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# Fuel Management

**Model: All**

**Production: All**

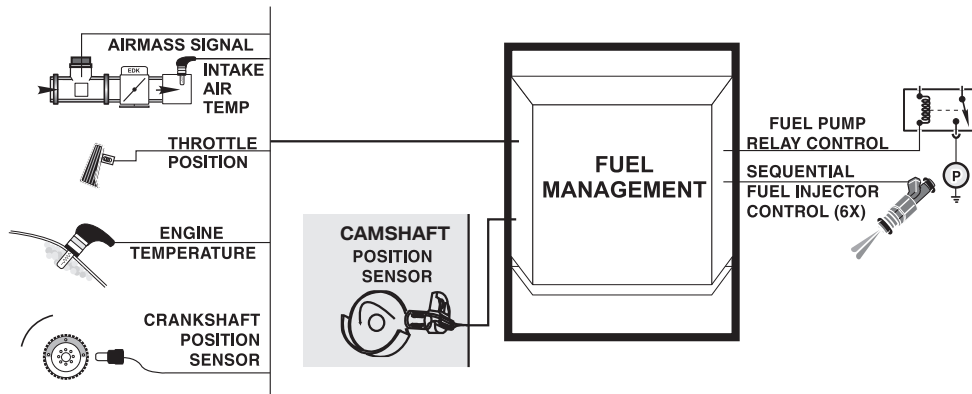
# OBJECTIVES

After completion of this module you will be able to:

- Understand and perform a low pressure fuel system test
- Understand all inputs used in determining the proper fuel injector operation
- Perform a scope test of fuel injectors
- Understand how a BMW high pressure fuel system operates

# Fuel Management

## Example of IPO for a Fuel Management System



## Principle of Operation

One of the main purposes of the ECM is Fuel Management which includes the actuation of several components. In the following pages you will find a generic explanation on how this system works. For more detailed information please access BMW Training Reference Manuals found online.

Fuel Management delivers fuel from the tank to the intake ports of the engine. To accomplish this, **fuel supply** must be available to the fuel injectors. Once this is accomplished, the fuel must be injected in the precise amount and at the correct time. The ECM does not directly monitor fuel supply, although it does control fuel supply. The **Fuel Pump** supplies fuel when it receives operating voltage from the Engine Control Module Relay supplying the **Fuel Pump Relay**. **The ECM controls and monitors fuel injection.**

The **Fuel Pump** will be activated when the ignition (KL\_15) is switched “on” and the ECM supplies a ground circuit to activate the Fuel Pump Relay. The Fuel Pump Relay supplies operating power to the in-tank mounted fuel pump. This is a momentary activation to “pressurize” (prime) the fuel system.

The ECM then requires an engine speed signal from the **Crankshaft Position/RPM** Sensor to maintain continuous Fuel Pump Relay activation.

If the engine RPM signal is not present, the ECM will deactivate the Fuel Pump Relay.

**The Fuel Injectors** will be opened by the ECM to inject pressurized fuel into the engine. The Fuel Injectors receive voltage from the Engine Control Module Relay. The ECM controls the opening by activating the ground circuits. The ECM will vary the duration (in milli-seconds) of “opening” time to regulate the air/fuel ratio.

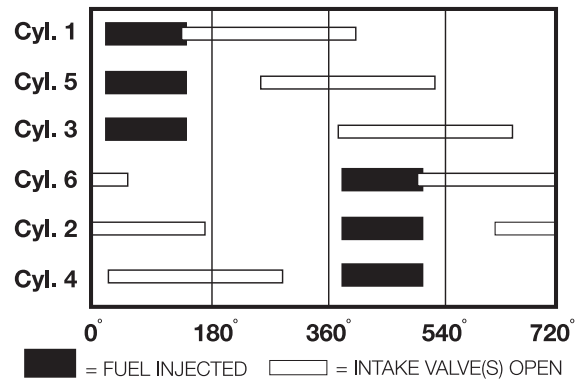
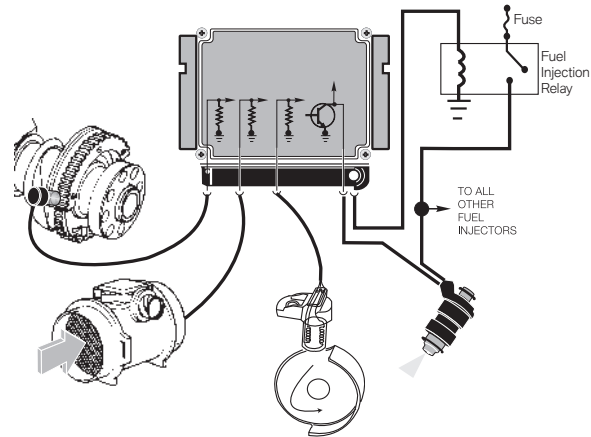
The ECM has the Final Stage output transistors that switch ground to the injectors. The Injector “triggering” is first established from the Crankshaft Position/RPM Sensor.

The ECM is programmed to activate the Final Stage output transistors once for every two revolutions of the crankshaft. in two groups (Semi-Sequential Injection).

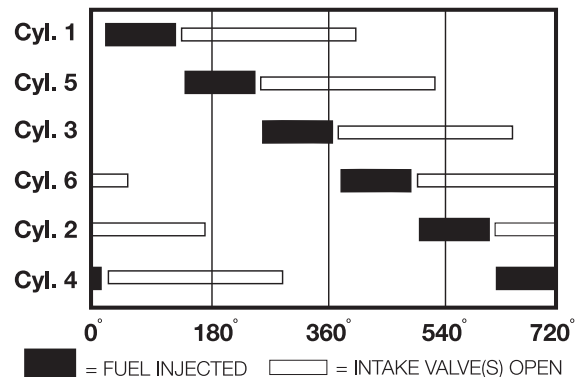
The injectors are opened in two groups for every complete “working cycle” of the engine. This delivers the fuel charge for cylinders 1,5,3 during one revolution of the crankshaft and cylinders 6,2,4 during the second revolution of the crankshaft. This process enhances fuel atomization during start up.

During start up, the ECM recognizes the Camshaft Position (Cylinder ID) input. The camshaft position is referenced to the crankshaft position. It then switches the injection to Full Sequential. This process “times” the injection closer to the intake valve opening for increased efficiency.

When activated, each injector delivers the full fuel charge at separate times during each engine working cycle.



**If this input is faulty, the ECM will activate the injectors in Parallel to maintain engine operation and set a fault code.**

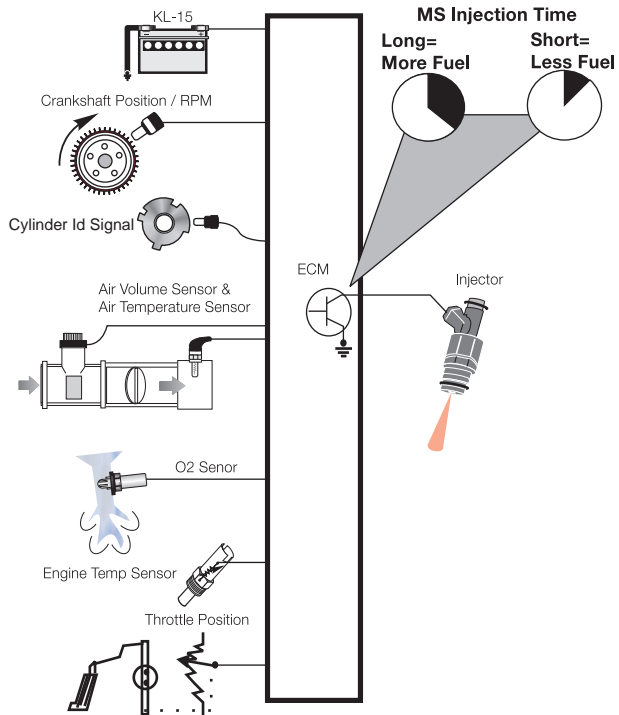


After the engine has been started, the ECM determines the **Injector “open” time** to maintain engine operation. The ECM will calculate the injection “timing” based on a combination of the following inputs.

- Battery Voltage
- Throttle Position
- Air Flow Volume/Mass
- Air Temperature
- Crankshaft Position/RPM
- Camshaft Position (Cylinder ID)
- Engine Coolant
- Oxygen Sensor

**Additionally in turbocharged engines the ECM also employs:**

- Boost Pressure Sensor.
- Charge Air Pressure and Temperature Sensor (Before EDK).
- Intake Manifold Pressure Sensor (After EDK).



The injection millisecond (ms) value will be regulated based on battery voltage. When cranking, the voltage is low and the ECM will increase the ms value to compensate for injector “lag time”. When the engine is running and the battery voltage is higher, the ECM will decrease the injection ms value due to faster injector reaction time.

Cold starting requires additional fuel to compensate for poor mixture and the loss of fuel as it condenses onto cold intake ports, valves and cylinder walls . The cold start fuel quantity is determined by the ECM based on the Engine Coolant Temperature Sensor input during start up.

During cranking, additional fuel is injected (in Semi-Sequential) for the first few crankshaft revolutions. After the first few crankshaft revolutions, the injected quantity is metered down as the engine comes up to speed. When the engine speed approaches idle rpm, the ECM recognizes the Camshaft Position and switches to Full Sequential injection.

When the engine is cold, optimum fuel metering is not possible due to poor air/fuel mixing and an enriched mixture is required. The Coolant Temperature input allows the ECM to adjust the injection “ms” value to compensate during warm up and minimize the injected fuel at engine operating temperature.

When the engine is at idle, minimum injection is required. Additional fuel will be added if the ECM observes low engine rpm and increasing throttle/air volume inputs (acceleration enrichment). As the throttle is opened, the ECM monitors acceleration and rate of movement. The ECM will increase the volume of injected fuel into the engine by increasing the injection “ms” value. The “full throttle” position indicates maximum acceleration and the ECM will add more fuel (full load enrichment).

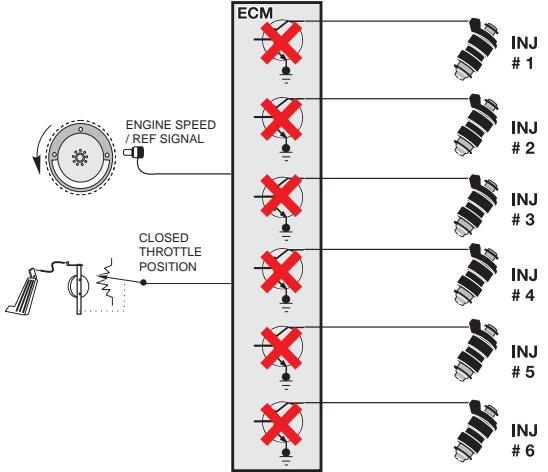
As the throttle is closed, the ECM decreases the injection “ms” value (fuel shut off) if the rpm is above idle speed (coasting). This feature decreases fuel consumption and lowers emissions. When the engine rpm approaches idle speed, the injection “ms” value is increased (cut-in) to prevent the engine from stalling. The cut-in rpm is dependent upon the engine temperature and the rate of deceleration.

The Hot-Film Air Mass (HFM) signal provides the measured amount of intake air volume/mass. This input is used by the ECM to determine the amount of fuel to be injected to “balance” the air/fuel ratio.

The Air Temperature Signal allows the ECM to make an additional calculation of air density. The varying voltage input from the NTC sensor indicates the larger proportion of oxygen found in cold air, as compared to less oxygen found in warmer air. The ECM will adjust the amount of injected fuel because the quality of combustion depends on oxygen sensing ratio.

The Crankshaft Position/RPM signals the ECM to start injection as well as providing information about the engine operation. This input is used in combination with other inputs to determine engine load which increases/decreases the injection “ms” value. Without this input the ECM will not activate the injectors.

The Camshaft Position (Cylinder ID) affects the injection timing (Semi-Sequential/Full Sequential). To accomplish this, the ECM contains six Final Stage output transistors that activate the injectors individually. The engine operates sufficiently on Semi-Sequential Injection (two groups of three), but more efficiently on Full Sequential Injection (six individual). If one of the fuel injector circuits faulted, the engine can still operate on limited power from the other remaining fuel injector circuits.





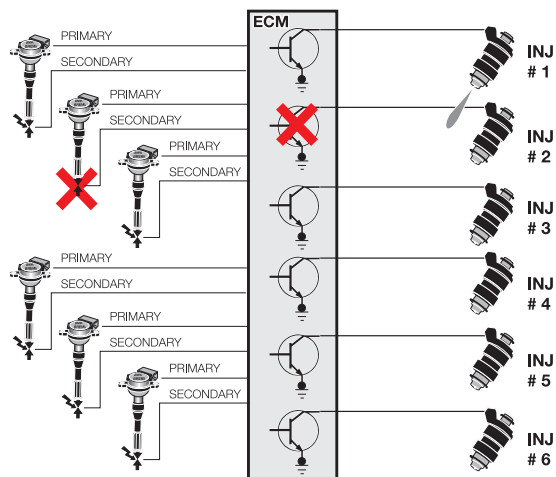
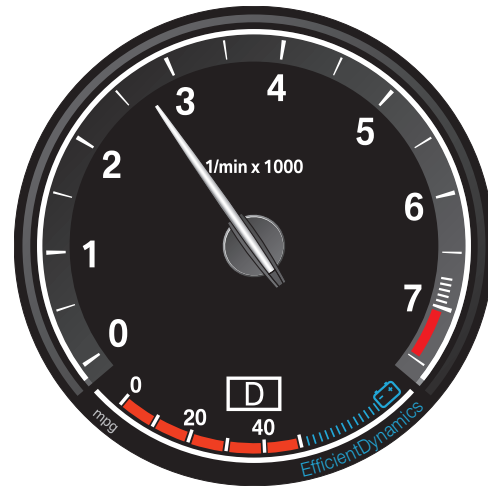
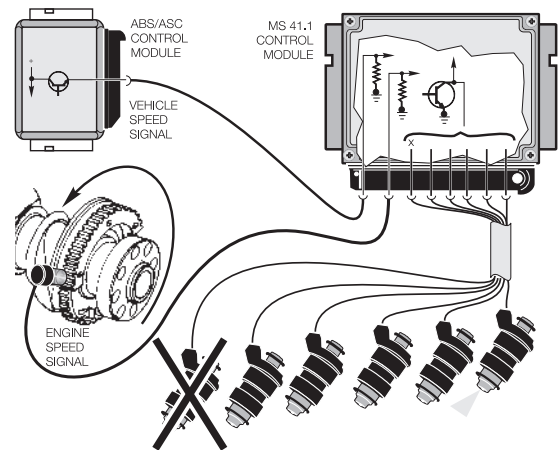
The ECM will selectively deactivate injectors to control maximum engine rpm (regardless of vehicle speed). When the engine speed reaches its “redline”, the injectors will be individually deactivated as required to protect the engine from over-rev. As the engine speed drops below “redline”, injector activation will be resumed. This feature does not protect the engine from a forced over-rev situation such as improperly downshifting a manual transmission equipped vehicle (driver error).

The ECM will also protect the Catalytic Converter by deactivating the injectors.

If the ECM detects a “misfire” (ignition, injection or combustion) it can selectively deactivate the Final Stage output transistor for that cylinder(s).

The injector(s) will not open, preventing unburned fuel from entering the exhaust system.

The ECM controls the individual injector circuits resulting in deactivation of one or multiples. This will limit engine power, but protect the Catalytic Converter.



**Maximum vehicle speed is also limited by the ECM selectively deactivating the injectors (regardless of engine rpm).**

**This limitation is based on the vehicle dimensions, specifications and installed tires (speed rating).**

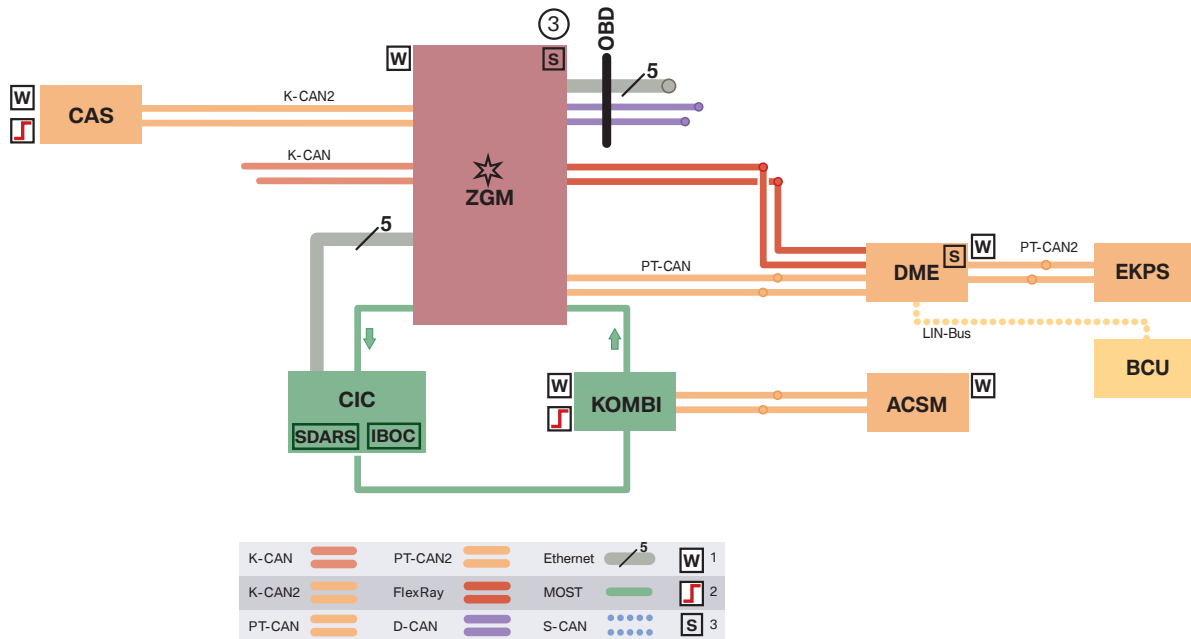
The ECM (DME) is connected to the EKP module via the PT-CAN network via a pulse width modulated (PWM) signal according to the fuel quantity required by the ECM. The electric fuel pump in the EKP system is activated as required. The DME calculates the amount of fuel required at the given point in time. The total volume required is transmitted as a message to the EKP control unit via PT-CAN.

