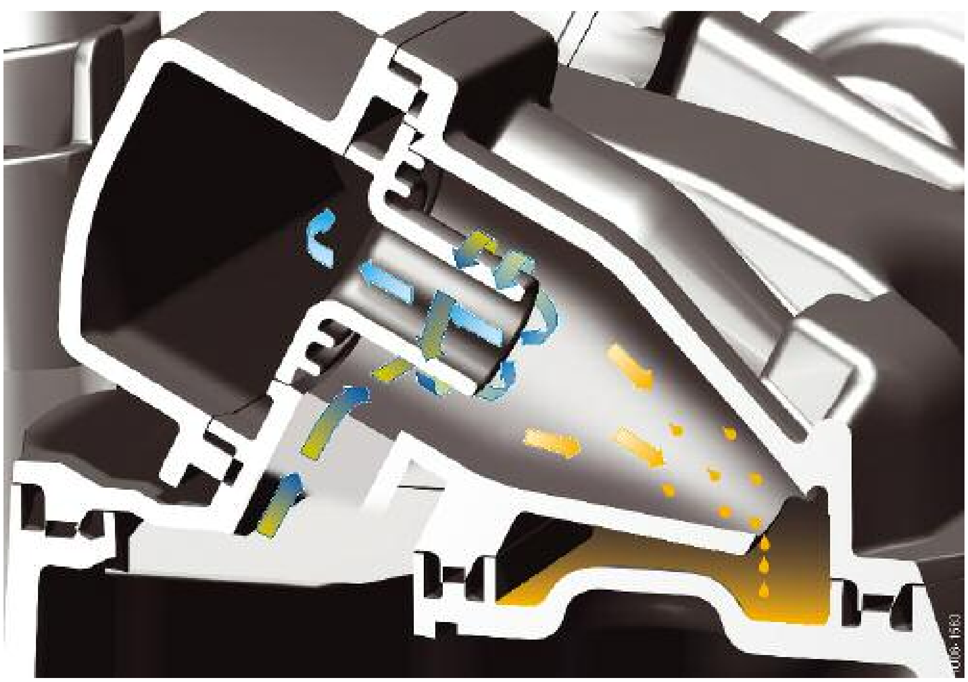
- The system uses a calibrated orifice to meter crankcase vapors into the engine
- Liquid oil is separated from the crankcase vapors is done by “cyclonic” action
- There are 2 channels for crankcase vapors depending upon the manifold pressure
- Most of the system components are integrated into the cylinder head cover

One of the most important features is the fact that most of the system components are integrated into the plastic cylinder head cover. This allows engine heat to warm the crankcase vapors which prevents any potential freezing of any water vapor trapped in the system. In contrast to the N52, there is only one heating element located at the intake manifold inlet.

Cyclone Separator

A cyclone oil separator is used in the N54 engine. Here, four of the described cyclones are integrated into the oil-separator housing. The oil mist drawn in from the crankcase is set into a spinning motion in the cyclone. As a result of the centrifugal forces, the heavier oil settles on the cyclone walls and from there drips into the oil drain.

The lighter blow-by gases are sucked out from the middle of the cyclone. The purified blow-by gases are then fed to the air-intake system.



Crankcase Ventilation System Function

The crankcase ventilation system of the N54 must be capable of venting the crankcase during two different modes of engine operation. When the engine is in deceleration, the intake manifold pressure is low (high vacuum). During acceleration or idling, the intake manifold pressure is higher (low vacuum). Therefore the system operates differently in these modes. This is what is unique about the crankcase venting system on the N54.

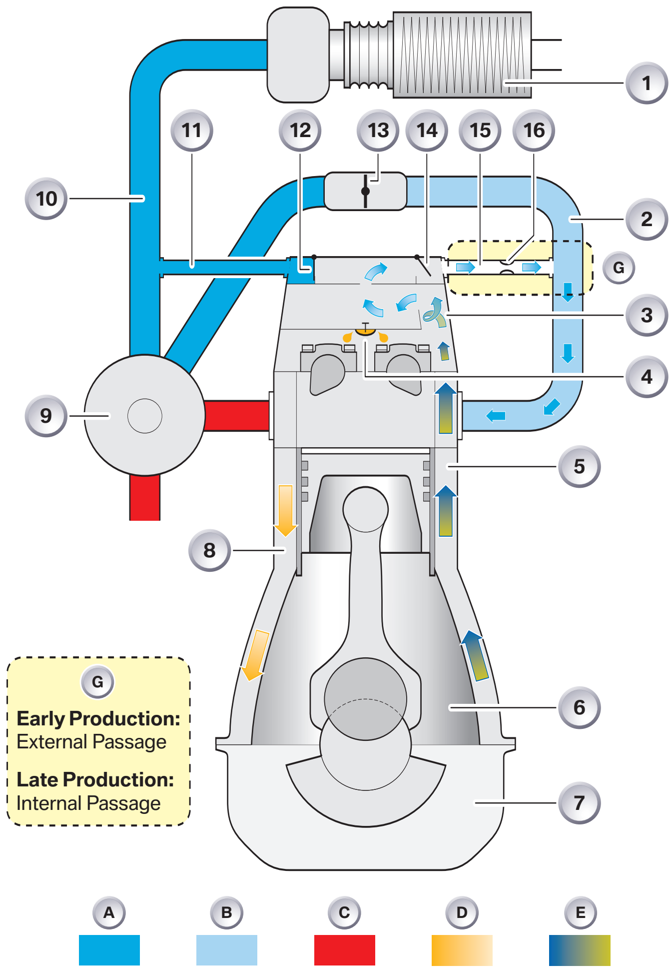
Index	Explanation	Index	Explanation
1	Check valve, charge air suction line	3	Check valve, manifold and pressure restrictor
2	Ventilation, turbocharged operation	4	Ventilation, naturally aspirated mode (decel)

Operation with Low Manifold Pressure

When the engine has low manifold pressure such as in decel, the crankcase vapors are routed through a channel (15) between the cylinder head cover and intake manifold. The liquid oil is separated before the channel in the cyclonic separators (3) in the cylinder head cover. The liquid oil returns to the engine via the oil discharge valve (4).

The channel contains a pressure restrictor (16) which regulates the flow of crankcase vapors. During deceleration, the crankcase vapors (E) are directed via a check valve (14) which is located in the cylinder head cover. The check valve is opened when low pressure is present in the intake manifold (throttle closed).

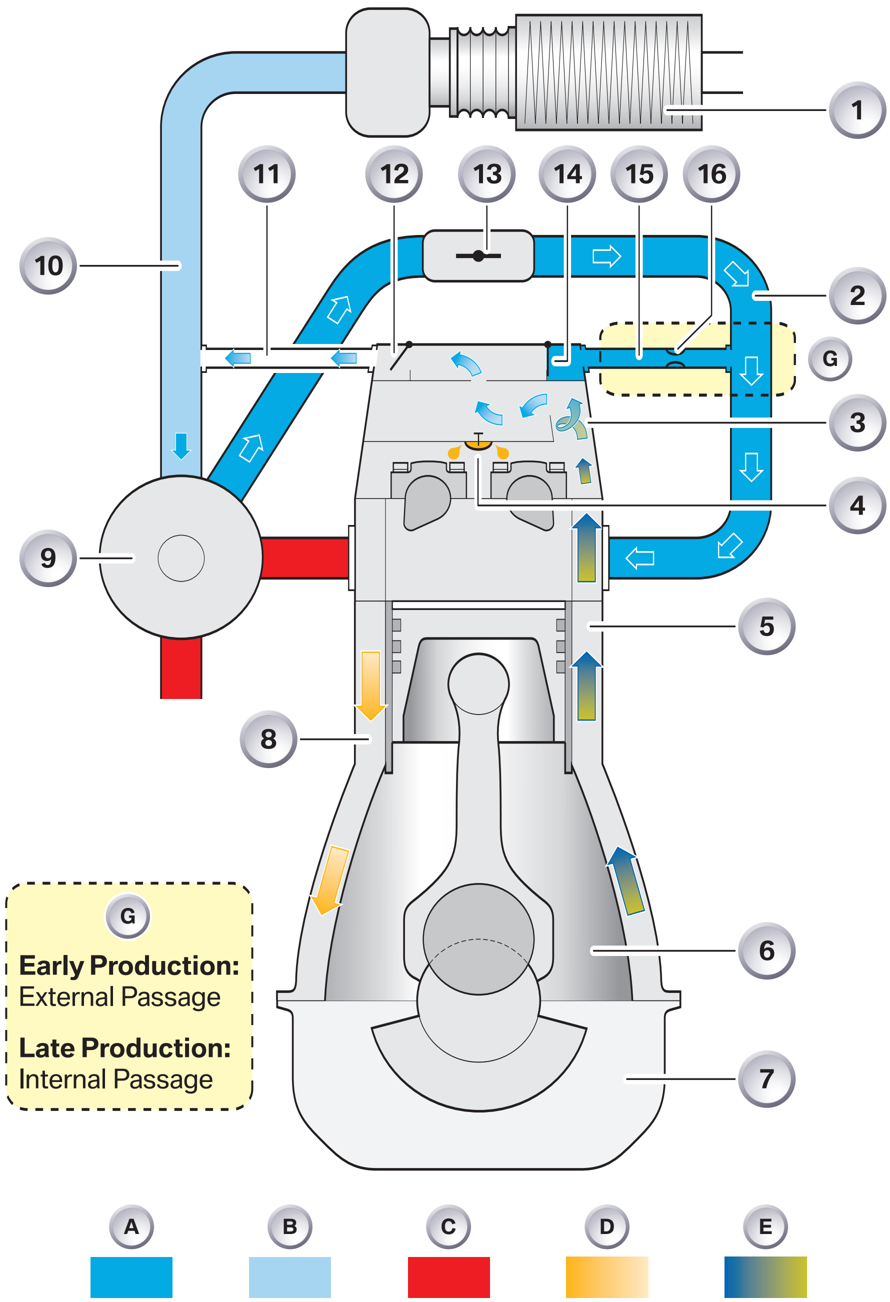
Also, a PTC heater has been integrated into the intake manifold inlet. The inlet pipe is connected to the channel (15) and prevent any moisture from freezing at the inlet.



Index	Explanation	Index	Explanation
A	Overpressure	7	Oil sump
B	Low Pressure (Vacuum)	8	Oil return channel
C	Exhaust gas	9	Turbocharger
D	Liquid oil	10	Charge air suction line, bank 2
E	Blow-by gases (Crankcase vapors)	11	Hose to charge air suction line, bank 2
1	Air cleaner	12	Check valve, manifold
2	Intake manifold	13	Throttle valve
3	Cyclone separators	14	Check valve, charge air suction line
4	Oil discharge valve	15	Channel to intake manifold
5	Venting channel	16	Pressure restrictor
6	Crankshaft cavity		

Operation with High Manifold Pressure

When in turbocharged mode, the pressure in the intake manifold increases and then closes the check valve (14). Now, a low pressure is present in the charge air suction line (10). This causes a low pressure in the hose (11) leading to the manifold check valve (12). The crankcase vapors (after separation) are directed through the check valve (12) into the charge air suction line (10) and ultimately back into the engine. The check valve (12) also prevent boost pressure from entering the crankcase when the intake manifold pressure is high.



Index	Explanation	Index	Explanation
A	Overpressure	7	Oil sump
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3	Cyclone separators	14	Check valve, charge air suction line
4	Oil discharge valve	15	Channel to intake manifold
5	Venting channel	16	Pressure restrictor
6	Crankshaft cavity		

Note: Be aware that any check valve failure could cause excessive oil consumption possibly accompanied by blue smoke from the exhaust. This should not be mistaken for a failed turbocharger. Always perform a complete diagnosis of the crankcase ventilation system, before replacing any turbocharger or associated components.

Crankcase Ventilation N52KP and N51

The crankcase ventilation system on the N52KP and N51 uses a crankcase ventilation valve which is incorporated into the cylinder head cover. Oil is separated via an internal labyrinth which is also incorporated into the cylinder head cover.

This system, like the N54, also benefits from the integral components. This design allows engine heat to warm the crankcase vapors which decreases the likelihood of any moisture freezing in the system during conditions of low ambient temperature.

NOTES PAGE

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2007 Engine Management

Initial Print Date: 09/06 Revision Date:

Subject **Page**

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2007 Engine Management

Model: All with 6-Cylinder for 2007

Production: from 9/2006

OBJECTIVES

After completion of this module you will be able to:

- Describe the changes to the new engine management systems
- Understand the operation of the HPI system
- Understand parallel turbocharging
- Understand the N51 SULEV II engine features

NG6 Engine Management

To accompany the new NG6 engines, 2 new versions of engine management systems are introduced for 2007. Both systems are variations of the MSV70 engine management which is familiar from the N52 engine for 2006.

