M47R DIESEL ENGINE
Workbook

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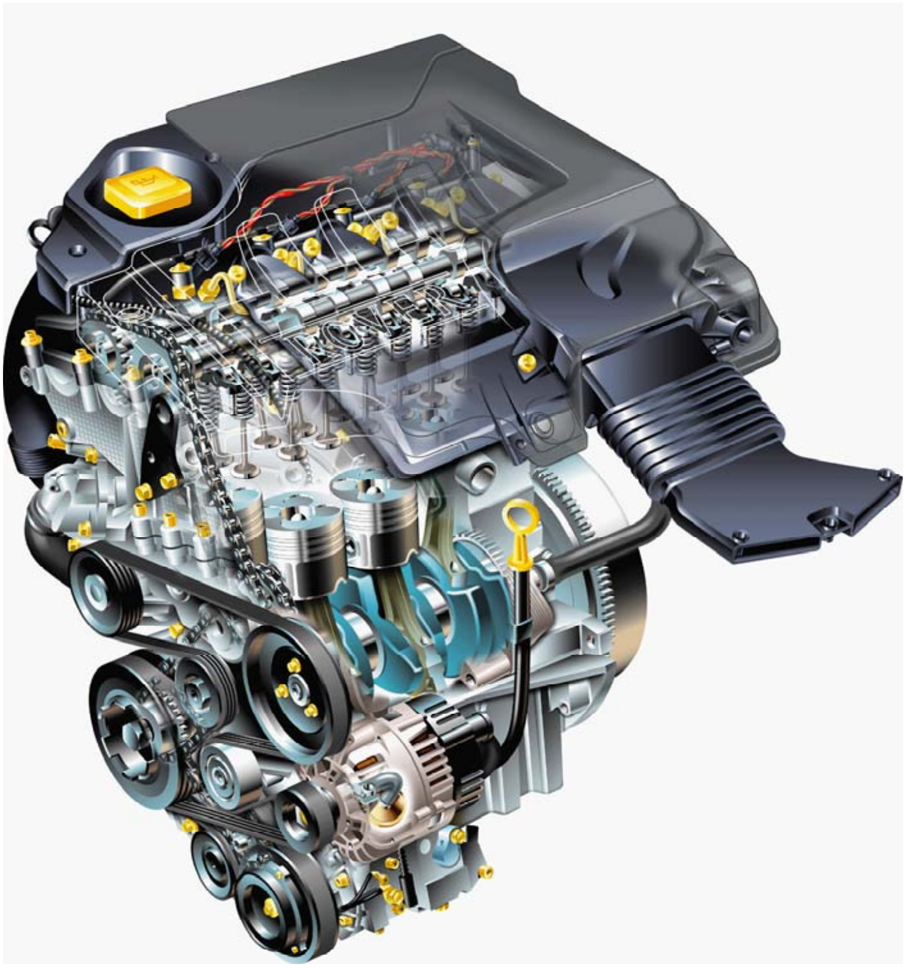
M47R diesel engine

Introduction

The diesel engine fitted to Rover 75 is known as the M47R (see Figure 1). This engine is a new member of the latest generation of diesel engines being developed by BMW and Rover engineers. It is made by BMW in Steyr, Austria.



Fi e M el e ine

Fitted with this engine, Rover 75 represents two firsts:

- It is the first British car with common rail diesel technology
- It is the first time a Rover car has been available with a diesel engine and automatic transmission

Equipped with a chain-driven overhead camshaft and four valves per cylinder, Rover 75 also becomes Rover's first 'multivalve' diesel.

Common rail technology appeared for the first time at the end of 1997 when Alfa Romeo launched the 2.4-litre 156. Mercedes then launched a 2.2-litre common rail engine in the C-class, and the technology has also appeared in Isuzu vehicles. M47R follows the launch of M47D (not common rail) in the BMW 3 series, and the six-cylinder M57R (common rail) in the BMW 5 and 7 Series.

Rover 75, with 85kW, is the most powerful two-litre common rail diesel available. It produces 43.6 kW/litre, compared with 40.3 kW/litre for the Alfa Romeo 156 1.9JTD, 41.9 kW/litre for the 156 2.4 JTD and 42.8 kW/litre for the Mercedes 220CDI.

Development objectives

The development objectives for the M47R diesel engine were;

- to develop a new four cylinder diesel engine featuring four valve technology and direct fuel injection
- to reduce fuel consumption
- to maintain operating refinements and interior acoustics comparable to those on indirect injection diesel engines
- to comply with the European commission directive stage 3 (ECD-3) exhaust emission limits from model launch and to create the conceptional prerequisites for achieving the stringent requirements of European on-board diagnostics (E-OBD)
- class competitive service times

Technical features and data

Technical features

The technical features of the M47R diesel engine are:

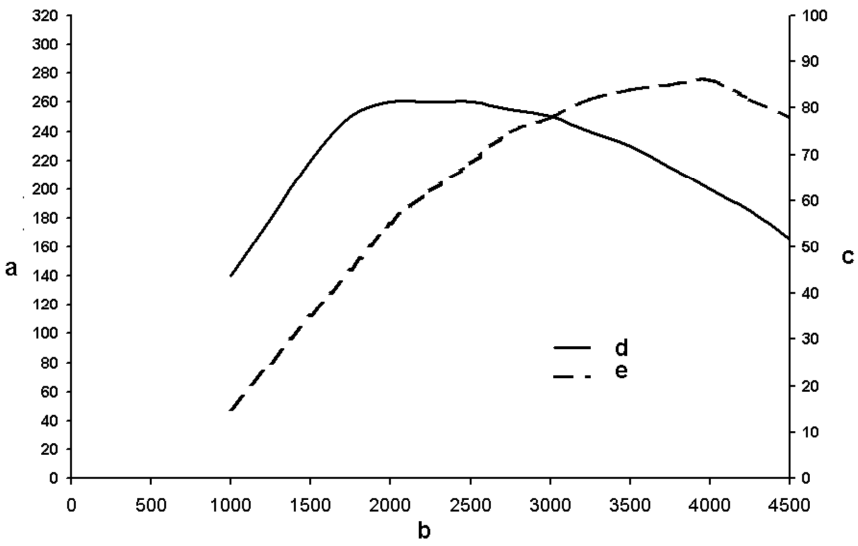
- In-line four cylinder engine with cast iron cylinder block and light alloy cylinder head
- Four valve technology with centrally arranged injectors
- Exhaust turbocharger with intercooler
- Direct fuel injection with common rail technology and electronic diesel engine management
- Electronically controlled exhaust gas recirculation (EGR) with hot-film mass airflow meter
- Exhaust re-treatment by means of a diesel-specific oxidation catalytic converter
- Average inspection intervals of 15,000 miles
- Swirl and tangential intake ports
- Chain driven camshafts
- Hydraulic valve adjustment
- Service indicator light for optimum service frequency (dependant on driving style)

Technical data

Technical data regarding the M47R diesel engine can be seen in table 'General technical data'.

General technical data

Description	Data
Engine designation	M47R
Model type	2.0 litre, direct injection, 16 valve, DOHC, turbo charged and intercooled
Cylinder arrangement	4 in-line, transverse, No.1 cylinder at front of engine
Firing order	1-3-4-2
Compression ratio	18.1 ± 0.5:1
Capacity	1950 cm^3
Bore	84.00 mm (3.307 in.)
Stroke	88.00 mm (3.465 in.)
Maximum power	85 kW (116 bhp) @ 4000 rev/min.
Maximum torque	260 Nm (192 lbf.ft) @ 2000 - 2500 rev/min
Idle speed	780 ± 50 rev/min.
Injection system	Common rail direct injection (1350 bar typical) controlled by a Bosch DDE 4.0 engine management system
Emission standard	ECD3
Head gasket	Multi layer steel, 3 sizes
Valve train	Chain driven camshafts, roller finger levers and hydraulic valve adjustment
Intake ports	One high swirl helical port and one tangential port
Turbocharger	Mitsubishi MR1



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a. Torque (Nm)
b. Engine speed (rpm)
c. Power (kW)
d. Torque
e. Power

The special tools required for the M47R diesel engine can be seen in table ’Special tools’:

Special tools

Tool number	Description
12-163	Ancillary belt tensioner wrench
12-165	Front crankshaft oil seal remover thrust pad
12-166	Front crankshaft seal replacement sleeve
12-167	Front crankshaft seal installer
12-168	Front crankshaft oil seal remover
12-171	Timing pin
12-172	Chain tensioner locking pin
12-173	Camshaft holding tool
12-174	Holding fixture
12-177	Holding tool for crankshaft pulley
12-178	Fuel pressure pump gear remover
12-179	Crankshaft oil seal installer handle
12-180	Rear crankshaft oil seal installer

Inlet and exhaust system

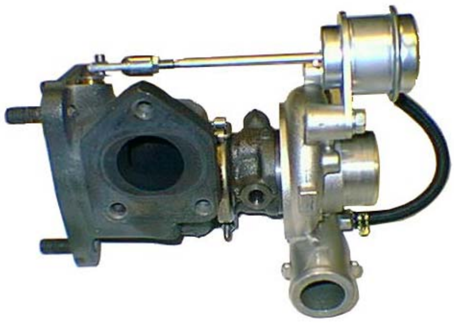
General

The inlet manifold directs cooled, compressed air from the turbocharger and intercooler into the cylinders where it is mixed with the fuel from the injectors. Exhaust gases from the exhaust manifold can also be directed into the inlet manifold via a pipe from the exhaust manifold and an EGR valve on the inlet manifold. The exhaust manifold directs combustion gases from the cylinders to the turbocharger and exhaust system.

The exhaust system is attached to the turbocharger and is positioned along the underside of the vehicle to emit exhaust gases from the tail pipe at the rear of the vehicle. A silencer is installed midway along the system and a tail silencer is located at the rear of the vehicle.

Turbocharger

The turbocharger (see Figure 3) is driven by the exhaust gases from the engine. The hot, pressurized exhaust gases are routed through the turbine of a turbocharger, thus providing the drive energy for the compressor. The turbine rotates at speeds upto 200,000 rev/min. The turbine inlet temperature can reach approximately 1000°C.



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At the inlet turbine, the combustion air is pre-compressed so that a higher mass of air in the intake tract enters the combustion chamber of the engine. This makes it possible to inject and combust a larger volume of fuel, thus increasing the power and torque developed by the engine.

In this way, the output of the turbocharged engine can reach that of a naturally aspirated engine with considerably higher displacement capacity. On the other hand, the turbo effect can also be utilized to achieve a certain power output with a smaller capacity engine in conjunction with reduced fuel consumption. In order to optimise the supercharging effect, modern turbochargers are equipped with a wastegate valve (control mechanism/by-pass valve), which regulates the volume of the exhaust gases that by-pass the turbine. This makes it possible to use small turbines with improved response characteristics, thus having a positive effect, on the acceleration behaviour at low engine speeds without producing high boost and turbine pressures.

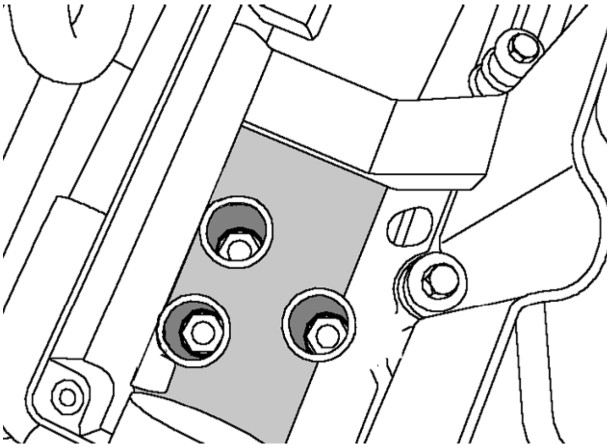
The frictional and thermal losses of a smaller capacity turbocharged engine are lower, an advantage reflected in reduced fuel consumption.

Due to the large air surplus, the operation of turbocharged diesel engines is characterized by particularly low exhaust emissions.

Exhaust system

The cast iron exhaust manifold is secured to the cylinder head. There are two metal gaskets used to seal the manifold with a turbocharger heatshield being an integral part of the right hand gasket.

A flange on the underside of the manifold provides the attachment for the turbocharger and can be accessed by removing the three grommets in the air filter housing (see Figure 4).



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A second flange, located on the left hand end of the manifold, provides the connection point for the exhaust gas recirculation (EGR) pipe.

A one-piece exhaust system is fitted and incorporates an oxidation catalytic converter and a tail silencer.

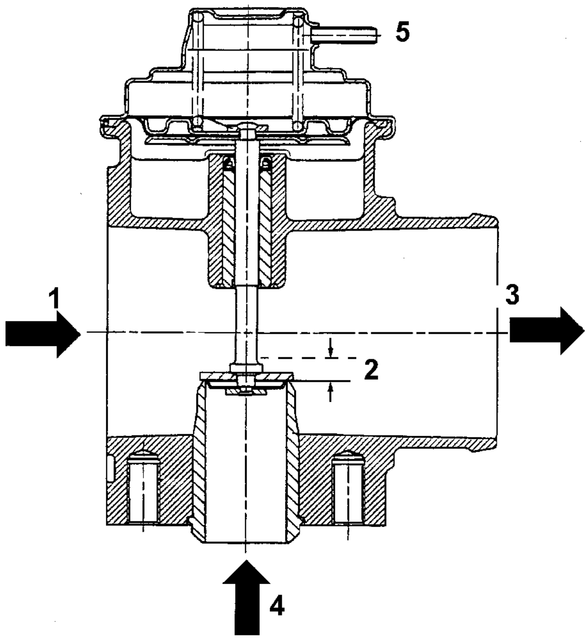
Exhaust gas recirculation

The purpose of EGR is to reduce the Nitrous Oxide emissions (NOx) produced during combustion.

NOx emissions occur at high combustion pressure and high combustion temperatures. Emission reduction is achieved by reducing the Oxygen content and thus reducing the combustion temperature.

To achieve this, a link is provided between the exhaust manifold and intake system. An EGR valve is located in this link and controls the volume of exhaust gas entering the inlet manifold.

The EGR valve opens when vacuum is applied and allows exhaust gas into the flow of fresh air via a connecting tube to the exhaust manifold (EGR tube). The opening stroke is 2.5 mm (see Figure 5). A gas-tight seal is provided by a blade-type seal.



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1. Fresh air
2. Opening stroke
3. Mixed gas
4. Exhaust gas
5. Vacuum

The applied vacuum level determines the amount the valve opens.

On the M47R, the exhaust gas recirculation housing is made of plastic. A steel cover is located at the top and bottom of the exhaust inlet to protect the housing at excessively high exhaust inlet temperatures.

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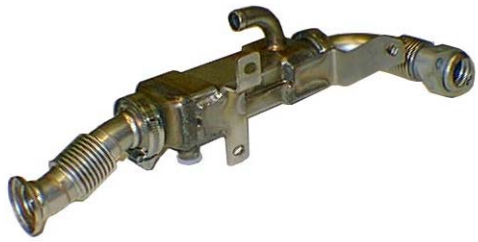
Rover is employing an exhaust gas recirculation cooling system for the first time on diesel vehicles fitted with automatic transmission. Due to the fuelling strategy used to compensate for any power loss through the automatic transmission, there tends to be a slight increase in NOx emissions.

EGR cooling can reduce NOx emissions by up to 15% and particle emissions by up to 8%.

The EGR cooler (see Figure 6) is fitted in the EGR line between the exhaust manifold and the EGR valve. The exhaust gas flows through a bundle of pipes flooded by coolant.



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Intake system

The intake system is made from glassfibre-reinforced polyamide (plastic) and consists of three main components:

1. Intake silencer with air filter
2. Intake manifold
3. Cylinder head cover

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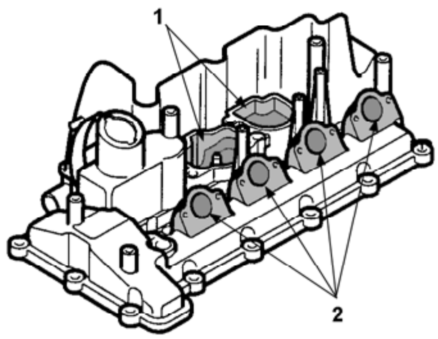
The intake silencer is linked to the engine and is integrated in the cylinder head cover. The air cleaner is designed in the form of an oval cartridge (see Figure 7).



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1. Crankcase ventilation system
2. Swirl inlet ports

The intake silencer serves the purpose of;

- reducing intake noise
- mounting the inlet air temperature and mass airflow sensors
- mounting the inlet and clean air connections
- filtering the engine intake air

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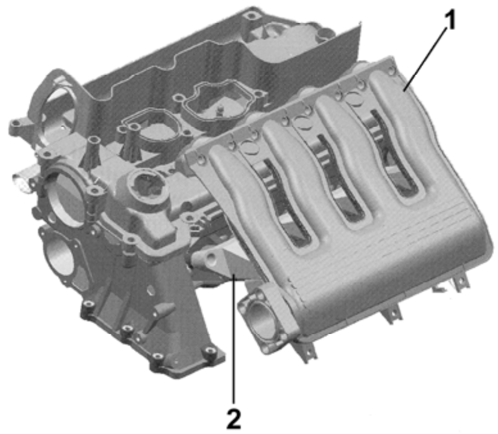
The intake system routes the incoming air through the tangential and swirl ports into the cylinder bores in readiness for compression (see Figure 8).



Fi e a r

1. Swirl port
2. Tangential port

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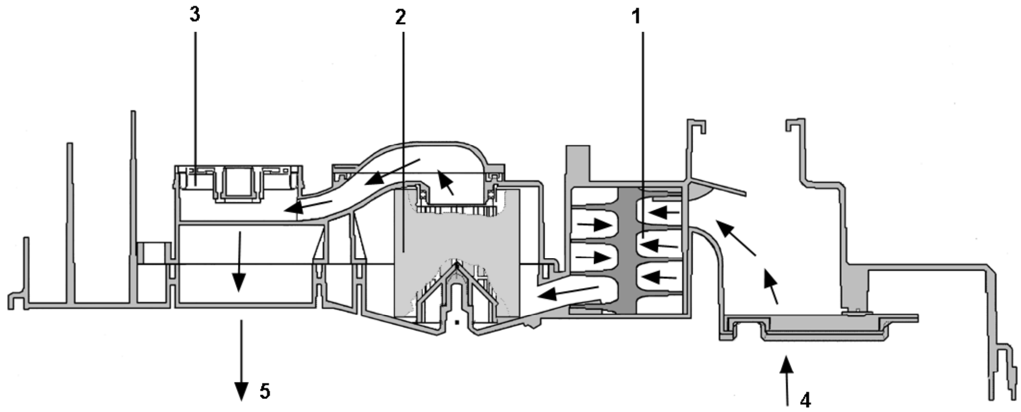
The cylinder head cover serves the purpose of;

- sealing off the oil chamber in the cylinder head
- crankcase ventilation
- shielding the valve gear housing
- shielding the oil spray from the camshaft and the chain drive gear
- sealing the swirl ports from the oil chamber in the cylinder head
- reducing weight
- improving acoustics
- mounting the oil separator (see Figure 9)



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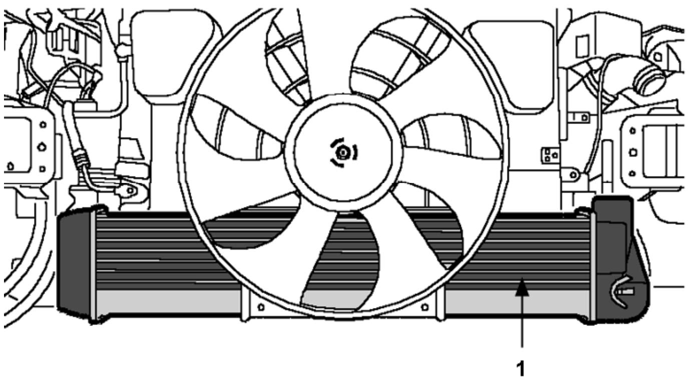
1. Cyclone (preliminary separation)
2. Yarn wrap (fine separation)
3. Pressure control valve
4. Ventilation from crankcase
5. Ventilation into intake system

The oil separator for the crankcase ventilation system is mounted at the centre top of the cover, which provides preliminary oil separation by cyclone, and fine separation using an internal yarn wrap filter. The separator unit also contains a pressure control valve.

