Fuel injection system

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25		11/87	10/87	7/88		
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Fuel injection system

K-Jetronic

Naturally aspirated engines are fitted with the Bosch K-Jetronic continuous fuel injection system.

The K-Jetronic system is a mechanically and hydraulically controlled fuel injection system that requires no form of drive.

The basic principle of operation is that the accelerator pedal controls the movement of the throttle plates which regulate the amount of air drawn into the engine. An air flow sensor fitted upstream of the throttle plates, monitors the quantity of intake air entering the system. Dependent upon the volume of air metered, a fuel distributor apportions a quantity of fuel to the injector adjacent to each cylinder.

The air flow sensor and the fuel distributor are combined into one assembly known as the mixture control unit (see fig. B2-2).

The precisely metered quantity of fuel is continuously sprayed from the injectors in a finely atomized form into the induction manifold behind the engine inlet valves. The air/fuel mixture is then drawn into the engine cylinders whenever an inlet valve opens.

Cars fitted with a catalytic converter also have a 'closed loop' (lambda control) system. This system accurately controls the air/fuel ratio about the stoichiometric value which is necessary to achieve efficient operation of the three-way catalytic converter.

Air flow sensing

The air flow sensor consists of an air cone in which moves an air flow sensor plate mounted on a pivoted lever (see fig. B2-3). When the engine is operating the sensor plate is deflected into the air cone, the deflection being dependent upon the volume of air passing through the cone. The air will deflect the sensor plate until a state of balance exists between the force on the air sensor plate and the counter force provided by fuel at a constant pressure acting on the end of the control piston.

The weight of the air sensor plate and connecting lever are balanced by a counterweight on the fuel distributor side of the lever.

Movement of the control piston and its horizontal control edge (see fig. B2-3) either increases or decreases the open area of the eight metering slits (one for each engine cylinder) in the fuel distributor.

Differential pressure valves (one for each cylinder) located within the fuel distributor, maintain a constant pressure drop across the metering slits.

Since the air flow sensor plate and the control piston are operated by the same lever, the rate of fuel discharge is proportional to the deflection of the air sensor plate which is governed by the calibrated cone within the funnel.

The mixture strength of each engine is adjusted at the engine idle speed setting, during manufacture of the vehicle. This is achieved by turning a screw which alters the position of the air flow sensor plate lever relative to the control piston. Turning the adjustment screw either raises or lowers the control piston for a given engine idle speed position of the air flow sensor plate, thereby richening or weakening the idle mixture. The adjustment screw is subsequently sealed and no further mixture adjustment should be necessary.

Fuel circuit

The fuel supply system comprises the primary circuit, control circuit, and the lambda control circuit (if fitted).

The fuel is at different pressures in various parts of the circuit as follows.

Primary circuit	5,2 bar to 5,8 bar (75.4 lbf/in² to 84.1 lbf/in²)
Differential pressure valves (upper chambers)	4,6 bar (67.0 lbf/in²)
Differential pressure valves (lower chambers)	4,7 bar (68.1 lbf/in²) nominal
Control circuit (variable dependent upon engine temperature)	0,5 bar to 3,6 bar (7.25 lbf/in² to 52.2 lbf/in²)
Fuel injector pressure	3,6 bar (52.2 lbf/in²)

Primary fuel circuit (see fig. B2-4)

The primary circuit fuel pressure is regulated by a plunger type valve to nominally 5,2 bar to 5,8 bar (75.4 lbf/in² to 84.1 lbf/in²).