The two systems are as follows:

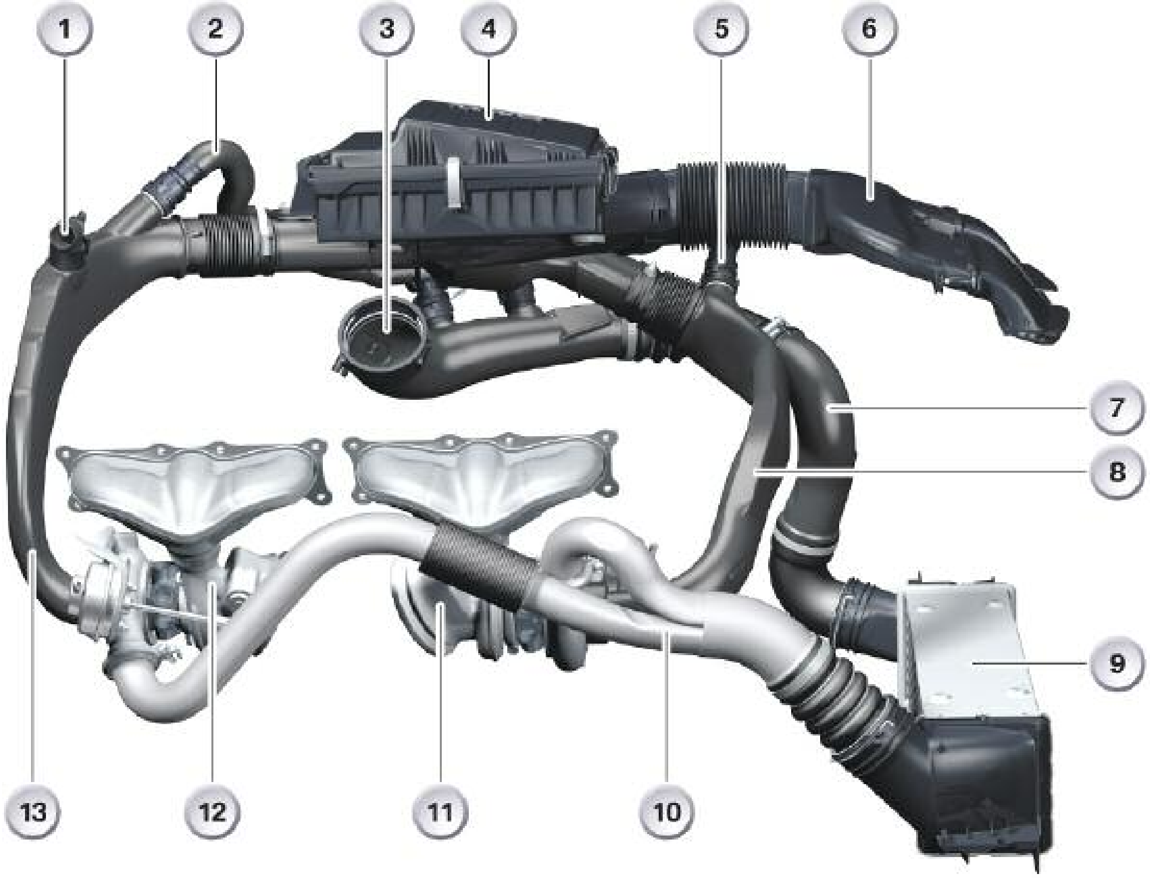
- MSV80 Engine Management for N52KP and N51 (SULEV II) engines
- MSD80 Engine Management for the N54 engine

Both systems use enhanced processing and are adapted to each of the specific engine applications. Both of the control modules are identical and adapted from MSV70.

The information contained within this training module is only intended to review the updates to the engine management systems as it applies to the N54, N52KP and N51 engines. For more detail on the NG 6 engines beginning with the N52, refer to the training module “ST501 - New Engine Technology”.

Air Management

With regard to the N54 engine, the air intake ducting plays a significant role due to the requirements for a turbocharged engine. In principle, the energy of the escaping exhaust gases is utilized to “precompress” the inducted fresh air and thus introduce a greater air mass into the combustion chamber. This is only possible if the air intake ducting is leak-free and installed properly.



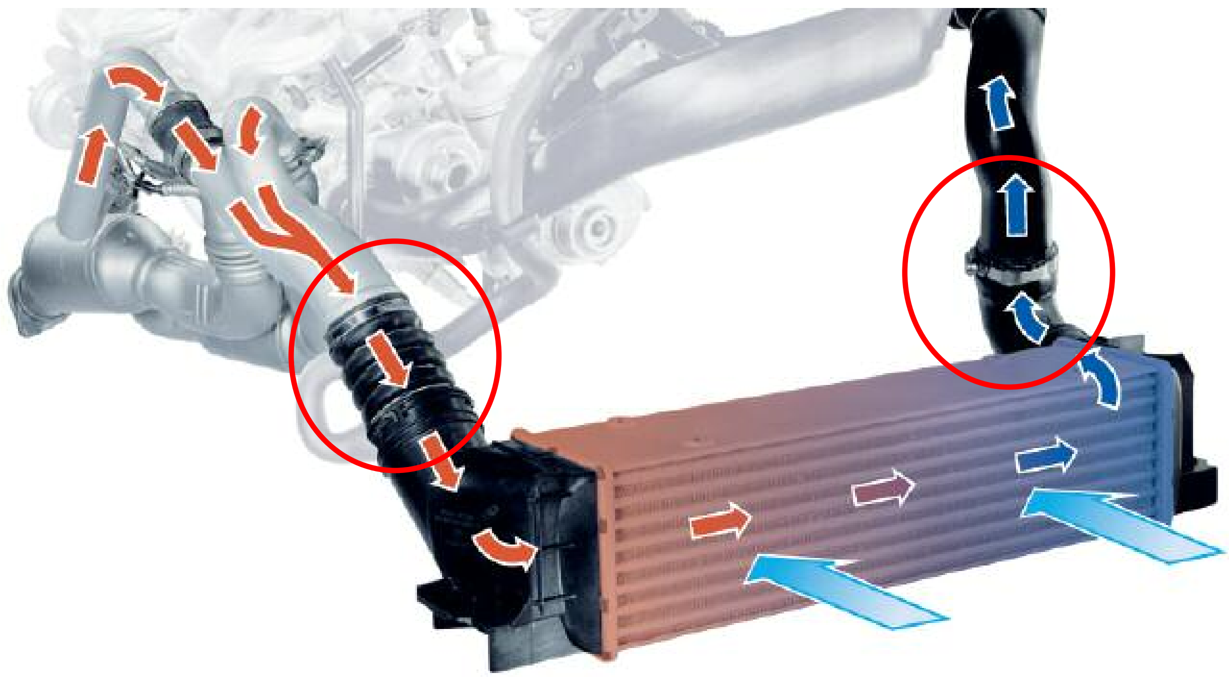
Index	Explanation	Index	Explanation
1	PTC heater, blow-by gases (in turbo mode)	8	Charge air suction line, bank 1
2	Recirculated air line, bank 2	9	Intercooler
3	Connecting flange, throttle valve	10	Charge air manifold
4	Air cleaner	11	Turbocharger, bank 1
5	Recirculated air line, bank 1	12	Turbocharger, bank 2
6	Air-intake snorkel	13	Charge air suction line, bank 2
7	Charge air pressure line		

It is important to note, when carrying out work on the air-intake ducting, it is very important to ensure that the components are installed in the correct positions and that all pipes are connected up with tight seals.

A leaking system may result in erroneous boost pressure. This would be detected by the engine management system and ultimately result in in "limp-home" operation. This would be accompanied by a noticeable loss of engine power.

For some of the connections, there are special tools designed to connect and disconnect some of the ducting to ensure proper "leak-free" connections.

Example of Intercooler Connections

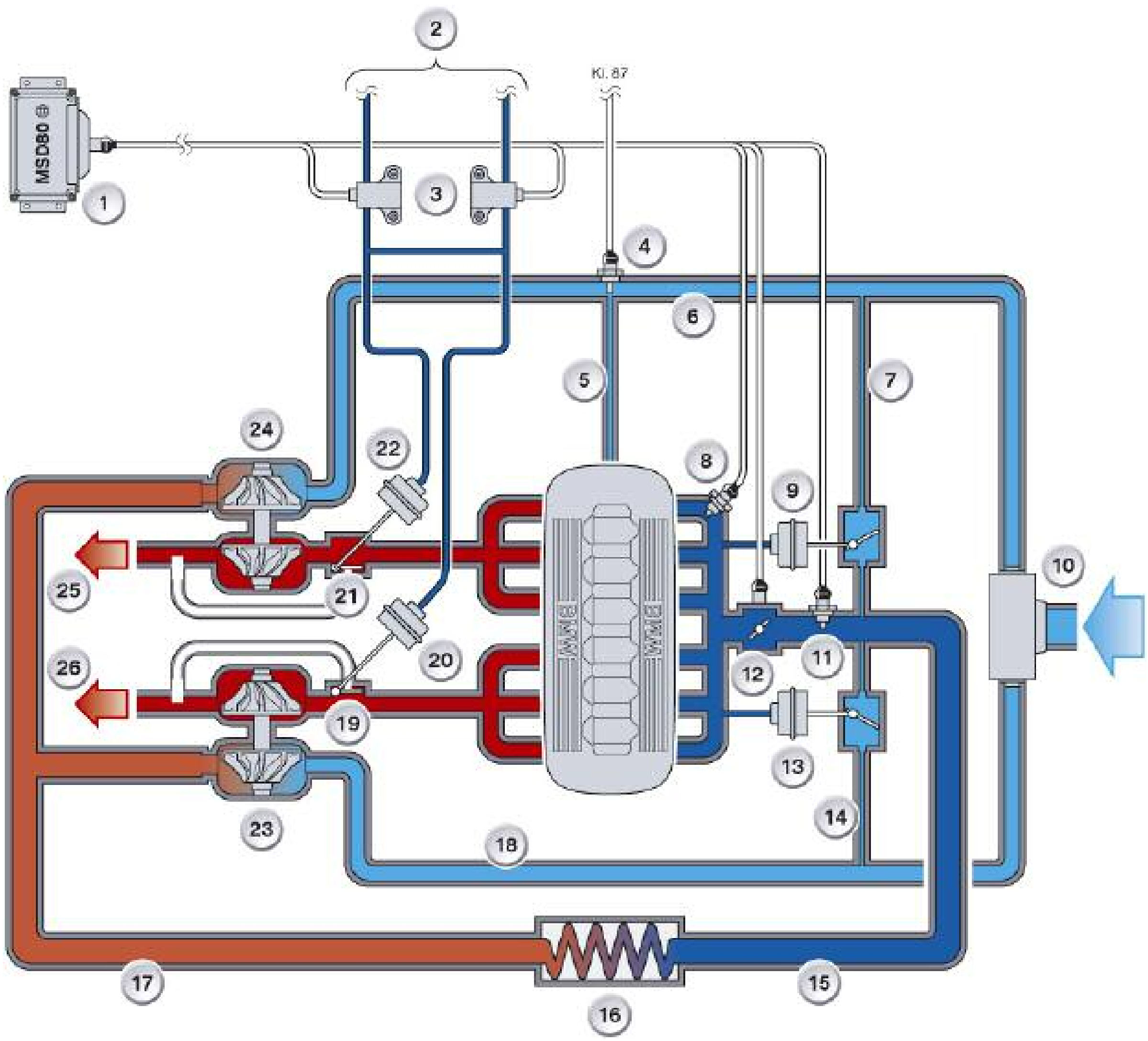


Air Ducting Overview

The fresh air is drawn in via the air cleaner (10) and the charge-air suction lines (6 + 18) by the compressors of turbochargers (23 + 24) and compressed.

Because the turbochargers can get very hot during operation, they are connected with the engine's coolant and engine-oil circuits. The charge air is greatly heated when compressed in the turbocharger, making it necessary for the air to be cooled again in an intercooler (16).

The compressed and cooled charge air is routed from the intercooler via the throttle valve (12) into the intake manifold. The system is equipped with several sensors and actuators in order to ensure that the load of fresh air is optimally adapted to the engine's respective operating conditions. How these complex interrelationships are controlled is discussed in the following.



Index	Explanation	Index	Explanation
1	MSD80 Engine control module	14	Recirculated-air line, bank 1
2	Lines to vacuum pump	15	Charge air pressure line
3	Electro-pneumatic pressure transducer	16	Intercooler
4	PTC heater, blow-by gases	17	Charge air manifold
5	Blow-by line turbocharged operation mode	18	Charge air suction line, bank 1
6	Charge air suction line, bank 2	19	Wastegate flap, bank 1
7	Recirculated-air line, bank 2	20	Wastegate actuator, bank 1
8	Intake manifold pressure sensor	21	Wastegate flap, bank 2
9	Blow-off valve, bank 2	22	Wastegate actuator, bank 2
10	Air cleaner	23	Turbocharger, bank 1
11	Charge air pressure and temperature sensor	24	Turbocharger, bank 2
12	Throttle valve	25	To catalytic converter, bank 2
13	Blow-off valve, bank 1	26	To catalytic converter, bank 1

Exhaust Gas Turbocharging

The turbocharger is driven by the engine's exhaust gases, i.e. exhaust gases under pressure are routed by the turbocharger turbine and in this way delivers the motive force to the compressor, which rotates on the same shaft.

It is here that the induction air is precompressed in such a way that a higher air mass is admitted into the engine's combustion chamber. 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 turbine and the compressor can rotate at speeds of up to 200,000 rpm.
The exhaust inlet temperature can reach a maximum of 1050°C. Because of these high temperatures, the N54 engine's turbochargers are not only connected with the engine-oil system but also integrated in the engine-coolant circuit.

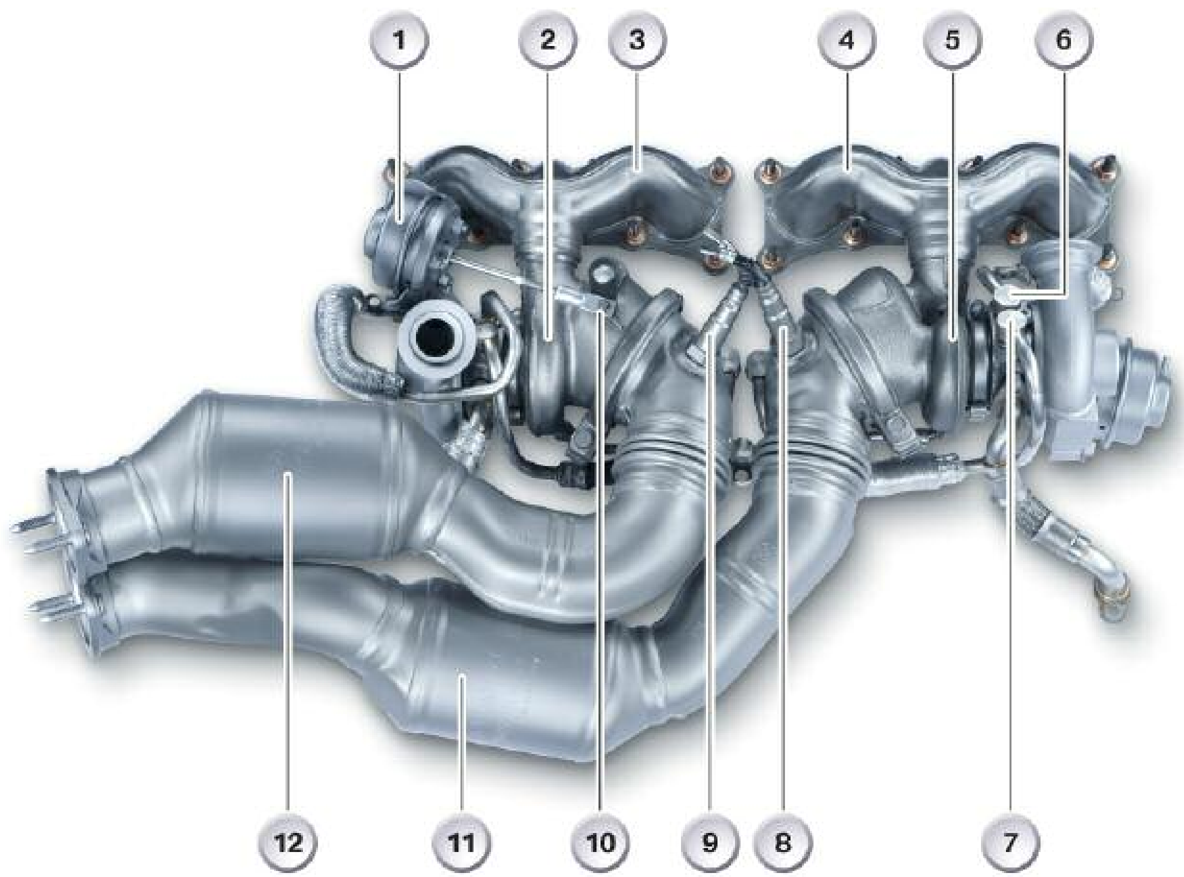
It is possible in conjunction with the N54 engine's electric coolant pump even after the engine has been switched off to dissipate the residual heat from the turbochargers and thus prevent the lube oil in the bearing housing from overheating.