Intercooler

The intercooler (see Figure 10) reduces the charge air temperature from the turbocharger and thus increases the density of the air compressed by the turbocharger. This means that the engine can be charged with a larger mass of air, which reduces fuel consumption and exhaust emissions while increasing power output.



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1. Intercooler

Common rail fuel system

History

A research company by the name of Elasis in Naples, developed common rail technology. In 1993 the Italians produced a prototype of their new fuel injection system. Problems with the tolerances of the injectors stopped the planned volume production and prompted the search for a partner at the turn of the year 1993/94. Bosch bought the patents and took over Elasis. Bosch presented the new system on the market one year earlier than any other manufacturers.

Introduction

In conventional systems, pressure generation is coupled to injection volume preparation. This has the following consequences for the injection characteristics:

- The injection pressure increases as the speed and volume increase
- The injection pressure increases during actual injection

Consequently;

- small injection volumes are injected at lower pressures
- the peak pressure is more than twice as high as the mean injection pressure

The peak pressure governs the load on the components of an injection pump and the pump drive. On the other hand, the mean injection pressure is important for the quality of fuel-air mixture in the combustion chamber.

Requirements

Increasingly stringent regulations governing exhaust and noise emissions and the demand for lower fuel consumption mean that the injection system of a diesel engine must consistently fulfil new requirements.

- Highest possible metering accuracy over the entire service life
- Pre-injection and main injection
- It is possible to independently determine the injection pressure and injection volume for every operating point of the engine which gives additional degree of freedom for ideal mixture preparation
- The injection volume and pressure should be as low as possible at the start of injection to prevent ignition delay between the start of injection and the start of combustion to obtain smoother engine operation (pre-injection)

Functional principle

The Rover 75 is the very first Rover diesel engine to be equipped with a high-pressure accumulator fuel injection system (common rail). With this new fuel injection process, a high-pressure pump delivers a uniform level of pressure to the shared fuel line (the common rail) which serves all the fuel injectors. Pressure develops to an optimum level for smooth operation. This means that each injector nozzle is capable of delivering fuel at pressures of up to 1350 bar.

The common rail system disconnects fuel injection and pressure generation functions. Fuel injection pressure is generated independently of the engine speed and fuel injection volume and is made available in the rail (high pressure fuel accumulator) for injection to the cylinders.

The fuel injection timing and fuel volume are calculated individually in the EDC control unit and delivered to each engine cylinder by the injectors, each of which is actuated by energising the appropriate solenoid valve.

Advantages:

1. Fuel injection at exactly the right moment
2. Precisely metered fuel quantity
3. Constant high pressure
4. Fuel consumption optimised
5. Emission reduction
6. Very smooth engine operation
7. Pre-injection:
   - The ignition delay at the point of main injection is shortened
   - Combustion pressure peaks are reduced (Smoother combustion)
   - Emissions are reduced
8. Main injection:
   - Variable operating pressure according to engine demands
   - The injection pressure remains constant over the entire injection period thus enabling more accurate volume metering
   - The main injection is responsible for torque generation

System structure

The fuel system is divided into 2 sub-systems:

- Low-pressure system
- High-pressure system

The low-pressure system features the following components:

- Fuel tank
- Advance fuel pump (in tank)
- Outlet protection valves
- In-line electric fuel pump
- Fuel filter with inlet pressure sensor
- Pressure relief valve (low pressure system)

and in the fuel return line:

- Fuel cooling control (bimetal valve)
- Fuel cooler

The high pressure system features the following components:

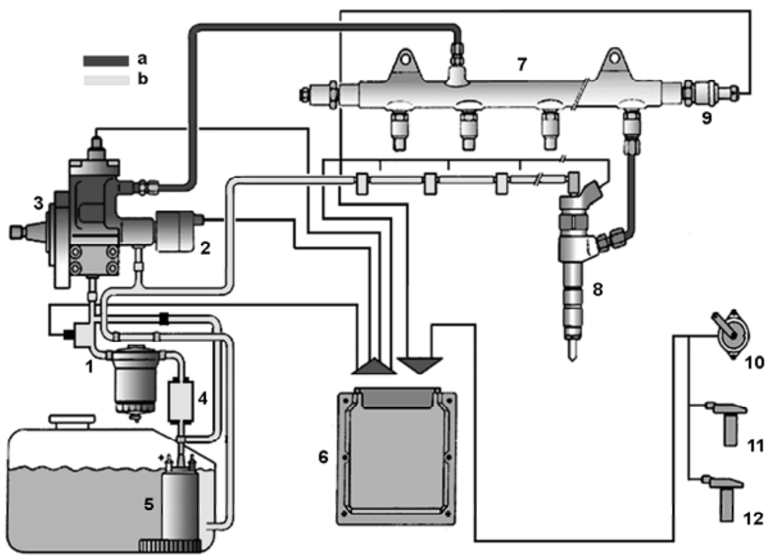
- High-pressure fuel pump
- Fuel high-pressure accumulator (rail)
- Pressure control valve
- Rail pressure sensor
- Injectors

Diesel fuel system

The diesel fuel system (see Figure 11) consists of an extra underbonnet fuel pump and fuel return lines. Also, a diesel cooler is fitted to the fuel tank return line. The right hand venturi on the diesel system is fed directly from the pump in the tank and a tee- joint feeds the venturi in the opposite side. Unlike the in-tank filter fitted to petrol derivatives, the diesel filter is fitted externally to the tank in an underbonnet location.

The extra pump is fitted before the fuel filter and increases the pressure to assist the fuel through any potential blockage of the filter during cold starts. The extra pump helps to ensure all engine fuelling requirements are satisfied in all conditions.

A pressure regulator is located after the filter and relieves fuel into the secondary pump feed.



Fi e fu u t

a. High-pressure
b. Low-pressure
1. Pressure sensor and fuel filter
2. Pressure relief valve
3. High pressure pump
4. In line electric fuel pump (low-pressure)
5. In-tank low-pressure electric fuel pump
6. Engine control module
7. High-pressure fuel rail
8. Injector
9. Fuel rail pressure sensor
10. Pedal demand sensor
11. Crankshaft position sensor
12. Camshaft position sensor

Fuel leaves the tank from an outlet on the top of the filter adapter unit and is transferred to a secondary low-pressure fuel pump. Both the primary and secondary low-pressure fuel pumps are controlled by the ECM via a single relay. When the ignition is switched to position II, the fuel pump relay is energised for up to 20 seconds, this operates the low-pressure fuel pumps to build up approximately 2.5 bar line pressure supply to the main fuel filter and high-pressure fuel pump. The spill return from the high-pressure pump and injectors is returned to the tank via a connection to the right hand section of the fuel tank. The excess fuel flow divides into two at a tee connection, one output passes fuel through a venturi which draws fuel from the left side of the tank and delivers it to the right side of the tank. The other output passes fuel through a venturi which draws fuel from the right hand side of the tank and delivers it to the swirl pot. This arrangement ensures that the left side of the tank is scavenged into the right side, and the fuel level in the swirl pot is always maintained regardless of vehicle movement.

Each side of the fuel tank contains a sender unit to detect fuel level. The senders are wired in series to the instrument pack. The instrument pack utilises an algorithm to calculate fuel level from both level sender units.

The ECM detects pressure in the low-pressure side of the system via a pressure sensor installed in the fuel filter head. The sensor output is required by the ECM to determine if the high-pressure fuel pump is receiving sufficient pressure. If the ECM detects insufficient inlet pressure to the high-pressure fuel pump, it will reduce engine speed and fuel rail pressure accordingly to prevent damage to the high-pressure fuel pump.

Comparison of a common rail system to a conventional system

Conve on je ci acteristics

In conventional injection systems, such as the use of distributor and in—line injection pumps, only a single injection takes place. Pressure generation is coupled to injection volume preparation. This has the following consequences for the injection characteristics:

- The injection pressure rises as the engine speed and injection quantities increase
- The injection pressure increases during injection

As a result:

- At low pressures small quantities are injected
- The peak pressure is more than twice the average fuel injection pressure

Peak pressure determines the load which can be applied to the components of an injector pump and its drive unit.

The average injection pressure is, however, important for the quality of the fuel/air mixture in the combustion chamber.

Common inj on c ris s

Common rail fulfils the following demands:

- It is possible to independently determine the injection pressure and injection volume for every operating point of the engine which gives an additional degree of freedom for the ideal mixture preparation
- After the start of combustion, it should be possible to select the injection pressure throughout the entire period of injection

These requirements have been fulfilled in the common rail accumulator injection system with preliminary and main injection.

Noise and vibration characteristics are affected to a large extent by the degree of combustion. Therefore, a carefully planned adaption of fuel injection has taken on an important role. The influencing of the engine combustion takes place by means of a preliminary injection in the common rail system. This makes disturbance-free combustion at lowest noise levels possible.

Because of its modular design the system can be easily matched to various engines; the conventional injection nozzle holder can be substituted by the common rail injectors and the high pressure pump can be mounted on the engine. The transition from conventional system to a common rail system can thus be made quite easily. A comparison between the conventional and common rail component structure can be seen in table ’Component comparison.

Component comparison

Description	Common rail system	Conventional system
High pressure generation	High pressure pump	Distributor-type injection pump
Pressure distribution	Thick high-pressure lines	High-pressure lines
Supply reservoir	Rail	N/A
Injection	Injector - electronic	Injection nozzle - mechanical

Data for the common rail fuel system can be seen in table ’Common rail technical data.

Common rail technical data

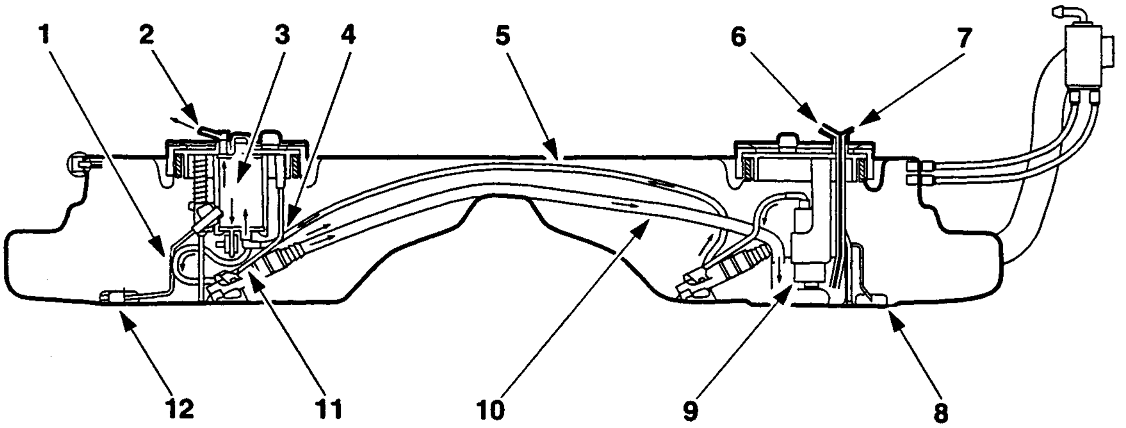
Description	Technical data
Pressure	250 - 1350 bar
Injection begin: • Pre-injection • Main injection	max. 60° BTDC max. 25° BTDC
Pump speed	0.75 x engine speed
Injection quantity	1 - 80 mm^3 per stroke
Maximum delivery volume	240 litres per hour

Common rail components

The following describes the functionality of the components that form the common rail fuel system.

Fuel tank

The M47R diesel is fitted with a blow moulded plastic saddle tank with plastic underfloor fuel and vent lines (see Figure 12). The fuel lines are covered with a flame retardant material.



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1. Left hand tank module
2. Filter unit adapter
3. Connection to adapter
4. Spill feed to left hand venturi
5. Spill fuel return to tank
6. Fuel outlet to secondary low-pressure fuel pump
7. Fuel outlet to fuel burning heater
8. Right hand fuel level sender
9. Primary low-pressure fuel pump
10. Scavenge flow to right hand side of tank
11. Pressure regulator
12. Left hand fuel level sender

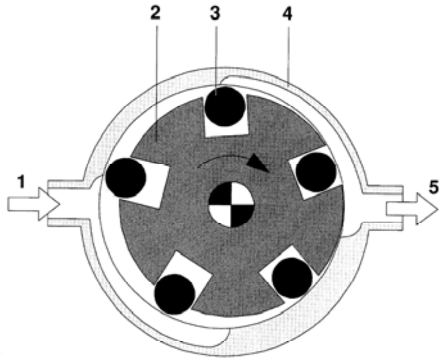
A submersible, low-pressure electric fuel pump is located in the right hand section of the fuel tank, this pump is called the primary low-pressure pump. The primary low-pressure pump draws fuel from the swirl pot and delivers it to a filter unit adapter mounted in the left hand section of the fuel tank. The adapter unit contains a pressure regulator which is calibrated to 3.6 bar, this will not open during normal operation of the system. The tank has a capacity of 66 litres gross (64.8 litres useable) and is secured to the vehicle foreplay using a H frame strap assembly. The filler is located on the right hand side (HRS.) of the rear wing panel. The tank is protected from the heat of the exhaust system by a reflective metallic heat shield.

el pump

The electrical fuel pump is located inside the fuel tank in the right-hand side.

The electrical fuel pump transports fuel from the swirl pot towards the engine (see Figure 13) and operates the level control venturis in the left and right sides of the tank. Both venturis deliver fuel to the swirl pot in the right-hand side of the tank.

In-tank electric fuel pump



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1. Suction side
2. Rotor disc
3. Roller
4. Base plate
5. Pressure side

The electrical fuel pump is activated by the ECM via the electrical fuel pump relay.

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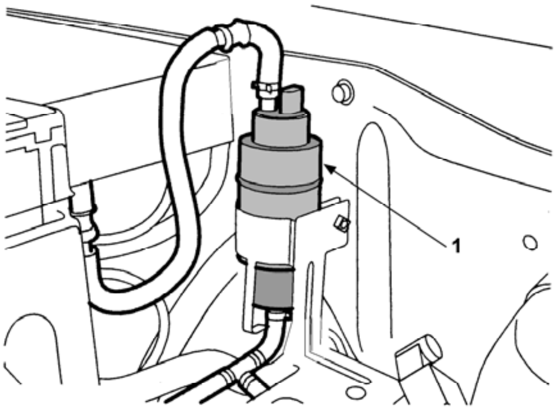
The in-line electrical fuel pump (see Figure 14) is located in the inlet line and has the task of providing the HPP with an adequate amount of fuel:

- In every operating condition
- At the required pressure
- Across the entire service life



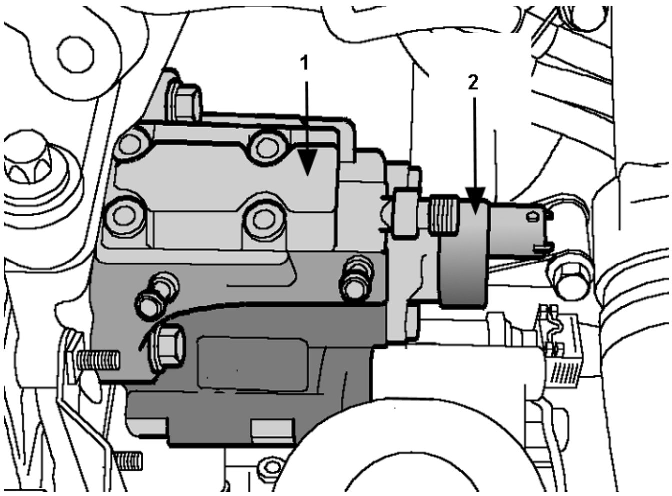
Fi l i f ump

1. In-line electrical fuel pump

The in-line electrical fuel pump is also activated by the ECM via the same electrical fuel pump relay.

High-pressure pump

The HPP is located at the front left side of the engine (see Figure 15), the same position as a distributor-type fuel injection pump.



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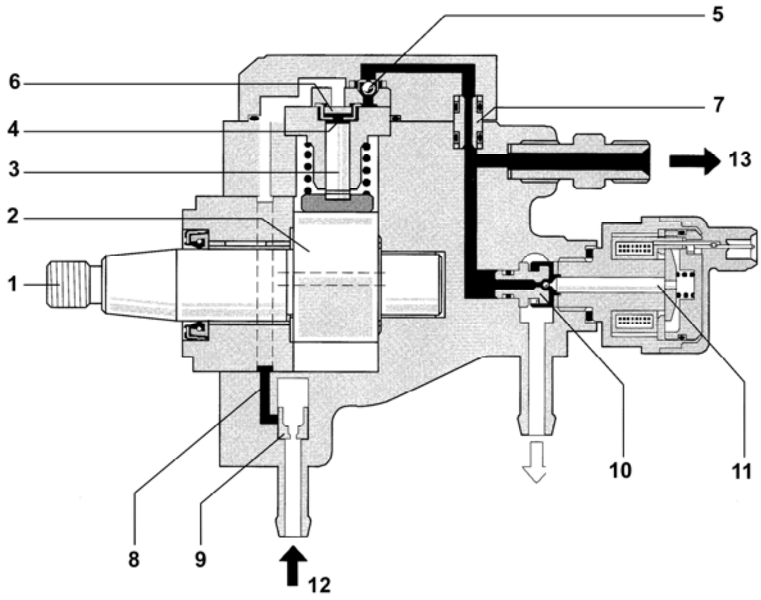
1. High-pressure fuel pump
2. Pressure control valve

The HPP is the interface between the low-pressure and the high-pressure sections. It has the task of ensuring that there is always enough fuel delivered at a sufficient pressure in every operating mode across the entire service life of the vehicle. This includes the delivery of spare fuel, required for a rapid start and pressure increase in the rail.



Fi r d ew)

1. Drive shaft
2. Eccentric cam
3. Pump element with pump piston
4. Element chamber
5. Exhaust valve
6. Suction valve
7. Sealing unit
8. Low pressure duct to pump element
9. Safety valve with throttle bore
10. Ball valve
11. Pressure control valve
12. Inlet
13. Fuel return
14. Pressurised fuel (to the rail)

Fuel is delivered via the filter to the HPP (see Figure 16) intake and the safety valve (9) situated behind it. It is forced through the throttle bore into a low-pressure duct (8). This duct is connected to the lubrication and cooling circuit of the high-pressure pump. It is therefore not connected to an oil circuit.

The drive shaft (1) is driven via the chain drive at three quarters engine speed. It moves the three pump pistons (3) up and down with its eccentric cam (2), depending on the cam shape.

If the pressure in the low pressure duct exceeds the opening pressure of the suction valve (6) (0.5 -1.5 bar), the advance delivery pump can force fuel into the element chamber where the pump piston moves downwards (suction stroke). If the dead-centre point of the pump piston is exceeded, then the intake valve closes. Fuel in the element chamber (4) can no longer escape. It is then compressed in the intake line by the delivery pressure. The accumulating pressure opens the exhaust valve (5) as soon as the pressure in the rail is achieved. Compressed fuel enters the high-pressure system.

The pump piston delivers fuel until the upper dead-centre point is reached (delivery stroke). Pressure then falls again, which closes the outlet valve. The remaining fuel is no longer subject to pressure. The pump piston moves downwards.

If the pressure in the element chamber falls below the pressure in the low-pressure duct, then the intake valve opens again. The whole process is repeated from the beginning.

The high-pressure pump constantly generates the system pressure for the high-pressure rail. The pressure in the rail is determined by the pressure control valve.

Since the high-pressure pump is designed for large delivery quantities, there is an excess of compressed fuel when the vehicle is idling or only subject to partial load. Since the compressed fuel is no longer subject to pressure once the excess fuel flows away, the energy generated by the compression is lost and/or heats the fuel.

This excess delivered fuel is returned to the tank via the pressure control valve and the fuel cooler.