The EKP control unit controls the electric fuel pump on the basis of mappings so that the electric fuel pump delivers the exact amount of fuel required.

The EKP control unit converts this message into an output voltage. This output voltage is then used to control the speed of the electric fuel pump. This achieves a delivery which corresponds with the requirements.

The illustrations shown below are from an E90 and an F10. The EKP module on the E90 contains one of the terminating resistors for the PT-CAN.

### F10 Fuel Requirement Signal Path



### Fuel Requirement Mappings

Fuel requirement mappings are stored in the EKP control unit. The fuel requirement mappings are encoded for each specific engine and model. The EKP control unit uses the mappings as the basis on which to calculate the total amount of fuel to be delivered from the following variable:

- Amount of fuel required by the engine (request from the ECM). This results in a pulse-width modulated output voltage from the EKP control unit. The output voltage of the EKP control unit is the supply voltage for the electric fuel pump. The EKP control unit controls the speed of the electric fuel pump via the supply voltage. The EKP control unit controls the speed by comparing the actual speed with the specification.

## Speed of the Electric Fuel Pump

The EKP control unit sends the current supply to the fuel pump (pulse-width modulated). This voltage is absorbed as a specific ripple due to the individual armature windings of the rotating electric motor. The ripple corresponds with the number of segments in the commutator which corresponds with the number of armature windings in the electric motor.

The number of waves produced per revolution is equal to the number of existing commutator segments.

This means that the EKP control unit can employ a patented procedure - "Ripple Counter" as the basis for calculating the actual speed of the fuel pump using power consumption ripple.

## Coding and Programming

The data for the electronically controlled fuel pump system is encoded as follows:

- In the ECM (DME), the engine and model-related characteristic curves for fuel delivery according to requirements.
- In the EKP control unit: specific characteristic curves for the relevant fuel system



### Failsafe Operation

**If the fuel quantity requirement from the ECM and/or the EKP rotation speed signal fails, the fuel pump will continue to operate with the greatest delivery rate (100%) when terminal KL\_15 is activated. This guarantees fuel supply even if the control signals fail.**

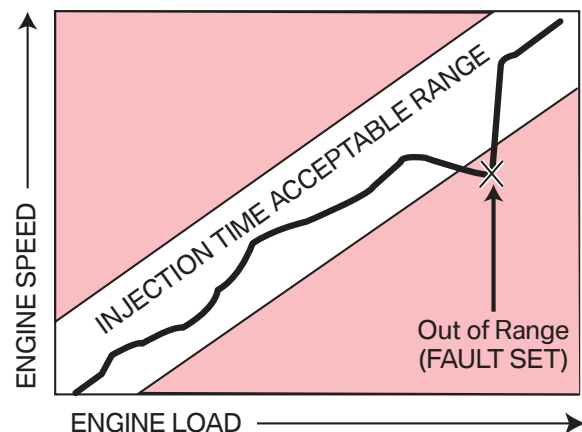
### Fuel Injection Control Monitoring

Fuel Injection Control Monitoring is performed by the ECM for OBD II requirements. Faults with the fuel injectors and/or control circuits will be stored in memory. This monitoring includes:

- Closed Loop Operation
- Oxygen Sensor Feedback

These additional corrections are factored into the calculated injection time. If the correction factor exceeds set limits a fault will be stored in memory.

When the criteria for OBD II monitoring is achieved, the "Malfunction Indicator Light" will be illuminated.



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## Fuel Supply

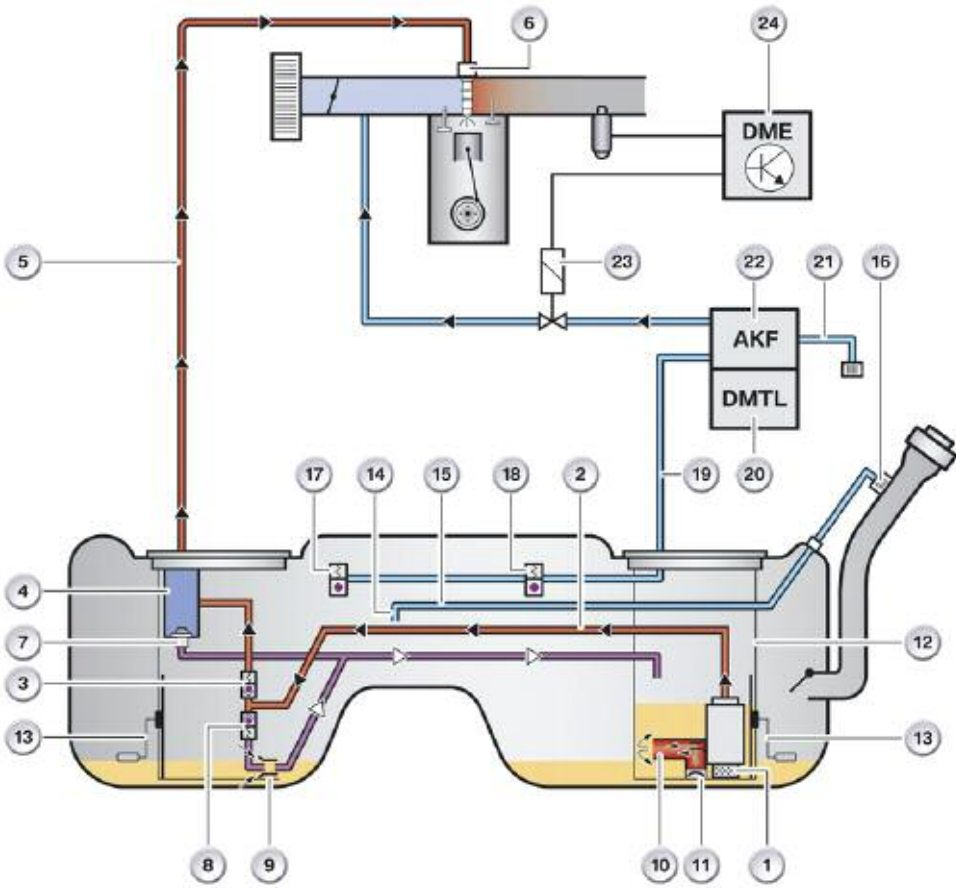
The fuel is delivered from the fuel tank to the engine in the following sequence:

- From the right half of the fuel tank;
- through the initial filler valve (11);
- into the fuel baffle (12);
- from the electric fuel pump (1);
- via a T-piece, on the one side, through the check valve (3) into the fuel filter (4);
- through the feed line (5) in the left-hand service opening to the engine;
- and, on the other side, via the check valve (8) to the left-hand suction jet pump (9) back into the fuel baffle;
- parallel from the electric fuel pump to the right-hand suction jet pump (10);
- and from the right half of the fuel tank into the fuel baffle.

The fuel filter (4) and pressure regulator (7) are located at the left-hand service opening. The check valve (8) opens at a fuel pressure above 2.5 bar. It ensures the engine receives sufficient fuel before the left suction jet pump cuts into the circuit.

As an example, on the N52 engine the pressure regulator (7) routes the fuel back into the fuel baffle (12). A 5 bar pressure regulator is used for vehicles with the N52 engine.

**Fuel supply system on E9x**



Index	Explanation	Index	Explanation
1	Electric Fuel Pump	13	Fuel Level Sensor
2	Feed Line	14	Refuelling Line Connection Piece
3	Check Valve	15	Refuelling Ventilation Line
4	Fuel Filter	16	Refuelling Ventilation
5	Feed Line to Engine	17	Left Operation Ventilation Valve
6	Fuel Injector	18	Right Operation Ventilation Valve
7	Pressure Regulator	19	Operation Ventilation Line
8	Check Valve	20	Diagnosis Module for Tank Leakage (DM-TL)
9	Left Suction Jet Pump	21	Atmosphere Line
10	Right Suction Jet Pump	22	Carbon Canister
11	Initial Filling Valve	23	Fuel Tank Vent Valve
12	Fuel Baffle	24	Digital Motor Electronics

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## **N55 Engine**

### **■ Fuel supply system**

The fuel pressure sensor sends a voltage signal, corresponding to the system pressure applied between the fuel pump and the high pressure pump, to the engine control unit (DME/ECM). The system pressure (fuel pressure) is determined with the fuel pressure sensor upstream of the high pressure pump. The target pressure is constantly compared to the actual pressure in the DME.

If the target pressure deviates from the actual pressure, the engine control unit increases or decreases the voltage for the electric fuel pump. This voltage is sent in the form of a message via the PT-CAN to the EKP control unit.

The electric fuel pump (EKP) control unit converts the message into an output voltage for the electric fuel pump, thus regulating the required delivery pressure for the engine (or high pressure pump). The electric fuel pump is pilot-controlled in the event of signal failure (fuel pressure sensor). Should the CAN bus fail the EKP control unit operates the electric fuel pump with the applied system voltage. The fuel flows via the high pressure line to the fuel rail. The fuel is buffered in the fuel rail and distributed to the fuel injectors.

### **■ Fuel quantity control**

The rail pressure sensor measures the current fuel pressure in the rail. The excess fuel is returned to the inlet of the high pressure pump when the quantity control valve in the high pressure pump opens. Vehicle operation is restricted in the event of the high pressure pump failing.

The quantity control valve controls the fuel pressure in the rail. The engine management actuates the quantity control valve with a pulse width-modulated signal. Depending on the pulse width, a variable throttle cross section is released, thus providing the quantity of fuel required for the current load status of the engine. It is also possible to reduce the pressure in the rail.

## **N63 Engine**

The fuel system on the F01/02 has gone under some design changes as compared to previous models. The familiar fuel tank with divided chambers is still in use. The familiar configuration which features the fuel pump on the right (passenger) side is also retained.

### **■ Fuel Supply System**

In order to comply with the regulations regarding evaporative emissions, there have been several changes to internal fuel tank components as well as the fuel tank itself.

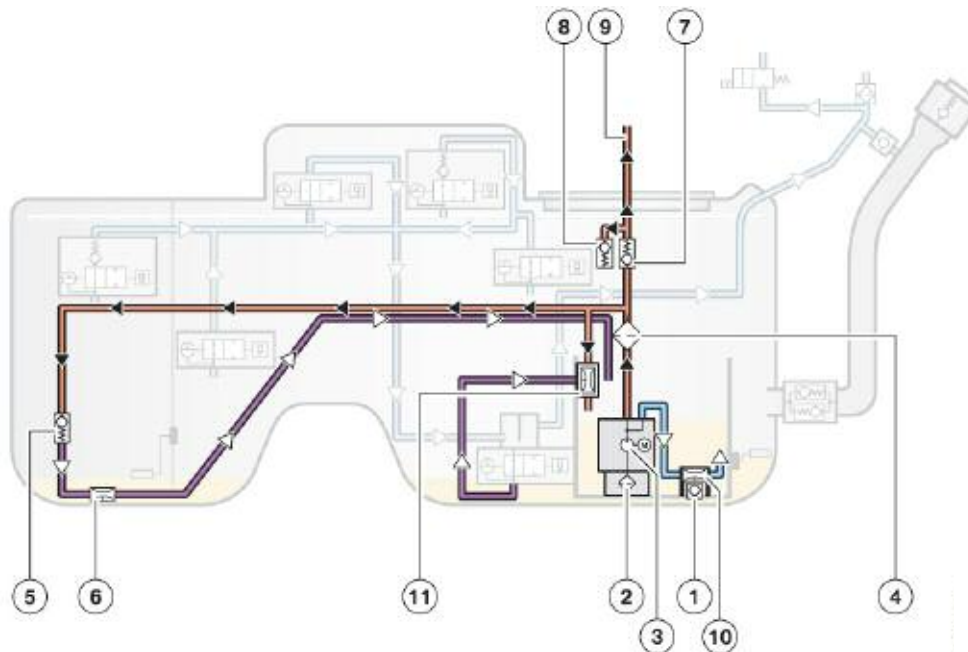
The fuel supply system has also been modified to eliminate the fuel pressure regulator. The following text summarizes the changes to the fuel supply system:

- the fuel supply system is now “pressure controlled”.
- the fuel pressure regulator has been replaced by the “pressure limiting valve” (8).
- the pressure in the fuel supply system is limited to a maximum of 5.8 bar by the pressure limiting valve (8).
- the EKPS will control the fuel pump in order to deliver only the amount of fuel required based on information from the fuel pressure sensor (low pressure).

Due to the nature of the installation space in the vehicle, the fuel tank is divided into two chambers. The fuel supply system has two delivery units that are accommodated in the right and left fuel tank halves.

In the event of the surge chamber being completely empty, initial fill valve (1) enables fuel to enter the surge chamber during the refueling process.

#### Fuel supply system on F01/F02 with N63 engine

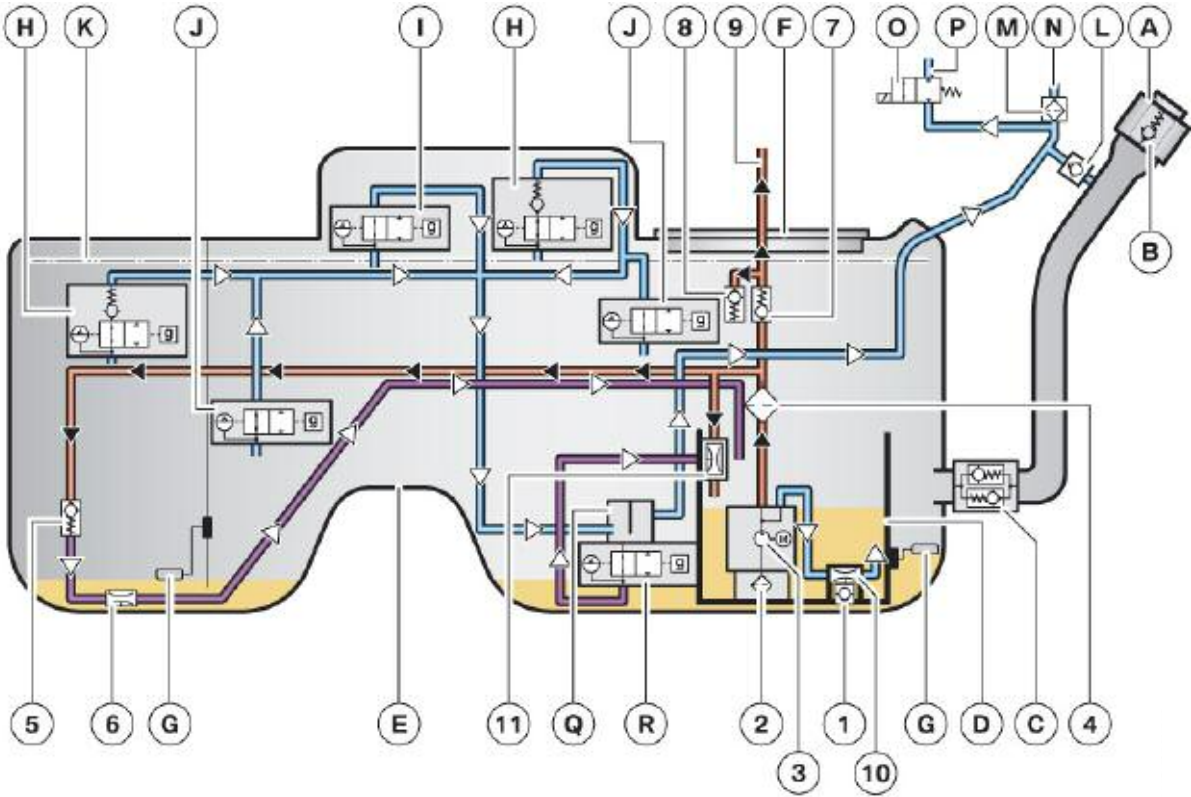


Index	Explanation	Index	Explanation
1	Initial fill valve	7	Anti-leak valve
2	Intake mesh filter	8	Pressure limiting valve
3	Fuel pump	9	Feed line
4	Fuel filter	10	Suction jet pump
5	Non-return valve	11	Suction jet pump
6	Suction jet pump		

### N63 System Overview

Fuel passes through suction strainer (2) and enters fuel pump (3) and is then pumped to feed line (9) through fuel filter (4). The fuel pump resides in the surge chamber. A pressure limiting valve (8) is integrated into the feed line in the fuel tank.

### Fuel tank on F01 with N63 engine



For the first time for a gasoline engine, we are no longer using a pressure regulator. Instead, operation of the electric fuel pump is pressure-regulated. In response to the signal from the low-pressure fuel sensor, the speed of the electric fuel pump is adjusted to achieve the desired delivery pressure upstream of the high-pressure pump.

A further line branches off downstream of the fuel pump into the left half of the fuel tank and carries fuel from the left half into the surge chamber by way of a non-return valve (5) and suction jet pump (6).