Index	Explanation
A	Compressor
B	Cooling/lubrication
C	Turbine

Bi-turbocharging
Utmost importance is attached to turbocharger response in the N54 engine. A delayed response to the driver's command, i.e. the accelerator-pedal position, is not acceptable. The driver therefore must not experience any so-called "turbo lag".

This requirement is met in the N54 engine with two small turbochargers, which are connected in parallel. Cylinders 1, 2 and 3 (bank 1) drive the first turbocharger (5) while cylinders 4, 5 and 6 (bank 2) drive the second (2).

The advantage of a small turbocharger lies in the fact that, as the turbocharger runs up to speed, the lower moment of inertia of the turbine causes fewer masses to be accelerated, and thus the compressor attains a higher boost pressure in a shorter amount of time.



Index	Explanation	Index	Explanation
1	Wastegate actuator, bank 2	7	Coolant supply
2	Turbocharger, bank 2	8	Planar broad-band oxygen sensor, bank 1
3	Exhaust manifold, bank 2	9	Planar broad-band oxygen sensor, bank 2
4	Exhaust manifold, bank 1	10	Wastegate actuating lever
5	Turbocharger, bank 1	11	Catalytic converter, bank 1
6	Coolant return	12	Catalytic converter, bank 2

Boost-pressure Control

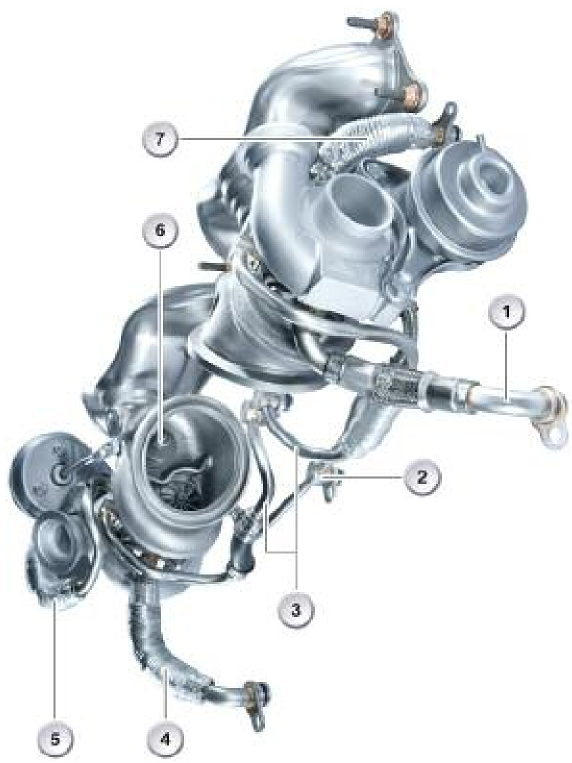
The boost pressure of the turbochargers is directly dependent on the flow of exhaust gas which reaches the turbocharger turbines. Both the velocity and the mass of the exhaust-gas flow are directly dependent on engine speed and engine load.

The engine-management system uses wastegate valves to control the boost pressure. These valves are operated by vacuum-pressure actuators, which are controlled by electropneumatic pressure transducers via the engine-management system.

The vacuum pressure is generated by the permanently driven vacuum pump and stored in a pressure accumulator. The system is designed to ensure that these loads and consumers do not have a negative influence on the brake-boost function.

The exhaust-gas flow can be completely or partially directed to the turbine wheel with the wastegate valves. When the boost pressure has reached its desired level, the wastegate valve begins to open and direct part of the exhaust-gas flow past the turbine wheel.

This prevents the turbine from further increasing the speed of the compressor.
This control option allows the system to respond to various operating situations.



Index	Explanation	Index	Explanation
1	Oil return, bank 1	5	Coolant return, bank 2
2	Oil supply	6	Wastegate valve
3	Coolant supply	7	Coolant return, bank 1
4	Oil return, bank 2	8	

In the idle phase, the wastegate valves of both turbochargers are closed. This enables the full exhaust-gas flow available to be utilized to speed up the compressor already at these low engine speeds.

When power is then demanded from the engine, the compressor can deliver the required boost pressure without any noticeable time lag. In the full-load situation, the boost pressure is maintained at a consistently high level when the maximum permissible torque is reached by a partial opening of the wastegate valves. In this way, the compressors are only ever induced to rotate at a speed which is called for by the operating situation.

The process of the wastegate valves opening removes drive energy from the turbine such that no further increase in boost pressure occurs, which in turn improves overall fuel consumption.

At full-load the N54 engine operates at an overpressure of up to 0.8 bar in the intake manifold.

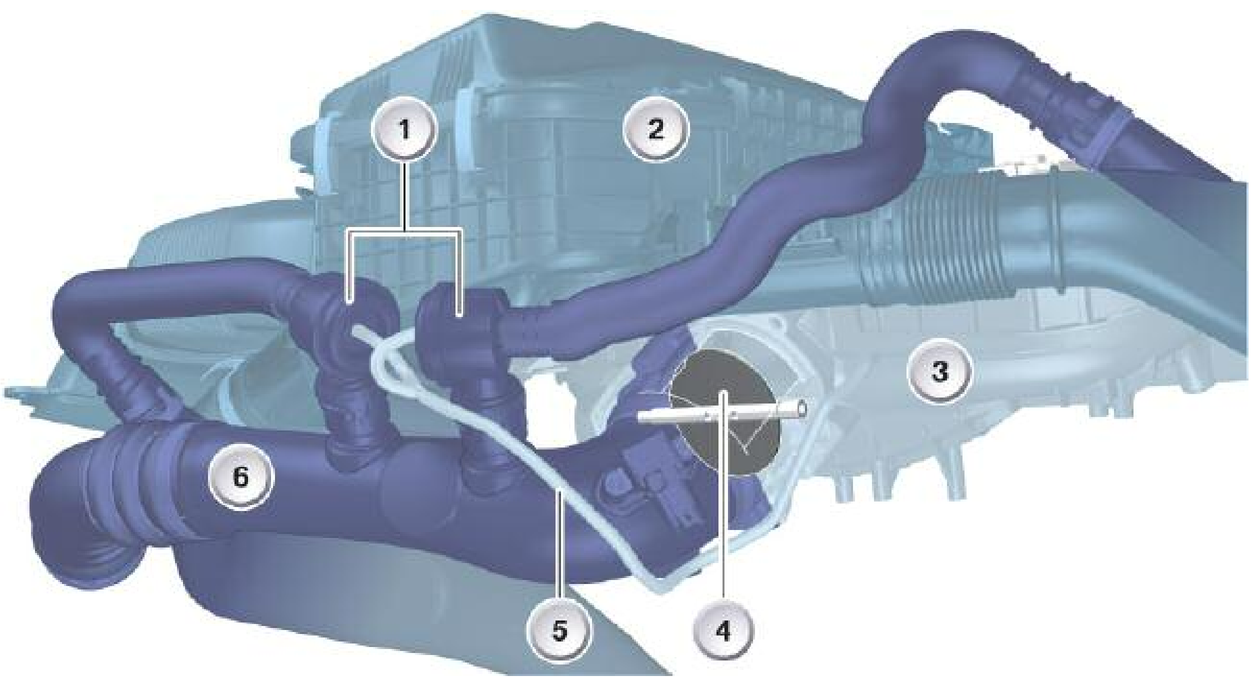
Blow-off Control

The blow-off valves in the N54 engine reduce unwanted peaks in boost pressure which can occur when the throttle valve closes quickly. They therefore have an important function with regard to engine acoustics and help to protect the turbocharger components.

A vacuum pressure is generated in the intake manifold when the throttle valve is closed at high engine speeds. This leads to a build-up of high dynamic pressure after the compressor which cannot escape because the route to the intake manifold is blocked.

This leads to a "pumping up" of the turbocharger which means that:

- a clearly noticeable, disruptive pumping noise can be heard,
- and this pumping noise is accompanied by a component-damaging load being exerted on the turbocharger, since high-frequency pressure waves exert axial load on the turbocharger bearings



Index	Explanation	Index	Explanation
1	Blow-off valves	4	Throttle valve
2	Air cleaner (ambient pressure)	5	Control line, blow-off valves
3	Intake manifold	6	Charge air pressure line

The blow-off valves are mechanically actuated spring-loaded diaphragm valves which are activated by the intake-manifold pressure as follows:

In the event of a pressure differential before and after the throttle valve, the blow-off valves are opened by the intake-manifold pressure and the boost pressure is diverted to the intake side of the compressor. The blow-off valves open starting from a differential pressure of 0.3 bar. This process prevents the disruptive and component-damaging pumping effect from occurring.

The system design dictates that the blow-off valves are also opened during operating close to idle (pressure differential Pcharger/Psuction = 0.3 bar). However, this has no further effects on the turbocharging system.

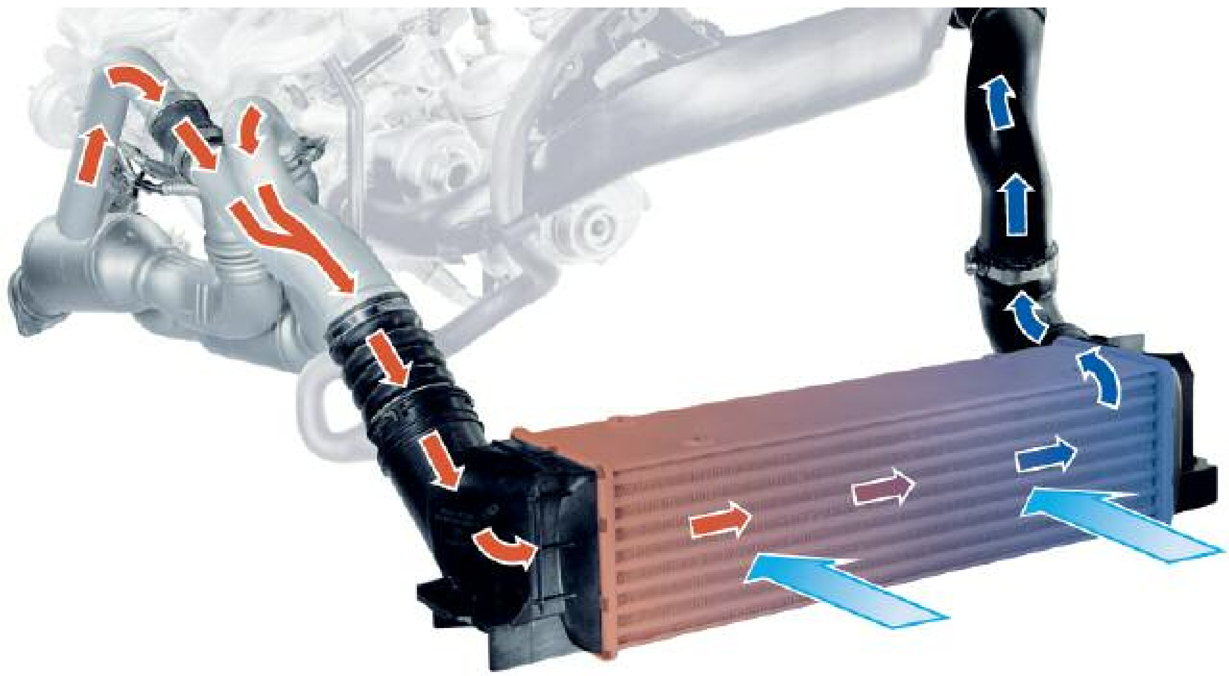
The turbocharger is pressurized with the full exhaust-gas flow at these low speeds and already builds up a certain level of induction-air precharging in the range close to idle. If the throttle valve is opened at this point, the full boost pressure required is very quickly made available to the engine.

One of the major advantages of the vacuum pressure-actuated wastegate valves is that they can be partially opened in the mid-range in order not to allow excessive induction-air precharging to the detriment of fuel consumption. In the upper load range, they assume the required control position corresponding to the necessary boost pressure.

Charge-air Cooling

Cooling the charge air in the N54 engine serves to increase power output as well as reduce fuel consumption. The charge air heated in the turbocharger by its component temperature and by compression is cooled in the intercooler by up to 80°C.

This increases the density of the charge air, which in turn improves the charge in the combustion chamber. This results in a lower level of required boost pressure. The risk of knock is also reduced and the engine operates with improved efficiency.