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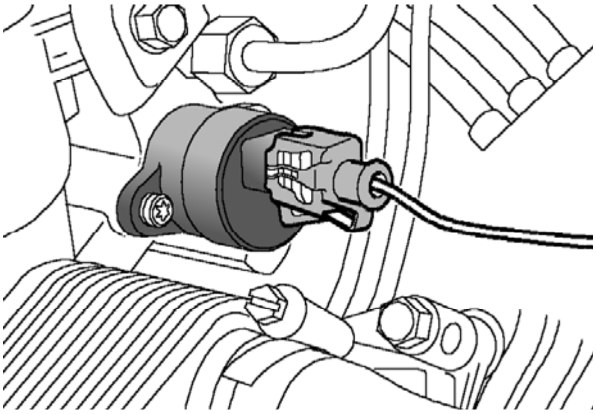
The pressure control valve is located at the back of the high-pressure pump (see Figure 17).



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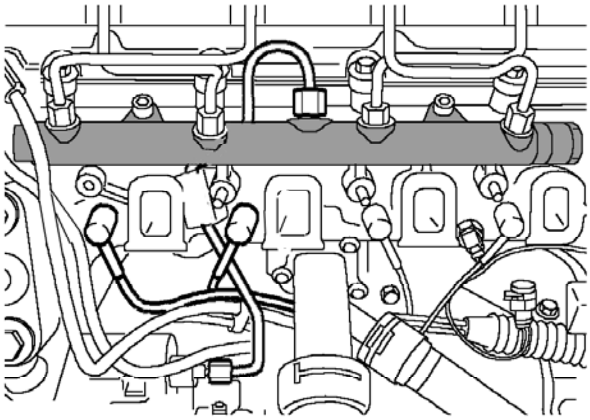
The pressure control valve has the task of setting and maintaining the rail pressure according to the load status of the engine.

- If the rail pressure is too high, the pressure control valve opens, which enables some of the fuel to pass from the rail to the fuel tank via a collector line
- If the rail pressure is too low, the pressure control valve closes and seals the high-pressure side from the low-pressure side

Fuel high-pressu accumu ail)

The fuel high-pressure accumulator (rail) is located beside the cylinder head cover (see Figure 18).



Fi e fu l

In the fuel high-pressure rail, the fuel is subjected to high pressure and delivered (accumulated) for injection.

This accumulator, which is used by all cylinders (where the name common rail originates from), maintains its internal pressure at the near constant value, even when handling larger quantities of fuel. This ensures that the injection remains at a near constant when the injector is opened.

Fluctuations in pressure, resulting from the pump delivery and injection, are dampened by the accumulator volume.

The fuel high-pressure rail is essentially a thick walled pipe with connections for lines or sensors.

On the M47R, the fuel high-pressure sensor is located at one end of the rail.

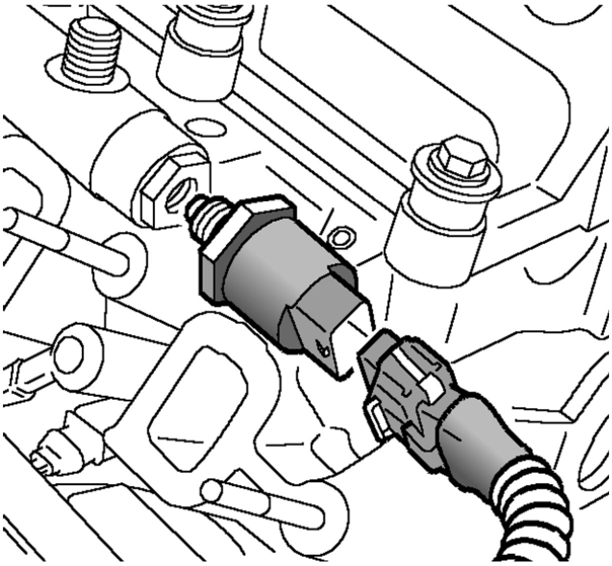
The fuel high-pressure rail is continuously supplied with fuel from the high-pressure pump. Fuel is delivered from this rail to the injectors via the injector connector lines. The rail pressure is set via the pressure control valve.

The volume present in the rail is constantly filled with the pressurised fuel. The spring action brought about by the high pressure is used to create an accumulator effect.

If fuel is removed from the rail for the purpose of injection, the pressure in the high-pressure rail remains at a near constant. Fluctuations in pressure created by the cycled supply of the high-pressure pump are damped and/or compensated.

Rail pres sensor

The rail pressure sensor is screwed onto the end of the rail (see Figure 19).



Fi n

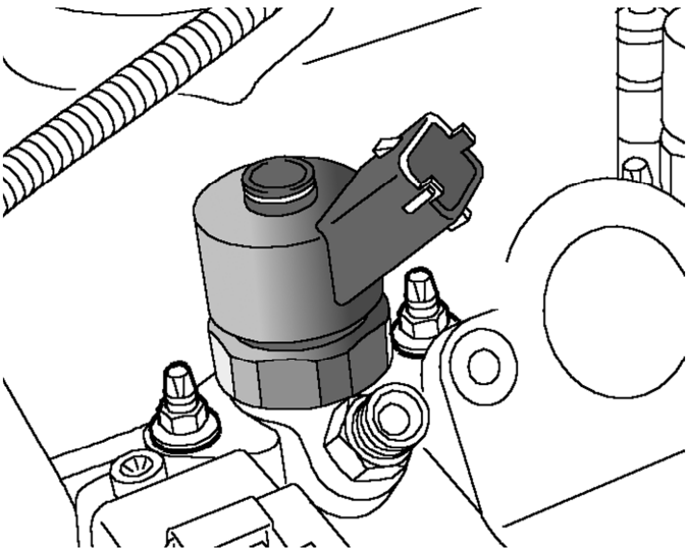
The rail pressure switch must measure the current fuel pressure in the rail;

- with sufficient accuracy and
- in a suitably short time

It must then supply a voltage signal to the control unit. The signal corresponds to the level of pressure present.

ors

The injectors are arranged in the central area above the combustion chambers in the cylinder head (see Figure 20).



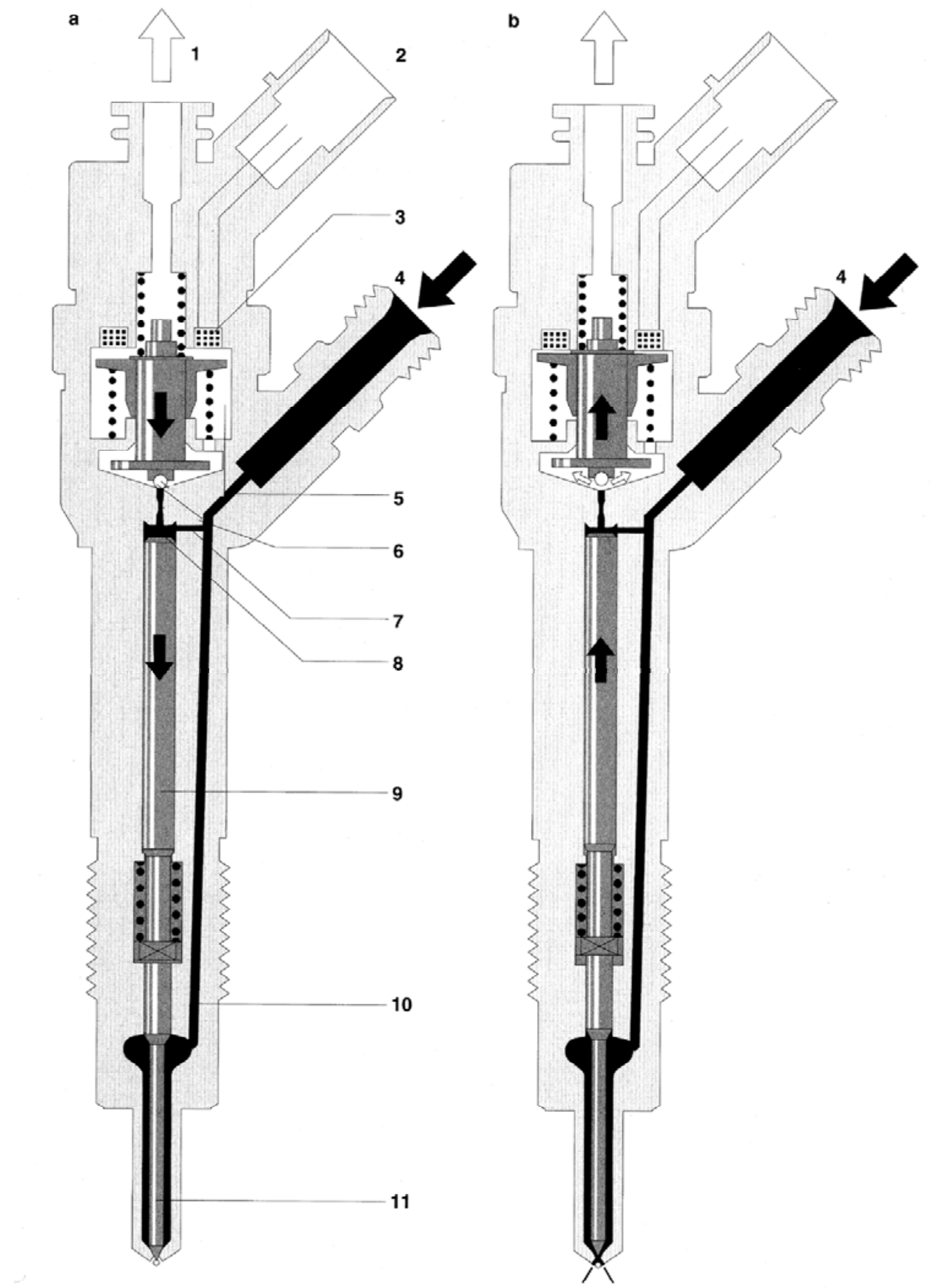
Fi e 2 on

The injectors are held in the cylinder head with what is known as clamping shoes. The common rail injectors are therefore suited for installation into existing directly injected diesel engines without any major alterations required.

The injector needle has a single guide so that the risk of needle friction can be prevented at a design level.

The injector can be divided into a variety of function blocks:

- Hole nozzle with injector needle
- The hydraulic servo system
- Solenoid valve
- Connections and fuel channels



Fi (s

a. Injector closed (at rest)
b. Injector open (injection)
1. Fuel return
2. Electrical connection
3. Activation unit (solenoid valve)
4. Fuel supply (inlet), high pressure from rail
5. Valve control chamber
6. Valve ball
7. Inlet port
8. Outlet port
9. Valve control piston
10. Supply channel to nozzle
11. Nozzle needle

Referring to figure 21, the high-pressure connection (4) guides the fuel through a channel (10) to the nozzle and also through the supply throttle (7) in the control chamber (5).

The control chamber is connected to the fuel return line (1) by the outlet throttle (8), which is opened by a solenoid valve. When the outlet throttle is closed, hydraulic force on the valve piston (9) exceeds that on the pressure stage of the injector needle (11). Consequently, the injector needle is pressed into its seat and seals the high-pressure channel off from the engine compartment. Fuel cannot enter the combustion chamber, although it is constantly pressurized at the high-pressure connection.

When the injector activation unit is actuated (solenoid valve), the outlet throttle is opened. This reduces the pressure in the control chamber, and therefore the hydraulic force on the valve piston.

As soon as the hydraulic force drops below that on the pressure stage of the injector needle, the injector needle opens, which allows the fuel to enter the combustion chamber through the spray apertures.

This indirect activation of the injector needle via a hydraulic force increasing system is used because the force required to open the injector needle using the solenoid valve cannot be produced directly. The control quantity required in addition to fuel quantity injected enters the fuel return line via the control chamber throttle.

In addition to the control quantity, fuel is also lost at the throttle needle and valve piston guide (leakage quantity).

The function of the injector can be sub-divided into four operating statuses when the engine is running and the high-pressure pump is delivering fuel:

- Injector closed (under high pressure)
- Injector opens (start of injection)
- Injector fully open
- Injector closes (end of injection)

These operating statuses are applied according to the distribution of force amongst the components of the injectors. If the engine is not running, the nozzle spring closes the injector.

o. ( )

When at rest, the solenoid valve is not activated and is therefore closed.

Because the outlet throttle is closed, the armature ball is pressed into the lodgment at the drain throttle by the valve spring. The rail high pressure accumulates in the valve control chamber. The same pressure is also exerted in the chamber volume of the nozzle. The forces applied by the pressure to the surfaces of the control piston and the force of the nozzle spring keeps the injector needle closed against the opening force attacking its pressure stage.

ector opens (st. je on)

The injector is at rest. The solenoid valve is activated by the starting current of 20 amps, which enables the solenoid valve to be opened quickly. The force of the activated electromagnet exceeds that of the valve spring and the armature opens the final throttle. After a maximum of 450 ms, the increased starting current of 20 amps is reduced to a lower retaining current of 12 amps from the electromagnet. This is possible because the air gap of the magnetic circuit is now smaller.

Opening the drain throttle allows fuel to flow out of the valve control chamber into the cavity above, and then to the fuel tank via the fuel return line. The inlet port prevents complete compensation from taking place and the pressure in the valve control chamber drops. As a consequence, the pressure in the valve control chamber is lower than the pressure in the chamber volume of the nozzle which still has the same level of pressure as the rail. The reduced pressure in the valve control chamber leads to less pressure being exerted on the control piston and to the injector needle being opened. Injection commences.

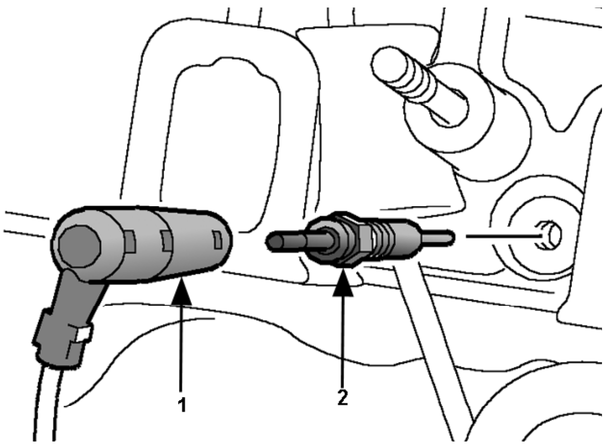
The speed at which the injector needle opens is determined by the difference in through put in the inlet and outlet throttle. After a stroke of approx. 200 µm, the control piston reaches its upper limit point and stays there, supported by a cushion of fuel. This cushion is the result of the stream of fuel created between the inlet and outlet throttle. The injector nozzle is now completely open and the fuel is injected into the combustion chamber at a pressure approaching that of the pressure in the rail.

ector clos nd injection)

If the solenoid valve is no longer activated, then the armature is forced downwards by the force of the valve spring. The ball then closes the outlet port. To prevent excessive wear from the contact between the ball and the valve's lodgment, the armature consists of two parts. Although the armature plate is guided downwards by a cam, it can also oscillate downwards by means of a reset spring, there by preventing the armature and ball from being subject to any downward forces. As in the rail, closing the outlet port causes pressure to accumulate in the control compartment through the inlet of the inlet port. This increased pressure exerts greater force on the surface at the head end of the control piston. This force from the valve control chamber and the spring force exceed the force from the chamber volume, the injector needle closes. The speed at which the injector needle closes is determined by the through put of the inlet port. Injection stops once the nozzle needle reaches its lower limit point.

ow plugs

The glowplugs provide a sufficiently high ignition temperature in the combustion chamber while the engine is still cold. The glow plugs are controlled by the glowplug relay and are located on the inlet side of the cylinder head (see Figure 22).

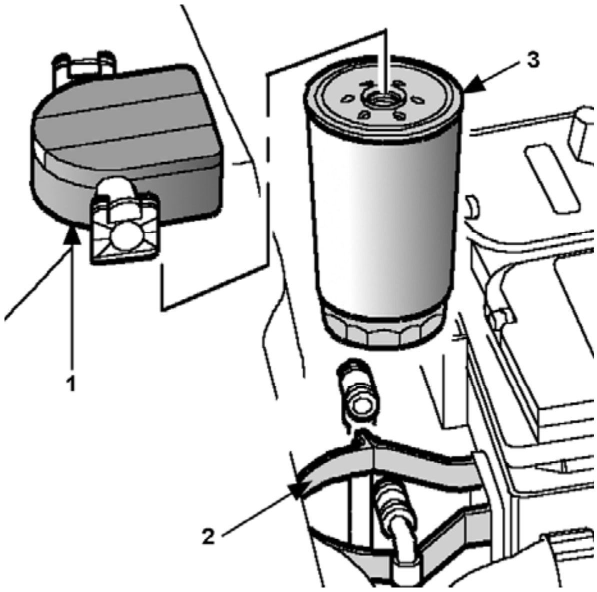


Fi e on

1. Electrical connection
2. Glowplug

F l filter

The fuel filter is located adjacent to the battery box (see Figure 23).



Fi n

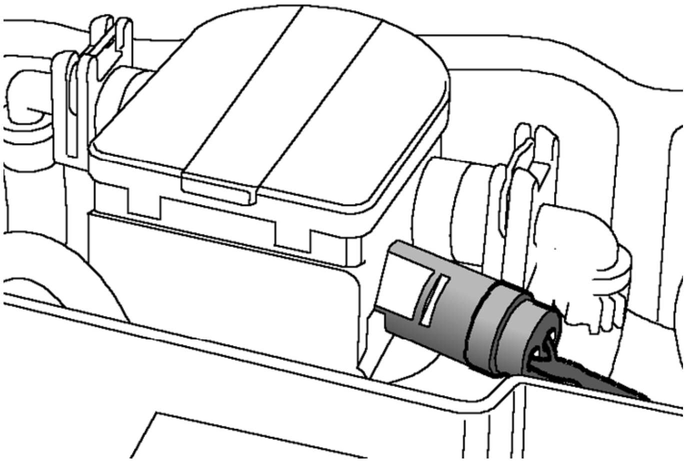
1. Fuel filter housing
2. Fuel filter holder
3. Fuel filter

The fuel filter cleans fuel from the fuel tank and helps prevent premature wear to delicate components. Insufficient filtration can cause damage to pump components, pressure valves and fuel injection nozzles. It does not feature any electrical fuel heating and does not have a water separator.

To prevent clogging up the filter at low temperatures, there is a bimetal valve in the return line. This valve prevents heated fuel residue from mixing with cool fuel from the tank.

Lov essu sensor

The low pressure fuel sensor (see Figure 24) is used to detect the system pressure in the low pressure fuel system from the in-line electric pump. The sensor is built into the turret of the fuel filter, adjacent to the battery box.



Fi e 2 f (on

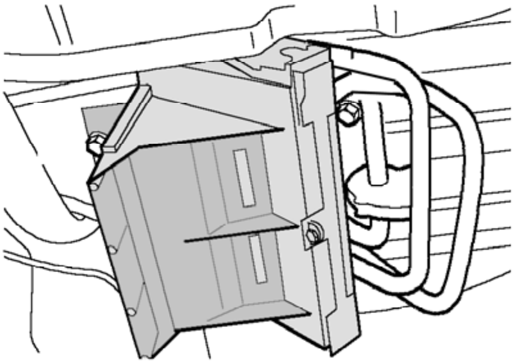
This sensors information enables the EDC EMS to reduce the fuel injection quantity at excessively low inlet pressures to the point where engine speed and rail pressure are reduced accordingly. The requisite inlet volume to the high-pressure pump is reduced. This makes it possible for the inlet pressure to the high-pressure pump to rise to the required level.

At an inlet pressure of less than 1.7 bar, high-pressure pump damage is possible due to inadequate lubrication. To protect the high-pressure pump, the EMS will shut down the engine if it receives a signal informing it of a low-pressure situation. The engine can be shut down if a differential pressure of less than or equal to 0.5 bar develops between the inlet and the return lines (pump protection).

Fuel h ng and cooling

The bimetal valve (thermocouple) is situated on the outside of the fuel filter housing, (for example, it is no longer directly situated on the fuel filter itself).