Index	Explanation	Index	Explanation
A	Fuel cap	P	Purge air line
B	Pressure relief valve	Q	Fuel trap
C	Non-return flap with pressure relief valve	R	Roll-over valve
D	Surge chamber	1	Initial fill valve
E	Fuel tank	2	Intake mesh filter
F	Service cover	3	Electric fuel pump
G	Lever-type sensor	4	Fuel filter
H	Service breather valve with over fueling protection	5	Non-return valve
I	Filler breather valve	6	Suction jet pump
J	Service breather valve without over fueling protection	7	Anti-leak valve
K	Maximum fill level	8	Pressure limiting valve
L	Non-return valve	9	Feed line
M	Carbon canister (AKF)	10	Suction jet pump
N	Opening	11	Suction jet pump
O	Fuel tank vent valve (TEV)		

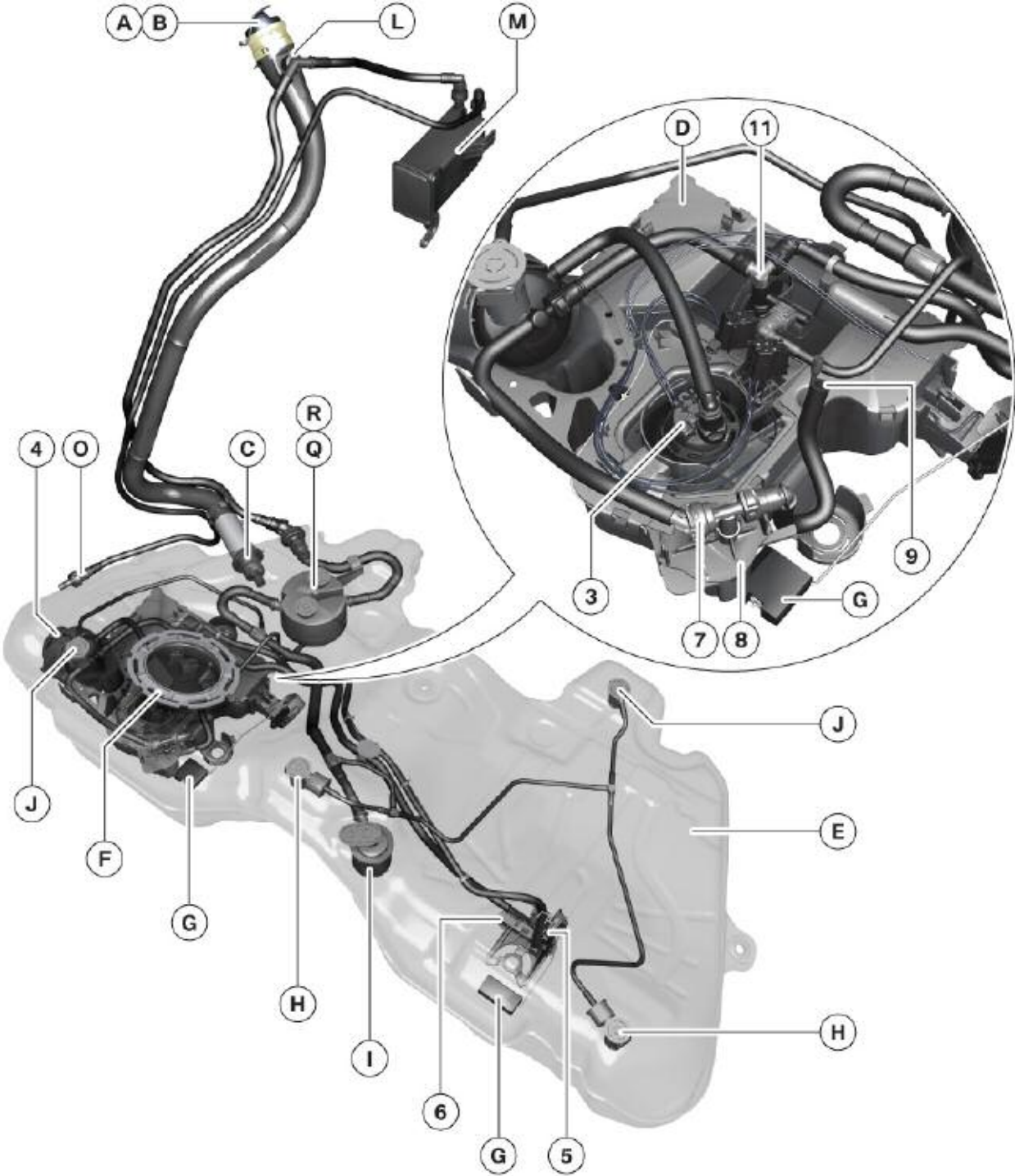
The non-return valve (5) prevents fuel from flowing back from the right half to the left half of the fuel tank while the engine is switched off.

When you switch off the engine, the feed line is depressurized but cannot run dry because, with the system being airtight, no air is able to enter the line. Anti-leak valve (7) prevents the fuel tank from leaking in the event of damage to the lines on the engine or underbody.

A further line en route to the left half of the fuel tank branches off to another suction jet pump (11), which sucks fuel out of the fuel trap and delivers it to the surge chamber.

Another line exits the pump carrying fuel pumped from the fuel tank to the surge chamber by suction jet pump (10).

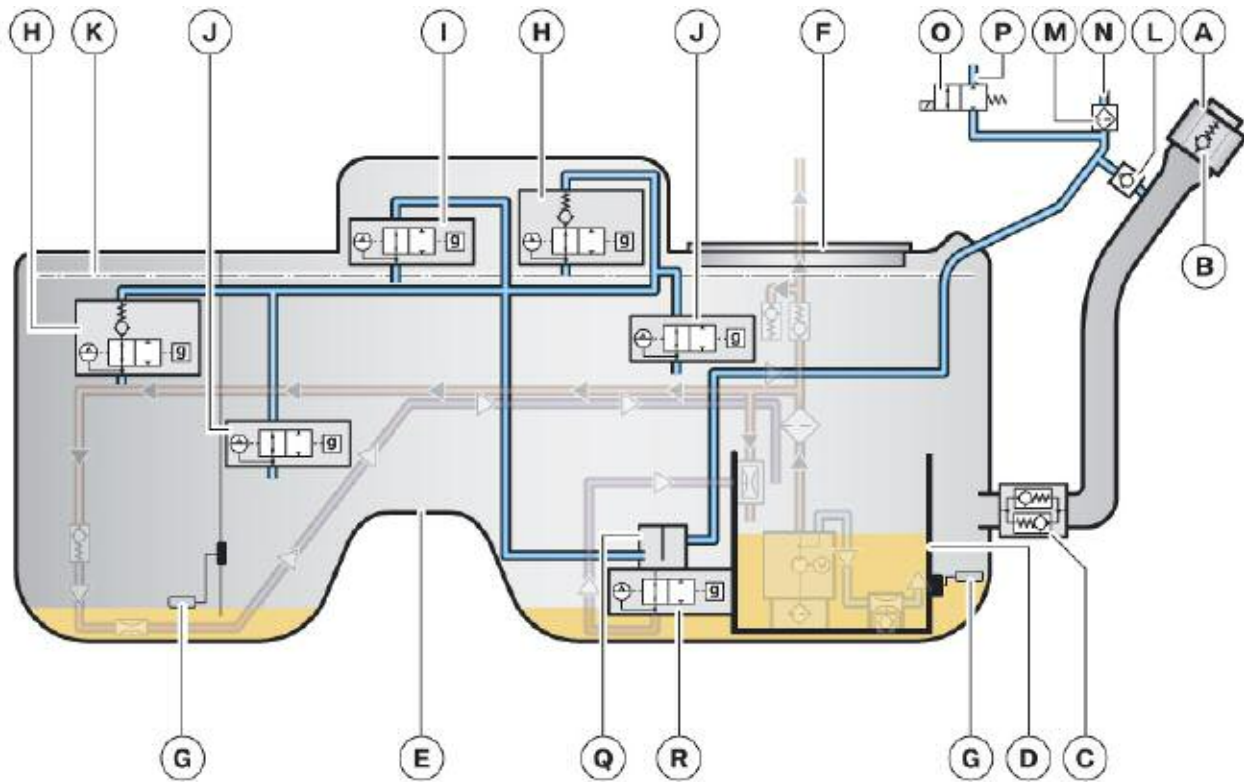
Fuel tank overview on F01 with N63 engine



<b>Index</b>	<b>Explanation</b>	<b>Index</b>	<b>Explanation</b>
A	Fuel cap	P	Purge air line
B	Pressure relief valve	Q	Fuel trap
C	Non-return flap with pressure relief valve	R	Roll-over valve
D	Surge chamber	1	Initial fill valve
E	Fuel tank	2	Intake mesh filter
F	Service cover	3	Electric fuel pump
G	Lever-type sensor	4	Fuel filter
H	Service breather valve with over fueling protection	5	Non-return valve
I	Filler breather valve	6	Suction jet pump
J	Service breather valve without over fueling protection	7	Anti-leak valve
K	Maximum fill level	8	Pressure limiting valve
L	Non-return valve	9	Feed line
M	Carbon canister (AKF)	10	Suction jet pump
N	Opening	11	Suction jet pump
O	Fuel tank vent valve (TEV)		

## Fuel Tank Breather System And Functions

### Fuel tank breather system on F01/F02 with petrol engine



Index	Explanation	Index	Explanation
A	Fuel cap	J	Service breather valve without over fueling protection
B	Pressure relief valve	K	Maximum fill level
C	Non-return flap with pressure relief valve	L	Non-return valve
D	Surge chamber	M	Carbon canister (AKF)
E	Fuel tank	N	Opening
F	Service cover	O	Fuel tank vent valve (TEV)
G	Lever-type sensor	P	Purge air line
H	Service breather valve with over fueling protection	Q	Fuel trap
I	Filler breather valve	R	Roll-over valve

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Fuel filler cap (A) has an integral pressure relief valve (B) to protect fuel tank (E) from excess pressure. At the end of the fuel filler neck, there is a non-return flap with a pressure relief valve (C). The non-return flap prevents fuel from sloshing back into the fuel filler neck. The non-return flap is sealed closed by a spring. In the event of a build-up of pressure in the fuel tank, the pressure relief valve in the non-return flap ensures that the excess pressure can escape through the fuel filler pipe and out of the fuel filler cap through the pressure relief valve.

The components in the fuel tank are accessible through the service cover (F). The fuel level is detected by the two lever-type sensors (G).

The surge chamber (D) ensures that the fuel pump never pumps dry. The surge chamber is permanently connected to the fuel tank and cannot be replaced separately.

The F01/F02 has a whole range of breather valves in the fuel tank. In principle, all of these valves fulfil the breather function, both during vehicle operation and during refueling.

Despite this, they are named to reflect their main purpose. They are therefore divided into filler valves and service breather valves. The service breather valves have a smaller opening, which means that, during refueling, they alone would not be able to let air escape from the fuel tank fast enough. There are service breather valves with and without over fueling protection.

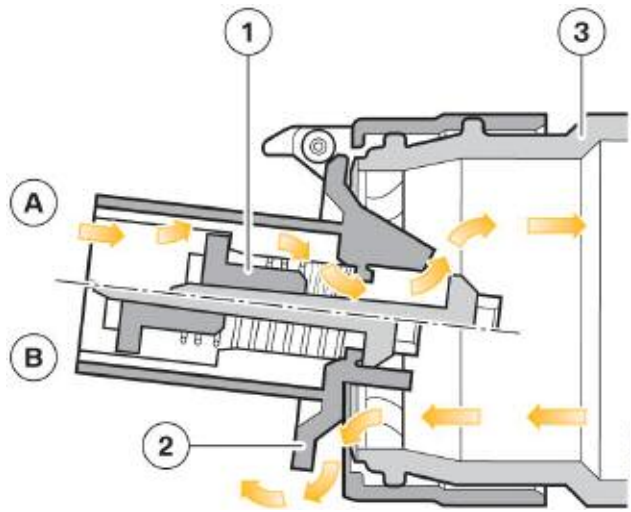
The service breather valves are arranged in such a way that air can still be released even if the vehicle is parked up on one side.

The filler breather valve is located at a high position. If the fuel level rises to this height during refueling, the valve closes. Air can no longer escape from the fuel tank fast enough, which causes fuel to rise up the filler pipe and switch off the fuel nozzle.

To enable the release of air to continue, there is a service breather valve located at the highest point. However, the presence of the valve in this location means that the fuel tank could be overfilled in the event of persistent refueling. Consequently, fuel would enter the activated charcoal filter and ultimately flow back out of the opening. To prevent this, the highest service breather valve is equipped with over fueling protection like the one on the left-hand side of the vehicle (as a safeguard if the vehicle were parked up on one side).

Fuel that is carried along with the release of air is collected in a fuel trap and pumped back into the surge chamber.

## Non-return Flap



Index	Explanation
A	Pressure relief valve open
B	Pressure relief valve closed
1	Pressure relief valve
2	Non-return flap
3	Fuel filler pipe

The non-return flap forms a tight seal. A force of approximately 0.15 N is required to open the non-return flap. This force is slightly exceeded during any type of refueling.

The non-return flap on the F01 is equipped with a pressure relief valve. The purpose of this pressure relief valve is to prevent excessive pressures from building up in the fuel tank. If the pressure in the fuel tank rises to over 150 mbar, the pressure relief valve opens and the pressure is able to escape through the fuel filler pipe and the breather line/pressure relief valve in the fuel cap.

The pressure relief valve in the non-return flap on the F01 is a new concept because the breather line is not protected by the body along its entire length. In the event of an accident, therefore, the breather line could be squeezed closed.

## Filler Breather Valve

The filler breather valve has several functions. As the name suggests, the valve fulfils the filler-neck breather function. In addition, however, it also performs the service breather function. It also has a rollover function.

The filler breather valve is notable for its large opening, which allows air to escape rapidly from the tank during refueling. If, during refueling, the float of the filler breather valve ascends with the rising fuel level and thereby closes the breather hole, fuel will rise up the fuel filler pipe and switch off the fuel nozzle.

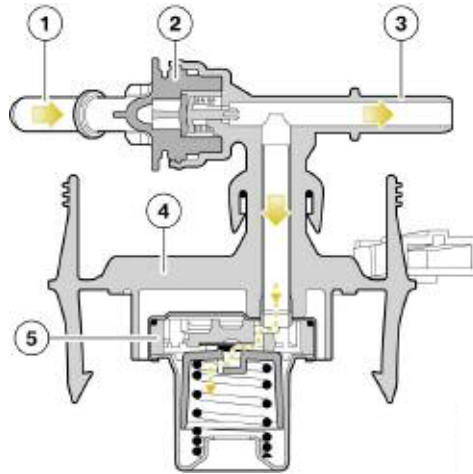
During vehicle operation, the pressure in the fuel system can rise as a result of the increase in temperature. This pressure is allowed to escape through the filler and service breather valve and the fuel trap. Fuel that is carried along in the process is collected in the fuel trap and sucked back while the fuel pump is in operation.

## ■ Pressure Limiting Valve

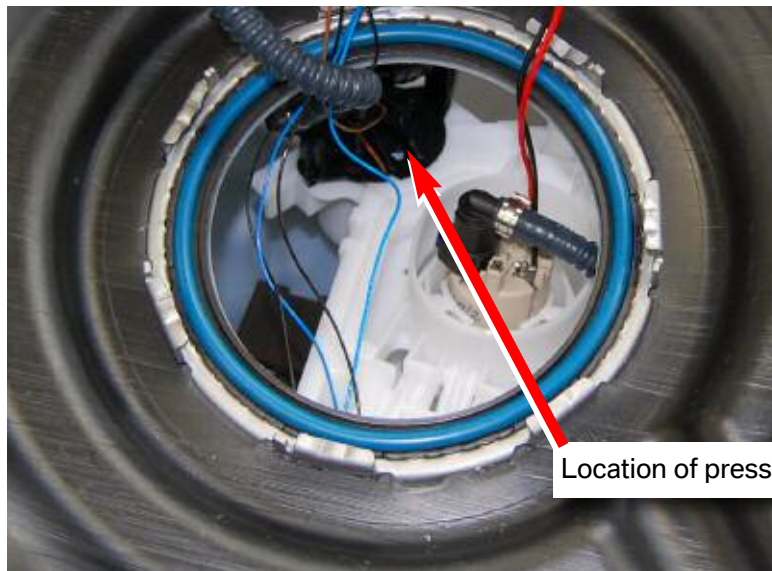
The pressure limiting valve is connected to ground by the plug-in contacts on the service cover. This prevents electrostatic charge on the valve.

The pressure limiting valve keeps fuel pressures in the feed section lower than approximately 5.8 bar in the N63 engines

This prevents excess pressures from building up in the feed line. Excess pressures would otherwise occur if the fuel filter were to become blocked, which would place the feed section of the fuel system under unnecessarily heavy loads.



Index	Explanation	Index	Explanation
1	Connection from electric fuel pump	4	Housing
2	Anti-leak valve	5	Pressure limiting valve
3	Connection to fuel filter		



Location of pressure limiting valve

---

## Fuel Tank Breather System

The increased demands on the evaporative emission systems require continuous development and improvements. The F01/F02 is no different. One of the first things to notice on the fuel tank is that there is only one service port. Also, the tank is made from two pieces and joined by a plastic “welding” process.

The only items which are serviceable at this time are the fuel pump, fuel filter and pressure limiting valve. There are several breather valves installed to help the fuel tank “breathe” during refueling and during operation.

These valves are therefore divided into filler valves and service breather valves. The service breather valves have a smaller opening, which means that, during refueling, they alone would not be able to let air escape from the fuel tank fast enough.

There are service breather valves with and without over fueling protection. The service breather valves are arranged in such a way that air can still be released even if the vehicle is parked up on one side.

The filler breather valve is located at a high position. If the fuel level rises to this height during refueling, the valve closes. Air can no longer escape from the fuel tank fast enough, which causes fuel to rise up the filler pipe and switch off the fuel nozzle.

To enable the release of air to continue, there is a service breather valve located at the highest point. However, the presence of the valve in this location means that the fuel tank could be overfilled in the event of persistent refueling.

Consequently, fuel would enter the activated charcoal filter and ultimately flow back out of the opening. To prevent this, the highest service breather valve is equipped with over fueling protection like the one on the left-hand side of the vehicle (as a safeguard if the vehicle were parked up on one side). Fuel that is carried along with the release of air is collected in a fuel trap and pumped back into the surge chamber.