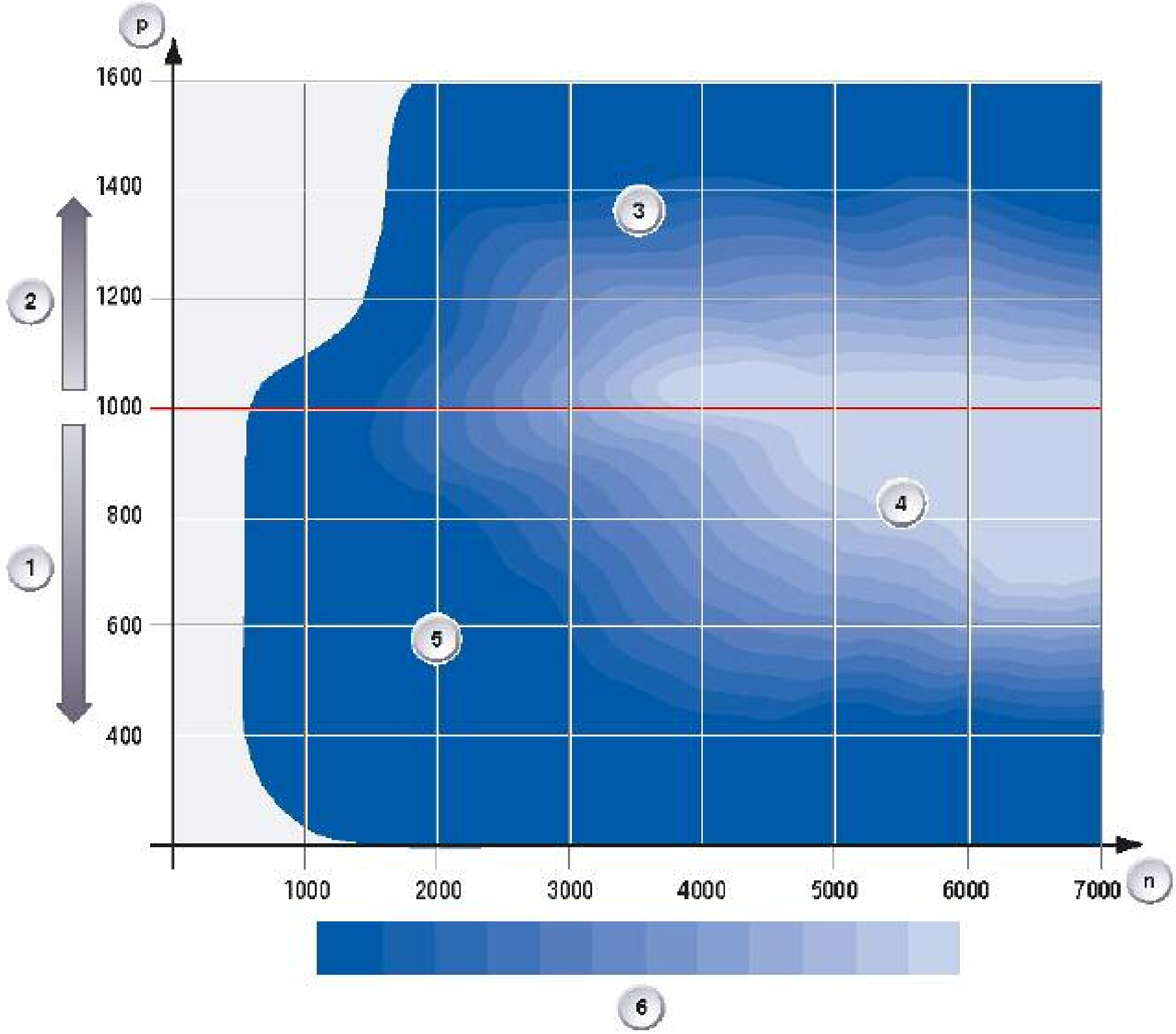
Load Control

Load control of the N54 engine is effected by means of the throttle valve and the waste gate valves.

The throttle valve is the primary component in this process. The wastegate valves are actuated to bring about a fine tuning of the boost pressure. At full load the throttle valve is completely open and load control is undertaken by the wastegate valves.

The load-control graphic shows that the wastegate valves are integrated in load control in all operating situations of the N54 engine on the basis of map control.

Load Control Overview



Index	Explanation	Index	Explanation
n	Engine speed in RPM	3	Wastegate controlled as a function of boost pressure
p	Absolute pressure in the intake in millibar	4	Wastegate partially opened
1	Naturally aspirated engine operation	5	Wastegate closed
2	Turbocharged operation	6	Dark = Wastegate fully closed Light = Wastegate fully open

Controlled Variables

The following variables, among others, influence control of the N54 engine's boost pressure:

- Intake-air temperature
- Engine speed
- Throttle-valve position
- Ambient pressure
- Intake-manifold pressure
- Pressure before the throttle valve (reference variable)

The electropneumatic pressure transducers are activated by the engine control unit on the basis of these variables. The result of this activation can be checked from the boost pressure achieved, which is measured before the throttle valve.

There follows a comparison of the boost pressure achieved with the setpoint data from the program map, which can if necessary give rise to an activation correction.
The system therefore controls and monitors itself during operation.

Limp-home Mode

In the event during operation of malfunctions, implausible values or failure of any of the sensors involved in turbocharger control, activation of the wastegate valves is shut down and the valve flaps are thus fully opened. Turbocharging ceases at this point.

The list below sets out those components or functional groups of the N54 engine in which a failure, a malfunction or implausible values result in boost-pressure control being deactivated. The driver is alerted to a fault of this type via an EML indication.

- High-pressure fuel system
- Inlet VANOS
- Exhaust VANOS
- Crankshaft sensor
- Camshaft sensor
- Boost-pressure sensor
- Knock sensors
- Intake-air temperature sensor

One principle of vehicle repair is particularly important in this respect:

It is important to focus on the causes rather than the effects.

With regard to the diagnosis and subsequent repair of turbocharging components, it is important to ensure that they are also actually identified as defective components with the diagnostic technology available.

It is always vital to ensure that the cause of the fault is determined and rectified and that if necessary work is not carried out on symptoms of fault consequences.
Thus, for instance, a leaking flange on the intercooler can have far-reaching consequences.

The N54 engine also is governed by three golden rules of procedure:

1. Do not rashly trace loss of power and engine malfunctions back to the turbocharger. To avoid the replacement of turbochargers which are in perfect working order, the following should be observed:

   When blue smoke emerges from the exhaust system, check whether the air cleaner is contaminated or the engine is consuming too much oil because of wear. Or, if the crankcase ventilation system is faulty. Only then resort to checking the turbocharger. If the turbocharger is running too loud, inspect all the connections on the turbocharger pressure side. If black smoke or a loss of power is detected, in this case too check the engine and the connecting pipes first.

2. Main causes of turbocharger damage:

   - Insufficient lubrication and consequently bearing failure. Compressor and turbine wheels will grind in the housings, the seals will be damaged and the shaft may also shear off.
   - Foreign bodies damage the turbine and impeller. The resulting imbalance will reduce efficiency and may cause the rotors to burst.
   - Contaminated lube oil causes scoring on shaft journals and bearings. Oilways and seals will become clogged and cause high oil leakage losses. Elements entering the turbocharger system from the outside such as sand, dirt, screws and the like will be trapped by a filter before the compressor.

     Service the filters at regular intervals (service intervals). Take care to keep the clean-air area of the air cleaner and the air ducting to the compressors clean and free from all types of particulates.

3. Do not make any alterations to the turbocharger. Never attempt to alter the boost-pressure control linkage. The turbocharger has been optimally configured at the factory. If the turbocharger operates at higher boost pressures than permitted by the engine manufacturer, the engine may run hot and pistons, cylinder heads or engine bearings may fail, or the safety function of the engine electronics may respond and activate the engine's limp-home program.

Air Management N52KP and N51

As far as the air management system on the N52KP and N51 engines is concerned, the previous intake manifold system on the N52 is carried over. Depending upon application, the engines will use the 3-stage DISA or the single stage (No DISA) intake manifold.

For more information on the DISA system refer to the previous training material in the training course “ST501 - New Engine Technology”.

Throttle Valve

On all variants of the new NG6 engines, the throttle valve has been upgraded an is now referred to as EGAS 08 by Siemens/VDO. The throttle valve flap itself is now made from plastic.

The primary difference between the new EGAS throttle as compared to the previous unit is the throttle feedback system. The previous system used a potentiometer, whereas the new throttle uses a "contactless" system featuring magneto-resistive technology.
The technology is similar to that used on the eccentric shaft sensor on Valvetronic systems.

The magneto-resistive sensor are integrated into the housing cover. This sensor allow throttle position feedback to achieve a an extremely high degree of accuracy.

In the throttle valve, these sensors permit 100 times the power than the previous potentiometers and therefore ensure reliable signal progression to the DME.
The sensors are also non-wearing. The one sensor outputs the analog signal in the range from 0.3 to 4.6 V and the other sensor inverts it again from 4.6 to 0.3 V.

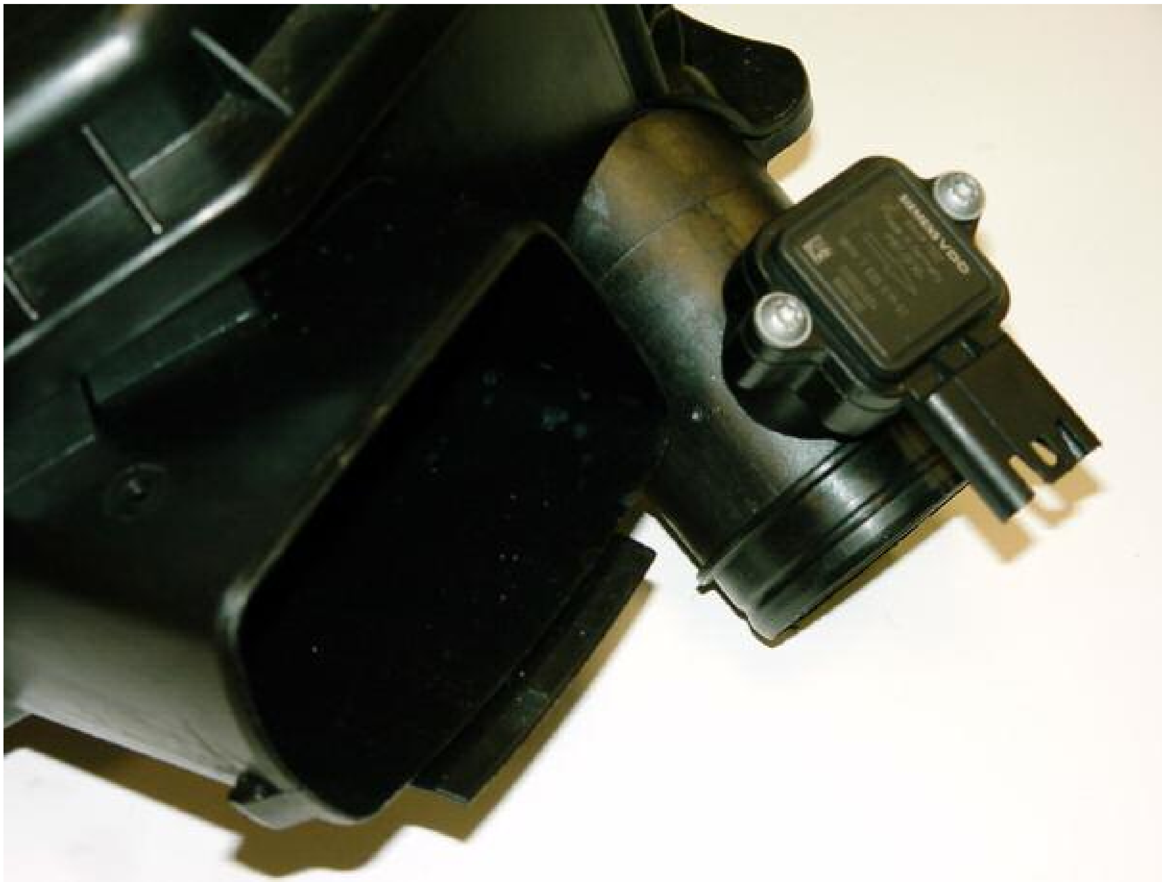
By forming the differential, the ECM calculates the plausibility of the signal. A new plug ensures optimum contact quality. In this plug, the contact force acting on the pin is decoupled from the plug-in force.

Consequently, the contact force is 10 times greater than that of a conventional plug connector.

Note: It is possible to twist the connector before plugging it in. This can cuase damage to the harness and connector. BE sure to install connector properly to avoid damage.

Hot-Film Air Mass Meter

The HFM on all new NG6 engines has been upgraded to a digital HFM. The output of the sensor is a digital signal in which the duty cycle responds to changes in air mass.

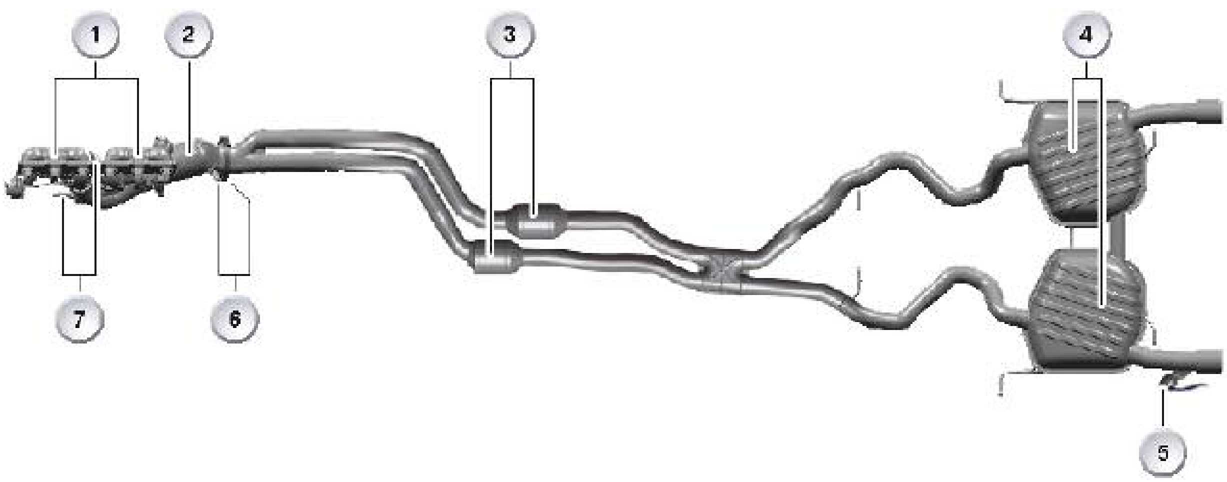


Exhaust System

E92 vehicles with N54 engines are equipped with a dual exhaust system. The entire system is made from stainless steel, which ensures that it will function throughout the vehicle's service life.