A fuel cooler is fitted next to the rear right hand wheel (see Figure 25), the same location as for the charcoal canister on petrol derivatives. The fuel returning from the engine is at a very high temperature and must be cooled before it is returned to the swirl pot. If the fuel is less than or equal to 63°C (± 3°C), 60% to 80% of the fuel return flows directly to the line feeding the in-line electric fuel pump and the fuel filter, the rest of the fuel returns to the fuel tank via the fuel cooler. When the fuel is greater than or equal to 73°C (± 3°C), 100% of the fuel is directed to the fuel cooler. From the cooler, the fuel is returned to the swirl pot, via an in-tank duck bill valve, where it is again picked up by the fuel pump.



Fı n

Because diesel engines produce less vapour than petrol engines, venting is carried out by a single centre vent.

Fuel system data can be seen in the table ’Fuel system technical data’.

Fuel system technical data

Description	Data
System	Common rail, direct injection
Fuel specification	EN590 diesel
Pressure regulator setting	350 kPa (3.5 bar)
Fuel tank pump	Electirc - in fuel tank
Fuel pump output	250 kPa (2.5 bar)
Fuel injection pump	Bosch CP1 mechanical high pressure pump
Fuel pump drive	Chain driven from crankshaft at approx. half engine speed
Pressure control valve limit	22 bar
Injector make	Bosch
Nozzle type	DSLA 145P 868
Position	Central
Injector operating pressure	250 - 1350 bar
Pre-injection	60° BTDC
Main injection	25° BTDC

Cooling system

Operation

When cold, the thermostat is closed and coolant is prevented from circulating through the radiator. Coolant is however able to circulate through the by-pass and heater circuits (see Figure 26).

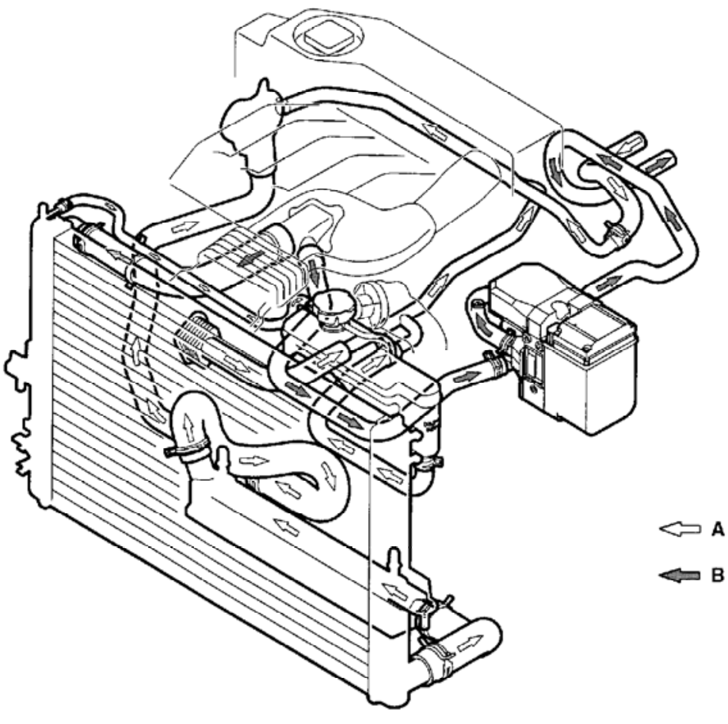
As the coolant temperature increases, the thermostat gradually opens, bleeding cool coolant from the radiator bottom hose into the cylinder block and allowing hot coolant to flow to the radiator via the top hose, balancing the flow of hot and cold coolant to maintain the optimum engine temperature. When the thermostat opens fully, the full flow of coolant passes through the radiator.

As excess coolant, created by heat expansion, is returned to the expansion tank through a bleed hose from the top of the radiator. The expansion tank has an outlet hose which is connected into the coolant circuit. This outlet hose supplies coolant into the system when the engine is cool, replacing coolant displaced to the expansion tank due to heat expansion.

Coolant flows through the radiator from the top right hand tank to the bottom left hand tank and is cooled by air passing through the matrix. The temperature of the cooling system is monitored vie a temperature sensor, located in the cylinder head, by the ECM, which in turn controls the cooling fan operation.

Coolant circuit

The coolant circuit is designed as a long term antifreeze and corrosion protection circuit.



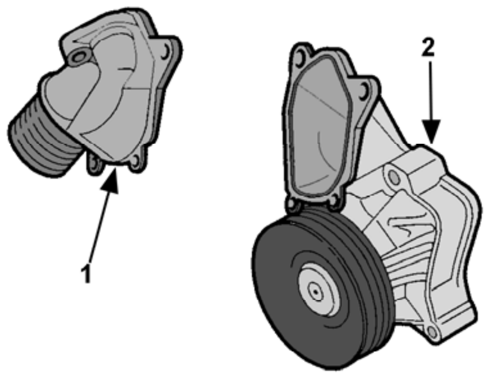
Fi e C a w

a. Cold
b. Hot

Wa pump and thermostat

The coolant is circulated by a centrifugal type pump (see Figure 27) mounted on the front of the engine, driven by the ancillary drive polyvee belt. The water pump circulates coolant around the cylinder block and cylinder head and to the radiator engine oil cooler, automatic transmission oil cooler and heater via the coolant hoses. Any coolant leakage from the water pump is directed through drainage tubes into the belt pulley.

The thermostat is a wax element type and has an opening temperature of 88°C ± 5°C. It is located in a plastic housing attached to the coolant pump on the inlet side of the cooling circuit. This allows a more stable control of the coolant temperature of the engine.



Fi e l m r s t

1. Thermostat
2. Water pump

R ator

The radiator is a cross flow type with an aluminium matrix and moulded plastic end tanks. The radiator end tanks have features that carry the fan assembly, expansion tank, intercooler and, if fitted, condenser, and/or transmission oil cooler.

A bleed screw is installed in the feed pipe to the fuel burning heater. This screw is used to bleed air from the cooling system during filling.

Lubrication system

Requirements and objectives

The following requirements and objectives apply to the lubrication system:

Requirements:
- To lubricate sliding surfaces in the engine
- To dissipate heat
- To absorb combustion residue of the fuel
- To seal off gap between cylinder and piston

Objectives:
- To lower oil consumption
- To increase engine performance
- To minimise engine wear

Lubricants

The lubricating systems are filled with high-performance lubricants giving prolonged life.

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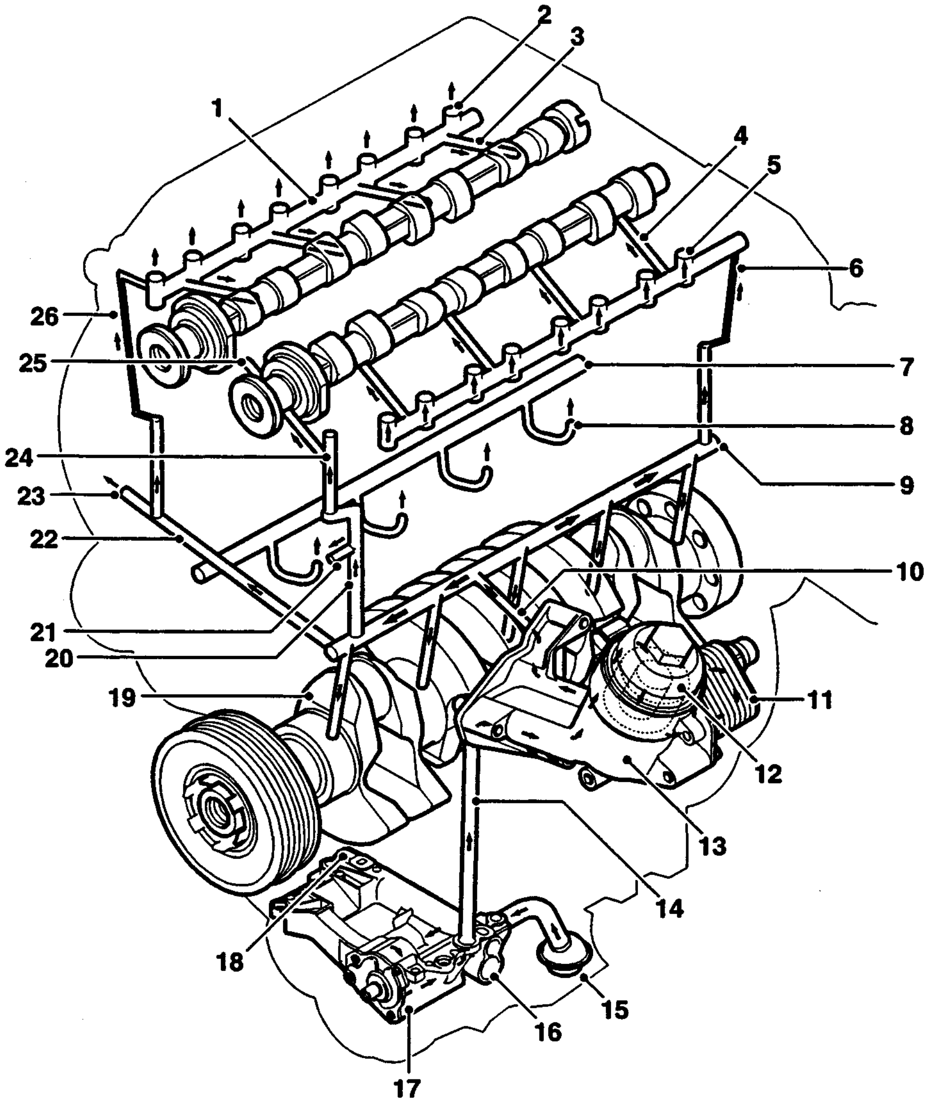
Oil to the correct specification contains additives which disperse the corrosive acids formed by combustion and prevents the formation of sludge which can block the oil ways. Additional oil additives should not be used.

Engine oil of 10W/40 or 15W/40, meeting specification RES.22.OL.PD2 or ACEA (Association des Constructeurs Européens d'Automobiles)B2:96, and having a viscosity band recommended for the temperature range of your locality.

System structure

The lubrication system consists of the following components:
- Oil pan with dipstick
- Oil pump
- Oil filter with integrated oil-to-water heat exchanger
- Oil spray nozzles for piston cooling



Fi e t

1. Hydraulic tappet gallery
2. Hydraulic tappet, exhaust side
3. Channels to camshaft bearings, exhaust side
4. Channels to camshaft bearings, inlet side
5. Hydraulic tappet, inlet side
6. Riser channel to tappet gallery, intake side
7. Cylinder block main gallery feed to lubrication jets
8. Piston lubrication jets
9. Cylinder block main oil gallery feed for crankshaft bearings
10. Oil filter housing to cylinder block
11. Oil cooler
12. Oil filter element
13. Oil filter housing
14. Oil pump to oil filter housing channel, through cylinder block
15. Oil pick-up pipe
16. Pressure relief valve
17. Oil pump assembly
18. Port to cylinder block main gallery, right hand side
19. Oil feed channels to crankshaft main bearings
20. Riser channel for chain lubrication jets
21. Pressure supply to chain tensioner
22. Pressure supply channel for turbocharger bearing lubrication
23. Out put port for turbocharger oil feed
24. Riser channel for upper chain lubrication
25. Pressure supply for upper chain lubrication
26. Riser channel for tappet gallery

Oil pan

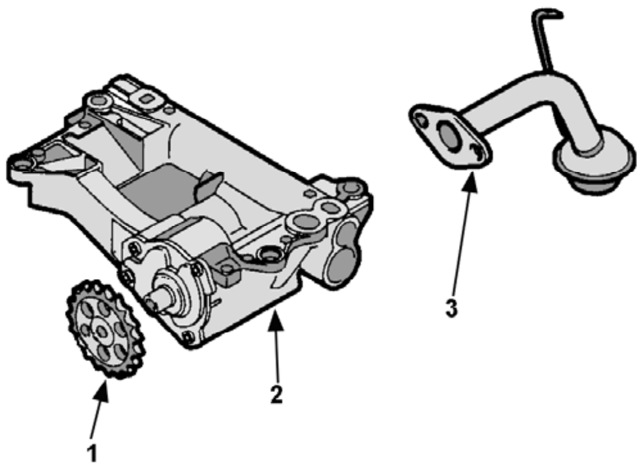
The two piece aluminium oil pan represents the bottom end of the engine and serves as an oil collection reservoir.

Oil pump

The oil pump (see Figure 29) is bolted to the bottom of the cylinder block and is located in front of the engine block stiffener plate. The pump is an internal rotor type with sintered rotors and is driven through a chain and sprocket system from the crankshaft.

A pressure relief valve is included at the outlet side of the oil pump to restrict oil pressure at high engine speeds by recirculating oil through the relief valve back around the pump to the inlet. The relief valve and spring is a plunger type; when oil pressure is great enough to lift the plunger, oil is allowed to escape past the plunger to relieve the pressure and prevent further rise.

Oil is delivered to the pump from the pick-up pipe, and the outlet side of the oil pump delivers pressurised oil flow to the engine block main oil delivery gallery.

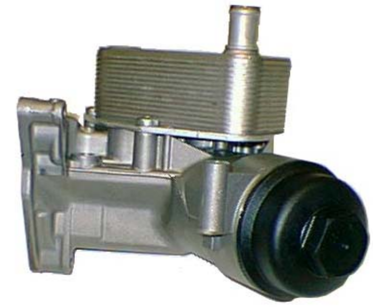


Fi ur a p

1. Pump sprocket
2. Pump body
3. Pick-up pipe

Oil filter with integrated oil-to-water heat exchanger

The oil-to-water heat exchanger assembly (see Figure 30) is located on the oil filter housing and is connected to both the oil circuit as well as the water circuit of the engine. Oil from the cylinder block passes through the oil filter housing and partial flow is directed through the oil cooler before it is returned to the cylinder block. The oil filter housing has an integral thermostatic valve which controls the amount of oil flowing through the oil cooler, dependant on the oil temperature. This arrangement ensures that the cooling water heats up the engine oil faster when the engine is cold while effectively cooling the engine oil when the engine is at operating temperature. Shortening the warm-up phase greatly contributes to reducing fuel consumption. The engine oil is cooled in order to increase its service life.



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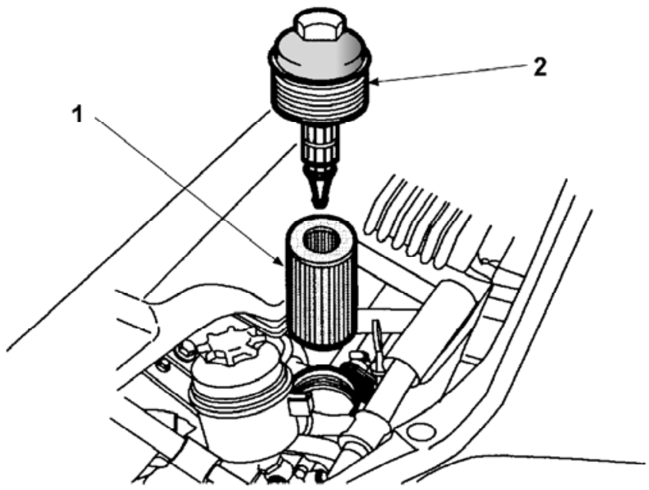
The oil filter is of the disposable paper type. The filter is removed by unscrewing the cap of the oil filter housing (see Figure 31).



Fi r y

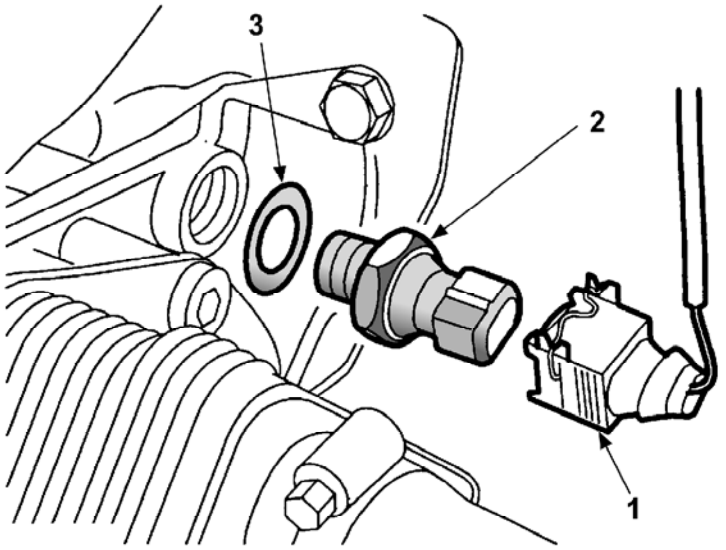
1. Oil filter element
2. Oil filter cap

For the operating conditions of the lubrication system, see table 'Technical data'.

Technical data

Operating conditions	
Oil flow rate	30 1/min.
Oil temperature	-40°C to +150°C
Oil pressure	1000 rev/min. approximately 1.5 bar 4000 rev/min. approximately 4.2 bar Peak pressure up to 20 bar
Oil capacity	1.4 litres (change with filter)
Pressure at idle	1.5 bar
Relief valve opening pressure	4.2 bar

The oil pressure switch is located in a port in the oil filter housing (see Figure 32). It detects when a low oil pressure condition occurs and initiates the illumination of a warning light in the instrument pack if the pressure drops below a given value.



Fi s s (n

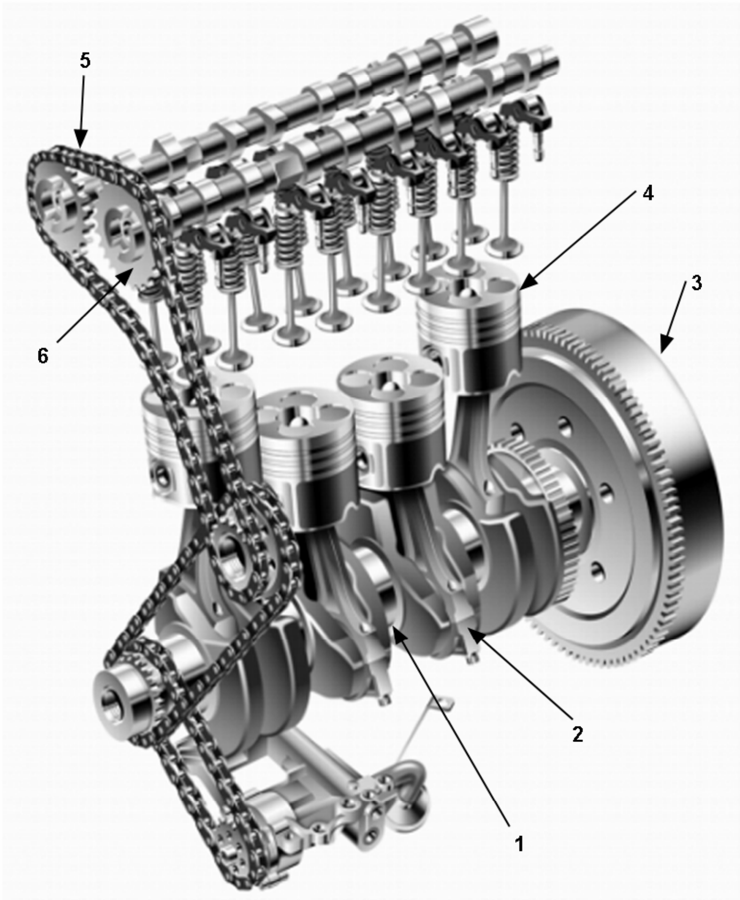
1. Electrical connection
2. Oil pressure switch
3. Sealing washer

Oil spray nozzles

The oil spray nozzles for piston cooling are mounted in the engine block. They are designed as hook-type nozzles (see Figure 33). The nozzles provide lubrication to the cylinder walls, and to the piston underskirt for cooling the pistons and lubricating the gudgeon pins and small end bearings. The input port to each lubrication jet mates with a port provided in each mounting position, tapped at the underside of the cylinder block from the main gallery.

il s

Engine components



ngine compon s

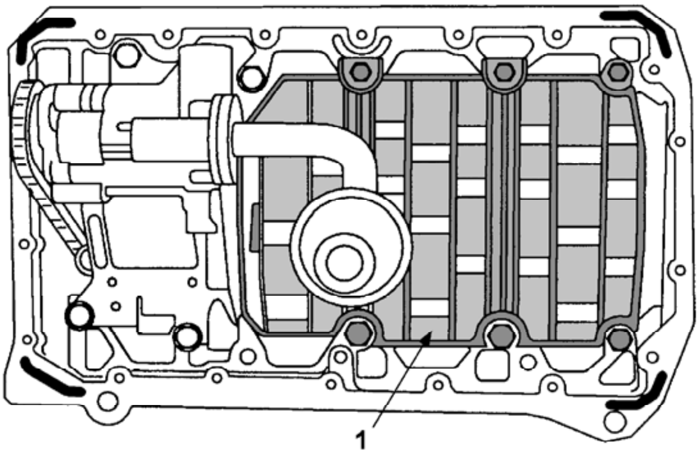
1. Crankshaft (housed in the cylinder block)
2. Connecting rods with bearings (housed in the cylinder block)
3. Dual-mass flywheel
4. Pistons with rings (housed in the cylinder block)
5. Chain drive
6. Valve gear (housed in the cylinder head)

Other components covered in this section include:

- Cylinder block
- Cylinder head
- Cylinder head gasket
- Ancillary components and belt drive

Cylinder block

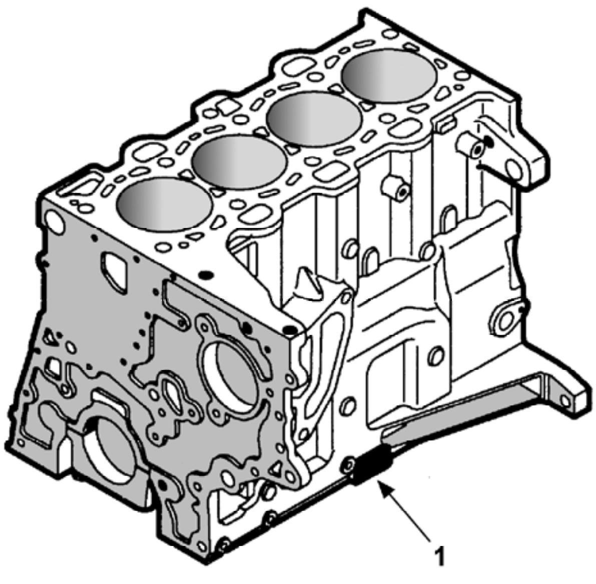
The cylinder block contains the cylinders and crankcase. It is a single cast iron construction with horizontal and vertical support spars and a cast aluminium stiffening plate bolted to the bottom to improve lower structure rigidity (see Figure 35).