## 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 the early 1950’s.



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 (N73 Engine). The N73 V-12 engine utilized direct injection with the combination of VAL-VETRONIC and the latest direct injection technology.

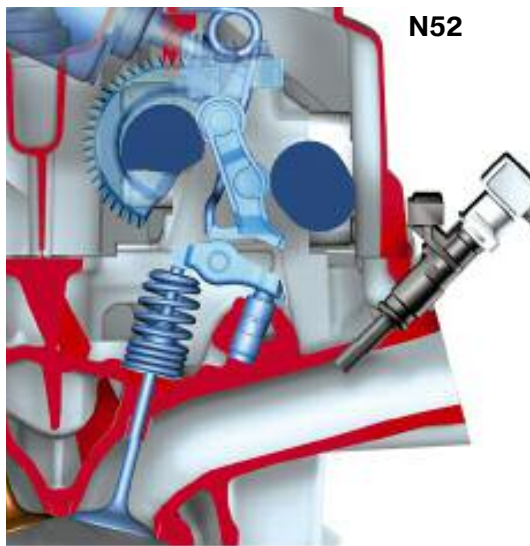
For the 2007 model year, BMW introduced a new 6-cylinder engine with direct fuel injection. The N54, which is turbocharged, uses the second generation of direct injection (DI 2), which is referred to as High Precision Injection (HPI).

Since then BMW introduced the N55, N63, S63 and N74, all of which incorporate Direct Injection Systems with either Piezo Injectors (HPI; N54, N63, S63, N74) or Solenoid type Injectors (HDEV; N55).

## 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). 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.

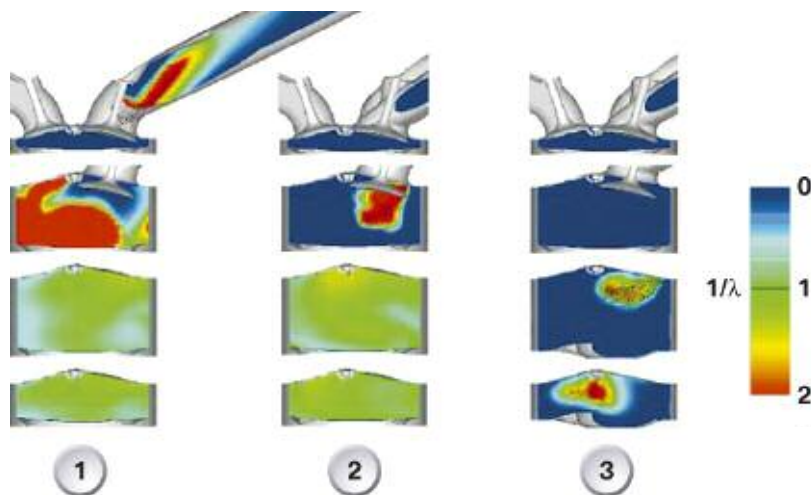


**Currently, BMW only uses engines which operate in this mode. The N52, N54, N55, N63 and N74, all operate mostly at  $\Lambda = 1$ .**

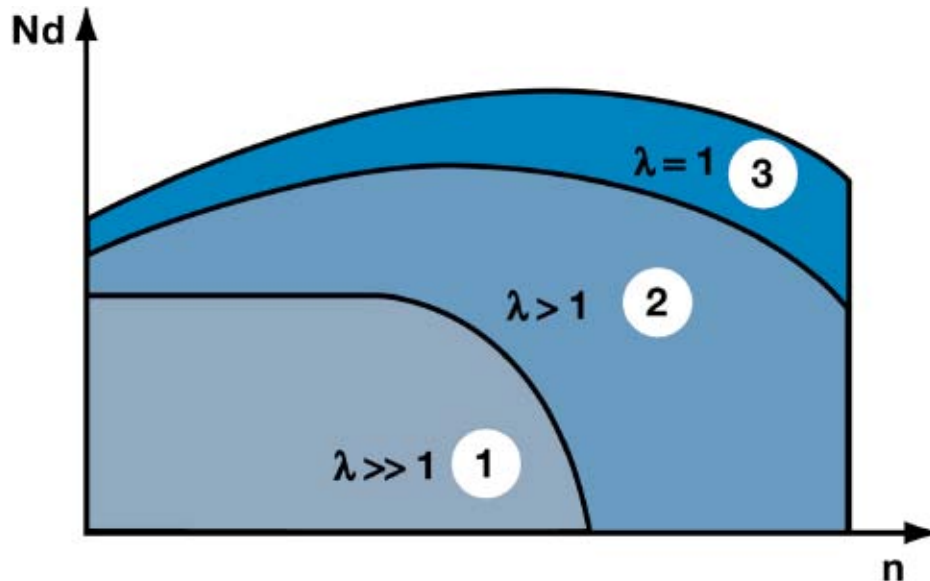
#### ■ Stratified Mixture Formation

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 of 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 NOx emissions. The increased NOx requires the use of a DeNOx 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.



**In the US market, BMW only uses engines that operate in “Homogeneous Mixture Formation”.**

## High Precision Injection (HPI)

BMW High Precision Injection (HPI) is the latest development of BMW direct fuel injection. This is the second generation 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.



Engine	Compression Ratio [ $\epsilon$ ]
N52 <sup>1</sup>	10.7
N54 <sup>2</sup>	10.2
N55 <sup>2</sup>	10.2
N62 <sup>1</sup>	10.5
N63 <sup>2</sup>	10.0
N73 <sup>1</sup>	11.5
N74 <sup>2</sup>	10.0

1 = NA Engine  
2 = Turbocharged Engine

High Precision Injection allows for a more precise metering of the fuel injection process and therefore permits higher compression ratios e.g. 10.2 to 1 in the N54 and N55 (see table). One of the key reasons that makes this possible is the use of the so called “spray guided” injection which cools the air charge and decreases the possibility of unwanted engine knock.

The operating pressure of the HPI system varies from 50-200 bar.



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

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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 a more 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 (or solenoid type in the N55) centrally between the valves. In this position, the new injector, which opens in an outward direction (inward in the N55), distributes a particularly uniform amount of tapered shaped fuel into the combustion chamber.

BMW HPI spark ignition engines operate according to the spray-directed process.

### **N54 - High Precision Injection**

Using the N54 engine as an example, the fuel is delivered from the fuel tank by the electric fuel pump via the feed line (5) at a “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.

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).



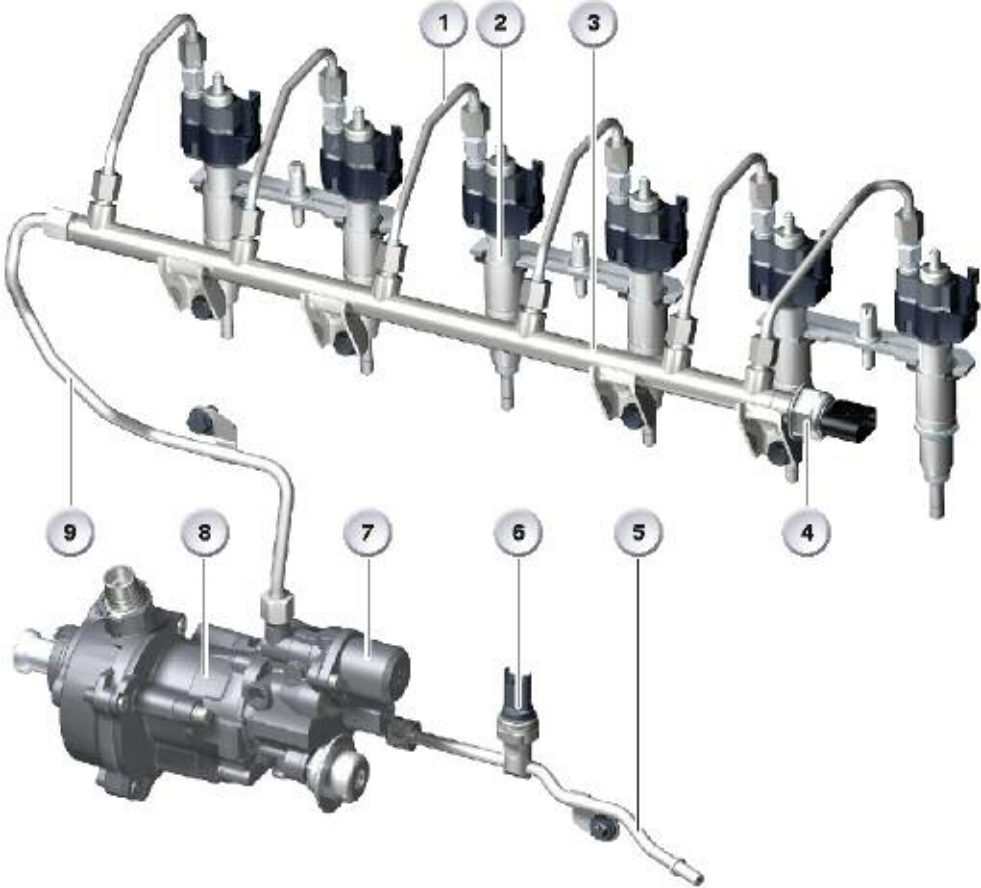
**If the low fuel pressure sensor fails, the electric fuel pump continues to run at 100% delivery with terminal KL\_15 ON.**



The required fuel delivery pressure is determined by the engine-management system as a function of engine load and engine speed among other variables. The reached pressure level 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 engine.

**N54 HPI System**



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 plunger high pressure pump
4	High pressure sensor	9	High pressure line (pump to rail)
5	Feed line from in-tank pump		

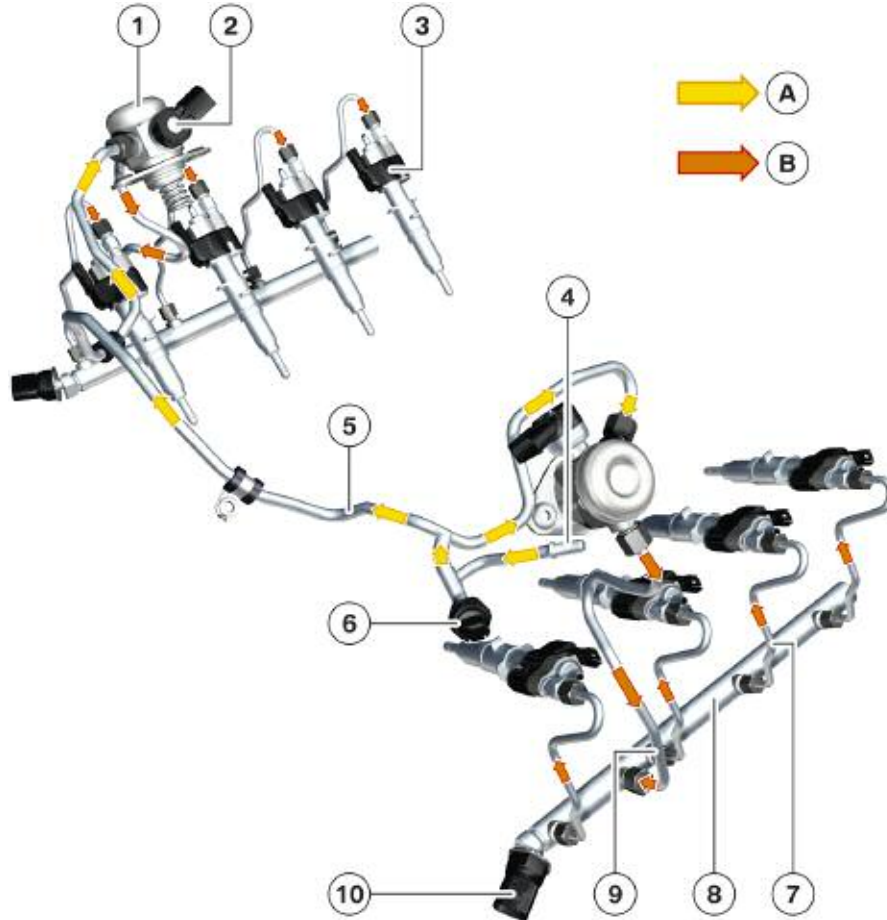


**200 bar is required only at high load and low engine speed.**

## N63 - High Precision Injection

The operation on the N63 engine is similar to that of the N54.

### N63 HPI System



Index	Explanation	Index	Explanation
1	High pressure pump (2 x)	6	Low pressure sensor
2	Volume control valve	7	High pressure fuel line
3	Piezo-injector	8	Fuel rail
4	Low-pressure feed from fuel pump	9	High pressure fuel line (pump to rail)
5	Low pressure feed line	10	Rail pressure sensor (2 x)



**If the low fuel pressure sensor fails, the electric fuel pump continues to run at 100% delivery with terminal KL\_15 ON.**

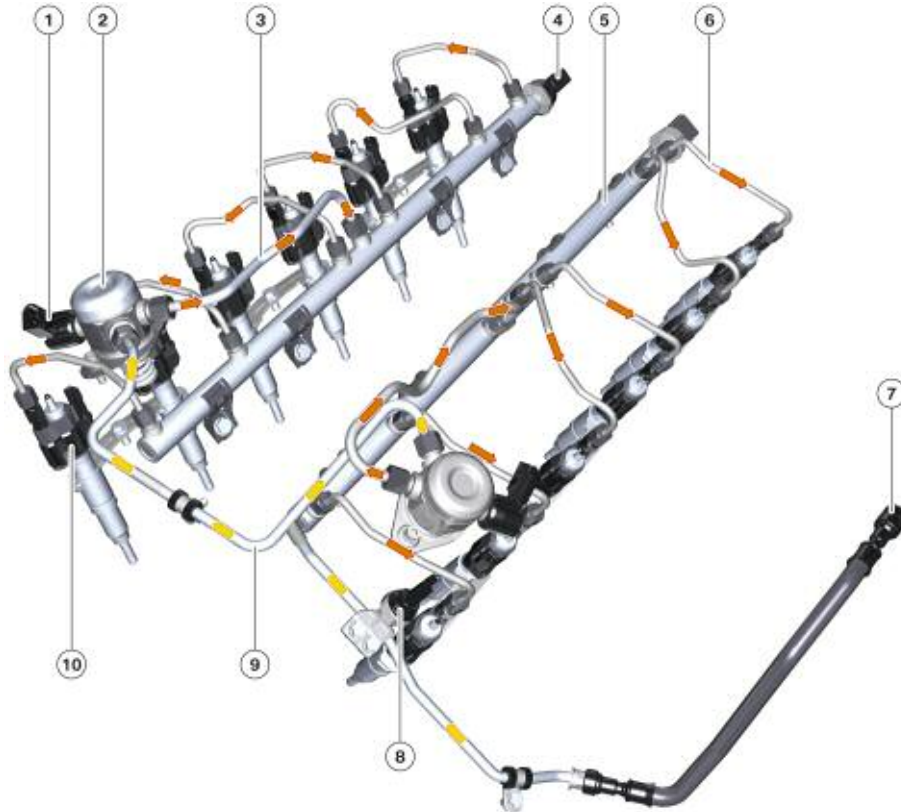
**200 bar is required only at high load and low engine speed.**



## N74 - High Precision Injection

The N74 engine is also equipped with HPI. This second generation direct fuel injection operates in homogeneous operation at all times and has the same structure as on the N63 engine.

### N74 HPI System



Index	Explanation	Index	Explanation
1	Quantity control valve	6	High pressure line (rail - injector)
2	High pressure pump	7	Fuel feed from the electric fuel pump
3	High pressure line (pump - rail)	8	Fuel pressure sensor
4	Rail pressure sensor	9	Feed line
5	Rail	10	Piezo injector



**If the low fuel pressure sensor fails, the electric fuel pump continues to run at 100% delivery with terminal KL\_15 ON.**

**200 bar is required only at high load and low engine speed.**

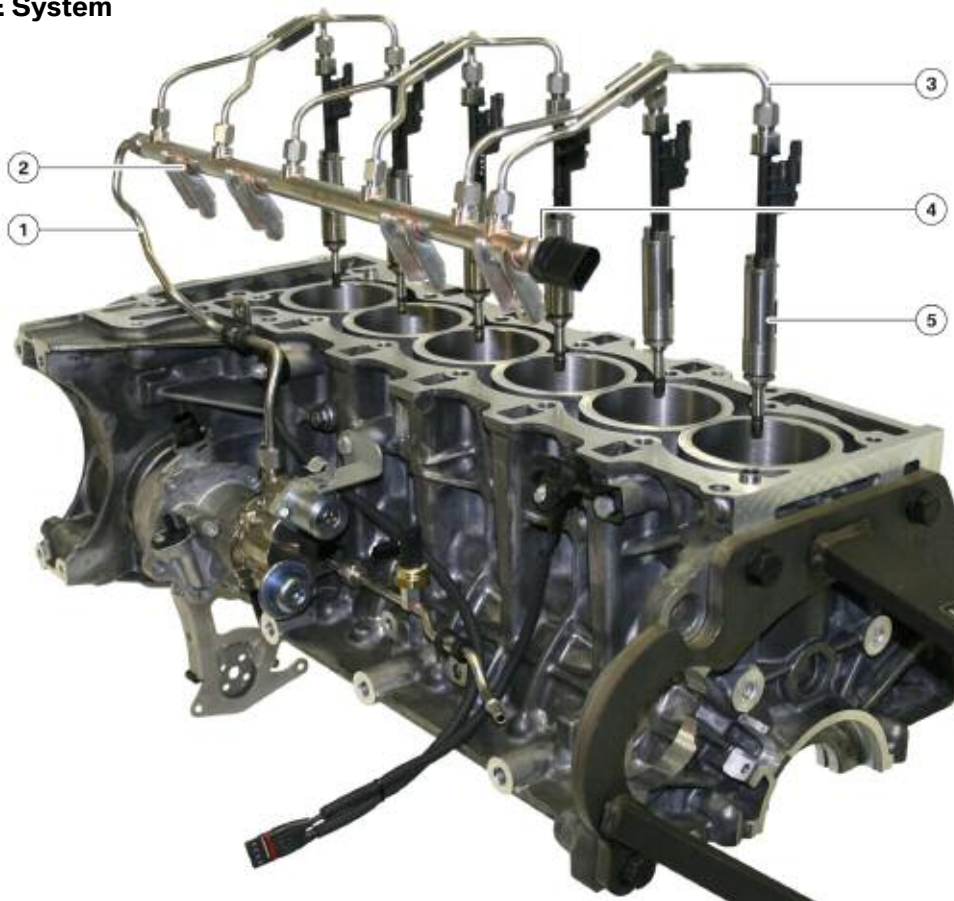
## High Pressure Fuel Injection (HDE)

### N55 - HDE

The high pressure fuel injection system (HDE) is used on the N55 engine. **In contrast to high precision injection (HPI), HDE uses solenoid fuel injectors with multi-hole nozzles.**

The following overview shows the complete fuel injection system. The system is similar to the N54 fuel injection. Although the same high pressure pump, pressure sensor, and fuel rail are used, the high pressure fuel injection valves are new. The HDE system uses Bosch high pressure solenoid type fuel injection valves with the designation HDEV5.2.