Upstream primary catalytic converters with downstream underfloor catalytic converters are used. The lambda oxygen sensors installed are the same as those in the N52 engine.

The N51 engine is also equipped with an additional underbody catalyst to complement the exisiting “near engine” catalyst. The N51 also features improved catalyst coatings to help comply with SULEV II requirements.



Index	Explanation	Index	Explanation
1	Exhaust manifold	5	Exhaust flap
2	Upstream catalyst - 2 x 0.7 liters	6	Oxygen sensors (catalyst monitoring)
3	Underfloor catalyst - 2 x 0.85 liters	7	Oxygen sensors - Wideband planar
4	Rear mufflers, each approximately 16 liters		

Fuel Supply and Management

Direct injection is one of the most decisive cornerstones in the concept of the N54 engine. The complex requirements of the combustion process can only be met with this injection process, which is described in the following.

Direct injection achieves a higher compression ratio when compared with a turbocharged engine with manifold injection. At the same time, the exhaust-gas temperature is reduced under full load. Another advantage of this injection process is the improved
efficiency in part-load operation.

The N52KP and N51 engines continue to use the conventional “manifold injection” system from the N52.

High Precision Injection (HPI)

High-precision injection represents the key function in the concept for as economic a use of fuel as possible. The new generation of petrol direct injection satisfies the expectations placed on it with regard to economic efficiency without compromising on the engine's dynamic qualities.

High-precision injection provides for amore precise metering of mixture and higher compression - ideal preconditions for increasing efficiency and significantly reducing consumption.

This is made possible by locating the piezo injector centrally between the valves. In this position, the new injector, which opens in an outward direction, distributes a particularly uniform amount of tapered shaped fuel into the combustion chamber.

The new direct injection of BMW HPI spark ignition engines operate according to the spray-directed process.

HPI Function

The fuel is delivered from the fuel tank by the electric fuel pump via the feed line (5) at an “feed” pressure of 5 bar to the high pressure pump. The feed pressure is monitored by the low-pressure sensor (6). The fuel is delivered by the electric fuel pump in line with demand.

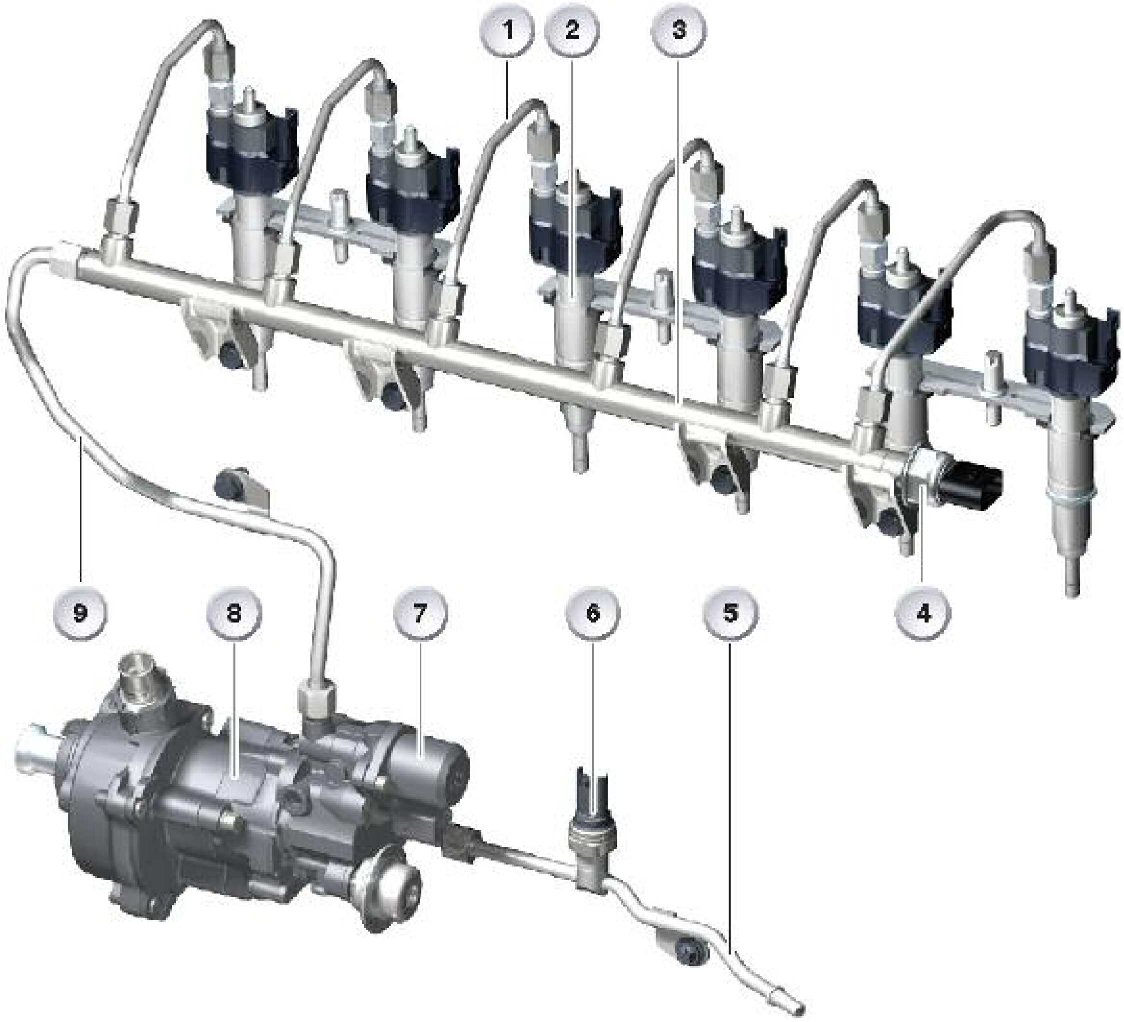
If this sensor fails, the electric fuel pump continues to run at 100% delivery with terminal 15 ON.

The high pressure pump is driven “in-tandem” with the vacuum pump which is driven by the oil pump chain drive assembly.

The fuel is compressed in the permanently driven three-plunger high-pressure pump (8) and delivery through the high-pressure line (9) to the rail (3). The fuel accumulated under pressure in the rail in this way is distributed via the high-pressure lines (1) to the piezo injectors (2).

The required fuel delivery pressure is determined by the engine-management system as a function of engine load and engine speed. The pressure level reached is recorded by the high-pressure sensor (4) and communicated to the engine control unit.

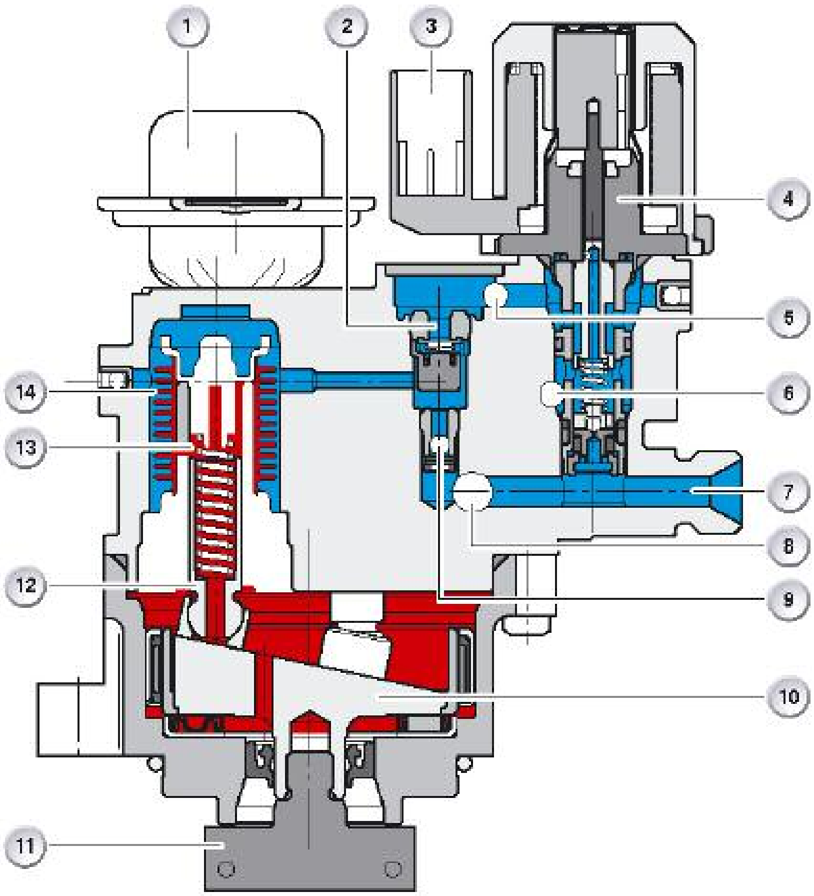
Control is effected by the fuel-supply control valve (7) by way of a setpoint/actual-value adjustment of the rail pressure. Configuration of the pressure is geared towards best possible consumption and smooth running of the N54 engine. 200 bar is required only at high load and low engine speed.



Index	Explanation	Index	Explanation
1	High-pressure line to injector (6)	6	Low-pressure sensor
2	Piezo injector	7	Fuel supply control valve
3	Fuel rail	8	Three pluger high pressure pump
4	High pressure sensor	9	High pressure line (pump to rail)
5	Feed line from in-tank pump		

High Pressure Pump Function and Design

The fuel is delivered via the supply passage (6) at the admission pressure generated by the electric fuel pump to the high-pressure pump. From there, the fuel is directed via the fuelsupply control valve (4) and the low-pressure non-return valve (2) into the fuel chamber (14) of the plunger-and-barrel assembly. The fuel is placed under pressure in this plunger-and-barrel assembly and delivered via the high pressure non-return valve (9) to the highpressure port (7).



Index	Explanation	Index	Explanation
1	Thermal compensator	8	Supply passage, pressure limiting valve
2	Low pressure non-return valve (check valve)	9	High pressure non-return valve (x 3)
3	Connection to engine management	10	Pendulum disc
4	Fuel supply control valve	11	Drive flange, high pressure pump
5	Return, pressure limiting valve	12	Plunger (x 3)
6	Supply from electric fuel pump (in-tank)	13	Oil filling, high pressure pump
7	High pressure port to fuel rail	14	Fuel chamber (x 3)

The high-pressure pump is connected with the vacuum pump via the drive flange (11) and is thus also driven by the chain drive, i.e. as soon as the engine is running, the three plungers (12) are permanently set into up-and-down motion via the pendulum disc (10).

Fuel therefore continues to be pressurized for as long as new fuel is supplied to the high-pressure pump via the fuel-supply control valve (4). The fuel-supply control valve is activated by means of the engine management connection (3) and thereby admits the quantity of fuel required.

Pressure control is effected via the fuel-supply control valve by opening and closing of the fuel supply channel. The maximum pressure in the high-pressure area is limited to 245 bar. If excessive pressure is encountered, the high-pressure circuit is relieved by a pressure-limiting valve via the ports (8 and 5) leading to the low-pressure area.

This is possible without any problems because of the incompressibility of the fuel, i.e. the fuel does not change in volume in response to a change in pressure. The pressure peak created is compensated for by the liquid volume in the low-pressure area.

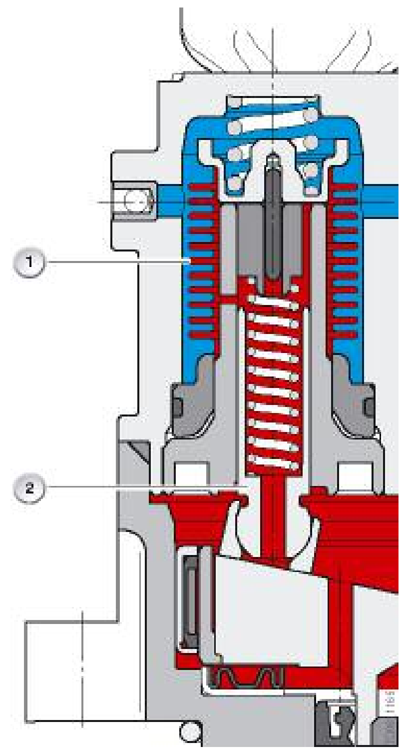
Volume changes caused by temperature changes are compensated for by the thermal compensator (1), which is connected with the pump oil filling.

Pressure Generation in High-pressure Pump

The plunger (2) driven by the pendulum disc presses oil (red) into the metal diaphragm (1) on its upward travel. The change in volume of the metal diaphragm thereby reduces the available space in the fuel chamber. The fuel thereby placed under pressure (blue) is forced into the rail.

The fuel-supply control valve controls the fuel pressure in the rail. It is activated by the engine management system via a pulsewidth modulated (PWM) signal.

Depending on the activation signal, a restrictor cross-section of varying size is opened and the fuel-mass flow required for the respective load point is set. There is also the possibility of reducing the pressure in the rail.