Fi : i ı on

1. Stiffening plate

The engine number is stamped on the right hand side of the cylinder block (see Figure 36).



Fi : n t on

1. Engine identification number

The cylinders are direct bored and plateau honed. Lubrication oil is supplied via lubrication jets for piston and gudgeon pin lubrication and cooling.

The four lubrication jets (one for each cylinder) have a hook-type nozzle and are fitted at the bottom right hand side of each cylinder by two socket screws. Oil from the jets is directed up towards the underside of the piston skirts.

Lubrication oil is distributed throughout the block via the main oil gallery to critical moving parts through channels bored in the block. These divert oil to main and big-end bearings via holes machined into the crankshaft. An oil cooler is fitted to the side of the oil filter assembly with ports in the oil cooler matching the ports in the oil filter assembly to facilitate coolant and oil flow from the cylinder block. An oil pressure switch is included in a tapping in the oil filter assembly which is used to determine whether sufficient oil pressure is available to provide engine lubrication and cooling.

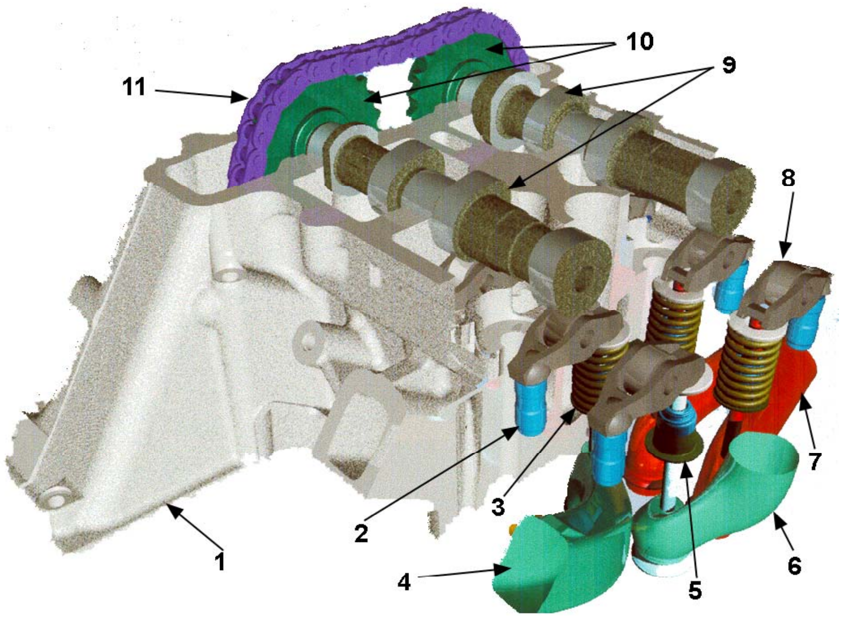
Cylinder cooling is achieved by coolant circulating through chambers in the engine block casting.

Not *e ter jac cor s.*

Two hollow metal dowels are used to locate the cylinder block to the cylinder head, one on each side at the front of the unit. Two hollow metal dowels are used to locate the timing cover to the cylinder block.

Cylinder head

The cast aluminium cylinder head represents the upper limit of the combustion chamber. It accommodates the necessary valve timing elements such as valves, injectors and camshafts (see Figure 37).



Fi a ly

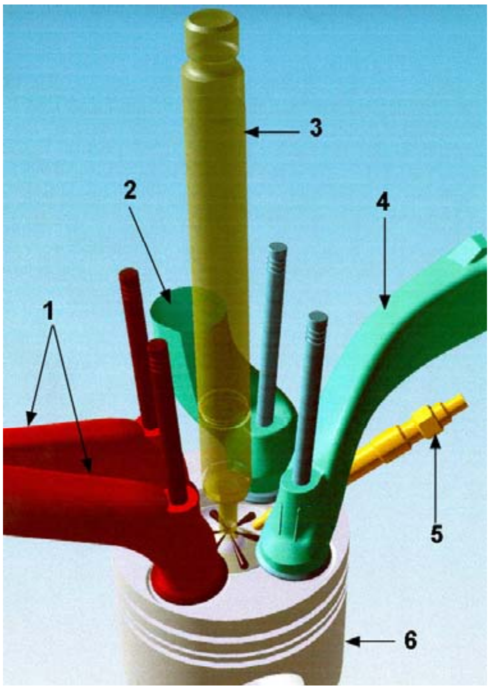
1. Cylinder head
2. Hydraulic valve adjuster
3. Valve spring
4. Tangential inlet port
5. Spring retainer with integrated valve stem seal
6. Swirl inlet port
7. Exhaust port
8. Roller rocker arm
9. Camshafts
10. Camshaft gears
11. Drive chain

The coolant system features combined longitudinal/transverse coolant flow, with the coolant outlet at the front end of the cylinder head integrated in the thermostat housing.

The M12 cylinder head bolts are arranged beneath the camshafts, necessitating the removal of both camshafts in order to remove the cylinder head.

Regarding the inlet ports, one is arranged laterally as a tangential port, also known as a charge port, and one is arranged as a swirl port from above. The exhaust ports are arranged as twin ports.

The glow plugs are mounted on the inlet side and the injectors are centrally mounted in a vertical position (see Figure 38).



Fi ; ɛ e nt

1. Exhaust ports
2. Swirl inlet port
3. Injector
4. Tangential inlet port
5. Glowplug
6. Piston

Vacuum pump

The vacuum pump is located on a support bracket at the rear right hand side of the cylinder head and is driven from the exhaust camshaft.

Chain drive

Two timing chains are utilised (see Figure39). The timing chain between the crankshaft sprocket and the fuel pump sprocket is a simplex type. The timing chain is contained between one fixed and one hydraulically adjustable tensioning rail.

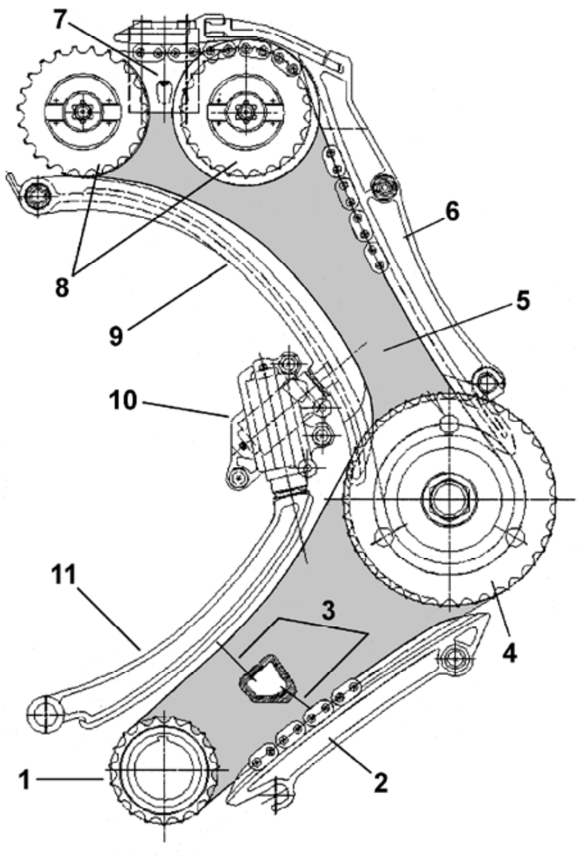
The chain drive from the fuel pump sprocket to the two camshaft sprockets is also a simplex type. The chain between the camshaft and injection pump runs between one fixed guide rail and a hydraulically adjustable tensioning rail to minimise chain flutter. An additional plastic chain guide is located above the two camshaft sprockets.

The adjustable tensioning rails are of aluminium die casting construction with clip-fastened plastic slide linings. The fixed guide rails are moulded plastic. The tensioner rails are attached to the front of the cylinder blocks using pivot bolts which allow the tensioner rail to pivot about its axis.

The hydraulic tensioner for both chains is provided from a single unit which contains two hydraulically operated plungers that operate on the tensioning rails at the slack side of each of the timing chains. Pressurised oil for the adjuster is supplied through the back of the unit from an oil supply port in the front of the cylinder block. The lateral movement in the tensioner arm causes the timing chain to tension and consequently, compensation for chain flutter and timing chain wear is automatically controlled.

The timing chains are oil splash lubricated via the oil pump and chain tensioner. Oil spray is directed to the chain from several oil supply ports in the front of the cylinder block and cylinder head.

An additional chain from the crankshaft sprocket connects to the oil pump sprocket for oil pump operation.



Fi *e*

1. Crankshaft sprocket
2. Guide rail
3. Oil spray nozzles
4. High pressure pump sprocket
5. Oil spray nozzle
6. Guide rail
7. Oil spray nozzle
8. Camshaft sprockets
9. Tensioning rail
10. Chain tensioner
11. Tensioning rail

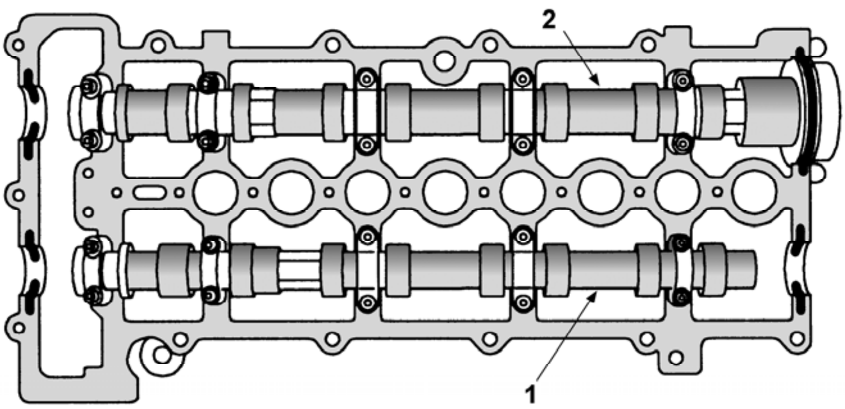
Valve gear

The valve gear consists of the following three main components:

1. Camshafts
2. Rocker arms
3. Valve and springs

Ca fts

Both the inlet and exhaust camshafts (see Figure 40) are hollow and are made from chilled cast iron. They employ a negative cam radius and are driven from the crankshaft using a simplex chain and sprocket arrangement.



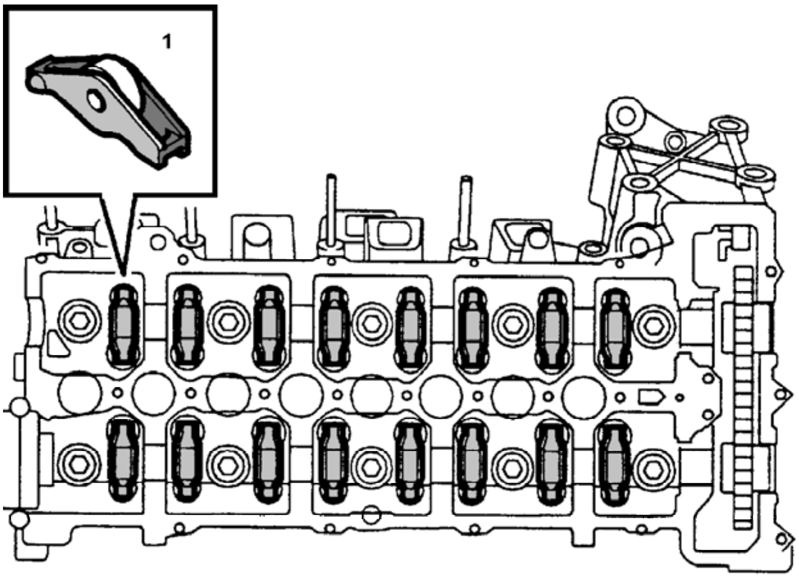
Fi 4 a t t s

1. Inlet camshaft
2. Exhaust camshaft

Valve timing	
Inlet valves: ⇒Opens ⇒Closes	 8° BTDC 28° ABDC
Exhaust valves: ⇒Opens ⇒Closes	 38° BBDC 4° ATDC

er arms

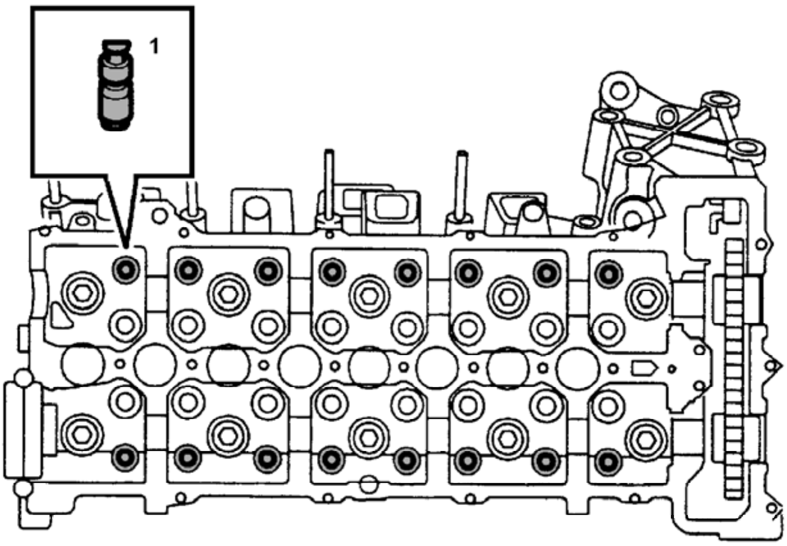
The valves are operated through roller-type finger rockers (see Figure 41) and hydraulic tappets, actuated by the camshaft lobes. When the camshaft lobe presses down on the top of a finger rocker, roller mechanism, the respective valve is forced down, opening the effected inlet or exhaust port. The use of this type of actuation method helps reduce friction in the valve timing mechanism.



Fi n on

1. Roller-type finger rocker

The body of the hydraulic tappets (see Figure 42) contain a plunger and two chambers for oil feed and pressurised oil. The pressurised oil is supplied to the tappets via the main oil galleries in the cylinder head and through a hole in the side of the tappet body. The oil passes into a feed chamber in the tappet and then through to a separate pressure chamber via a one way ball valve.



on

1. Hydraulic tappet

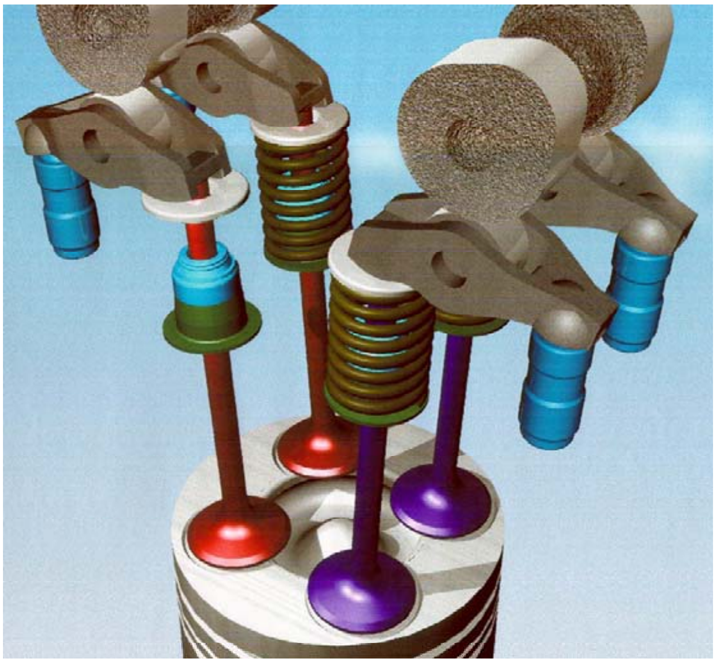
Oil flow from the pressure chamber is determined by the amount of clearance between the tappet outer body and the centre plunger. Oil escapes up the side of the plunger every time the tappet is operated, the downward pressure on the plunger forcing a corresponding amount of oil in the tappet body to be displaced. When the downward pressure from the camshaft and finger rocker is removed (i.e. after the trailing flank of the camshaft lobe has passed), oil pressure forces the tappet's plunger up again. This pressure is not sufficient to effect the valve operation, but eliminates the clearance between the finger rocker and top of the valve stem.

lves and springs

The inlet and exhaust valves (see Figure 43) are identical and have ground, solid one-piece head and stems made from Nimonic material which is resistant to alkalines, acids, wear and high temperatures.

The valve springs are made from spring steel and are of the parallel single-coil type. The bottom end of each spring rests on the flange of a spring retainer which has an integrated valve stem seal. The top end of the spring is held in place by a spring retainer which is held in position at the top end of the valve stem by split taper collets. The taper collets have grooves on the internal bore that locate to grooves ground into the upper stems of the valves.

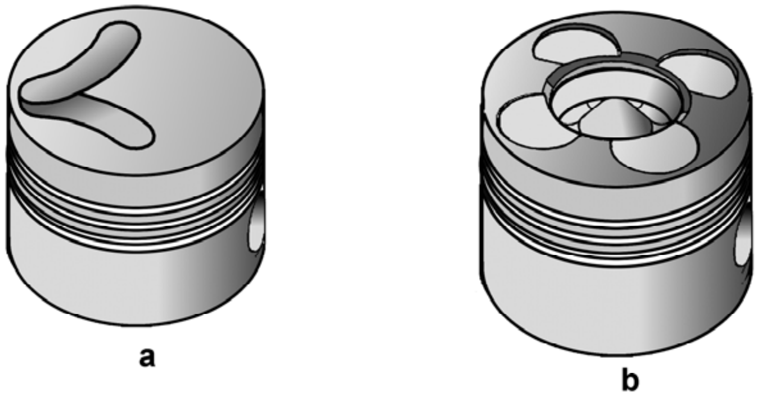
Valve seats and valve guides are interference fit in the cylinder head.