### N55 HDE System

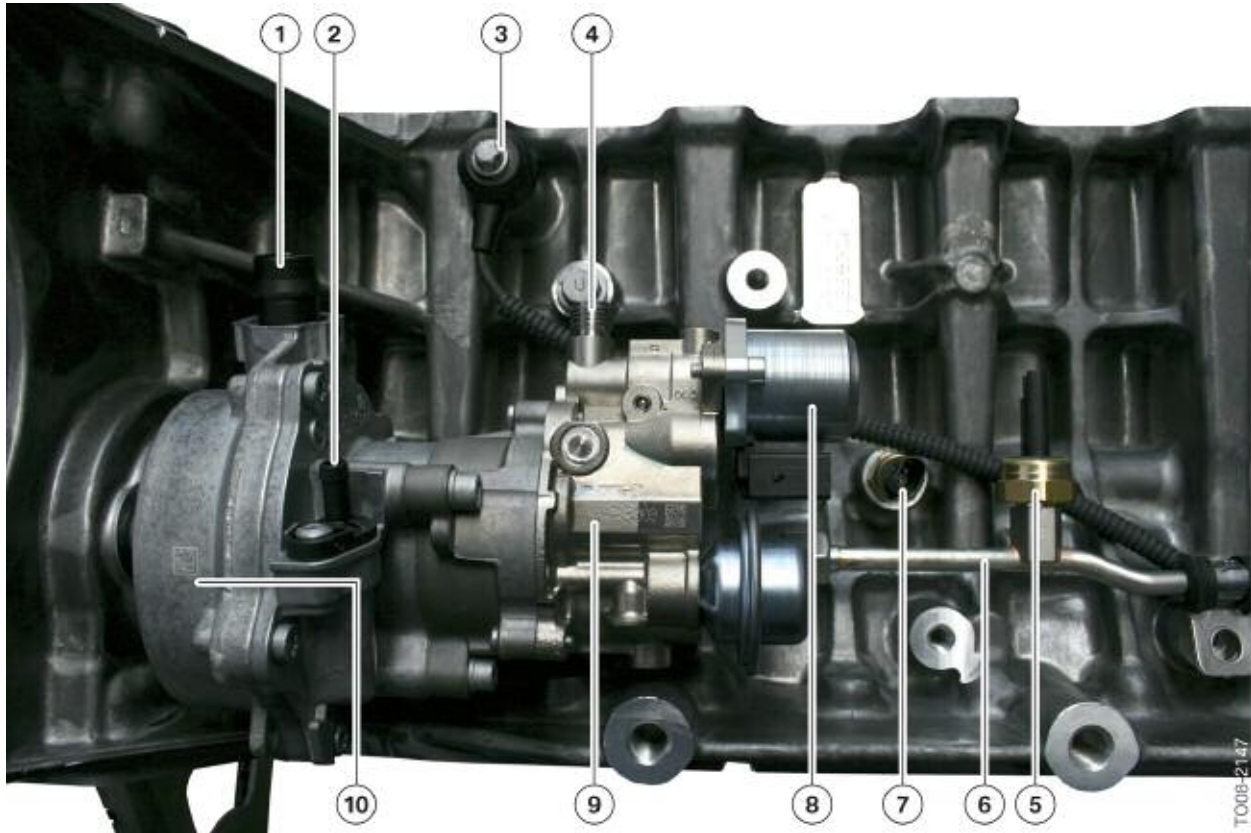


Index	Explanation
1	High pressure line
2	Rail
3	High pressure line
4	Fuel rail pressure sensor
5	Solenoid valve fuel injector

## High Fuel Pressure Pump

The fuel is supplied at a primary pressure of **5 bar** by the electric fuel pump from the fuel tank via the supply line to the high pressure pump. The primary pressure is monitored by the fuel pressure sensor (5). The fuel is delivered by the electric fuel pump corresponding to engine requirements. The same **fuel pressure sensor** is used in the N54, N55, N63 and N74.

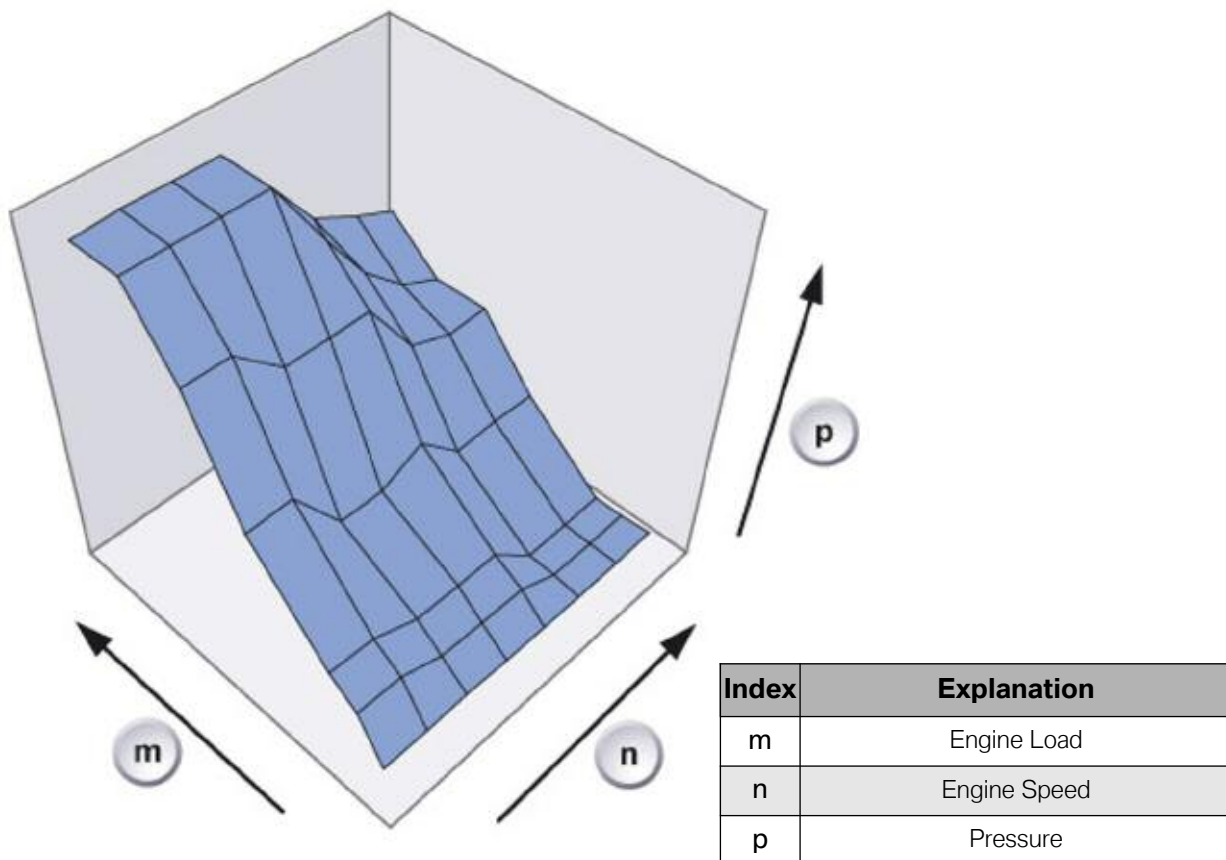
### N55 High Fuel Pressure Pump



Index	Explanation	Index	Explanation
1	Non-return valve for brake booster	6	Fuel supply line
2	Non-return valve for auxiliary consumers	7	Oil pressure sensor
3	Knock sensor	8	Quantity control valve
4	Connection, high pressure line to fuel rail	9	High pressure pump
5	Fuel pressure sensor	10	Vacuum pump

The fuel is pressurized in the permanently driven three-piston high pressure pump and delivered to the fuel rail via the high pressure line. The fuel stored under pressure in the fuel rail is distributed via the high pressure lines to the high pressure fuel injection valves. The required fuel pressure is determined by the engine management as a function of the engine load and engine speed. The pressure level is registered by the rail pressure sensor and sent to the engine control unit. The fuel is regulated by the quantity control valve based on a target/actual value comparison of the rail pressure. The pressure level is configured such to achieve the smoothest running properties with the best possible fuel consumption.

### High Fuel Pressure diagram



**As you can see on the diagram, a pressure of 200 bar is only required at high load and low engine speed.**

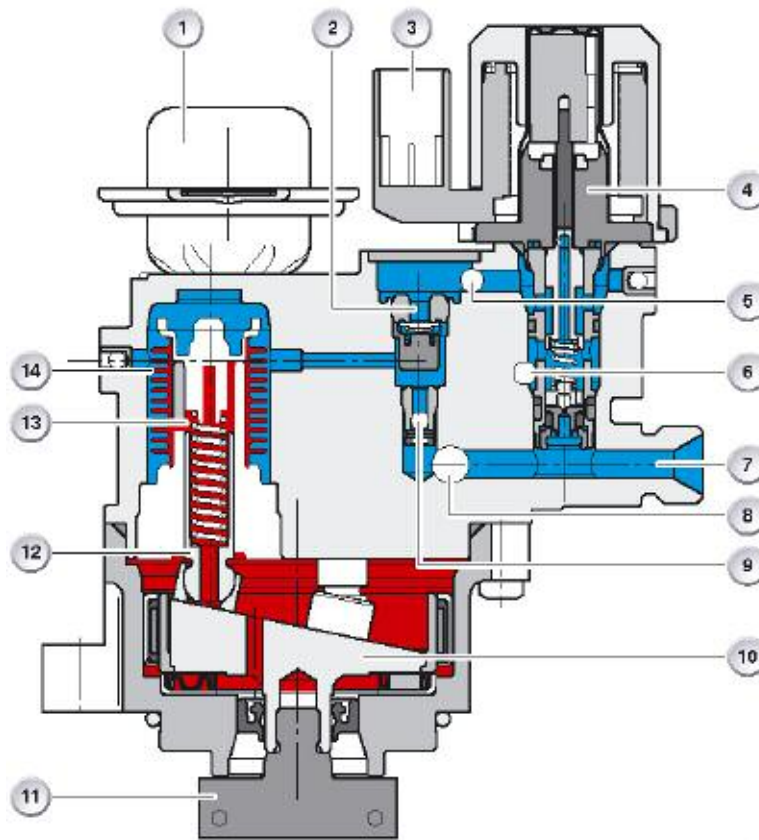
**The high pressure pump is of the same design in the N54 and N55 engines.**

## High Pressure Pump Function and Design

### ■ N54/N55

In the N54/N55 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 fuel supply 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 high pressure port (7).

### N54/N55 High Pressure Fuel Pump



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)



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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.

#### ■ N63/N74

The fuel is delivered via the supply passage at the admission pressure generated by the electric fuel pump to the high pressure pump.

From there, the fuel is directed via the volume control valve and the low pressure non-return valve into the fuel chamber of the plunger and-barrel assembly.

The high pressure pump on the N74 is in principle, the same as the one used on the N63 engine. The only difference is that the fuel lines are positioned at a different angle.

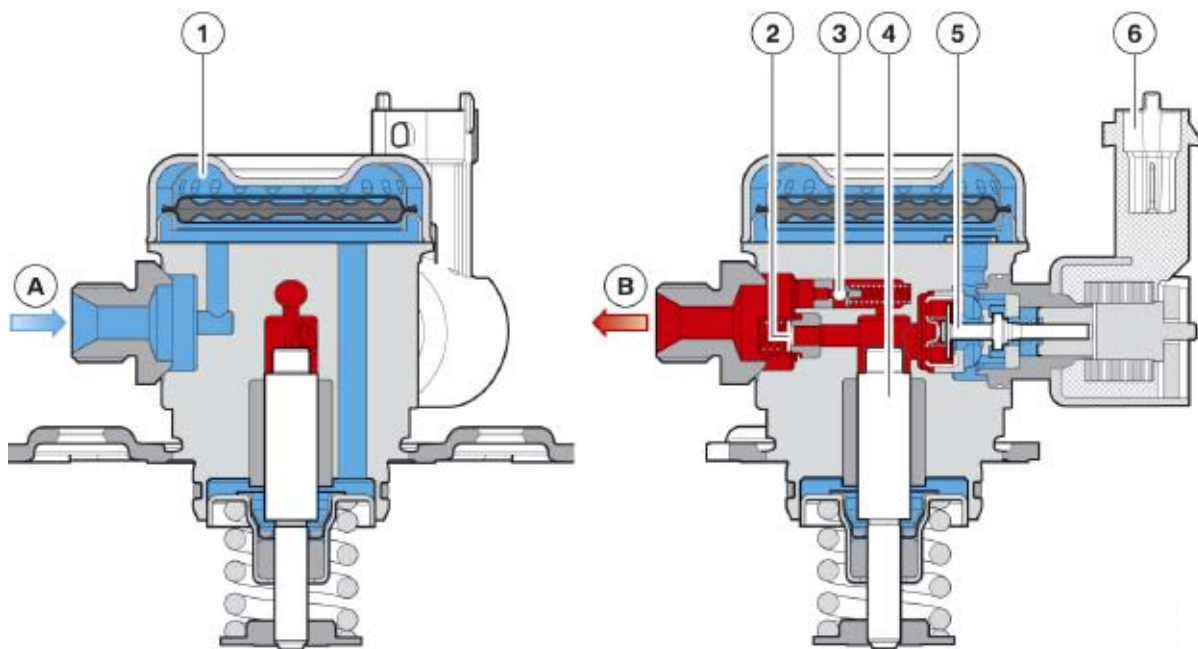
**N63**



The fuel is delivered to the high-pressure pump via the inlet with delivery pressure generated by the electric fuel pump. The fuel is then fed via the volume control valve and into the compression chamber of the pump element. In this pump element, the fuel is placed pressurized by a plunger and supplied via the high-pressure non-return valve to the high-pressure connection.

The high-pressure pump is bolted onto the cylinder head and is driven by the camshaft by a triple cam. This means that, as soon as the engine is running, the triple cam continuously moves the plunger. Fuel is pressurized until new fuel is delivered via the volume control valve into the high-pressure pump. The volume control valve is activated by the engine management system; it specifies the delivered volume of fuel. Pressure regulation takes place via the volume control valve in that it is opened or closed by the pump element towards the fuel feed. When the quantity control valve is opened, most of the fuel drawn in by the piston is pressed back into the fuel feed.

### N63/N74 High Pressure Fuel Pump



Index	Explanation	Index	Explanation
A	Low pressure connection	3	Pressure relief valve
B	High pressure connection	4	Piston
1	Equalization chamber	5	Volume control valve
2	High pressure non-return valve	6	Electrical connection for the volume control valve

The **maximum pressure** in the high-pressure area is restricted to **245 bar**. If the maximum high pressure is reached, the high-pressure circuit is relaxed to the low-pressure area by a pressure limiting valve. In this case the pressure peak in the low pressure area is compensated for by the fluid volume in the area and pressure damper in the compensating chamber. The compensating chamber is integrated into the inlet towards the high pressure pump.

This set-up ensures that pressure peaks are lowered by connecting and disconnecting the high and low-pressure areas. When the piston generates pressure, fuel flows between the piston and its guide. This is deliberate, as it lubricates the pair of sliding elements. On downward movement of the pressure piston, a high pressure would arise at its rear side. This would lead to danger if the fuel is pressed through the sealing of the piston from the pump into the oil circuit of the engine.

The connection to the compensating chamber means that there is never a higher pressure behind the piston than in the fuel feed. This prevents pressure fluctuations from being transferred into the low pressure fuel system, as the volume changes in front of and behind the piston are balanced.

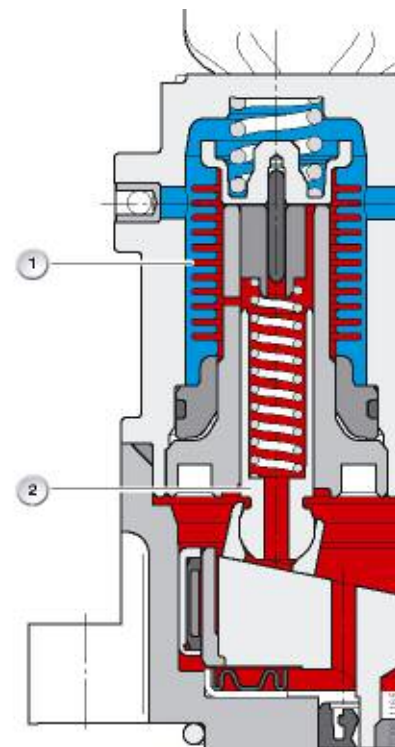
#### ■ Pressure Generation in High-pressure Pump

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.

