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2007 Engine Technology

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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.

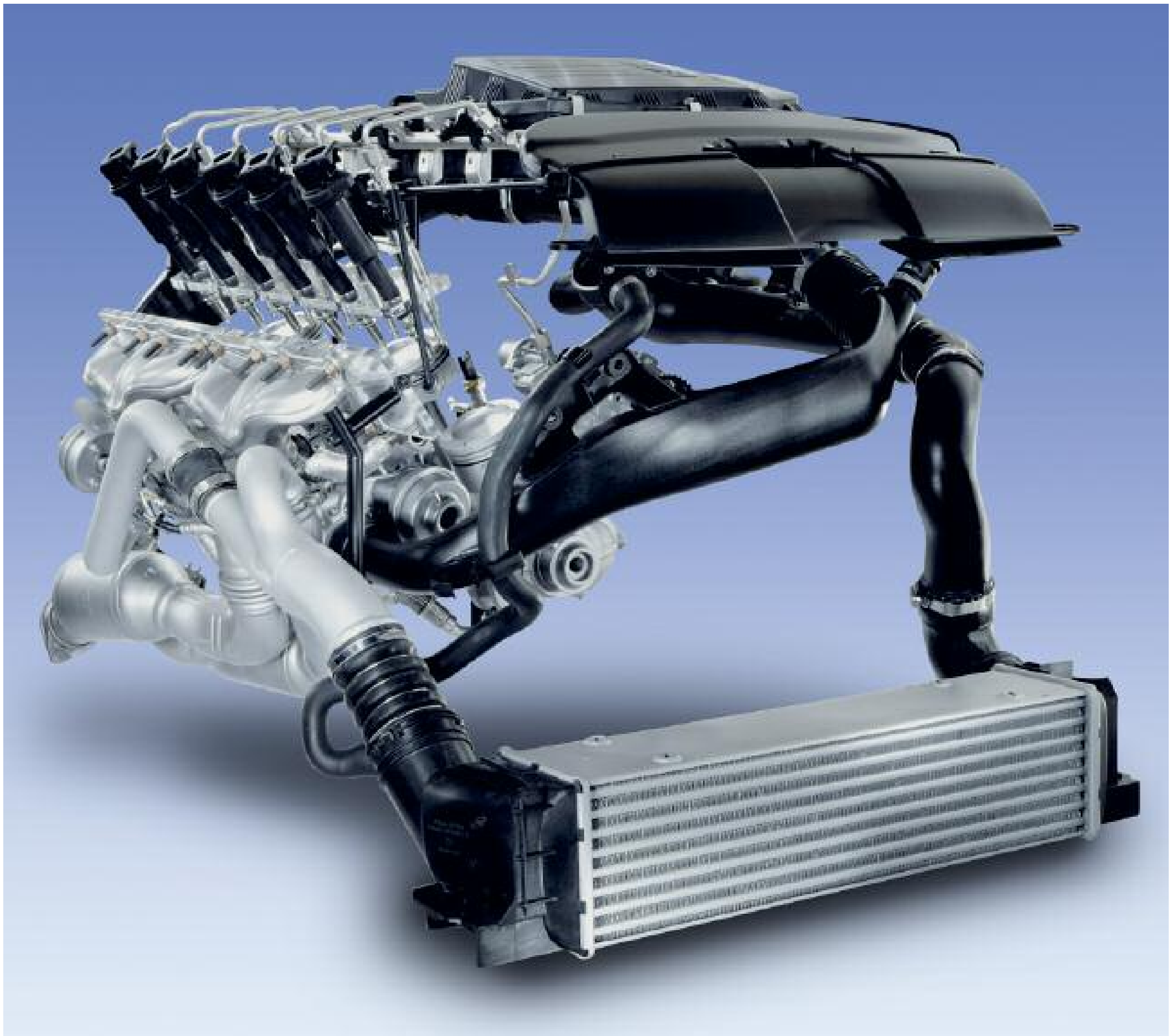
Supercharging can be broken down into two categories, those engines which use a mechanical supercharger and those which use an exhaust driven supercharger. Today, BMW is only using turbochargers, which are exhaust driven.

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.