Fi nd ng e

Pistons and rings

The pistons have a graphite coated aluminium skirt, with a recessed combustion chamber (unique to directly injected engines) (see Figure 44) and oil cooling channels. There is a steel ring carrier inserted in the piston to locate the piston rings.

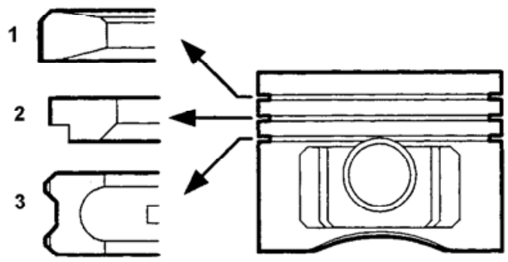


Fi t s

a. Indirect
b. Direct

The piston forms the moving bottom wall of the combustion chamber. Its especially designed shape contributes to ensuring optimum combustion. The piston rings seal off the gap between the piston and cylinder wall so as to ensure high compression and as little gas as possible enters the crankcase.

The first compression ring has a barrel edge (chamfer) and is installed with this edge facing upwards. The second compression ring has a taper face (stepped) which faces downwards (see Figure 45).



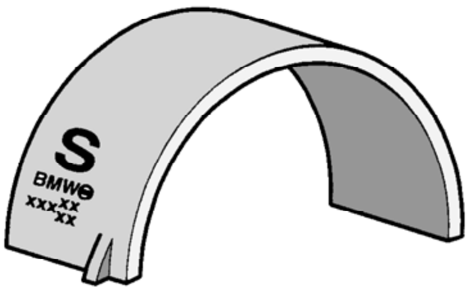
Fi o ng on

1. 1st compression ring
2. 2nd compression ring
3. Oil ring

Connecting rods with bearings

The forged 'H' section connecting rod connects the piston to the crankshaft. Each connecting rod is mounted such that it can rotate and has a length of 135mm.

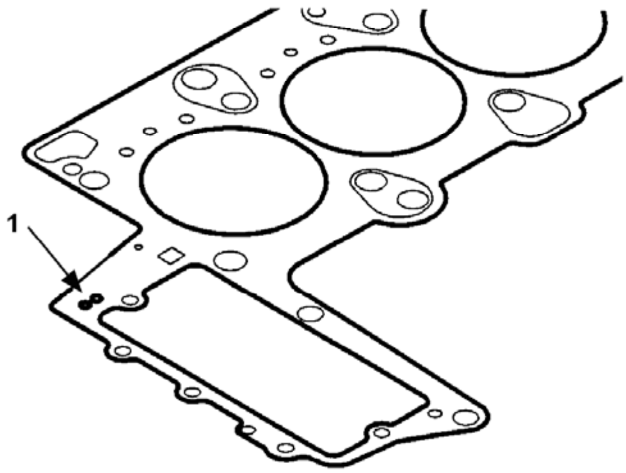
The big-end bearing (see Figure 46) half on the con-rod end is designed as a sputter bearing. Sputter bearings have four layers of a cathodic surface coating making the bearing shells particularly hard and durable.



Fi e e b ell

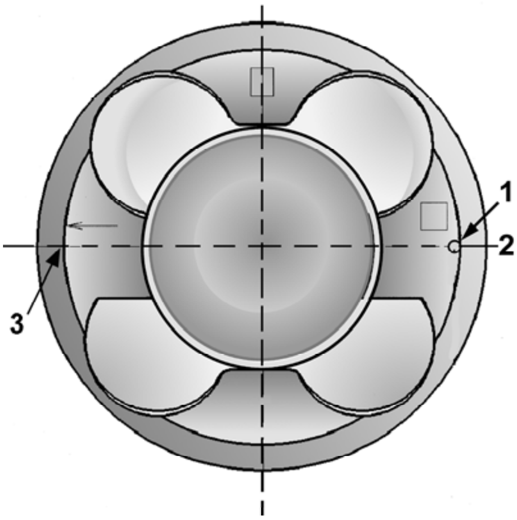
Cylinder head gasket

The multi-layer steel cylinder head gasket seals off the transition points between the engine block and cylinder head. There are three different gasket thicknesses (see Figure 47), selected according to determined piston clearance (see Figure 48) and identified by one, two or three holes.



Fi e (((de n

1. Identification holes



Fi[illegible]e [illegible] ent

1. Measurement position 1
2. Engine longitudinal axis
3. Measurement position 2

Measured piston protrusion	Selection of gasket thickness
Less than 0.92 mm	One hole gasket
0.92 to 1.03 mm	Two hole gasket
More than 1.03 mm	Three hole gasket

Crankshaft

The crankshaft converts the linear stroke motion of the pistons into rotary motion.

There are five bearings, four main and one thrust at number four journal. The shells are grooved in the crankshaft and plain in the bearing caps.

The crankshaft also incorporates the reluctor ring for the crankshaft speed sensor.

The crankshaft seal used on the M47R is made of polytetrafluoroethylene (PTFE) which is a tough translucent polymer that is resistant to chemical action and has a low coefficient friction.

Electronic diesel control engine management system

Introduction

The electronic diesel control (EDC) engine management system (EMS) fitted to the M47R diesel engine is a Bosch digital diesel electronics (DDE) 4.0 system. The system features a single electronic control module (ECM) (see Figure 51).

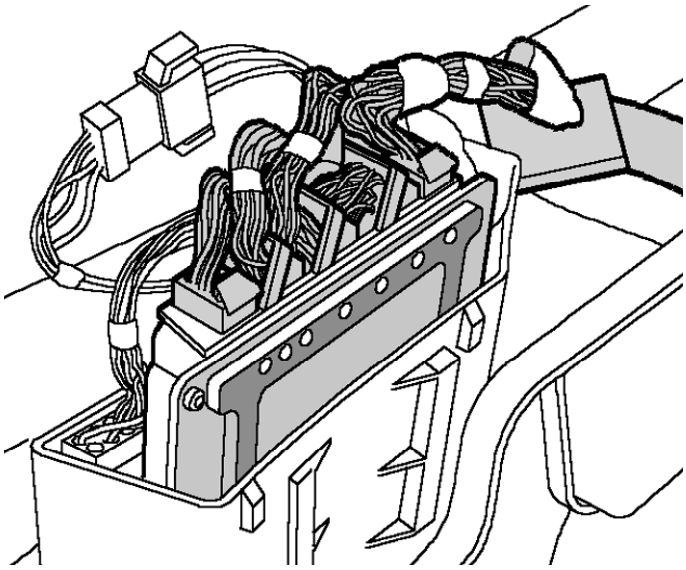


Fig [illegible]

Within the EDC system, all inputs are converted into electrical signals and processed by the ECM. Inputs are received from various sensors located on and around the engine and also from other systems. The ECM fully controls the fuel injection system and supports a sequential injection strategy by way of the electronic injectors. The system utilises ’drive-by-wire’ technology and, therefore, does not incorporate a direct mechanical connection between the throttle pedal and the engine.

Components and locations

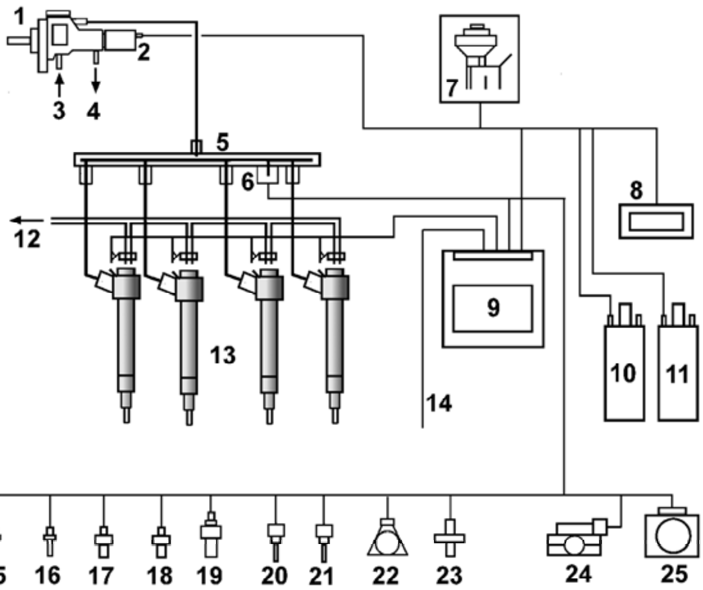
The locations of the components that form the EDC system can be seen in the table ’Electronic diesel control components and locations’.

Electronic diesel control components and locations

Component	location
Ignition switch	Steering column
Pedal demand sensor	On pedal assembly, in cab
Brake switch	On pedal assembly, in cab
Clutch switch (manuals only)	On pedal assembly, in cab
Crankshaft sensor	Bottom rear of engine oil sump
Camshaft sensor	Camshaft cover
Coolant temperature sensor	Engine cylinder block
Boost pressure sensor	Front end of intake manifold
Low pressure fuel sensor	Fuel filter housing
Rail pressure sensor	End of fuel rail
Mass airflow/inlet air temperature	Intake manifold
Fuel pressure regulator valve	Rear of high-pressure pump
EWS-3 control unit	Passenger compartment
Starter relay	EWS-3 control unit
Instrument pack	Dashboard
Automatic transmission control unit	Passenger compartment
Cruise interface	Passenger compartment
ABS/traction control	Under bonnet
HEVAC	Dashboard
Inertia switch	Passenger compartment
Main relay	Underbonnet fuse box
Fuel pump relay	Passenger compartment fuse box
Glow plug relay	In plenum, next to ECM in cover
Exhaust gas recirculation modulator	Front end of cylinder block
Cooling pack	Bottom of radiator

ture

In addition to the EDC ECM, the EMS consists of diverse sensors and actuators (see Figure 52). The sensors supply information and the actuators receive variables from the ECM.



Fi e

1. High-pressure pump
2. Pressure regulating valve
3. Fuel in
4. Fuel return
5. Fuel rail
6. Fuel rail pressure sensor
7. EGR actuator
8. Glow plugs
9. EDC ECM
10. In-tank electric fuel pump
11. Low-pressure electric fuel pump
12. Fuel return
13. Injectors
14. CAN-Bus
15. Brake switch
16. Clutch switch (manual transmission only)
17. Crankshaft sensor
18. Camshaft sensor
19. Wheel speed sensor
20. Coolant temperature sensor
21. Intake air temperature sensor
22. Boost pressure sensor
23. Low pressure fuel sensor
24. Throttle position sensor
25. Airflow meter

The ECM has a steel casing to provide protection from electromagnetic radiation and is located in the front passenger side of the plenum.

The ECM contains data processors and memory microchips. The output signals to actuators are in the form of earth paths provided by driver circuits contained within the casing. The ECM driver circuits produce heat during normal operation and dissipate this heat via the casing. The airflow around the ECM should not be obstructed. There are regulated voltage outputs to some sensors which use less than 12 volts to avoid voltage drop during engine cranking.

The ECM cannot be tested directly, diagnosis must be performed by ensuring that inputs and outputs conform to specifications. TestBook is available for this purpose. If the ECM is to be replaced, the new ECM will be supplied 'blank' and must be configured to the vehicle using TestBook. When the ECM is fitted to the vehicle it must also be synchronised to the immobilisation ECU using TestBook. Engine control modules must not be swapped between vehicles.

Inputs a outp s

The ECM is connected to sensors fitted to the engine which allow it to monitor engine operating conditions. The ECM processes these signals and decides the actions necessary to maintain optimum engine performance in terms of driveability, fuel efficiency and exhaust emissions. The memory of the ECM is programmed with instructions for how to control the engine, this is known as the strategy. The memory also contains data in the form of maps which the ECM uses as a basis for fuelling and emission control. By comparing the information from the sensors to the data in the maps, the ECM is able to calculate the various output requirements. The ECM contains an adaptive strategy which updates the system when components vary due to production tolerances or ageing

The ECM has an interface of 134 pins via five connectors providing both input information and output control. Not all 134 pins are used.

Driver inputs

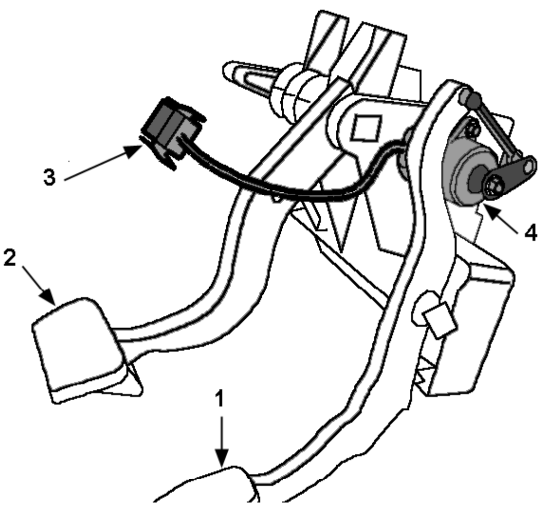
The system receives several inputs from the driver. The ECM processes the information received and controls the outputs accordingly.

I on switch

The ignition switch does not supply the ECM with a signal when the ignition switch is in position 0 or 1 ('off' or auxiliary). When the ignition switch is in position 2 the ECM wakes-up and completes self-tests and security functions in preparation for start. The ECM does not receive a starting signal, it only knows the engine is cranking by monitoring the crankshaft sensor.

demand sensor

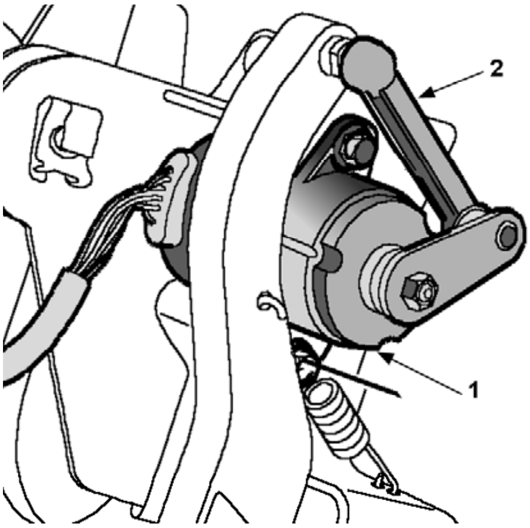
The pedal demand sensor comprises of two potentiometers housed within its body and is located precisely on the throttle pedal housing (see Figure 53).



Fi e F d a n

1. Accelerator pedal
2. Brake pedal
3. Electrical connection
4. Pedal demand sensor

The pedal demand sensor can be replaced as a separate component (see Figure 55).



((tion

1. Pedal demand sensor
2. Linkage

The pedal demand sensor signal is proportional to the accelerator pedal position. The ECM provides a 5 volt supply to both potentiometers and receives two input signals back, one from each potentiometer.

At idle, throttle released (0° throttle angle), potentiometer one will return approximately 0.7 volts, whilst potentiometer two will return approximately 0.4 volts. As the throttle angle increases, the voltage of each potentiometer increases to a maximum of 4.2 volts for potentiometer one and 2.1 volts for potentiometer two. The two potentiometers operate simultaneously in response to accelerator movement. The ECM receives an analogue signal from the throttle position pedal sensor and monitors the throttle angles for plausibility.

The ECM calculates the maximum allowable fuel quantity from:

- Air flow into the engine
- Engine speed
- Temperature

This calculation also includes information on strategies regarding:

- Smoke limitation
- Active surge damping
- Automatic gear change
- Fuel reduction

When driving, if the drivers request signal, from the accelerator pedal, is smaller than the maximum allowable fuel quantity, then the requested quantity is injected. However, if the requested quantity is greater than the maximum allowable fuel quantity, then the latter quantity is injected rather than the drivers demand. If either one of the potentiometers should fail, the vehicle will enter a 'limp-home' mode and the engine speed will increase to approximately 1250 rev/min. at idle, for a vehicle with manual transmission, and approximately 1500 rev/min. at idle for a vehicle with automatic transmission, with no throttle response. If the brake pedal or clutch pedal (on vehicles with manual transmission) is activated, the idle speed reverts to normal.

ke pe(: h

The brake pedal switch provides the ECM with information regarding the position of the brake pedal via a Hall effect sensor. It comprises of a main body, 2 pole sensors and electrical connections. The two poles/switches are designed to operate simultaneously in response to the pedal movement. The ECM receives a digital input comparing the polarity state between the individual poles/switches.

When the brake pedal is released, one switch is normally open and one is normally closed. In this state, the open switch will not allow current to flow, whilst the closed switch will allow current to flow. When the brake pedal is pushed the switches will change state. At this time the previously open switch will change state to closed and the previously closed switch will change state to open, as seen in the table 'Brake switch operation'. The use of two switches increases the systems fail-safe capability.

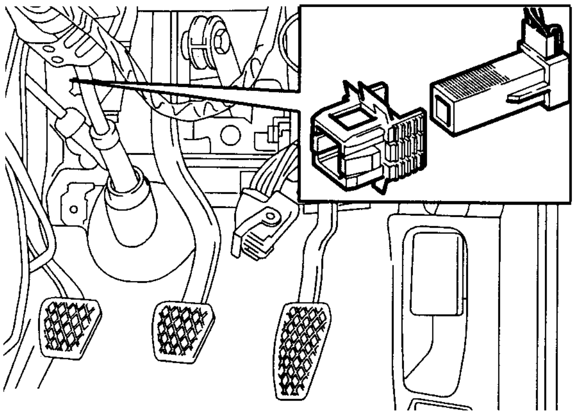
Brake switch operation

Switch	Brake not pressed	Brake pressed
brake light test	open circuit	battery voltage
main brake light	ground	6 - 8 volts

The brake switch inputs are used by the ECM to cancel cruise control operation if it is set at the time. Therefore, if the switch fails, cruise control will not activate, or, if already in operation, will cancel.

ch s h

The clutch switch (see Figure 55) is a Hall effect sensor and is only fitted to vehicles with manual transmission. When the clutch is engaged (when the is pedal released) the switch will be in the open state. When the pedal is pushed and the clutch is disengaged, the switch will change to the closed state. The ECM will suspend cruise control operation in response to this change of state. The ECM also reduces fuelling in response to this digital signal to reduce engine surging (dampens the effects of fast throttle transitions to eliminate jerky vehicle movements). If the clutch switch fails at any time then the EMS will not support cruise control operation. In addition, the engine will be more susceptible to surging at times when the engine is decelerating quickly.



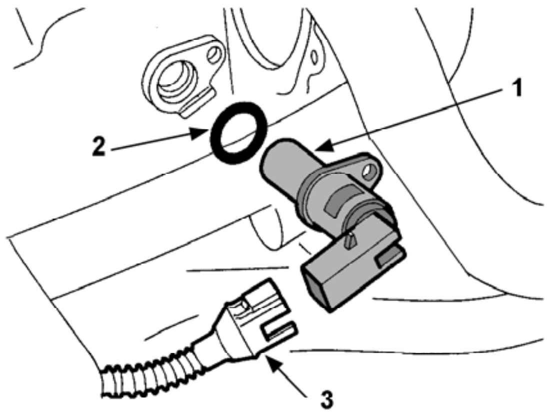
Fi e : h

Engine sensor inputs

The ECM requires information on the current operating conditions of the engine. It uses several electrical devices to feed back this information. It uses the information received to calculate the precise opening time and the opening duration of the injectors which, in turn, determines the quantity of fuel injected into the engine.

a t nsor

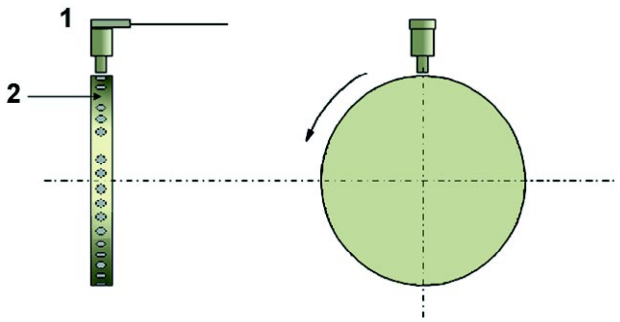
The engine speed is registered by the crankshaft sensor (see Figure 56).



a h tion

1. Crankshaft sensor
2. Seal
3. Electrical connection

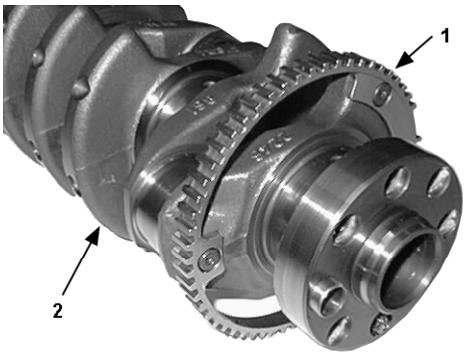
The crankshaft sensor (1) is mounted radially in relation to a target located on the reluctor ring (2) (see Figure 57).