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.



**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.**



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



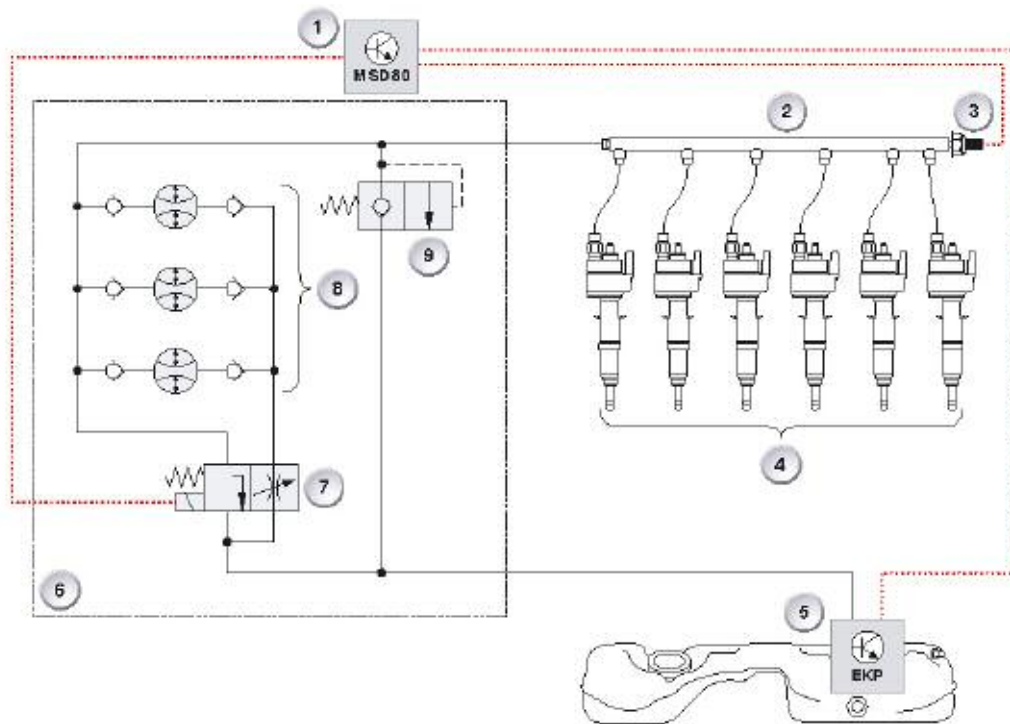
## Hydraulic Circuit Diagram of Fuel System

The volume control valve controls the fuel pressure in the rail. It is activated by the engine management system via a **pulse-width 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.

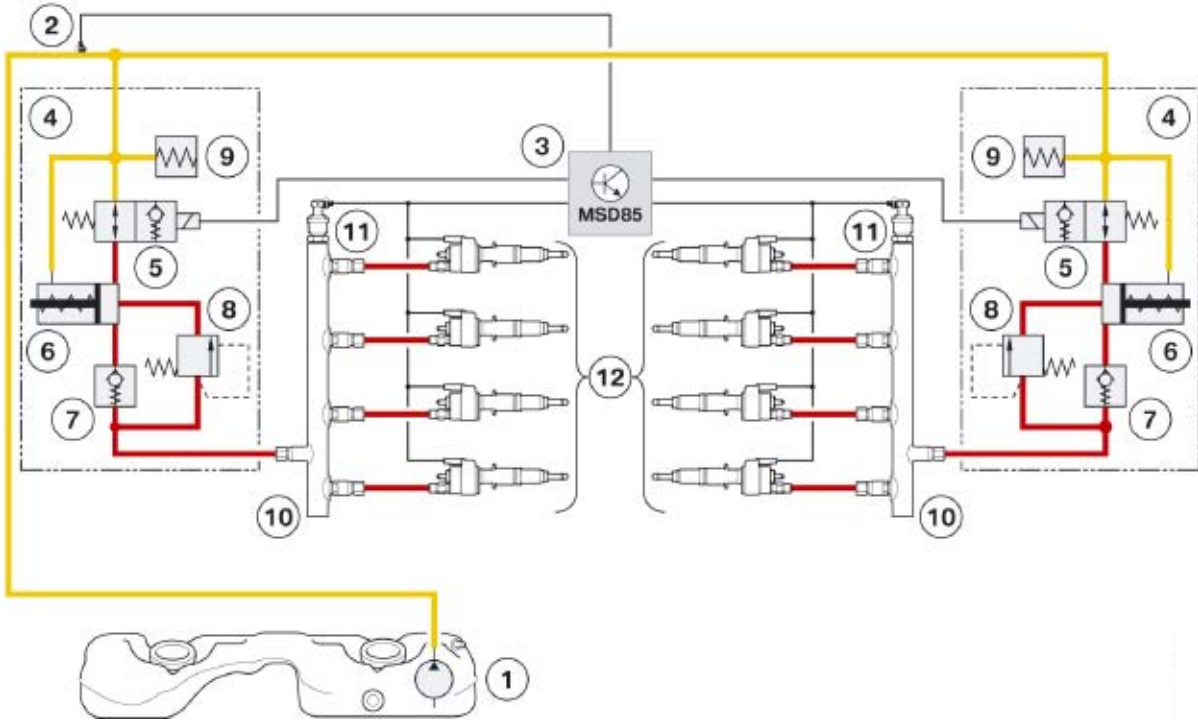
The pressure relief valve additionally provides the option of reducing the pressure in the fuel rail by directing the fuel out of the high pressure system back into the pump element.

### N54/N55 Fuel System, Hydraulic Circuit Diagram



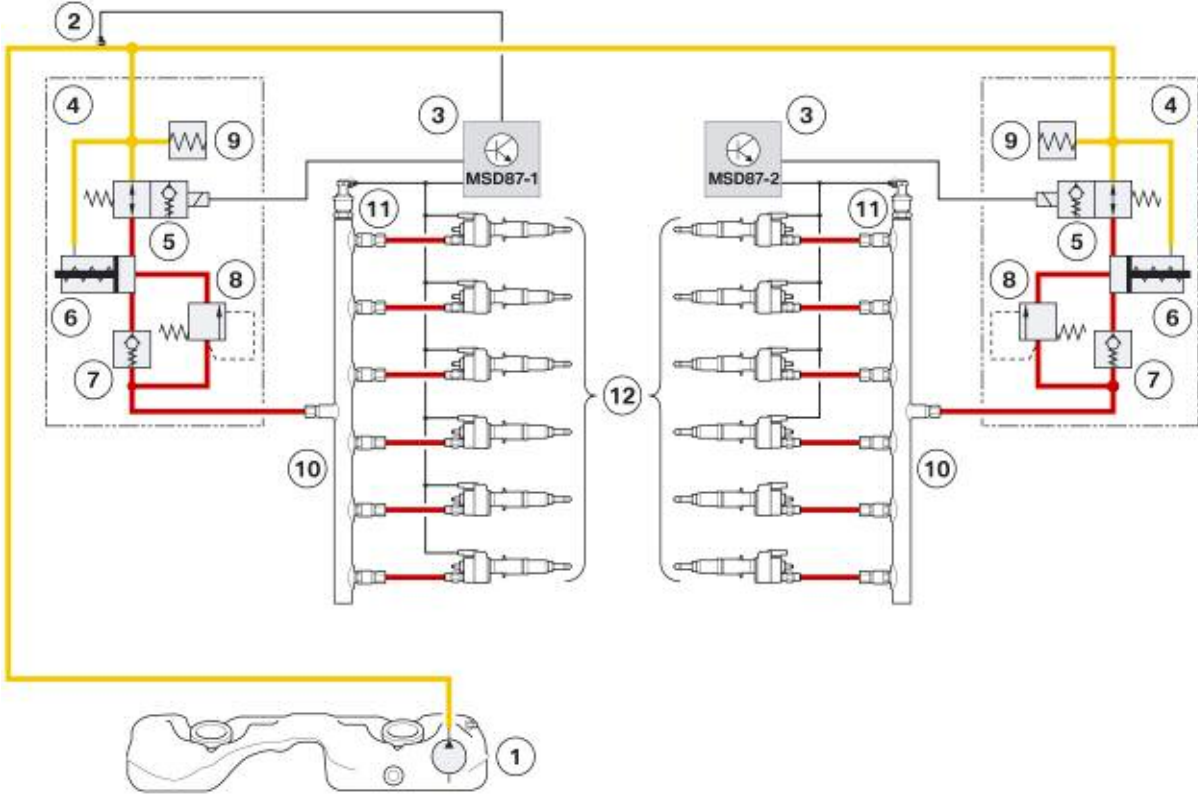
Index	Explanation	Index	Explanation
1	Engine control module (MSD80)	6	High-pressure pump
2	Fuel rail	7	Fuel supply control valve
3	High pressure sensor	8	High pressure pump with non-return valves
4	Piezo injectors	9	Pressure limiting valve with bypass
5	Electric fuel pump		

**N63 Fuel System, Hydraulic Circuit Diagram**



Index	Explanation	Index	Explanation
1	Electric fuel pump	7	High pressure non-return valve
2	Low pressure sensor	8	Pressure relief valve
3	Engine control module	9	Rail
4	High pressure pump	10	Rail pressure sensor
5	Volume control valve	11	Piezo-injectors
6	High pressure pump element		

**N74 Fuel System, Hydraulic Circuit Diagram**



Index	Explanation	Index	Explanation
1	Electric fuel pump	7	High pressure non-return valve
2	Fuel pressure sensor	8	Pressure limiting valve
3	Engine control unit	9	Compensating chamber
4	High pressure pump	10	Rail
5	Quantity control valve	11	Rail pressure sensor
6	High pressure pump element (piston)	12	Piezo injectors

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## Fuel Injectors/Fuel Rail

The type of fuel injector depends on the engine design. BMW for the most part utilizes two different configurations:

- Injectors mounted into the cylinder head spraying fuel into the intake port and;
- Injectors mounted into the cylinder head spraying fuel directly into the combustion chamber, also known as **Direct Injection**.

Furthermore, BMW uses two different types of injectors:

- Solenoid Injector (in low and high pressure systems)
- Piezo Injector (only used in high pressure systems)

### Piezo Fuel Injectors (HPI)

It is the outward-opening piezo-injector that renders possible spray-directed direct injection and thus the overall innovations of BMW engines i.e. N54, N63 & N74. 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.

### Piezo Fuel Injecto (HPI)



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.

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The gas movement is influenced on the one hand by the geometry of the intake passages and on the other 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.

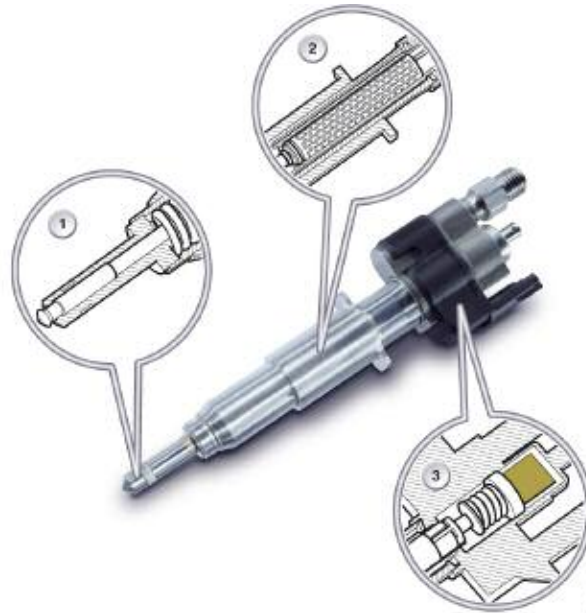


**When working on HPI/HDE Fuel Systems it is important to ensure that the ignition coils are not fouled by fuel. The resistance of the silicone material is significantly reduced by heavy fuel contact. This can cause sparkover at the spark-plug head and with it misfires.**

- **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

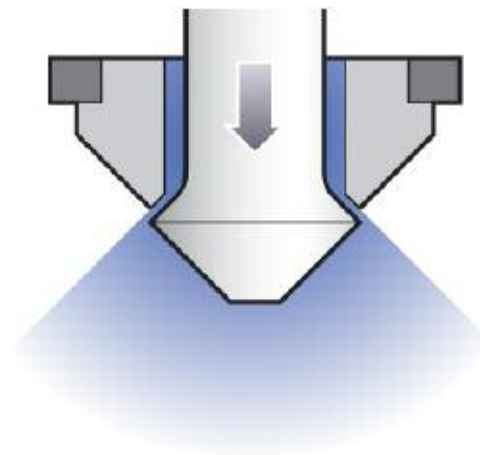
The piezo-injector essentially consists of three sub-assemblies. The expansion of the energized piezo-element lifts the nozzle needle outwards from its valve seat. To be able to counter the different operating temperatures with comparable valve lifts, the injector has a thermal compensating element.



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.

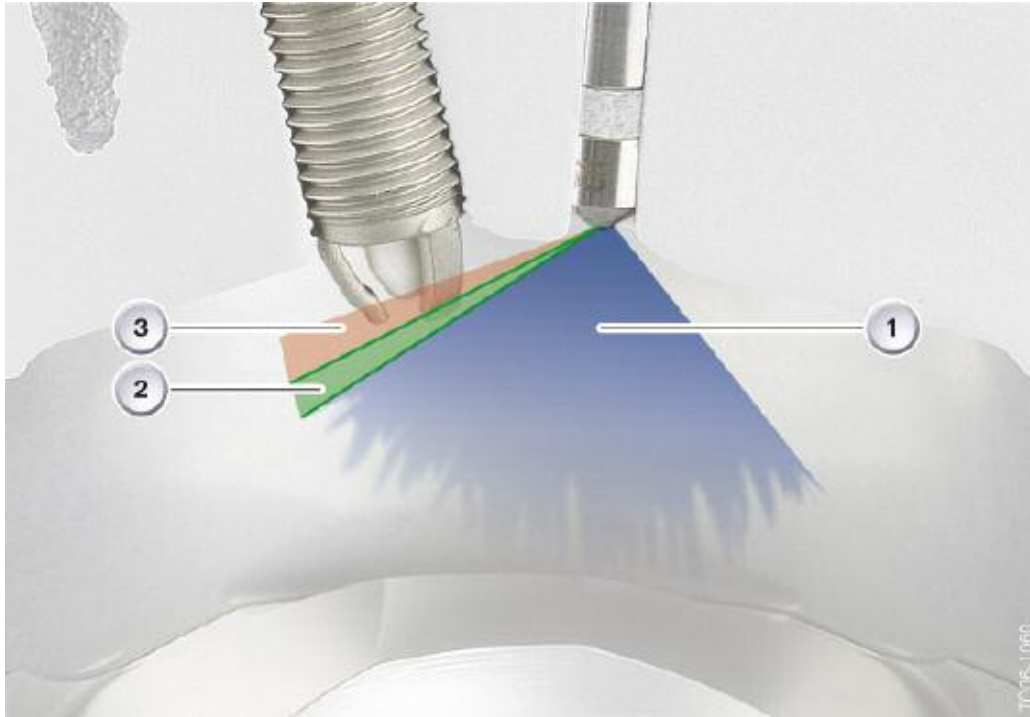
### Outward opening injector nozzle needle



**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.**

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		



**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 piezo injector 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.**

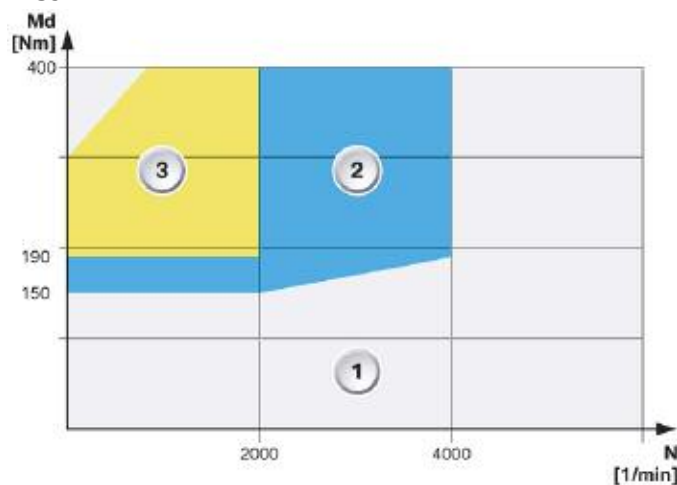
## Injection Strategy

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.

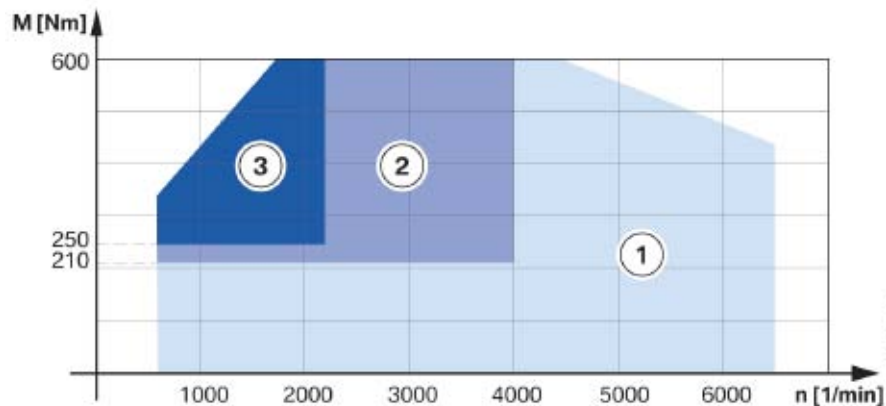
A special situation during the operation of any engine is the range in which a high load occurs at low engine speed, so-called "Low End Torque" operation. In this operating situation, the required fuel mass is metered to the engine in three individual injections.