Index	Explanation
Red	Oil filling
Blue	Fuel
1	Metal diaphragm
2	Plunger

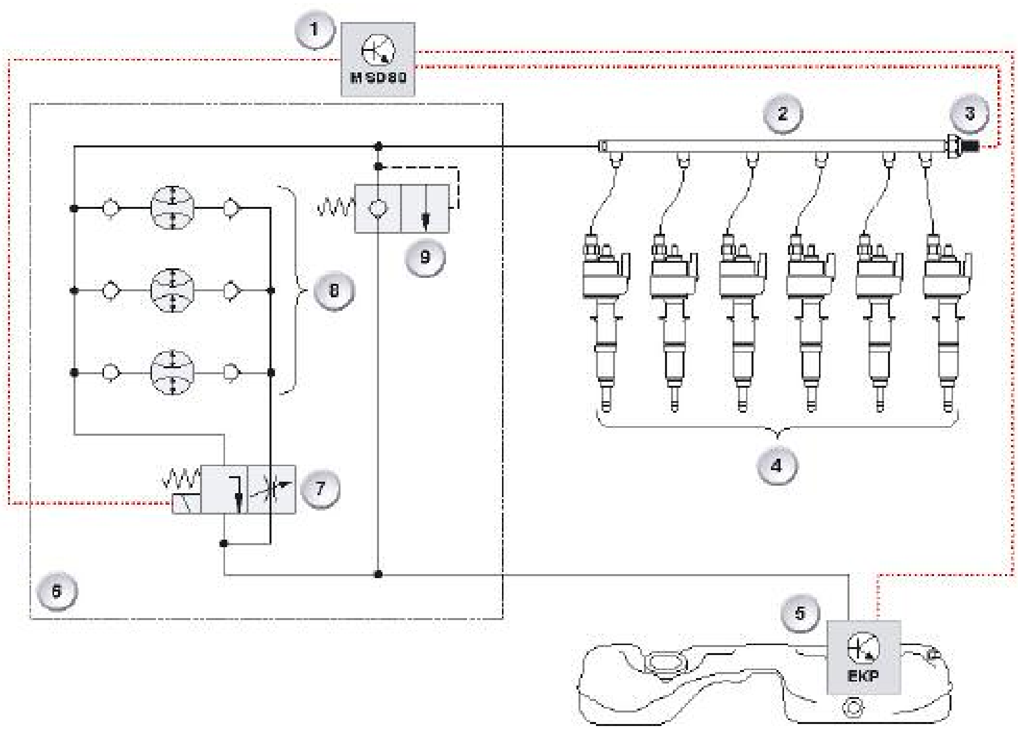
Limp-home Mode

If a fault is diagnosed in the system, such as e.g. failure of the high-pressure sensor, the fuel-supply control valve is de-energized; the fuel then flows via a so-called bypass into the rail.

In the event of HPI limp-home mode, turbocharging is deactivated by an opening of the wastegate valves.

Causes of HPI limp-home mode can be:

- Implausible high-pressure sensor values
- Failure of the fuel-supply control valve
- Leakage in the high-pressure system
- Failure of the high-pressure pump
- Failure of the high-pressure sensor

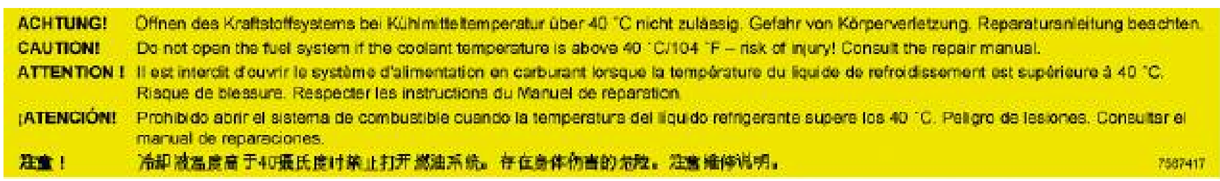


Index	Explanation	Index	Explanation
1	Engine control module (MSD80)	6	High-pressure pump
2	Fuel rail	7	Fuel supply control valve
3	High pressure sensor	8	High pressure pump with non-return valves
4	Piezo injectors	9	Pressure liming valve with bypass
5	Electric fuel pump		

Fuel System Safety

Working on this fuel system is only permitted after the engine has cooled down. The coolant temperature must not exceed 40 °C. This must be observed without fail because otherwise there is a danger of fuel sprayback on account of the residual pressure in the high-pressure system.

When working on the high-pressure fuel system, take particular care to ensure conditions of absolute cleanliness and follow the work sequences described in the repair instructions. Even the tiniest contaminants and damage to the screw connections on the high-pressure lines can cause leaks.



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Do not attempt to open any fuel lines or connections on the HPI injection system until the coolant temperature is below 40 degrees Celsius (approximately 104 degrees Fahrenheit)

Piezo Fuel Injectors

It is the outward-opening piezo-injector that renders possible spray-directed direct injection and thus the overall innovations of the N54 engine. Due to the fact that only this component ensures that the injected fuel spray cone remains stable, even under the prevailing influences of pressure and temperature in the combustion chamber.

This piezo-injector permits injection pressures of up to 200 bar and extremely quick opening of the nozzle needle. In this way, it is possible to inject fuel into the combustion chamber under conditions released from the power cycles limited by the valve opening times.

The piezo-injector is integrated together with the spark plug centrally between the inlet and exhaust valves in the cylinder head. This installation position prevents the cylinder walls or the piston crown from being wetted with injected fuel. A uniform formation of the homogeneous air/fuel mixture is obtained with the aid of the gas movement in the combustion chamber and a stable fuel spray cone.

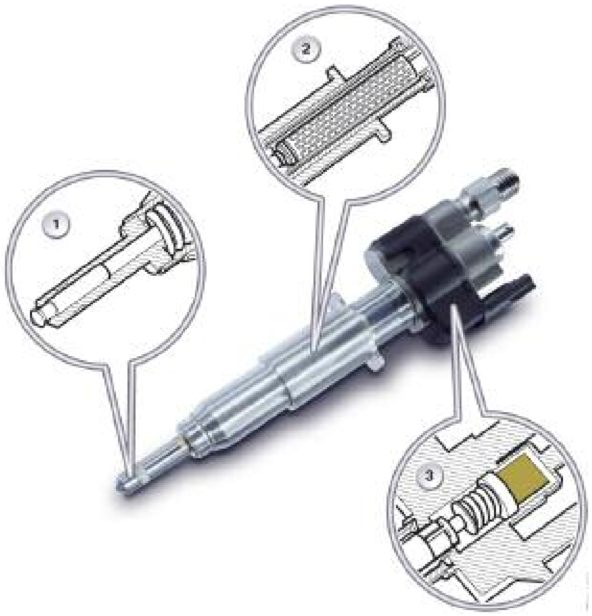
The gas movement is influenced on the one hand by the geometry of the intake passages and on the other hand by the shape of the piston crown. The injected fuel is swirled in the combustion chamber with the boost air until a homogeneous mixture is available throughout the compression space at the point of ignition.

Note: When working on the fuel system of the N54 engine, it is important to ensure that the ignition coils are not fouled by fuel. The resistance of the silicone material is significantly reduced by heavy fuel contact. This can cause sparkover at the spark-plug head and with it misfires.

- Before making modifications to the fuel system, remove the ignition coils without fail and protect the spark-plug slot against the ingress of fuel with a cloth.
- Before refitting the piezo-injector, remove the ignition coils and ensure conditions of absolute cleanliness.
- Ignition coils heavily fouled by fuel must be replaced.

Injector Design and Function

The piezo-injector essentially consists of three sub-assemblies. The expansion of the energized piezo-element lifts the nozzle needle outwards from its valve seat. To be able to counter the different operating temperatures with comparable valve lifts, the injector has a thermal compensating element.



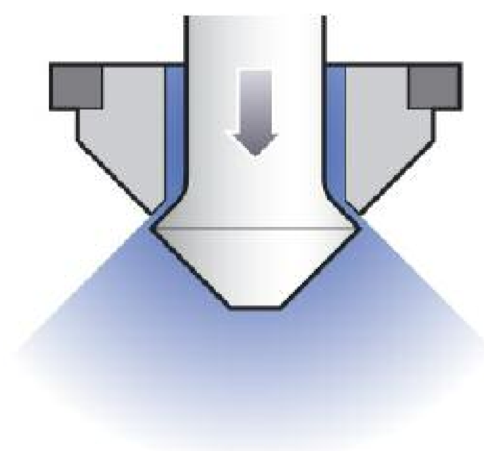
Index	Explanation	Index	Explanation
1	Outward opening nozzle needle	3	Thermal compensator
2	Piezo-element		

The nozzle needle is pressed outwards from its tapered valve seat. This opens up an annular orifice. The pressurized fuel flows through this annular orifice and forms a hollow cone, the spray angle of which is not dependent on the backpressure in the combustion chamber.

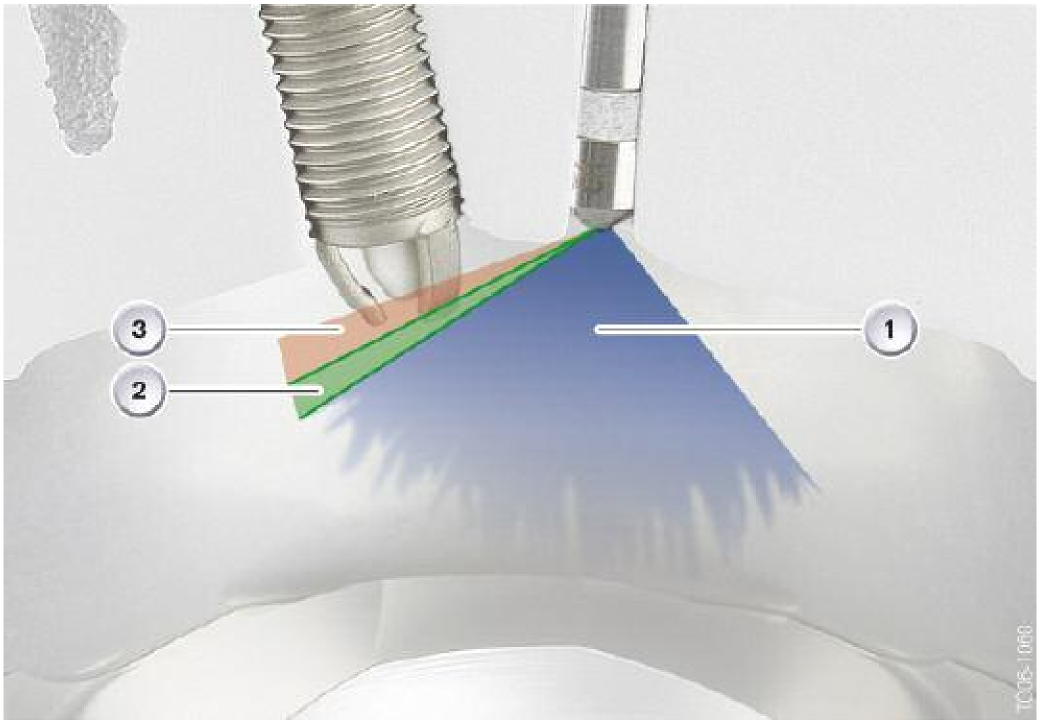
Note: Do not attempt to clean the injectors in any way. This may result in damage which can effect the spray pattern.

Any divergence in the spray pattern can cause damage to the spark plug or the engine itself.

Outward opening injector nozzle needle



The spray cone (1) of a piezo-injector can diverge during operation (2). Due to the formation of soot inside the engine, such divergence is perfectly normal and acceptable to a certain extent. If, however, spray divergence reaches the stage where it begins to spray the spark plug wet, the spark plug may incur damage.



Index	Explanation	Index	Explanation
1	Ideal "spray" cone	3	Non-permitted divergence of spray cone
2	Permitted divergence of spray cone		

Note: Replace the Teflon sealing ring when fitting and removing the piezo-injector. This also applies when an injector that has just been fitted has to be removed again after an engine start.

A piezo-injector provided with a new Teflon sealing ring should be fitted as quickly as possible because the Teflon sealing ring could swell up. Please observe the repair instructions and follow without fail.

When fitting, make sure that the piezoinjector is correctly seated. The hold-down element for securing the piezo-injectors must rest on both injector tabs, otherwise the necessary force is not applied to the piezo-injector. Do not clean the nozzle-needle tip of the piezo-injector.

Injection Strategy

Injection of the fuel mass required for the operating situation can take place in up to three individual injections. Which option is used in the relevant operating situation is dependent on engine load and speed. Here, the actual time resulting from the engine speed available for metering the fuel is an important framework quantity.

A special situation during the operation of any engine is the range in which a high load occurs at low engine speed, so-called "Low End Torque" operation. In this operating situation, the required fuel mass is metered to the engine in three individual injections.

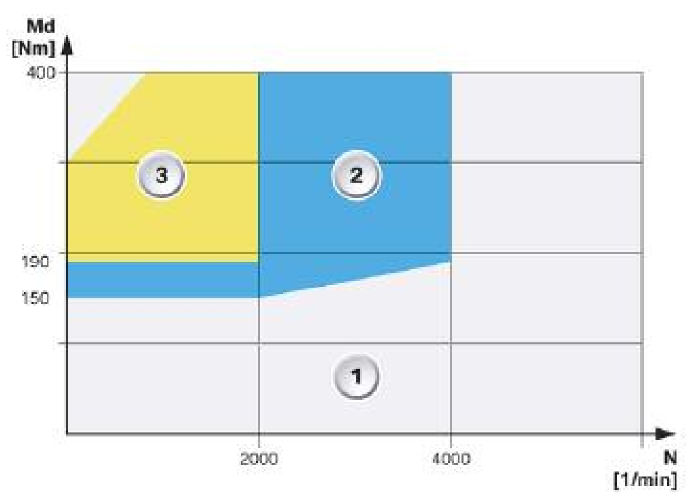
This results in a highly effective mixture formation which in the final analysis has the effect of both increasing power output and saving fuel.

In order to bring the catalytic converters up to operating temperature as quickly as possible, the N54 engine has a catalyst-heating mode for when the engine is started from cold. In this mode, combustion heat is intentionally introduced into the exhaust train and not used first and foremost to develop power output.

The point of ignition is moved to 30° (crankshaft degrees) after TDC. The main quantity of the required fuel is injected before TDC and mixed with the boost air. The piston is situated after TDC in its downward travel such that the air/fuel mixture is already expanding again, which reduces the ignitability of the mixture.

In order to ignite the mixture reliably, a small residual quantity of fuel is injected 25° after TDC and this guarantees an ignitable mixture at the spark plug. This small fuel quantity therefore provides for ignition of the residual charge in the combustion chamber.

This operating mode is set by the engine-management system after a maximum period of 60 seconds from engine starting but is terminated if the catalytic-converter response temperature is reached earlier.