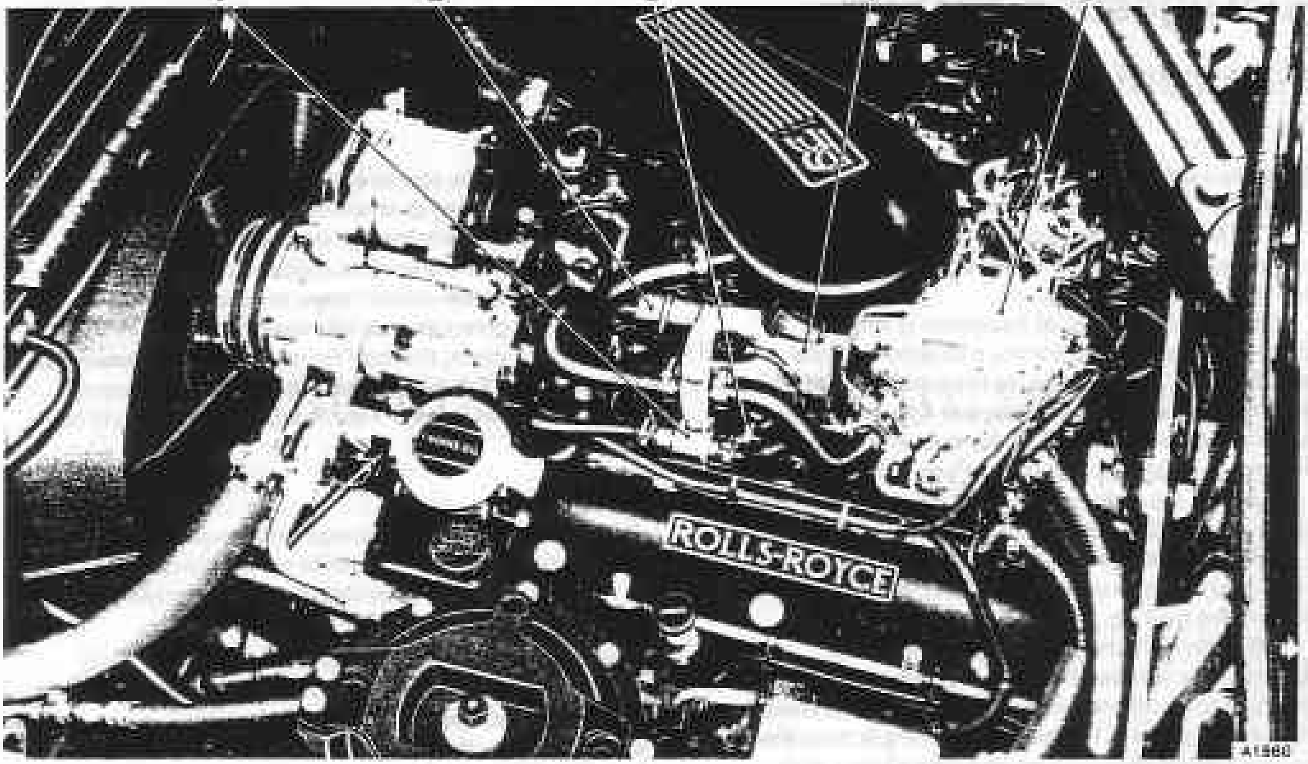
In the fuel distributor the fuel initially enters a passage which joins with the lower chambers of the differential pressure valves via a small fixed orifice (see fig. B2-7).

When the engine is operating the fuel flows through the metering slits (machined into the barrel of the fuel distributor) to the upper side of the diaphragm in the differential pressure valves. Then through injector lines to the injector valves.

The injector valves have an opening pressure of approximately 3,6 bar (52.2 lbf/in²) and are designed to spray finely atomized fuel under all operating conditions.

From the primary fuel circuit a fuel line feeds the cold start injector.

When the engine is stopped, the primary system pressure regulator allows the system pressure to drop rapidly to a pressure governed by the fuel accumulator which is just below the injector opening pressure and maintains it at this level by sealing the return line to the fuel tank. This seal is effected by a rubber 'O' ring fitted to the valve which is compressed against the fuel distributor housing (see fig. B2-5).