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

### N54 Injection Strategy



### N63 Injection Strategy



Index	Explanation	Index	Explanation
n	Engine speed	2	Two-time injection
m	Torque	3	Three-time injection
1	One-time injection		



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### ■ Catalytic Converter Heating Mode

In order to bring the catalytic converters up to operating temperature as quickly as possible, BMW engines enter a catalyst-heating mode when the engine performs a cold start. 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 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.**

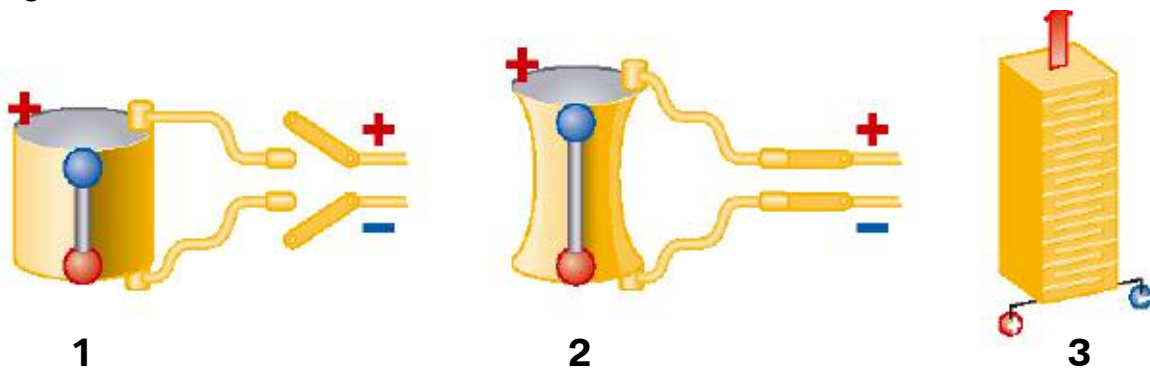
## ■ Piezo Element

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.

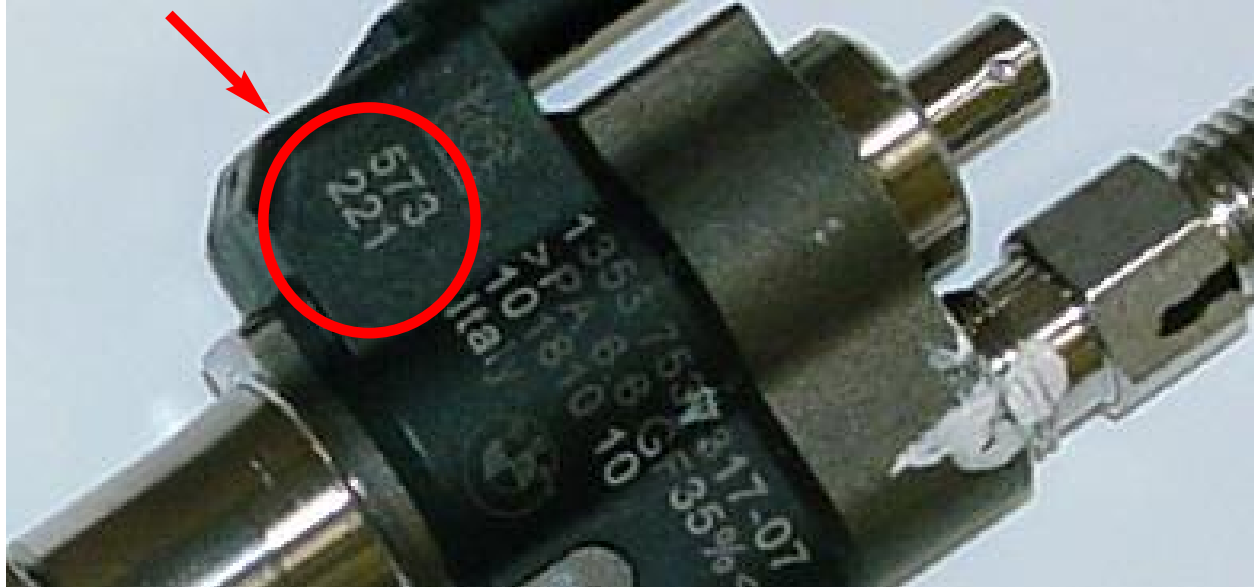
Information on the lift performance of the injector is also added for injector voltage adjustment. Injector adjustment is required because of the individual voltage demand of each piezo actuator. An allocation is made to a voltage demand category, which is included in the number combination on the injector.

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.



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

Tolerance range numbers



### ■ 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:

- Rail pressure
- Injector opening time
- 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. BMW engines can be safely and reliably operated with these program-map values.

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## ■ 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 energy 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 BMW engines.



**Overall adaptation of the injectors is limited to a 15% additional quantity.**

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## Solenoid Type Fuel Injectors N55 (HDE)

The high pressure fuel injection valve Bosch HDEV5.2 is a solenoid type injector. In contrast to the piezo-electric injectors used on the current BMW engines, the solenoid valve fuel injectors are designed as inward-opening multi-hole valves with highly variable jet angle and form. They operate at a system pressure of up to 200 bar.

**CAUTION!!!**

**Do not open the fuel system if the coolant temperature is above 40°C/104°F. The residual pressure in the high pressure fuel system could cause bodily injury.**

It is essential to observe the utmost cleanliness when working on the high pressure fuel system and to follow the proper working procedures described in the repair instructions. Even minute soiling or damage at the thread connections of the high pressure lines could cause leaks.



**Special tool # 13 0 270 must be used to remove the HDEV5.2 high pressure injector valves from the engine. Damage to the injector or the related components may occur otherwise. See the Service Information section in this training material for more information.**

**Particular care must be taken when working on the fuel system of the N55 engine to ensure that the ignition coils are not wet with fuel. The resistance of the silicone insulating material of the coils is greatly reduced by the contact with fuel. This could result in arcking at the top of the spark plug and misfiring. See the Service Information section and repair instructions for more information.**

The following graphic shows the arrangement of the individual components in the combustion chamber of the N55. It can be seen that the BMW (spray-guided) high precision injection (HPI) system is not used but rather a Bosch solenoid valve fuel injector with multi-hole nozzle. The fuel injection is specially adapted to the combination of Valvetronic III and turbocharging. For better illustration, a set of valves has been removed in the graphic.

**N55, combustion chamber with components**



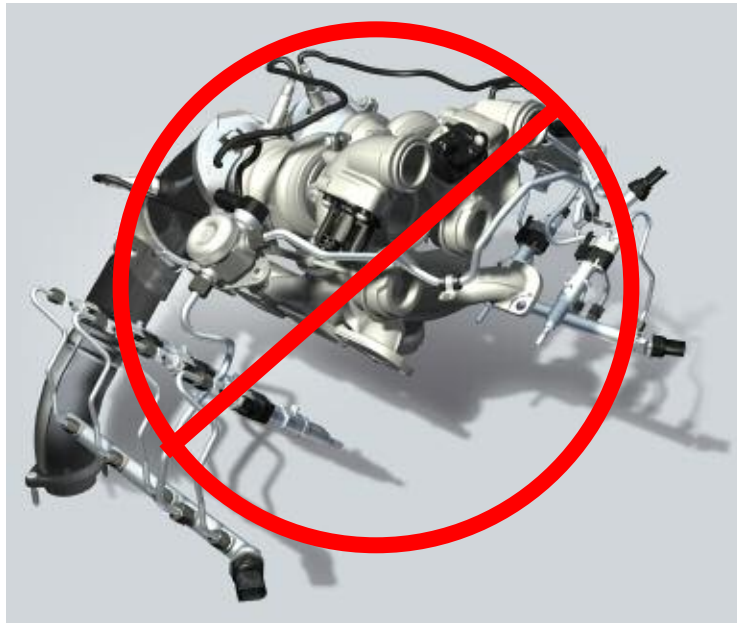
Index	Explanation
1	Valve seat, exhaust valve
2	Exhaust valve
3	Spark plug
4	Fuel injector
5	Intake valve
6	Valve seat, intake valve
7	Piston

# Service Information

## HPI/HDE System Service

### Fuel System Safety

- Working on the fuel system is only permitted after the engine has cooled down. The coolant temperature must not exceed **40°C/104°F**. This must be observed without fail, otherwise there is a danger of fuel sprayback on account of the residual pressure in the high pressure fuel 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.
- When working on the fuel system of BMW engines, 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 cause 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 piezo-injectors, remove the ignition coils and ensure conditions of absolute cleanliness.
- Ignition coils heavily fouled by fuel must be replaced.



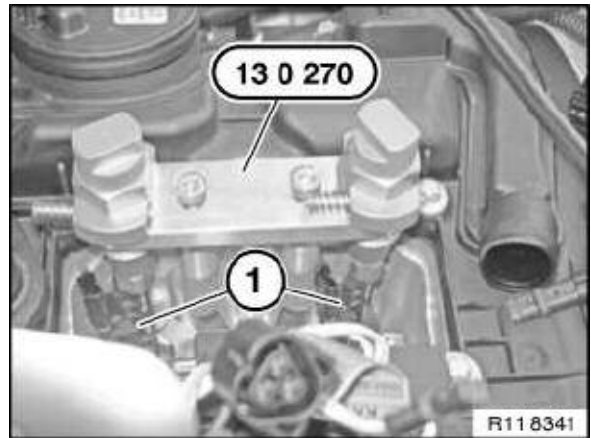
**ACHTUNG!** Öffnen des Kraftstoffsystems bei Kühlmitteltemperatur über 40 °C nicht zulässig. Gefahr von Körperverletzung. Reparaturanleitung beachten.  
**CAUTION!** Do not open the fuel system if the coolant temperature is above 40 °C/104 °F – risk of injury! Consult the repair manual.  
**ATTENTION!** Il est interdit d'ouvrir le système d'alimentation en carburant lorsque la température du liquide de refroidissement est supérieure à 40 °C. Risque de blessure. Respecter les instructions du Manuel de réparation.  
**¡ATENCIÓN!** Prohibido abrir el sistema de combustible cuando la temperatura del líquido refrigerante supera los 40 °C. Peligro de lesiones. Consultar el manual de reparaciones.  
**注意!** 冷却液温度高于40摄氏度时禁止打开燃油系统。存在身体伤害的危险。请仔细阅读说明。

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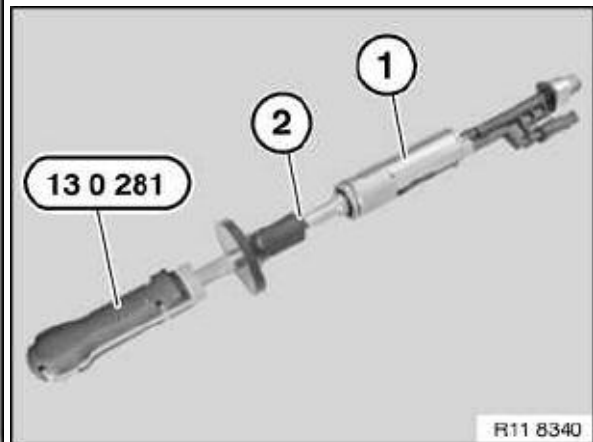
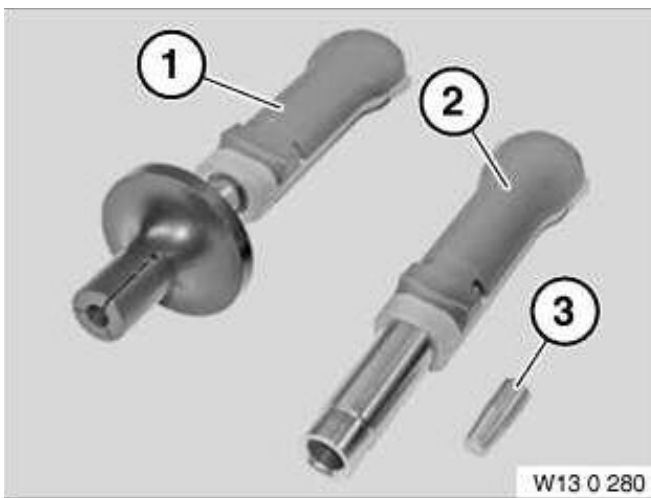


## Fuel Injectors - N55

In order to remove the N55 fuel injectors from the cylinder head, special tool **#13 0 270** must be utilized. Failure to use the special tool will result in damage to the injectors.



There is a new tool **# 13 0 280** that must be used when replacing the PTFE seals on the tips of the solenoid valve injectors. As with piezoelectric injectors these seals must be replaced if and when the injectors are being re-installed.



**Do not open the high pressure fuel injection system if the coolant temperature is above 40°C . The residual pressure in the high pressure fuel system could cause bodily injury.**

**It is essential to follow the repair instructions and observe the utmost cleanliness when working on the high pressure fuel system. Even minute soiling or damage at the connections of the high pressure lines and cause leaks.**

---

## High Pressure Fuel Injector Valve (HDEV5.2)

The HDEV5.2 solenoid type injector valves used on the N55 engine are a new development.

### **1 Booster phase:**

Opening of the HDEV5.2 is initiated in the booster phase by a high booster voltage from the DME. The booster phase ends on reaching approximately 10 amps. The high current is achieved by a voltage of up to approximately 65 Volt.

### **2 Energizing phase:**

In the energizing phase, the HDEV5.2 is completely opened by controlling the current to approximately 6.2 amps. At the end of the energizing phase, the current is reduced to the holding current level of approximately 2.5 amps.

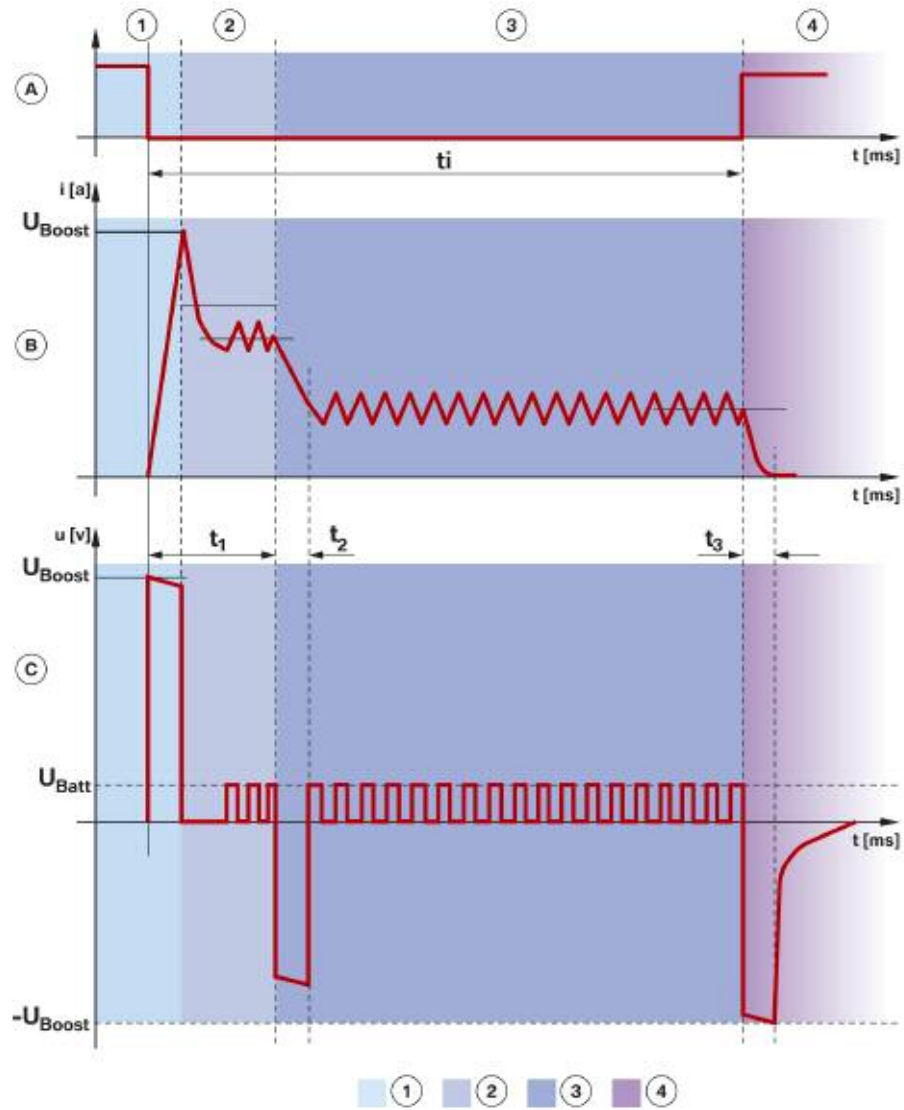
### **3 Hold phase:**

The energized HDEV5.2 is kept open by controlling the current at approximately 2.5 amps in the hold phase.

### **4 Switch off phase:**

The current is switched off at the end of the injection time (in the switch off phase). At least 2 milliseconds elapse between two injection cycles.