Fi ng

1. Crankshaft sensor
2. Reluctor ring

The reluctor ring (mounted on the crankshaft, inside the cylinder block) (see Figure 58) has a capacity for sixty teeth, however, two teeth have been removed leaving a gap (leaving a total of 58 teeth). The crankshaft sensor uses this gap to determine top dead centre (TDC).



Fi e n

1. Reluctor ring
2. Crankshaft

This inductive sensor provides a signal to the ECM in the form of an analogue sine-wave signal and enables the ECM to calculate the exact speed and position of the crankshaft.

The signal is generated by the sensor in response to the gap located on the circumference of the reluctor ring. The 58 teeth are in close proximity to the end of the crankshaft sensor. As the crankshaft rotates, the gaps alter the magnetic flux formed around the end of the sensor. The change in magnetic flux caused by this movement generates the voltage signal.

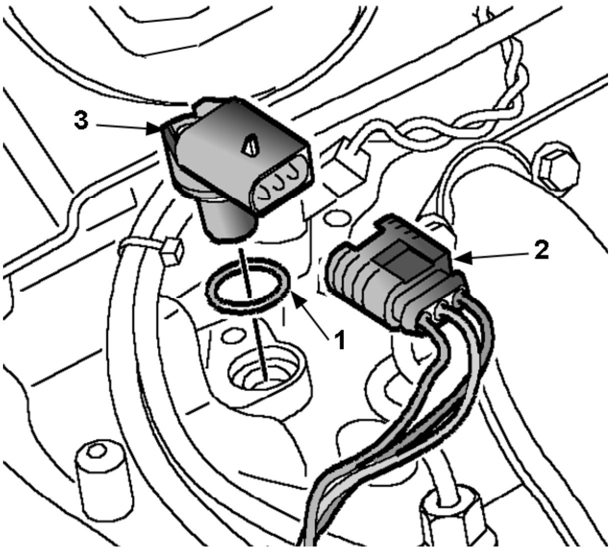
As previously mentioned, the teeth on the crankshaft wheel feature two missing teeth, and because the missing teeth equate to TDC, the ECM is able to calculate the exact position of the crankshaft within each 360° rotation.

The signal supplied to the ECM by the crankshaft sensor is used to support its fuelling strategy. The ECM also uses this signal to calculate engine speed and supplies this information to a number of other vehicle systems. The ECM is also able to calculate the exact position of the crankshaft relative to the firing position of the engine. This information is used to calculate the exact point of injection.

If the signal from the crankshaft sensor fails or is corrupted the engine will cease to run and will not start again until the problem has been rectified and a fault will be stored in the ECM. For a quick diagnosis, check the tachometer needle for response during cranking.

C haft sensor

The camshaft sensor (see Figure 59) is a Hall effect sensor used in conjunction with the camshaft wheel to identify the position of the camshaft. A camshaft wheel reluctor is used as a target. The information transmitted by this sensor to the ECM is used to synchronise the timing of the fuel injectors.



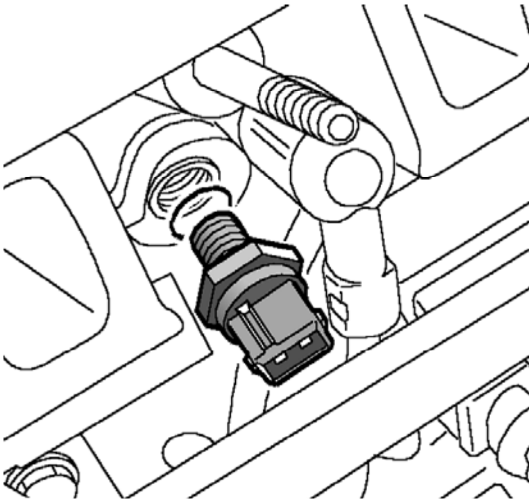
Fi n

1. Sealing ring
2. Electrical connection
3. Camshaft sensor

The target on the camshaft wheel provides little information to the ECM and cannot be used as a back up signal if the crankshaft sensor fails. The benefits are that the ECM can now achieve camshaft synchronisation at the same time as crankshaft synchronisation, giving sequential fuelling during cranking.

Coola tempe ure sensor

The coolant temperature sensor (see Figure 60) supplies a non-linear (negative temperature coefficient-NTC) analogue output voltage to the ECM, which is used to determine the temperature of the engine coolant. The ECM uses this information to modify its basic fuelling calculations, especially during cold starts. The ECM sends the engine coolant signal to the instrument pack to drive the temperature gauge. The ECM also uses this signal to alter the condenser fan and compressor clutch operation, whenever the coolant temperature exceeds a predetermined value.



Fi e C t n

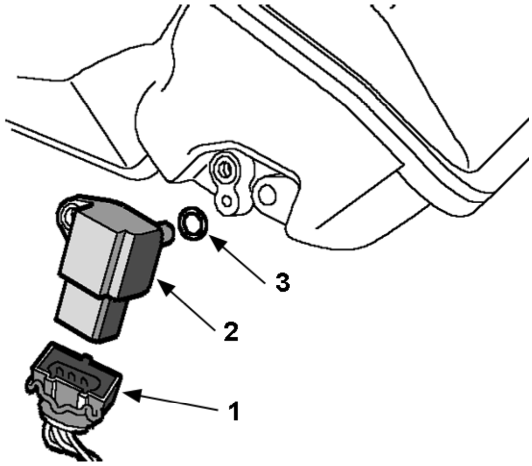
If the signal from the coolant temperature sensor is interrupted or corrupted at any time, the ECM implements a substitute value of, –10° before start-up and +80° when the engine is running, as a back up signal, but does not illuminate the instrument pack warning lamp. This signal is sent out on the CAN-Bus.

Possible indications of a coolant temperature sensor failure are:

- Long engine cranking
- Cooling fans on constantly
- No air-conditioning operation
- No EGR operation
- No temperature gauge response
- Temperature warning lamp

Boost pressure sen r

The boost pressure sensor (see Figure 61) signal is a non-linear analogue signal. It is dependent on the absolute pressure and air temperature in the intake manifold to calculate volume air flow into the engine. If this sensor fails, a substitute value of 900 millibars is used by the ECM producing a reduction in power due to a fuel quantity limiting and EGR shut off.



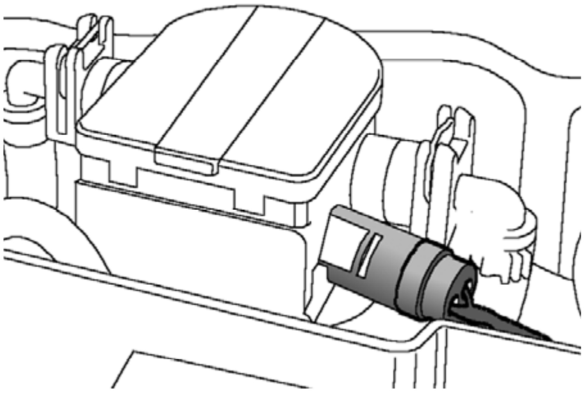
Fi e n

1. Electrical connection
2. Pressure sensor
3. Seal ring

Lov essu sensor

The low pressure fuel sensor (see Figure 62) registers the delivery pressure between the fuel filter and the high pressure fuel delivery pump, approximately 3.6 bar. If a fault occurs, this sensor indicates whether the problem is on the low-pressure or high-pressure side. It also protects the high-pressure pump against internal damage if the pressure drops below 1.7 bar and there not being sufficient fuel to lubricate the pump, by stopping the engine.

The analogue signal is proportional to the absolute pressure before the high pressure fuel delivery pump. If this sensor fails, a instrument pack warning lamp will be illuminated and the engine will stall or not start.



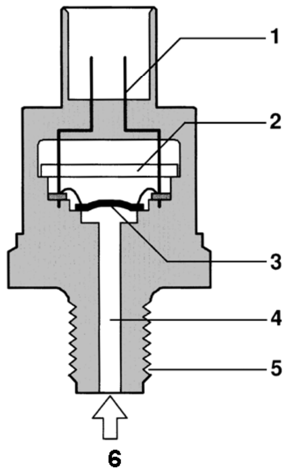
Fi f on

Rail pres sensor

The rail pressure sensor (see Figure 63) signal is proportional to the absolute pressure in the high pressure fuel rail.

The rail pressure sensor consists of the following main components:

- An integrated sensor element
- A printed board with an electrical evaluation switch
- A sensor housing with an electrical plug connection



Fi (n (or

1. Electrical connections
2. Evaluation switch
3. Diaphragm with sensor element
4. High pressure connection
5. Retaining thread
6. Fuel pressure

The fuel reaches a sensor diaphragm through the high pressure connection. There is a sensor element located on this diaphragm (semiconductor component) to convert the changes in shape caused by pressure into an electrical signal. The signal generated is sent to an evaluation switch via connecting lines, which relays the prepared measuring signal to the control unit via the connections.

The rail pressure sensor operates according to the following principle:

The diaphragm's electrical resistance varies when its shape changes. This change in shape (approx. 1 mm per 500 bar) created by the accumulation of system pressure alters the electrical resistance and changes the voltage of the resistance bridge which has a supply of 5 volts.

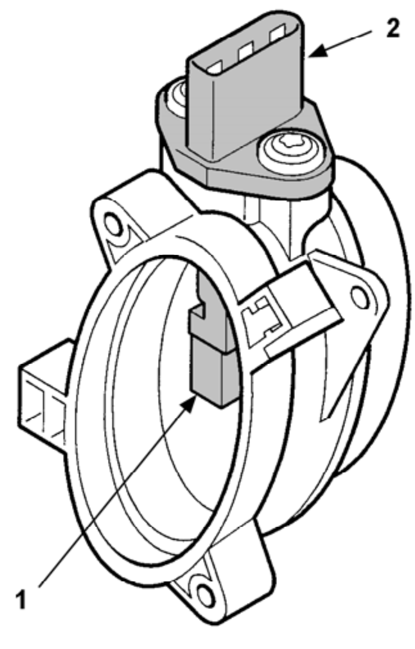
This voltage is in the 0-70 mV range (depending on the pressure) and is increased by the evaluation switch to a range of 0.5-4.5 volts. The exact measurement of the rail pressure is essential if the system is to function correctly. For this reason, the permissible tolerance ranges for the pressure sensor are also kept to a minimum. In the main operating range, there is a tolerance of 30 bar, which equates to approx. ± 2 % from the final value. If the rail pressure sensor malfunctions, the pressure control valve is activated by the control unit's emergency function. For data regarding the fuel pressure sensor, see table 'Rail pressure sensor technical data'.

Rail pressure sensor technical data

Pressure measuring range	0 - 1500 bar
Overpressure without damage	1800 bar
Burst pressure	3000 bar
Temperature range	-40 to +140°C
Useful life	≥ 4000 hours (≥ 10 years)
Pressure medium	Diesel fuel
Installation	In rail; (near engine)
Housing design	Screw in sensor with direct plug Passenger car plug with gold contacts Mounting threads M12 x 1.5
Power supply	5V

t i or

The mass airflow/inlet air temperature sensor (see Figure 64) specifications and dimensions are critical and precisely determine the airflow. It is, therefore, important that the mass airflow/inlet air temperature sensor tube is not altered or modified in any way and that it is not repositioned or fitted incorrectly. Any of these actions will adversely effect airflow and the performance of the mass airflow/inlet air temperature sensor in correctly determining the quantity of air entering the engine.



Fi w e a or

1. Sensor
2. Electrical connection

The mass airflow/inlet air temperature sensor uses 'hot film' technology to produce an accurate reading of the amount of air entering the engine. Mass air flow is determined from the cooling effect of inlet air flowing over a hot film sensor and the monitoring of the amount of electrical current required to keep this film inside the meter at a predetermined temperature. The amount of current required to do this will vary in response to the amount of air entering the engine. The mass airflow/inlet air temperature sensor modifies a voltage and returns it to the ECM in proportion to the amount of current being consumed (the amount of air entering the engine).

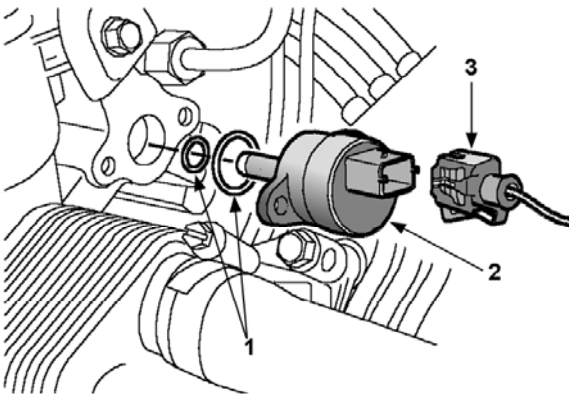
If the ECM detects that the mass airflow/inlet air temperature sensor has failed, the instrument pack warning lamp will be illuminated and the ECM will not attempt to operate EGR. For these failure modes see table 'Exhaust gas recirculation failure modes'.

Exhaust gas recirculation failure modes

Failure modes	Description
Air temperature	over rich fuelling, some black smoke, slight rough running
Airflow	reduced power, EGR shut down, idle control to default
Default	air temperature -5°C (airflow default map is based on engine speed)

F l p su tor e

The fuel pressure regulator valve is mounted at the back of the HPP (see Figure 65) and is used to adjust a constant pressure in the fuel rail (and lines).



s n

1. Seal rings
2. Pressure control valve
3. Electrical connection

The EDC ECM controls the armature via a coil. The armature presses a ball into the seal, sealing the high-pressure side from the low-pressure side. When the system is inactive, the ball is controlled by a spring. The entire armature is coated with fuel from the fuel pump for lubrication and heat dissipation.

The pressure control valve has two circuits:

- an electrical control circuit to set a variable pressure value in the rail
- a mechanical control circuit to compensate for high-frequency pressure vibrations

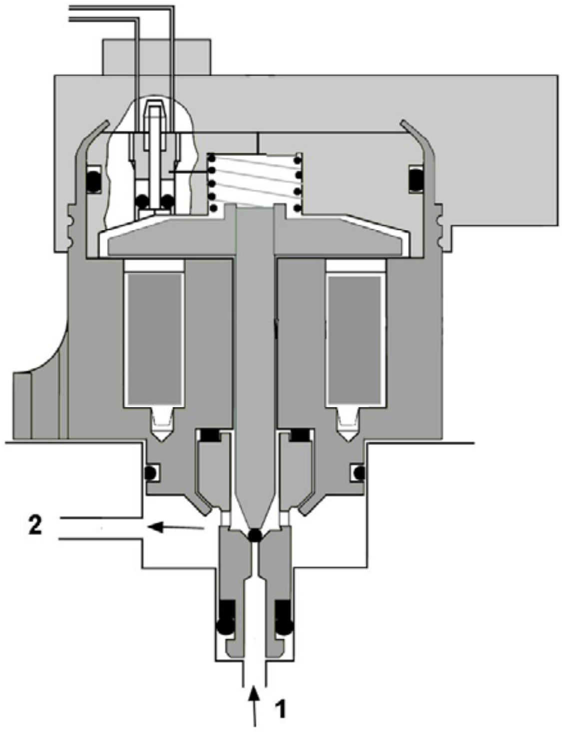
Since the time factor plays an important role in controlling the pressure, the electrical control circuit compensates for slow pressure fluctuations and changes, and the mechanical control circuit compensates for the rapid changes.

Non-a vat pressu control valve

The high-pressure present in the rail or in the high-pressure pump output is exerted on the high pressure intake of the pressure control valve. Since the de-energized electric magnet is not in effect, the force of the high-pressure is greater than the force of the spring, which opens the pressure control valve. The spring's design creates a maximum pressure of 100 bar.

su cc rc d

If the pressure in the high-pressure circuit is to be raised, the magnetic force must be increased. The pressure control valve is activated and closed until there is a balance between the high-pressure force on the one side and the magnetic and spring forces on the other. The magnetic force exerted by the electromagnet is in direct proportion to the activation current. Variation in the activation current is achieved by pulse width modulation (PWM). The PWM frequency is 1 kHz, for example, high enough to prevent disturbance from armature movements and/or fluctuation in pressure (see Figure 66).



lve

1. Fuel pressure
2. Fuel return

Inputs from other vehicle systems

The following additional vehicle systems communicate with the EDC ECM.

mob ation

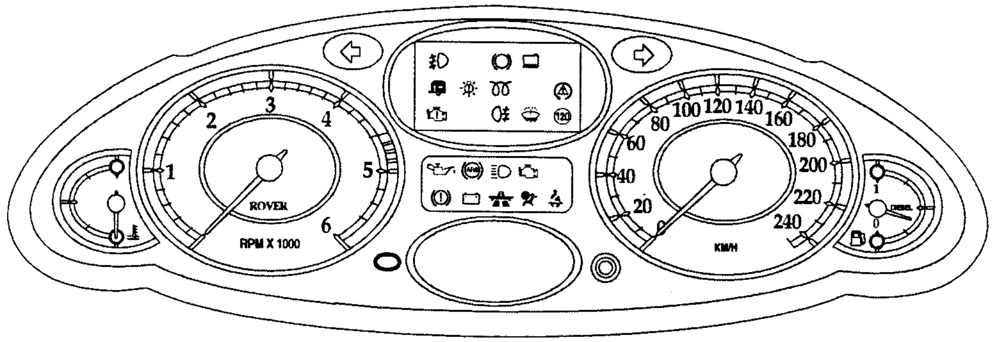
Once the EWS-3 (elektronische wegfahrsperre) has confirmed that a valid key is requesting the starting of the vehicle, it will energise the starter motor relay and inform the ECM that starting has clearance by sending the correct code to the ECM. The EWS-3 ECU controls the starting of the engine by communicating with the ECM via a unidirectional data line. It also uses data sent by the ECM on the CAN-bus (control area network) via the instrument pack and the K-bus (karosserie) the EWS-3 ECU. The EWS-3 ECU governs the overall immobilisation and re-mobilisation of the engine. Without it receiving a valid signal from the key transponder it will inhibit starting of the engine. The starter motor will be disabled and the ECM will not initiate fuelling of the vehicle. The ECM plays a big role in the immobilisation of the vehicle. Engine fuelling will be inhibited until the ECM synchronises with a coded signal received from the EWS-3 ECU (see Figure 67).

Fi e 3c l t

ter y

The starter motor relay is also ignition key controlled, activated with the key in ignition position three only. Releasing the key, after cranking, cuts supply to the relay and switches ’off’ the starter motor. The EWS-3 ECU also has a feed into the relay control.

I rument p k



Fi e u nt ck

The instrument pack (see Figure 68) is the gateway for the Bus-systems and for the EMS to communicate with other vehicle systems. The EMS provides the following data to the instrument pack for driver information:

- Engine speed (rev/min.)
- Coolant/engine temperature
- Glowplugs (operation)
- Fuel consumption (trip computer)
- Cruise active - via cruise control interface ECU
- [illegible] **Not**[illegible] *a* [illegible] *ch a* [illegible] *syr s*
- Malfunction indi[illegible] (MIL) **Not**[illegible] *s oc* [illegible] *e hicle is like in iss s*

Auto tic sion

The automatic transmission control unit (ATCU) is constantly exchanging information with the EMS ECM to control smooth operation of gear changes. Throttle angle and engine speed is continually sent to the ATCU from the ECM, via CAN. The ATCU controls gear shifts from this information.