Index	Explanation	Index	Explanation
1	Single injection event	3	Triple injection event
2	Double injection event		

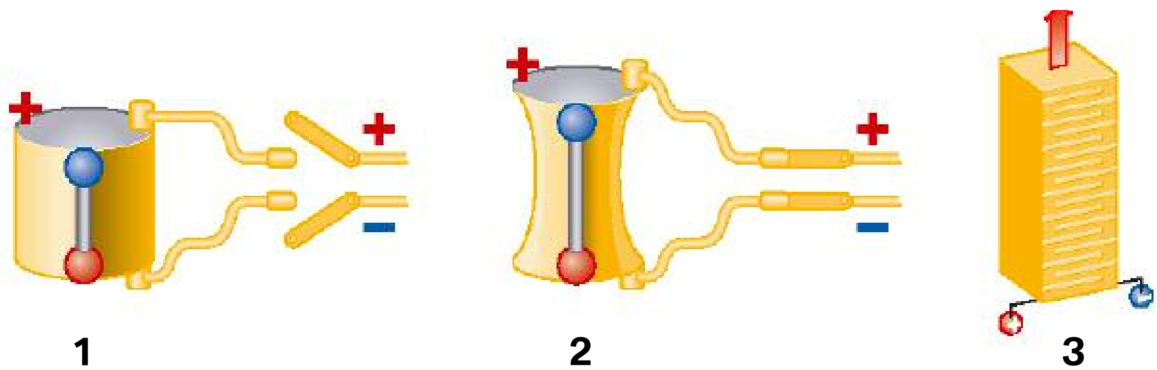
Piezo Element

The movement of the nozzle needle in the injector is generated no longer 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 which converts electrical energy directly into mechanical energy (force/travel). A familiar application is the piezo cigarette lighter - when a piezo-crystal is pressed, voltage is generated until a spark flashes over and the gas ignites.

In the case of the piezo-actuator, voltage is generated so that the crystal expands. In order to achieve greater travel, it is possible to design a piezo-element in several layers.

The actuator module consists of layers of the piezo-ceramic material connected mechanically in series and electrically in parallel. The deflection of a piezo-crystal is dependent on the applied voltage up to a maximum deflection; the higher the voltage, the greater the travel.



Index	Explanation	Index	Explanation
1	Piezo crystal - not energized	3	Piezo element in layers (stacked)
2	Piezo crystal - energized		

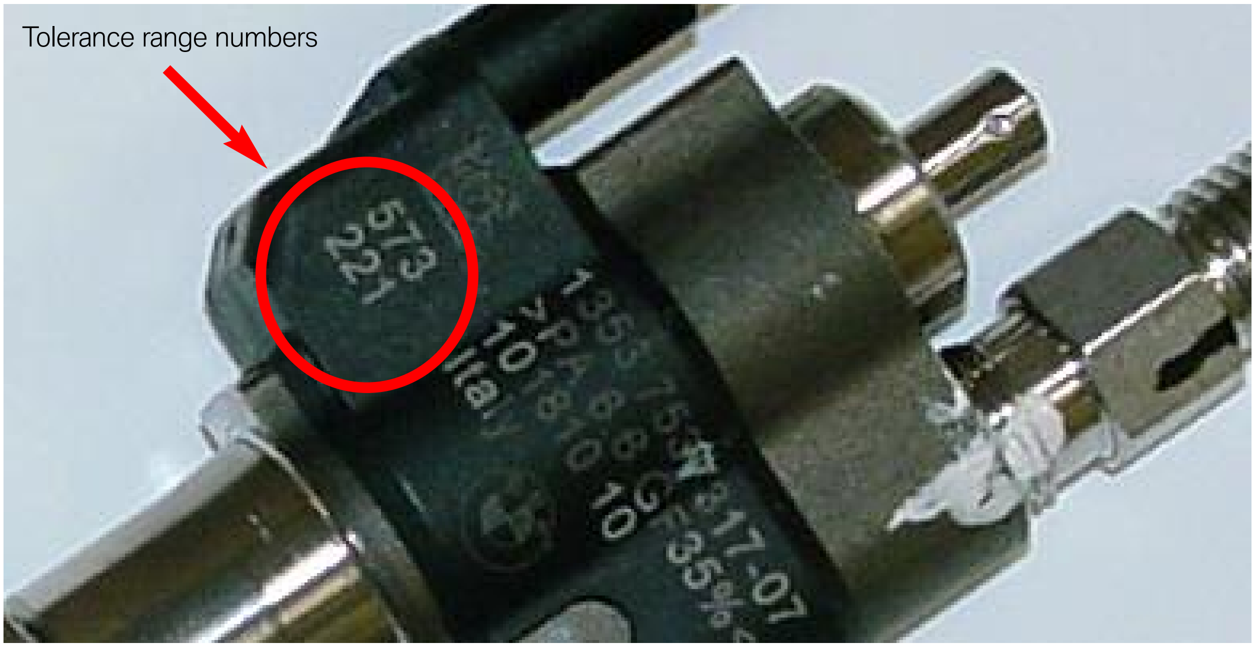
Injector Adjustment

When the injectors are manufactured, a multitude of measurement data is recorded at specific points in the factory. In this way, the tolerance ranges for injector-quantity adjustment are determined and specified in a six-digit number combination.

Information on the lift performance of the injector is also added for injector voltage adjustment. Injector adjustment is required because of the individual voltage demand of each piezo actuator. An allocation is made to a voltage demand category, which is included in the number combination on the injector.

These data items are transmitted to the ECM. During engine operation, these values are used to compensate for deviations in the metering and switching performance.

Note: When replacing an injector, it is absolutely essentially to carry out an injector adjustment.



Injector Control and Adaptation

The fuel mass required for the operating situation is injected by the piezo-injector into the combustion chamber. This mass can be influenced by three correcting variables:

- the rail pressure
- the injector opening time
- and the injector opening lift

The injector opening time and the injector opening lift are activated directly at the piezo injector. The opening time is controlled via the ti signal and the opening lift via the energy quantity in the activation of the piezo-injector.

Injector Adaptation

The fuel masses and injection cycles determined from the load/speed map are included in a pilot-control program map. Here, while further framework parameters are taken into consideration, the energy quantities and injector opening times required to activate the injectors are determined.

The N54 engine can be safely and reliably operated with these program-map values.

Optimization

For optimization of:

- Emission values
- Smooth running
- Fuel consumption
- Power output

the controlled variables of energy quantities and injector opening times are continuously monitored. This occurs on a bank-selective basis by way of lambda closed-loop control.

The residual oxygen in the exhaust gas is measured in each case for cylinder bank 1 and cylinder bank 2. This measurement result is compared with the values expected from the set correcting variables. The result of a deviation is that the injector opening signal is adapted. This adaptation is stored in the control unit and is therefore available for subsequent engine operation. However, these stored values are lost when the system is flashed and must be relearned. A further adaptation of the injector activation takes place depending on time and use. This cylinder-selective adaptation involves a check of the residual-oxygen content with a conclusion as to the cylinder causing the situation. To this end, it is necessary for part of the exhaust-gas flow not to be swirled in the turbocharger. For this reason, the flap of the wastegate valve must be fully opened, i.e. swung out of the exhaust-gas flow. This wastegate-flap position extends beyond its normal opening position in engine operation. Based on the result of this cylinder-selective monitoring, the nergy quantity is adapted if necessary to activate the injectors.

Furthermore, the cylinder-selective adaptation includes if necessary an adaptation of the injector opening signal based on smooth running monitoring of the N54 engine. Overall adaptation of the injectors is limited to a 15% additional quantity.

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Ignition Management

Most of the ignition system components have remained the same for all NG6 engines for 2007. There are some minor changes to the ignition coils that apply to all versions. The coils have been optimized for more durability.

Spark Plugs

The spark plugs for the N51 and N52KP remain the same as N52. However, the N54 uses a completely new spark plug from Bosch. The spark plug design consists of a 12mm thread which contrasts from the 14mm design on the N52 which prevents any possibility of improper installation. The hex on the spark plug is also a 12 point design which requires a special tool. The tool (socket) has a “thinwall” design to facilitate access in the confined area of the N54 cylinder head.

Spark Plug Diagnosis (N54)

Due to the proximity of the spark plug to the fuel injector nozzle, any divergence in the fuel spray may cause possible spark plug damage. This makes spark plug diagnosis an important part of N54 service concerns. Information gained by the spark plug diagnosis may indicate possible fuel injector faults. Spark plug replacement interval has been reduced to 45,000 miles for the N54.

The illustrations below can be used to assist in spark plug diagnosis:

The spark plug above shows a normal wear patttern with no excessive electrode wear or insulator damage.

The spark plug above shows a normal wear patttern for a spark plug with high mileage. Spark plug is due for replacement.

The spark plug above shows erosion of the electrode on one side which could be an indication of fuel spray “diversion”.

The spark plug above shows erosion of the electrode on one side and damage on the insulator nose. This could also be an indication of fuel spray “diversion”.

Emissions Management

The N54 and N52KP meet ULEV II requirements for 2007. There are not many changes to the emissiom systems on these engines. The N54 engine has 2 underbody catalysts in addition to the “near engine” catalysts already in use from the N52.

The N51 engine, however, is a SULEV II compliant engine which meets the 2007 requirements. In addition to the 5 exisiting SULEV states of California, New York, Maine, Massachusetts, and Vermont - four states have been added for 2007. These states include, Connecticut, Rhode Island, Oregon and Washington State.

The N51 emissions measures include:

- Secondary Air System with mini-HFM
- Radiator with “Prem-air” coating
- Lower compression ratio (10:1) via modified combustion chamber and pistons
- Underbody catalyst in addition to “near engine” catalyst
- Activated carbon air filter in air filter housing
- Steel fuel lines with threaded fittings and sealed fuel tank
- Crankcase ventilation system integrated into cylinder head cover
- Purge system piping made from optimized plastic

Note: The SULEV II information above is only preliminary and is accurate as of 8/06. Additional information will be released as it becomes available.

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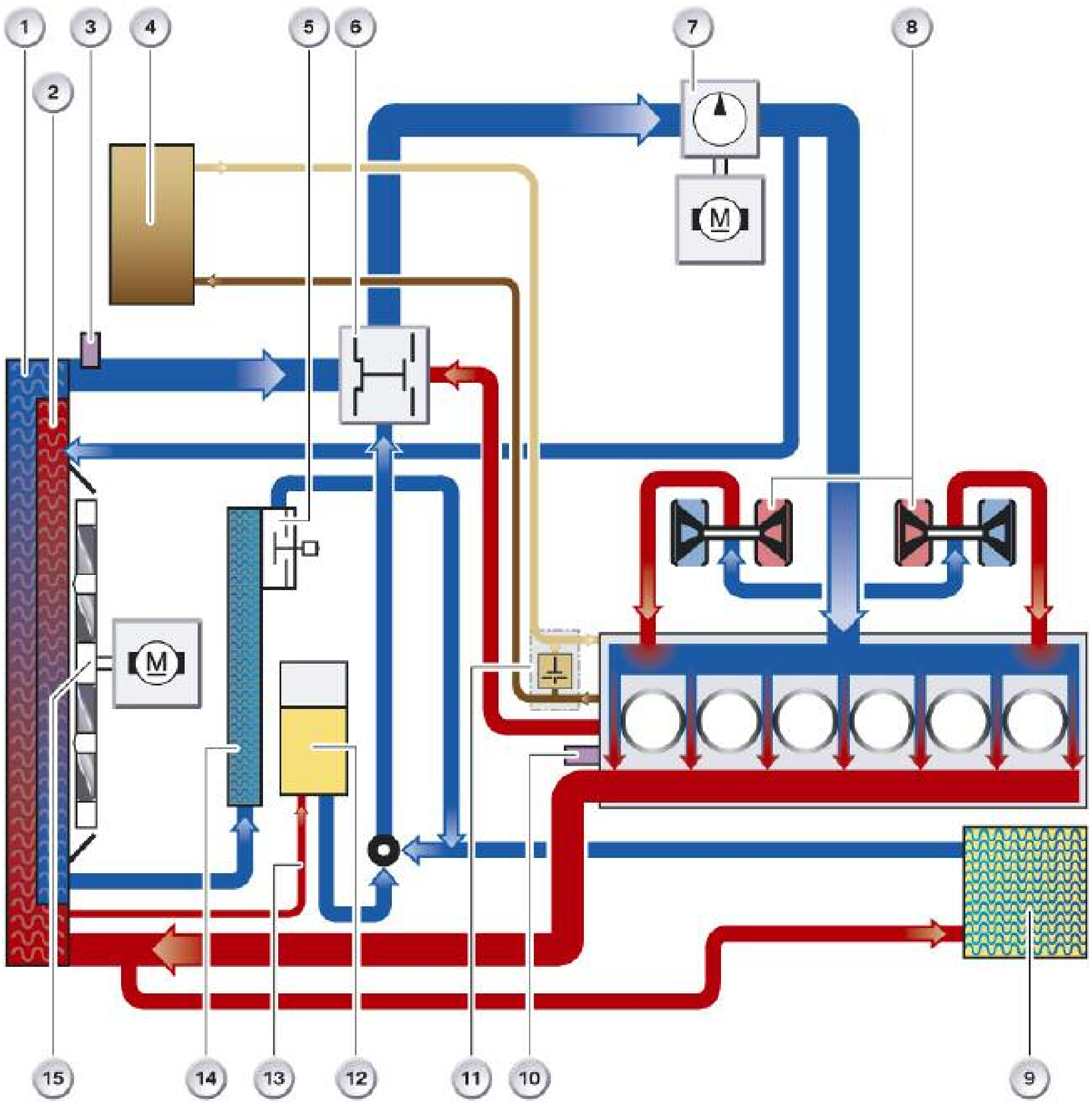
Cooling System

The cooling system of the N54 engine consists of a radiator circuit and an isolated oil cooling circuit. The fact that there is an isolated oil-cooling circuit ensures that heat is not introduced via the engine oil into the engine's coolant system.



Index	Explanation	Index	Explanation
1	Radiator	9	Heat exchanger
2	Gear-box oil cooler	10	Outlet temperature sensor, cylinder head
3	Outlet temperature sensor	11	Thermostat, engine oil cooler
4	Engine oil cooler	12	Coolant expansion tank
5	Thermostat for gearbox oil cooler	13	Vent line
6	Map thermostat	14	Gearbox oil cooler
7	Electric coolant pump	15	Fan
8	Exhaust turbocharger		

There is a significantly greater quantity of heat on account of this engine's increased power of 75.5 kW/l in comparison with other 3-liter spark-ignition engines.