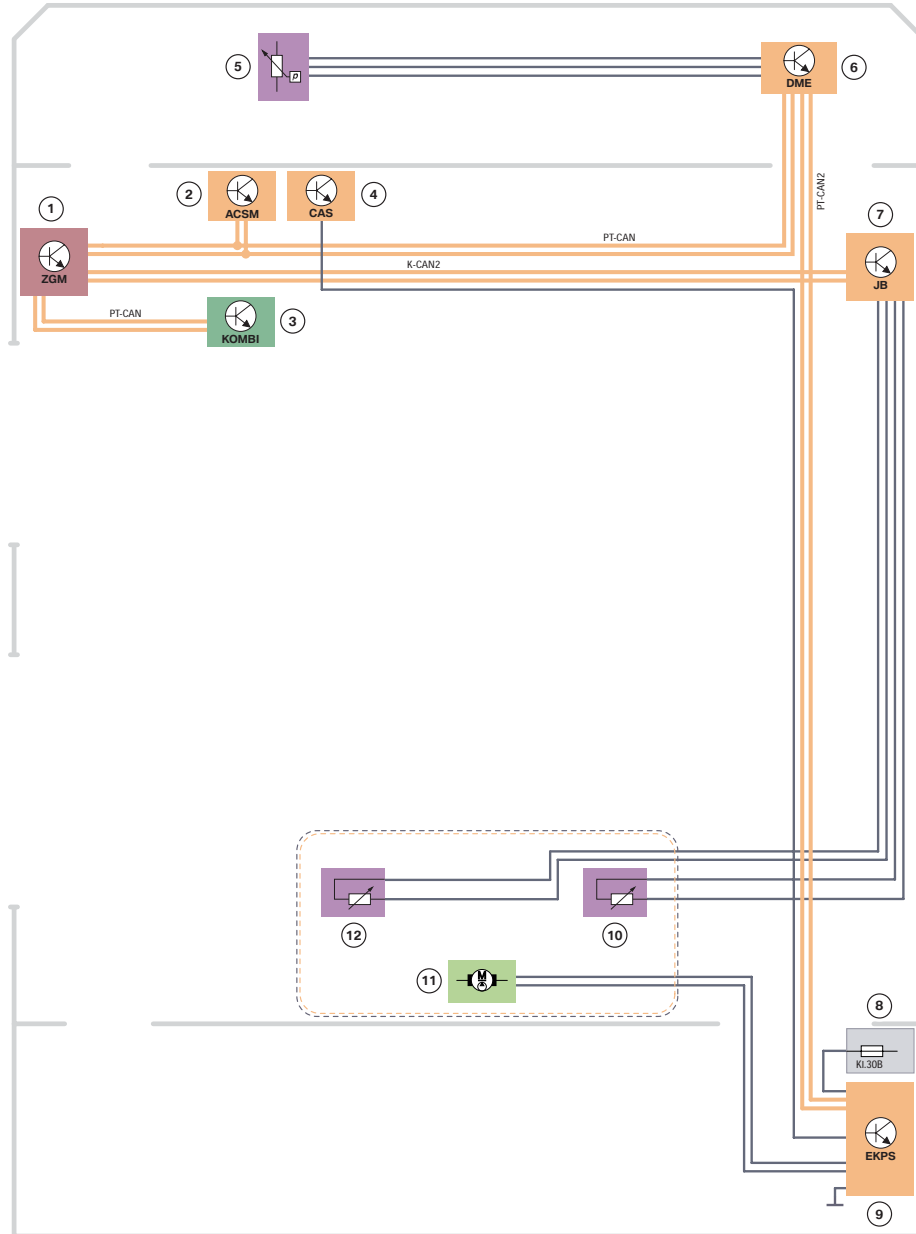
## N55, Actuation Phases of the HDEV5.2



Index	Explanation	Index	Explanation
A	DME actuation signal	1	Booster phase
B	Current flow HDEV5.2	2	Energizing phase
C	Voltage at HDEV5.2	3	Hold phase
		4	Switch off phase

# Fuel Supply and Control Schematic Overview on BN2020

ISTA wiring schematic: SSP-BSB-T6109018 Fuel Supply



Index	Explanation	Index	Explanation
1	Central Gateway Module	7	Junction Box Electronics
2	Advanced Crash Safety Module	8	Power distribution box, right rear
3	Instrument Cluster	9	Electric Fuel Pump Module
4	Car Access System	10	Fuel level sensor, right
5	Fuel pressure sensor	11	Electric fuel pump
6	Engine Control Module (DME)	12	Fuel level sensor, left

---

## Workshop Hints

Before any service work is performed on any fuel system related component, always adhere to the following:

- Observe relevant safety legislation pertaining to your area.
- Ensure adequate ventilation.
- Use exhaust extraction system where applicable (alleviate fumes).
- DO NOT OPERATE THE FUEL PUMP unless it is properly installed in the fuel tank and is submersed in the fuel (fuel lubricates the pump).
- Always wear adequate protection clothing including eye protection.
- Use caution when working around a hot engine compartment
- During fuel system repair that involves “sealing rings”, always replace them with new COPPER rings only.
- BMW does not recommend any UNAUTHORIZED MODIFICATIONS to the fuel system. The fuel system is designed to comply with strict federal safety and emissions regulations. In the concern of product liability, it is **unauthorized** to sell or perform modifications to customer vehicles, particularly in safety related areas.
- Always consult the Repair Instructions on the specific model you are working on before attempting a repair.

### Fuel

Fuel quality should always be considered when diagnosing a driveability complaint. The type of fuel, proper AKI/PON rating, impurities and moisture are not factored by the ECM.

Please refer to the Owner's Manual and following Service Information Bulletins regarding fuel:

- SI B 13 07 06 Gasoline Quality & Detergent Additives
- SI B 13 02 10 Fuel Systems
- SI B 13 02 06 Top TIER Detergent Gasoline in BMW Vehicles
- SBS 1996-13 06 96 (139) Group 13 (on ISTA>Workshop/Operating fluids)

## Draining the Fuel Tank

In order to remove the fuel tank it must be drained first to avoid fuel spills and handling excessive weight. In some cases depending on the fuel tank dimensions (vehicle specific), it is also necessary to drain the fuel tank to replace the sending units and/or fuel pump.

**CAUTION!!!**

**In some vehicles, the sending units/fuel pump is mounted lower than the top of the fuel tank. A fuel spill will be encountered if the fuel is not drained.**



**Consult the BMW Service Workshop Equipment for the proper evacuation equipment. The saddle type tank requires an additional step to drain the fuel from the driver side. The evacuation equipment should be attached to the tank compensating hose (arrow) to drain out the remaining fuel.**

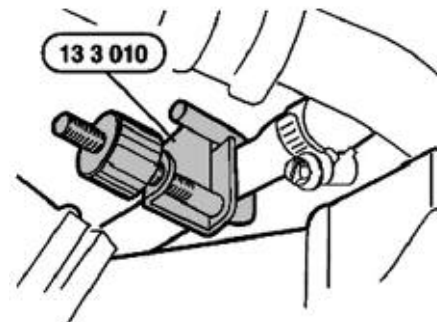
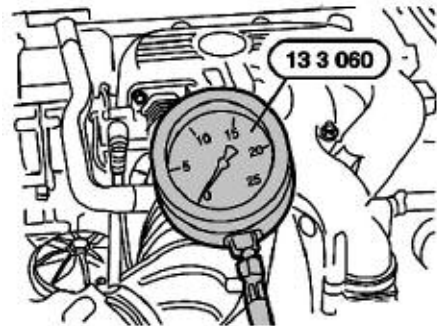
## Fuel Pump/Pressure Regulator - Testing

The fuel pump should be tested for delivery pressure and volume. Caution when disconnecting fuel hoses because there is the possibility of residual fuel pressure! Install the fuel pressure adapter and IMIB pressure sensing lead to the fuel pressure fitting \*IMIB starts with atmospheric pressure as the base.

If the 3.5 (\*+ atmosphere IMIB base starting point) bar fuel pressure is not achieved or bleed off is more than 0.5 bar, refer to

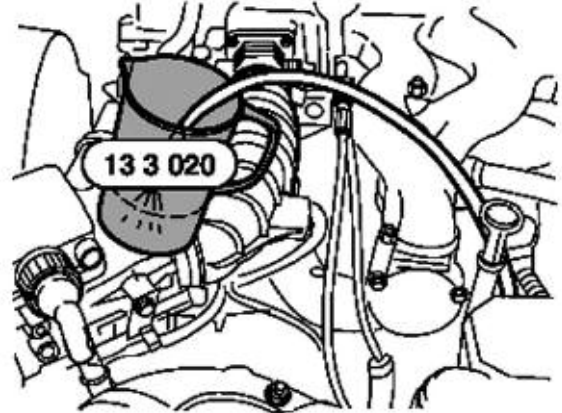
- REP 13 31 032 Check fuel pressure
- REP 13 31 029 Checking fuel pump delivery pressure (N52)
- REP 13 31 029 Checking fuel pump delivery pressure (M54)

for further diagnosis. The Fuel Hose Clamp Tool can be used to isolate bleed off from the pump (non-return check valve) or the pressure regulator (restriction valve). Also verify power supply to the fuel pump.



### Fuel volume must be tested to verify:

- Fuel Pump Output
- Restrictions are not present in the pump pickup lines/hoses and fuel filter.



### Fuel Injectors

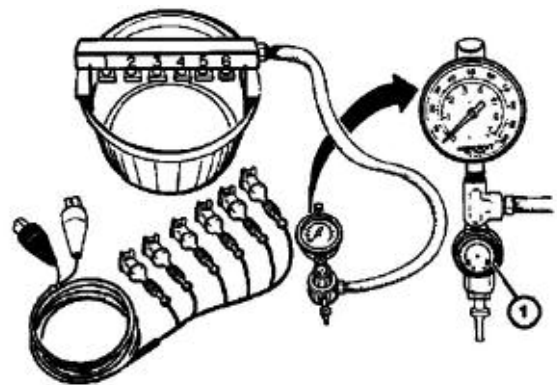
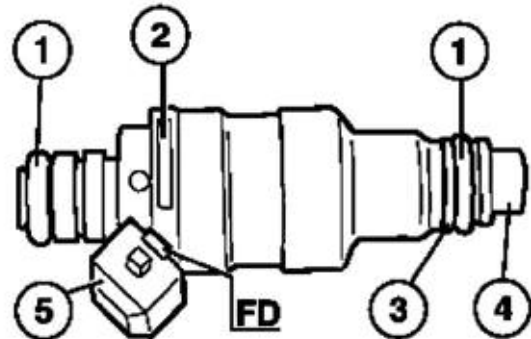
When inspecting the fuel injectors, consider the following:

- O-rings should be replaced, lubrication with Vaseline or SAE 90 gear oil for installation.
- Verify the code number (different engine applications)
- Plastic spacer washer is not damaged
- Color code of housing (different engine applications)

Fuel injectors can leak which bleeds off fuel pressure and increases emissions. The injectors can be tested using the Fuel Injector Leakage Tester.

The fuel injectors can be cleaned, refer to:

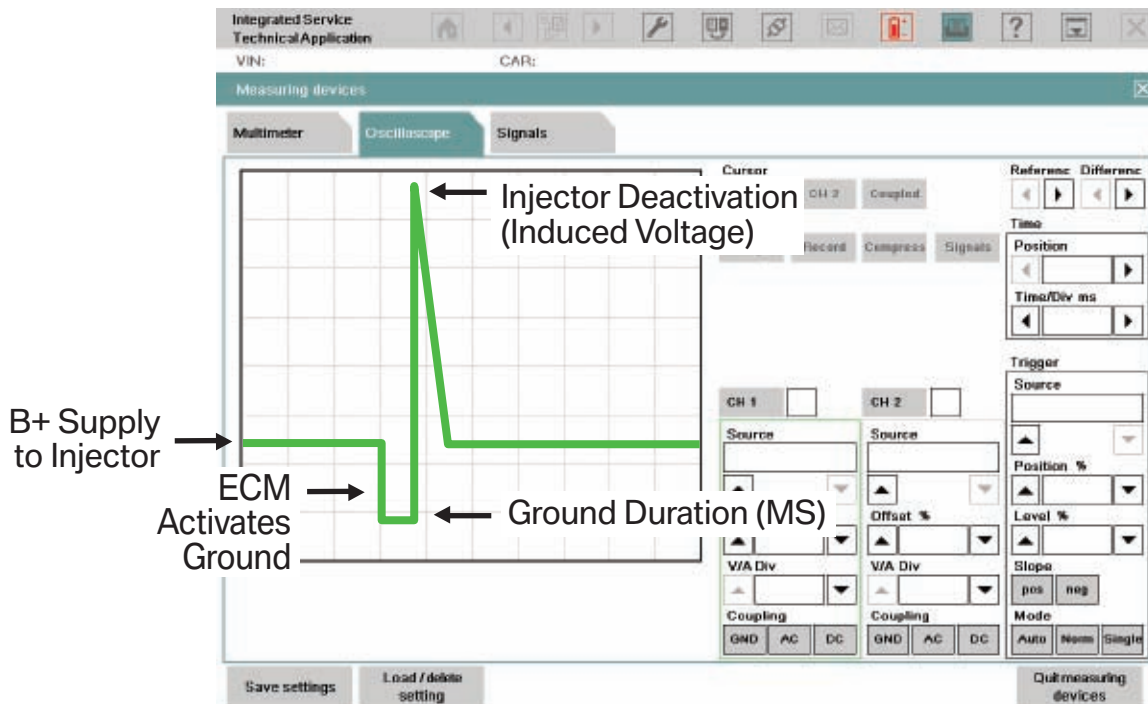
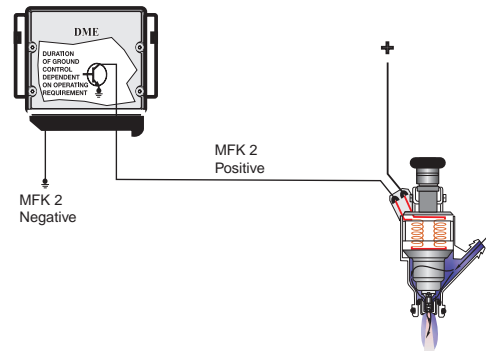
- SI B 04 07 07 Fuel Injection and Induction System Cleaning





The Fuel Injectors should also be tested using the ISTA for:

- Resistance
- Power Supply
- Status Display - Fuel Injection Signal
- ECM Final Stage transistor activation. This test functions is found under the oscilloscope Preset list - "Ti Injection Signal". Install the Universal Adapter, Diagnostic cable, MFK 2 negative lead to ECM ground and MFK 2 positive lead to the ground activation circuit for the injector. This test is performed with the engine cranking or running.



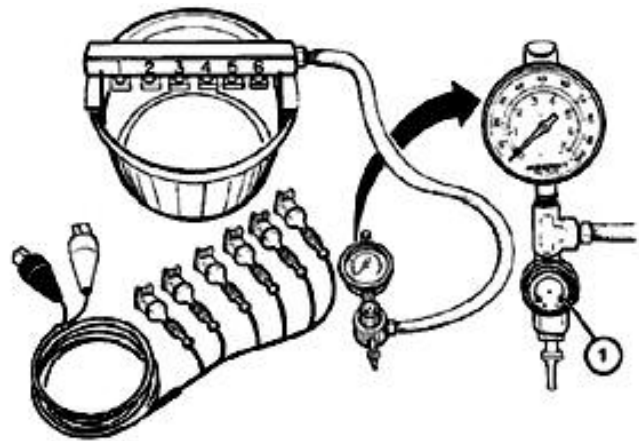
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When testing fuel pressure, the hand held fuel pressure gage (SWZ 13 3 060) can be used.

Caution: Residual fuel pressure may be present!

The IMIB is equipped with a pressure measuring function, found in Measurement testing. The following adapters (Special Tool numbers) will be necessary:

- SWZ 13 6 051
- SWZ 13 6 055
- SWZ 13 6 057



These adapters install “inline” in the fuel pressure hose.

For vehicles equipped with “quick-release” couplings, install special tool (SWZ 13 5 270) between the fuel filter (1) and pressure supply hose (2). This tool will couple to the IMIB Pressure Adapter (3).

Later production fuel rails are equipped with a threaded adapter fitting (1).

This threaded adapter fitting allows Adapter (SWZ 13 5 220) to be threaded on to the fuel rail and coupled to the IMIB Pressure Adapter.

When testing the fuel injectors for leakage, use Special Tool #88 88 5 000 362. Leak testing the fuel injectors is one of the diagnostic steps listed in:

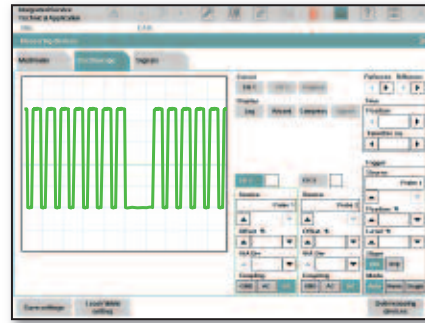
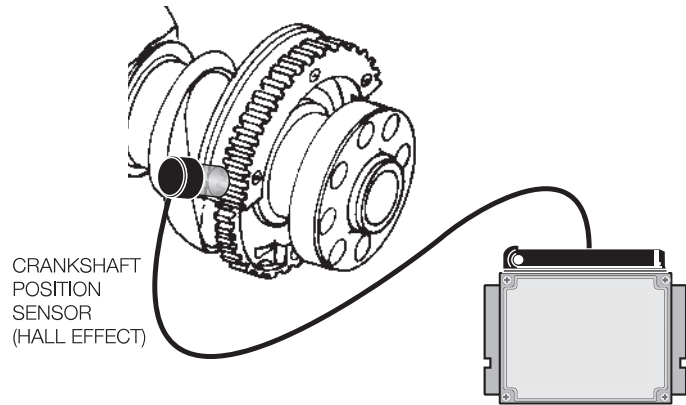
- SI B 13 08 90 (3096) Long Cranking Times.

This tool pressurizes the injectors with air and the injector tips are submersed in water. If air bubbles are present, this indicates the leaking injector(s).

## Crankshaft Position/RPM Sensor

This sensor should be tested using the IMIB for:

- Power Supply
- DC Voltage
- Status Display
- Oscilloscope Display found under Preset Measurements - “Engine Speed Sensor Signal”



**SMOOTH RUNNING ENGINE  
(NOTE SQUARE WAVE SIGNAL)**

## Crankshaft Sensor (N55)

The function of the new crankshaft sensor is identical to that of the crankshaft sensors used for the automatic engine start-stop function (MSA). The engine reversal detection is required for the MSA function. (MSA is not currently offered in the US.)



Index	Explanation
1	Connector
2	Dust seal
3	Sensor

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NOTES

PAGE