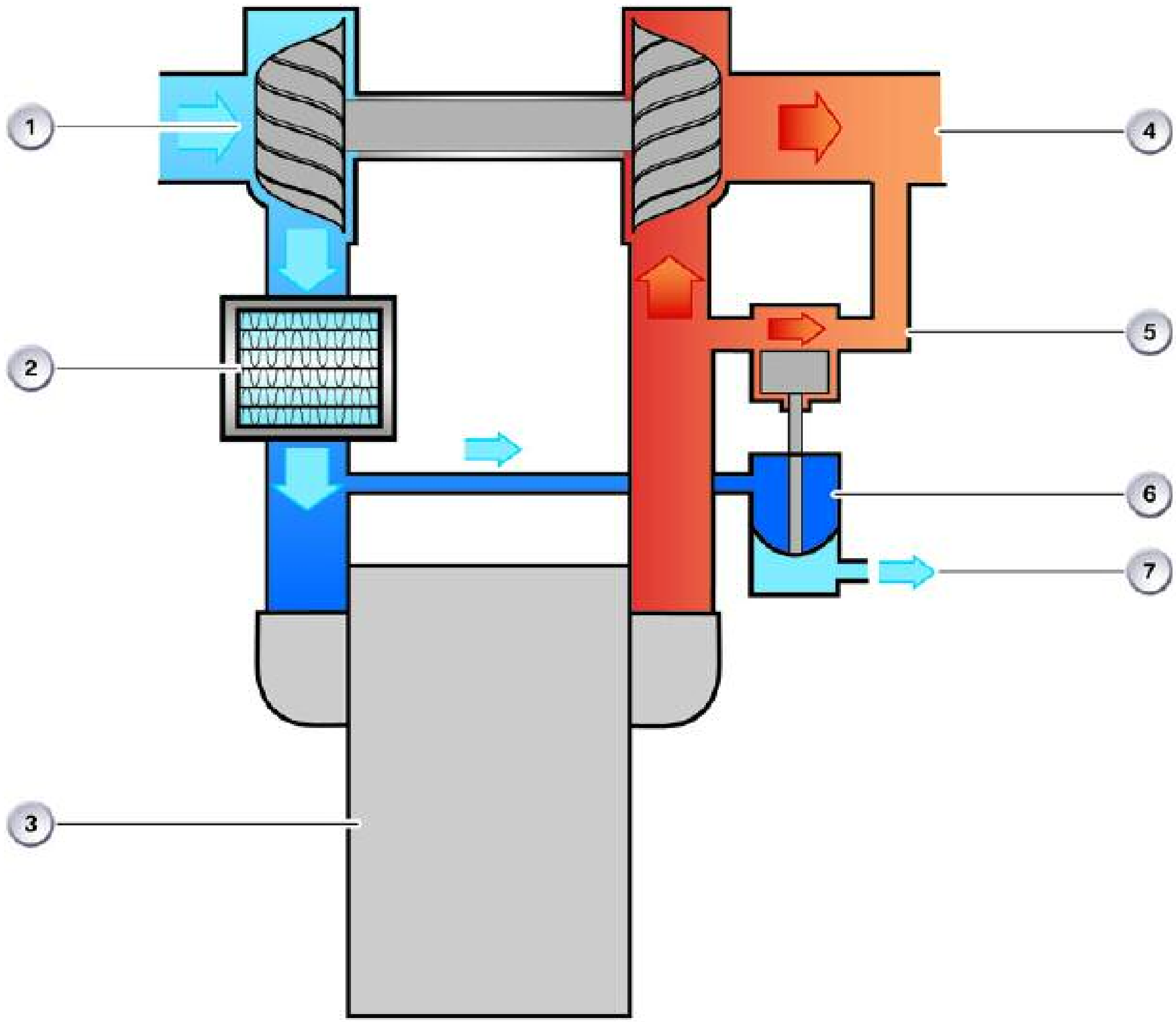
This increased density during the intake stroke ultimately adds up to the creation of more engine output torque. Of course, this increased density much be accompanied by additional fuel to create the desired power. This is accomplished by engine management system programming to increase injector “on-time”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