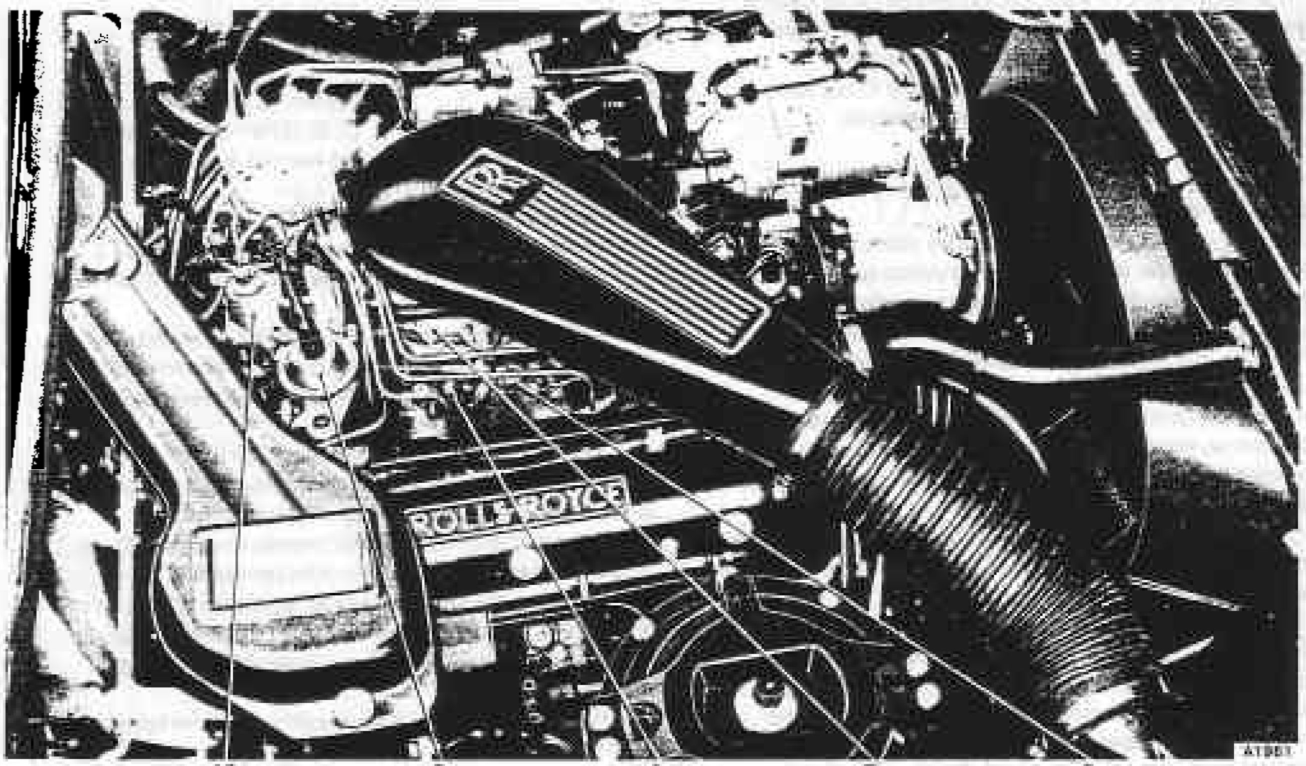


Fig. B2-1 Engine compartment details

1 Idle speed control solenoid
2 Fuel pressure damper
3 Fuel pressure control valve
4 Auxiliary air valve
5 Fuel distributor
6 Secondary throttle spindle
7 Air meter
8 Primary throttle spindle
9 Acceleration enrichment switch
10 Warm-up regulator

Simultaneously a push valve, integral with the system pressure regulator closes and prevents leakage through the control circuit. This retention of fuel pressure in the system is important because during 'hot soak' conditions it prevents fuel vaporization and subsequent poor starting. In addition, the sudden pressure drop at the fuel injectors (causing them to close) prevents 'dieseling' (i.e. the tendency of an engine to continue 'running-on' after the ignition has been switched off).

Control fuel circuit (see fig. B2-4)
The control circuit provides the control pressure that acts upon the upper end of the control piston and provides the balancing force for the air load acting on the air sensor plate. In addition, it also provides a means of enriching the mixture for cold starting.

The control circuit is supplied with fuel from the primary circuit through a restrictor in the fuel distributor (see fig. B2-7). The fuel then passes either into the chamber above the control piston via a damping restrictor or via an external connection to the warm-up regulator, where nominal control pressure of 3,6 bar (52.2 lbf/in²) [3,5 bar (50.7 lbf/in²) on cars fitted with a lambda control system] is maintained at normal engine operating temperature (at sea level).