This boundary condition is satisfied by the engine cooling system with its increased performance. This increase in power was to be realized in spite of some factors less advantageous to cooling.

Factors to be mentioned here are:

- Approximately 15% less flow area is available on account of the intercooler located below the radiator.
- The already small amount of space provided by the engine compartment is further limited by the accommodation of further components.
- Because the exhaust turbochargers are cooled by the coolant, an additional quantity of heat is introduced into the system via these turbochargers.

Measures for increasing cooling-system performance:

- Coolant pump with increased power - 400 W/9000 l/h
- Separation of water and engine-oil cooling
- Radiator with increased power
- Electric fan with increased power 600W for all gearbox variants

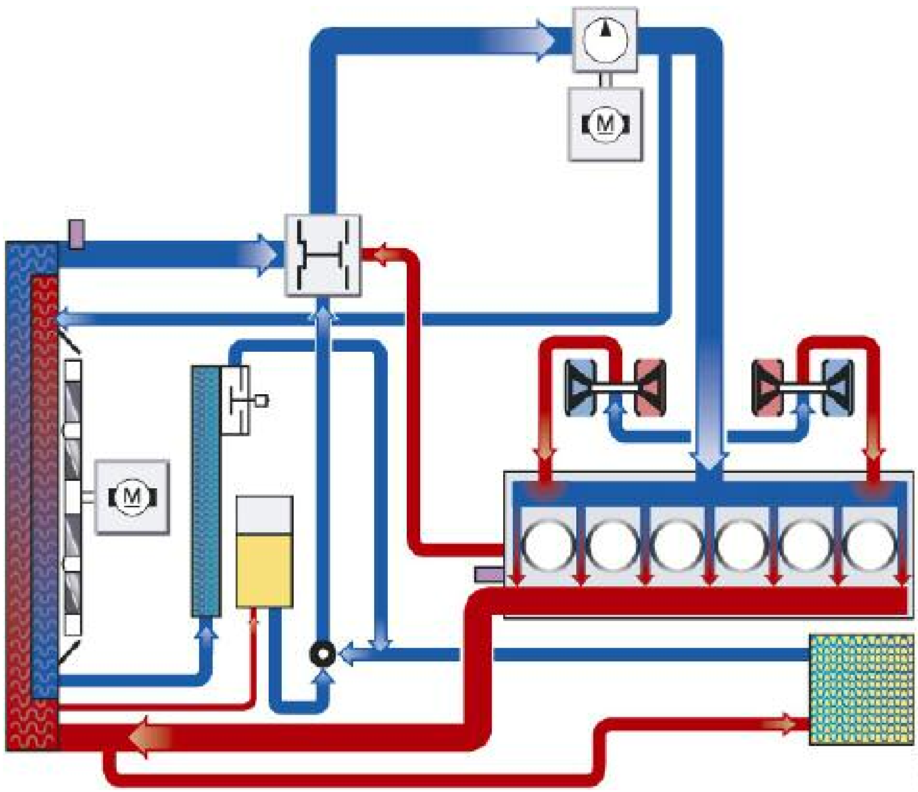
Charge-air cooling is described in the section dealing with air-intake ducting.

Cooling System Overview

The structure of the coolant circuit is the same as that of the N52 engine. The engine is flushed through with coolant in accordance with the cross-flow concept. Cooling output can be influenced as a function of load by activating the following components:

- Electric fan
- Electric coolant pump
- Map thermostat

It is also possible in an N54 engine in conjunction with an automatic gearbox to utilize the lower area of the radiator to cool the gearbox by means of the gearbox-oil cooler. This is achieved as in the N52 engine with control sleeves, which are introduced into the radiator tank.



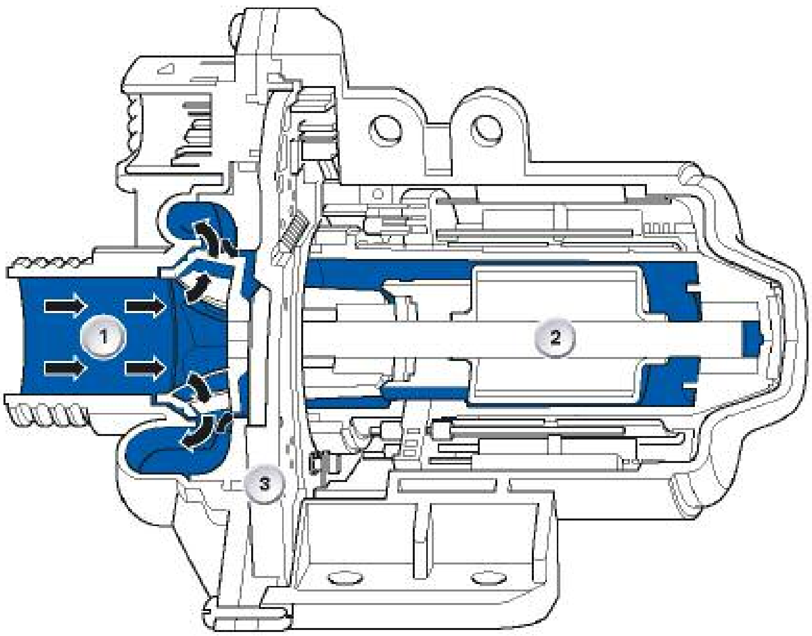
Radiator

Design measures have been used to increase the performance of the radiator itself. The performance of a radiator is dependent on its radiation surface. However, the intercooler still had to be installed underneath the radiator, and this meant that is was necessary to compensate for the smaller flow area available.

Compared with the N52 engine, the radiator used in the N54 engine has a block depth which has been increased to 32 mm. In addition, the water pipes are situated closer together than in previously used radiators. The upshot of this is an increase in the utilizable radiation surface.

Electric Coolant Pump

The coolant pump of the N54 engine is an electrically driven centrifugal pump with a power output of 400W and a maximum flow rate of 9000 l/h. This represents a significant increase in power of the electric coolant pump used in the N52 engine, which has a power output of 200 W and a maximum flow rate of 7000 l/h.



Index	Explanation	Index	Explanation
1	Pump	3	Electronics for coolant pump
2	Motor		

The power of the electric wet-rotor motor is electronically controlled by the electronic module (3) in the pump. The electronic module is connected via the bit-serial data interface (BSD) to the MSD80 engine control unit.

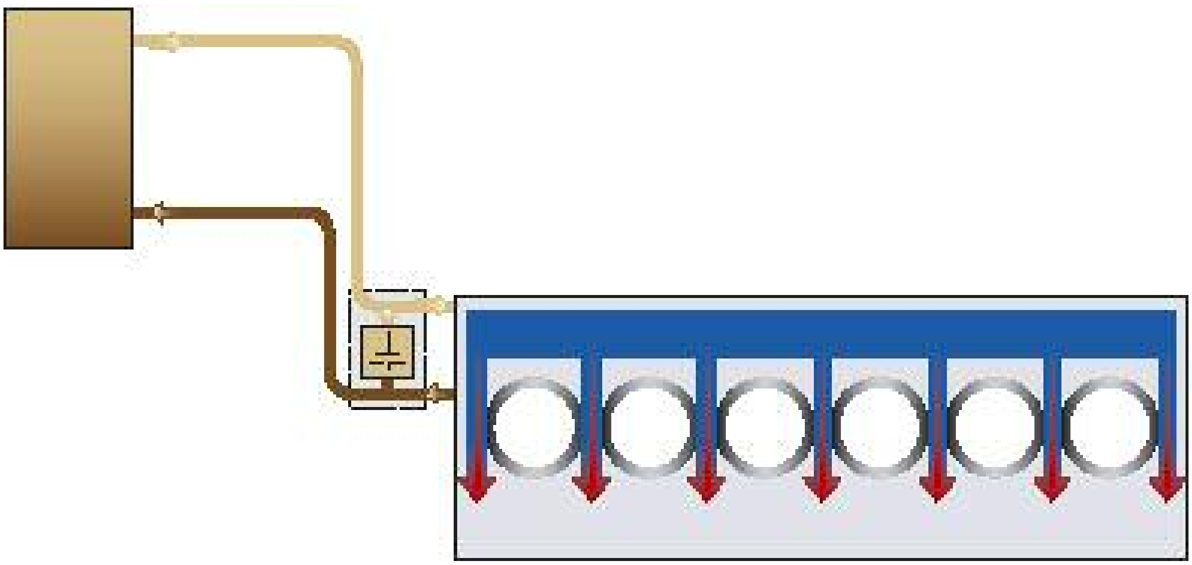
The engine control unit uses the engine load, the operating mode and the data from the temperature sensors to calculate the required cooling output. Based on this data, the engine control unit issues the corresponding command to the electric coolant pump.

The electric coolant pump regulates its speed in accordance with this command.
The system coolant flows through the motor of the coolant pump, thus cooling both the motor as well as the electronic module. The coolant lubricates the bearings of the electric coolant pump.

Note: The same rules apply to all electric coolant pumps. The pump must be filled with coolant when removed for service to prevent any corrosion. Also, the pump impeller must be turned by hand before installation to ensure the pump is not siezed.

Engine-oil Cooling

The N54 engine is equipped with a highperformance engine-oil cooler. The pendulum-slide pump delivers the oil from the oil sump to the oil filter. A thermostat flanged to the oil-filter housing admits the oil to the engine-oil cooler. The engine-oil cooler is located in the right wheel arch in the E92. The thermostat can reduce the resistance opposing the oil by opening the bypass line between the feed and return lines of the engine-oil cooler. This ensures that the engine warms up safely and quickly.



Heat Management

The engine control unit of the N54 engine controls the coolant pump according to requirements:

- Low output in connection with low cooling requirements and low outside temperatures
- High output in connection with high cooling requirements and high outside temperatures

The coolant pump may also be completely switched off under certain circumstances, e.g. to allow the coolant to heat up rapidly during the warm-up phase. However, this only occurs when no heating is required and the outside temperature is within the permitted range.

The coolant pump also operates differently than conventional pumps when controlling the engine temperature. To date, only the currently applied temperature could be controlled by the thermostat.

The software in the engine control unit now features a calculation model that can take into account the development of the cylinder head temperature based on load.
In addition to the characteristic map control of the thermostat, the heat management system makes it possible to use various maps for the purpose of controlling the coolant pump. For instance, the engine control unit can adapt the engine temperature to match the current operating situation.

This means that four different temperature ranges can be implemented:

- 108°C ECO mode
- 104°C Normal mode
- 95°C High mode
- 90°C High + map-thermostat mode

The control system aims to set a higher cylinder-head temperature (108°C) if the engine control unit determines ECO (economy) mode based on the engine performance.
The engine is operated with relatively low fuel consumption in this temperature range as the internal friction is reduced.

An increase in temperature therefore favors slower fuel consumption in the low load range. In HIGH and map-thermostat mode, the driver wishes to utilize the optimum power development of the engine. The cylinder-head temperature is reduced to 90°C for this purpose. This results in improved volumetric efficiency, thus increasing the engine torque. The engine control unit can now set a certain temperature mode adapted to the respective operating situation. Consequently, it is possible to influence fuel consumption and power output by means of the cooling system.

The temperatures specified only ever represent a target value, the attainment of which is dependent on many factors. These temperatures are first and foremost not attained precisely.

The consumption-reducing and power increasing effects arise in each case in a temperature spectrum. The function of the cooling system is to provide the optimal cooling output according to the boundary conditions under which the engine is being operated.

Intelligent Heat Management Options

The previous section dealt with the various temperature ranges in which heat management is effected. However, an electrically driven coolant pump makes available even further options. For instance, it is now possible to warm up the engine without recirculating the coolant or to allow the pump to continue to operate after turning off the engine to facilitate heat dissipation. The advantages offered by this type of pump are listed in the following table:

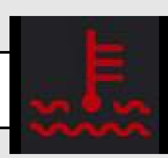
Consumption	• Faster warm-up as coolant is not recirculated until needed • Increased compression ratio due to greater cooling output all full load as compared to similar engines without this option
Emissions	• Faster engine warm-up by drastically reduced pump speed and the lower volumetric flow of coolant • Reduced friction • Reduced fuel consumption • Reduced exhaust emissions
Power Output	• Component cooling independent of engine speed • Requirement controlled coolant pump output • Avoidance of power loss
Comfort	• Optimum volumetric flow - Heating capacity reduced as required - Residual heat with engine stationary
Component Protection	• After-running of electric coolant pump = improved heat dissipation from engine switch off point. Allows protection of turbochargers by reduced oil “coking” during heat soak.

System Protection

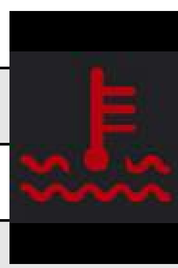
In the event of the coolant or engine oil being subject to excessive temperatures while the engine is running, certain functions in the vehicle are influenced so that more energy is made available to the engine-cooling system, i.e. temperature-increasing loads are avoided.

These measures are divided into two operating modes:

- Component protection
- Emergency

Engine oil temp (T-oil C)	Operating mode	Display in Cluster	Power output reduction, Air conditioning	Power output reduction, Engine	Torque converter clutch lockup
148			Start 0 %	Start 0 %	
149			–		
150	Component Protection		–		
151	Component Protection		–	From here = clear reduction	
152	Component Protection		End - 100 %		
153	Component Protection				
154	Component Protection				
155	Component Protection				
156	Component Protection				
157	Component Protection			End @ 90 %	
158	Emergency				Active
159	Emergency				Active
160	Emergency				Active
161	Emergency				Active
162	Emergency				Active
163	Emergency				Active

Measures and Displays for Coolant Temperature

Coolant (T-Coolant)	Operating mode	Display in Cluster	Power output reduction, Air conditioning	Power output reduction, Engine	Torque converter clutch lockup
115					
116					
117	Component Protection		Start 0 %	Start 0 %	
118	Component Protection		–	From here = clear reduction	
119	Component Protection		–	–	
120	Component Protection		End - 100 %	–	
121	Component Protection			–	
122	Component Protection			–	Active
123	Component Protection			–	Active
124	Component Protection			End @ 90 %	Active
125	Emergency				Active
126	Emergency				Active
127	Emergency				Active
128	Emergency				Active
129	Emergency				Active

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