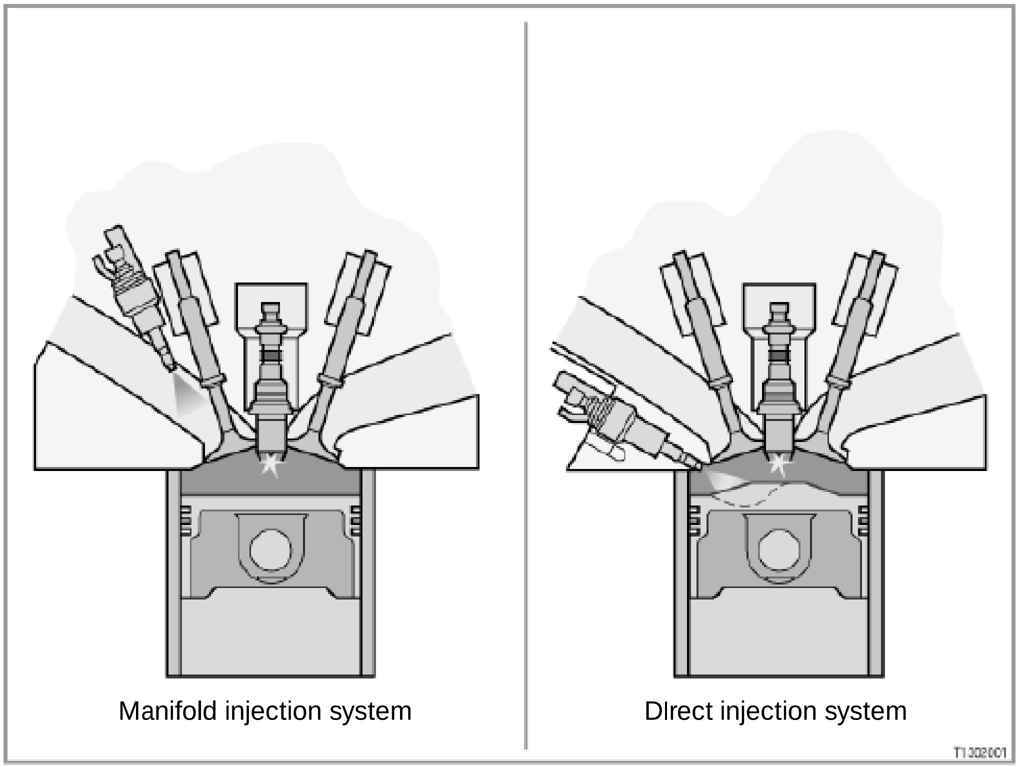
The first application of this technology on a BMW was in 2003 on the 760Li. The new N73 V-12 engine utilized direct injection with the combination of Valvetronic and the latest direct injection technology.

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.

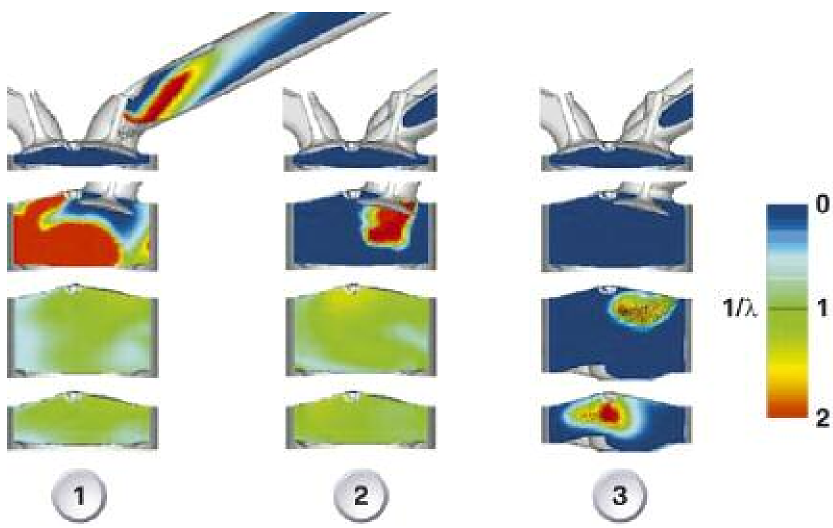
Mixture Formation

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.

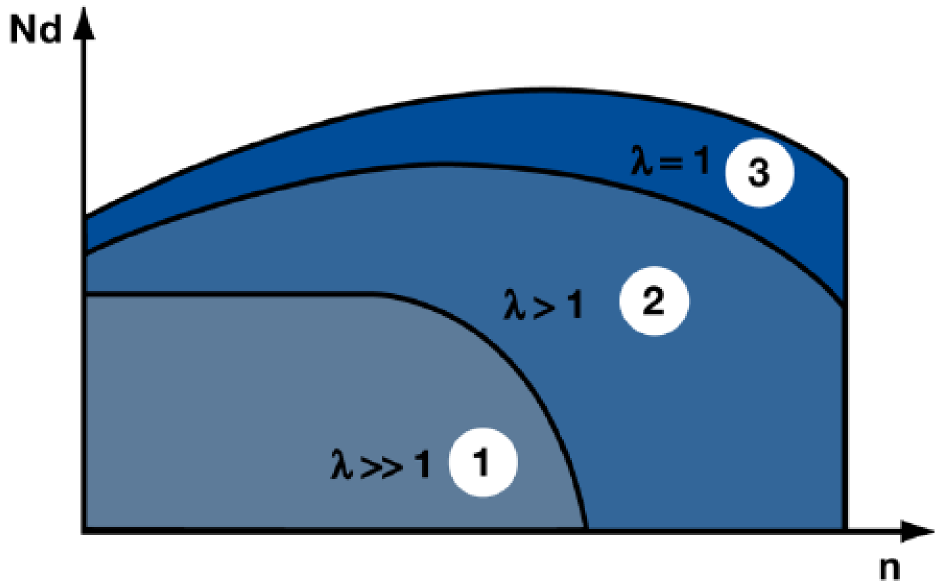
A DI fuel system has two basic operating concepts:

- 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 NOx 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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