When cruise control is engaged the ATCU needs to receive a signal relating directly to throttle position so that it can control gear selection. As this is a drive-by-wire system with no pedal movement, during cruise the ECM signals the 'virtual' throttle angle to the ATCU.

When a gear change is about to occur, the ATCU signals to the ECM for a momentary reduction in engine torque for a smoother operation.

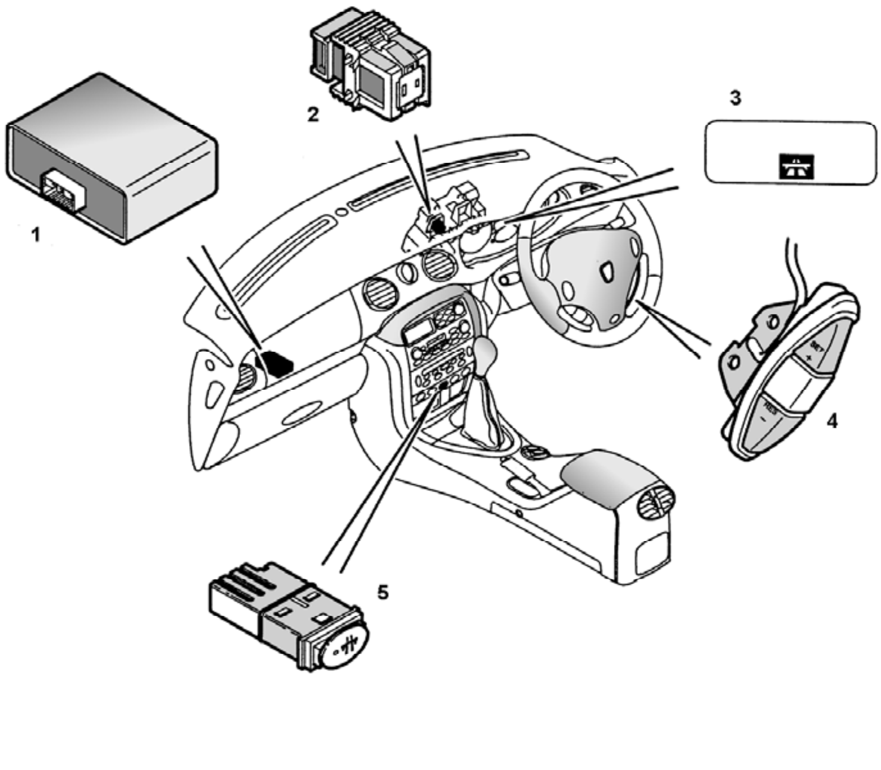
The data sent on the CAN-Bus system, which is used by the ATCU, is as follows:

- Actual throttle angle
- Virtual throttle angle
- Engine speed
- Coolant temperature
- Ignition switch position

The data sent by the ATCU on the CAN-Bus system that is relevant to the engine management system is as follows:

- Torque reduction request
- Gear lever position
- Current selected gear and target gear, if shifting is occurring

Cruise cc l



Fi c o c on

1. Cruise interface
2. Brake/clutch switches
3. Cruise control indication lamp
4. Steering wheel switches
5. Cruise control switch

The master cruise switch (see Figure 69) provides an analogue signal to the diesel cruise interface unit. The interface unit then communicates with the ECM to enable the set and resume/suspend operation. To the driver, this switch turns the system 'on' and 'off' via the interface unit (with loss of stored speed when it is turned 'off'). The interface unit does this by refusing to react to the pressing of either of the steering wheel switches if the master is 'off'. The master switch will also cancel the cruise if turned 'off' when the cruise system is actively controlling the vehicle.

The cruise control system utilises two steering wheel switches labelled ’SET +’ and ’RES -’. When either switch is activated, a 12 volt analogue signal is sent to the diesel interface unit which then converts these signals into a serial message which the ECM will understand.

Depending on all the right conditions existing, a single application of the ’SET +’ switch will store a road speed in the ECM. The ECM will then control fuel quantity entering the engine in order to maintain the stored speed. If the switch is activated and held, the cruise system will control fuelling to gently accelerate the vehicle. When the switch is released, the ECM will store the achieved road speed in its memory and maintain that speed. If the switch is tapped (held down for less than 500 ms), the ECM will only increase the vehicle speed by 1 k.p.h.

If the ’RES-’ switch is activated whilst cruise is inactive, without a set speed value existing in its memory after the master switch has been turned ’on’, the system will not respond. However, if a valid value does exist in its memory the cruise system will move the throttle so that the vehicle achieves that speed value. If, whilst cruise is active the ’RES-’ switch is activated, the cruise will cancel.

The set/acceleration switch and the suspend/resume switch require the following conditions to operate:

- Master switch must be in the 'on' position
- Vehicle speed must be in the range of 22 mph to 125 mph
- Brake pedal must not be depressed
- Clutch pedal must not be depressed (manual transmission)
- Drive is selected (automatic transmission)

Anti-lock braking/tra on control

Vehicle speed is an important input to the ECM strategies and comes from the ABS ECU. The ABS ECU derives the speed signal for the ECM from the front left hand ABS sensor. The frequency of this signal changes in accordance with road speed. The ABS ECU transmits the road speed on a hardwired connection to the ECM as a Pulse Width Modulated (PWM) signal. The ECM requires this signal to determine the following:

- How much to reduce engine torque during gear changes (automatic gearbox models).
- When to allow cruise control.
- Cruise control operation.
- Implementation of idle strategy when vehicle is stationary for.

The frequency of this signal changes in accordance with road speed. This signal is then communicated directly (hardwired) to the ECM.

The traction control ECU can request a reduction in engine torque via the CAN-Bus system. The engine management system will then reduce engine torque by a precise reduction in fuel quantity delivery. This is only one of the options the traction control system can use to improve wheel traction. Data transmitted on the CAN-Bus for traction control functions are:

- Throttle angle
- Torque increase/decrease commands
- Current engine torque

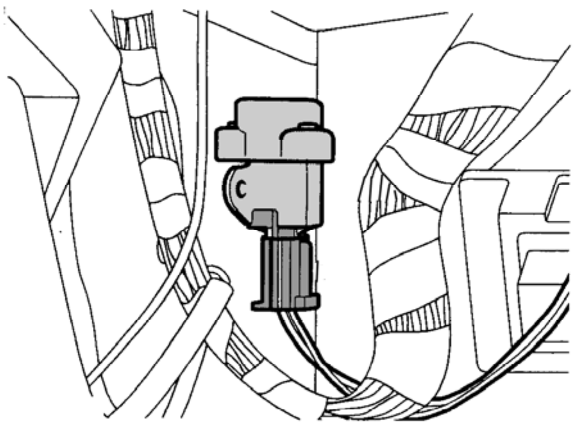
Heating, venti   anc   r-conditioning

Air-conditioning requests are sent via the CAN-Bus system, from the instrument pack to the ECM. Air-conditioning requests to the instrument pack are sent via the K-Bus system. The ground module (GM6) controls the request for manual air-conditioning and, automatic temperature control requests, for air-conditioning, are sent by the system ECU. Upon receiving an air-conditioning request, the ECM will engage the compressor clutch and alter the engine speed to compensate for the extra load.

The cooling strategy employed by the EMS is affected by the heating, ventilation and air-conditioning (HEVAC) system. A single fan is used with 3 speeds that operate depending on coolant temperature by sending a 140 Hz PWM signal to the cooling pack. Priority is given to the highest requested fan speed. When air-conditioning is selected, the fan speed immediately switches to speed 1 (low) unless the coolant temperature sensor reading requires a higher speed to be selected. If the medium pressure switch in the trinary switch is triggered, the fan speed is set to speed 2 (medium). The EMS remains powered up for 10 minutes following ignition switch 'off' to continue cooling in high temperatures, if necessary.

I   tia sw   h

The inertia switch (see Figure 70) is wired in series with the fuel pump relay. Whenever the inertia switch is tripped by sudden deceleration of the vehicle (over and above the capacity of the braking system), the main power feed to the ECM will be interrupted. This action will stop the fuel pump. The vehicle will not restart until the inertia switch has been reset.



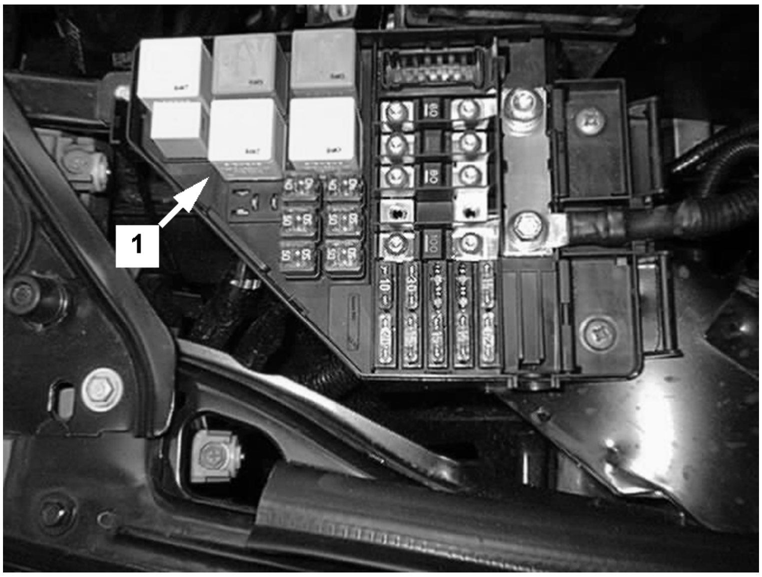
I   ch

Engine control module outputs

The EDC ECM collects information, processes it and then sends signals back out.

l y

The main relay (see Figure 71) supplies power to the EDC ECM and is controlled via the ignition switch in position two.

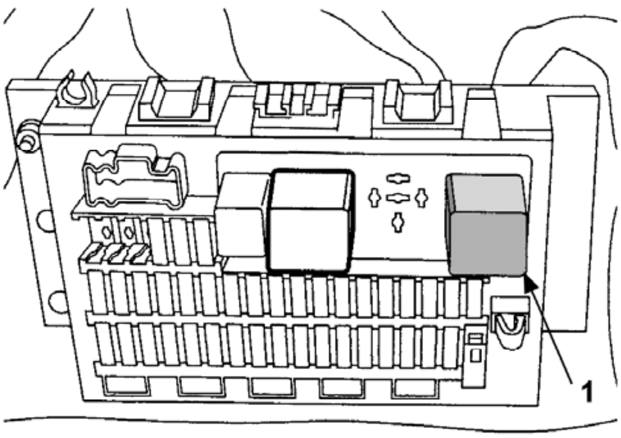


Fi e l n

1. Main relay

Fuel pump relay

The fuel pump relay is energised when the ignition switch is ’on’. With the ignition switched ’on’ the fuel pump operates for approximately one minute



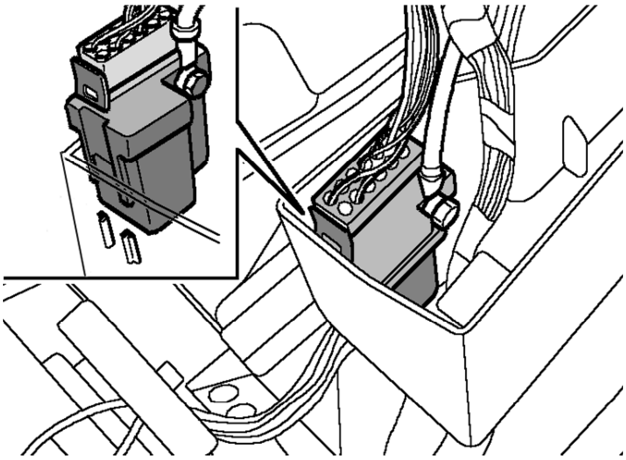
Fi i y

1. Fuel pump relay

ow plug relay

The ECM controls the pre-heating relay which activates the glowplugs depending on the coolant temperature at the time of engine start. The ECM also controls the length of time the glow plugs are operative via the glowplug relay.

The glowplug relay (see Figure 73) contains the power switch which supplies the four glow plugs with voltage as required. This relay also detects breaks in the external wiring, malfunctions of the relay and a break in the fuse by sending an inverted signal back to the ECM, for example, if the ECM sends 12 volts to the relay and receives 0 volts back, then it assumes all is functioning correctly, where as 12 volts returned to the ECM would indicate a fault and the glowplug warning lamp will not illuminate during start up.

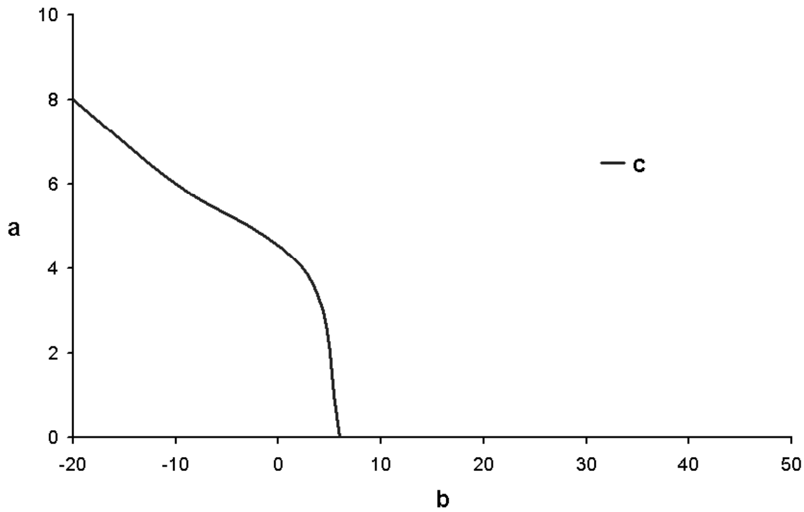


Fi o l l on

The EDC ECM has an engine Pre-heat period control which takes battery voltage into account. The engine heater plugs are energised via the heater plug relay.

Pre-heating can be initiated when the engine is stopped and the coolant temperature is within the activation range.

The Pre-heating duration depends on the engine coolant temperature (see Figure 74). Pre-heating enhances the engines starting characteristics. The Pre-heating duration is extended if the temperature is low and the battery is not fully charged.



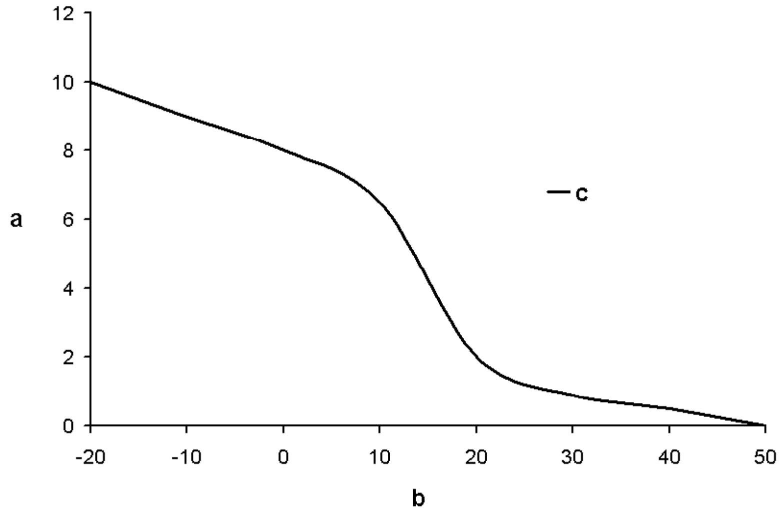
Fi e e

a. Seconds
b. Coolant temperature (°C)
c. Pre-heating time

The driver is notified of the process by the Pre-heating warning lamp (see Figure 75) and should wait until the visual indicator goes off before starting the engine.

Fi ov mp

The post-heating phase commences when the engine starts. The purpose of this phase is to reduce engine noise, improve idling quality and reduce hydrocarbon emissions as soon after the start as possible by promoting efficient combustion. The post-heating duration depends on the coolant temperature (see Figure 76).



Fi e rve

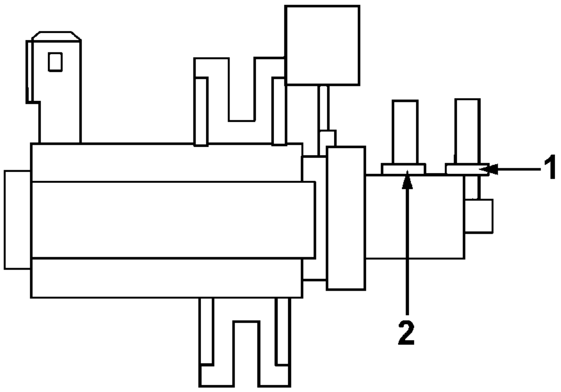
a. Seconds
b. Coolant temperature (°C)
c. Post-heating time

If the coolant temperature sensor is defective, the intake-air temperature is used as the substitute input variable.

hau gas recir at modu or

The EGR modulator unit supplies a varying vacuum signal to the EGR diaphragm valve on the exhaust manifold by varying the open time of the solenoid valve, which operates at a constant frequency of 300 Hz. Effectively, the signal pressure is controlled between supplied vacuum, from the vacuum pump, and atmospheric pressure, via the air filter. The operation of this is to recycle the exhaust gases into the combustion chamber of the engine.

The EGR modulator activates the EGR valve at engine idle (providing the engine coolant has reached operating temperature) and at partial load. It can also activate the EGR valve if the coolant temperature is –10°C or below to aid cold start warm up. The modulator converts the control signals from the electronic diesel control (EDC) engine management system (EMS) into a pilot vacuum for the EGR valve. Both the full vacuum of the vacuum pump (see Figure 77) as well as atmospheric pressure are applied to the valve. Electrical activation of the modulator mixes the low pressure air with air at atmospheric pressure so that a controllable vacuum is produced.



Fi t oı o tor

1. Supply from vacuum pump
2. Vacuum supply to the EGR valve

Activation of the EGR modulator takes place on a frequency of 140 Hz and at a variable pulse duty factor of between 5% and 95%.

Cooling pack

The EDC ECM controls the main cooling fan request for engine cooling and air-conditioning. It can request one of three fan speeds dependant upon cooling temperature, which are shown in table 'Fan speed operation', by sending a 140 Hz PWM signal to the cooling pack. The ration of the duty cycle determines the fan speed.

Fan speed operation

Fan speed	Temperature on	Approx. temperature off
Fan speed 1	100°C	95°C
Fan speed 2	106°C	102°C
Fan speed 3	112°C	106°C

On vehicles fitted with air conditioning the EDC ECM will grant air conditioning, dependant on coolant temperature, and fan speed one when the air conditioning is requested via the CAN-Bus from the instrument pack. The fastest fan speed from either system always assumes priority.

Glossary

The following, explains the abbreviations used within this brochure:

ABS	Anti-lock braking
ACEA	Association des Constructeurs Européens d'Automobiles
ATCU	Automatic transmission control unit
AUX.	Auxiliary
BMW	Bavarian Motor Works
BTDC	Before top dead centre
CAN	Control area network
CC	Cubic capacity
°C	degrees centigrade
DDE	Digital diesel electronics
ECD3	European commission directive stage 3
ECM	Engine control module
ECU	Electronic control unit
EDC	Electronic diesel control
EGR	Exhaust gas recirculation
EMS	Engine management system
EOBD	European on-board diagnostics
EWS-3	Elektronische Wegfahrsperre
FBH	Fuel burning heater
GM6	Ground module
HEVAC	Heating, ventilation and air-conditioning
HFM	Hot-film airflow meter
HPP	High pressure pump
K-bus	Karosserie (body)
Max	Maximum
MIL	Malfunction indication lamp
mm	Millimetres
mm^3	Millimetres cubed
ms	Milliseconds
Mv	Millivolts
NTC	Negative temperature coefficient
PTFE	Polytetrafluorethylene
PWM	Pulse width modulation
Rev/min	Revolutions per minute
RHS	Right hand side
TC	Traction control
TDC	Top dead centre