The pressure regulator in the warm-up regulator is tensioned by a bi-metal spring when the engine is cold. This in turn reduces the load on the regulating valve and correspondingly lowers the control pressure.

With a lower control circuit pressure, the air flow sensor plate is allowed to travel further downwards in the air cone for a given rate of air consumption which in turn, moves the control piston further up in the barrel of the fuel distributor. This increases the opening of the fuel metering slits and thereby enriches the mixture.

The bi-metal of the warm-up regulator is heated electrically whenever the engine is running. This causes the effect of the bi-metal to be reduced with a corresponding reduction in the amount of mixture enrichment.

The warm-up regulator is mounted so that it can assume the temperature of the engine. Therefore, when the engine is started in the semi-warm condition, unnecessary enrichment of the air/fuel mixture is avoided.

Fuel from the warm-up regulator flows through the push valve assembly which assists in maintaining the pressure by closing the primary circuit when the engine is switched off. Excess fuel flows around the push valve and into the fuel tank return line which is not under pressure (see fig. B2-4).

Fuel distribution (see fig. B2-4)
To ensure that the fuel is uniformly distributed to the cylinders a control piston and barrel assembly is used (see fig. B2-11). This assembly operates by controlling the open cross sectional area of the metering slits machined in the barrel.

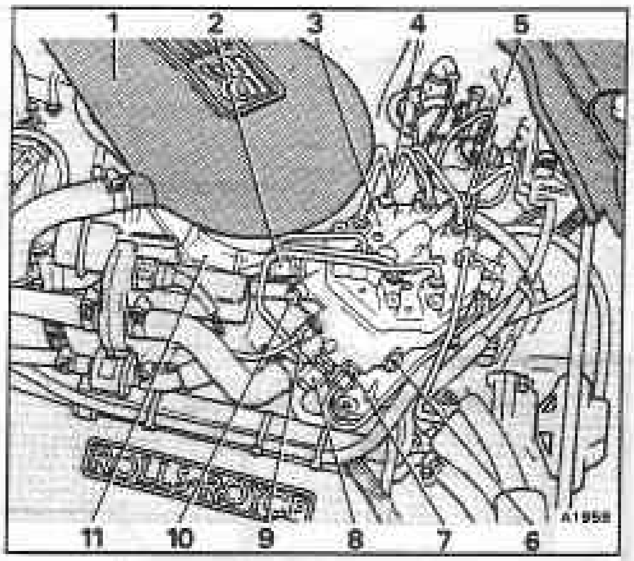


Fig. B2-2 Mixture control unit
1 Air intake
2 Fuel supply to distributor
3 Fuel distributor
4 Fuel feed to injector
5 Fuel feed to warm-up regulator
6 System pressure regulator
7 Fuel return from warm-up regulator
8 Fuel return to tank
9 Fuel feed to cold start injector
10 Fuel feed to pressure control valve
11 Air meter

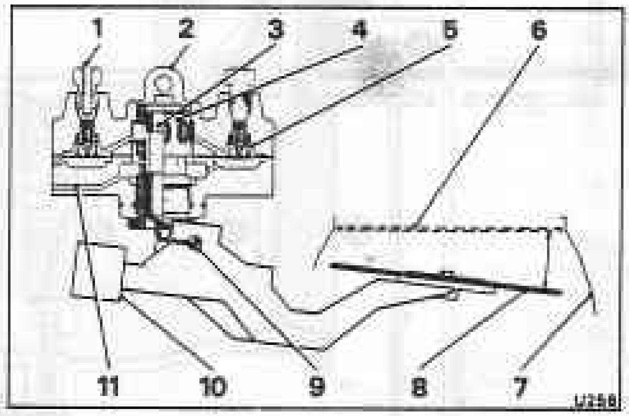


Fig. B2-3 Air flow sensor and fuel distributor (mixture control unit)
1 Fuel feed pipe to injector
2 Fuel distributor assembly
3 Control piston
4 Fuel distributor barrel
5 Differential pressure valve
6 Position of air sensor plate at idle speed
7 Air meter
8 Air flow sensor plate
9 Pivot
10 Counterbalance weight
11 Fuel inlet

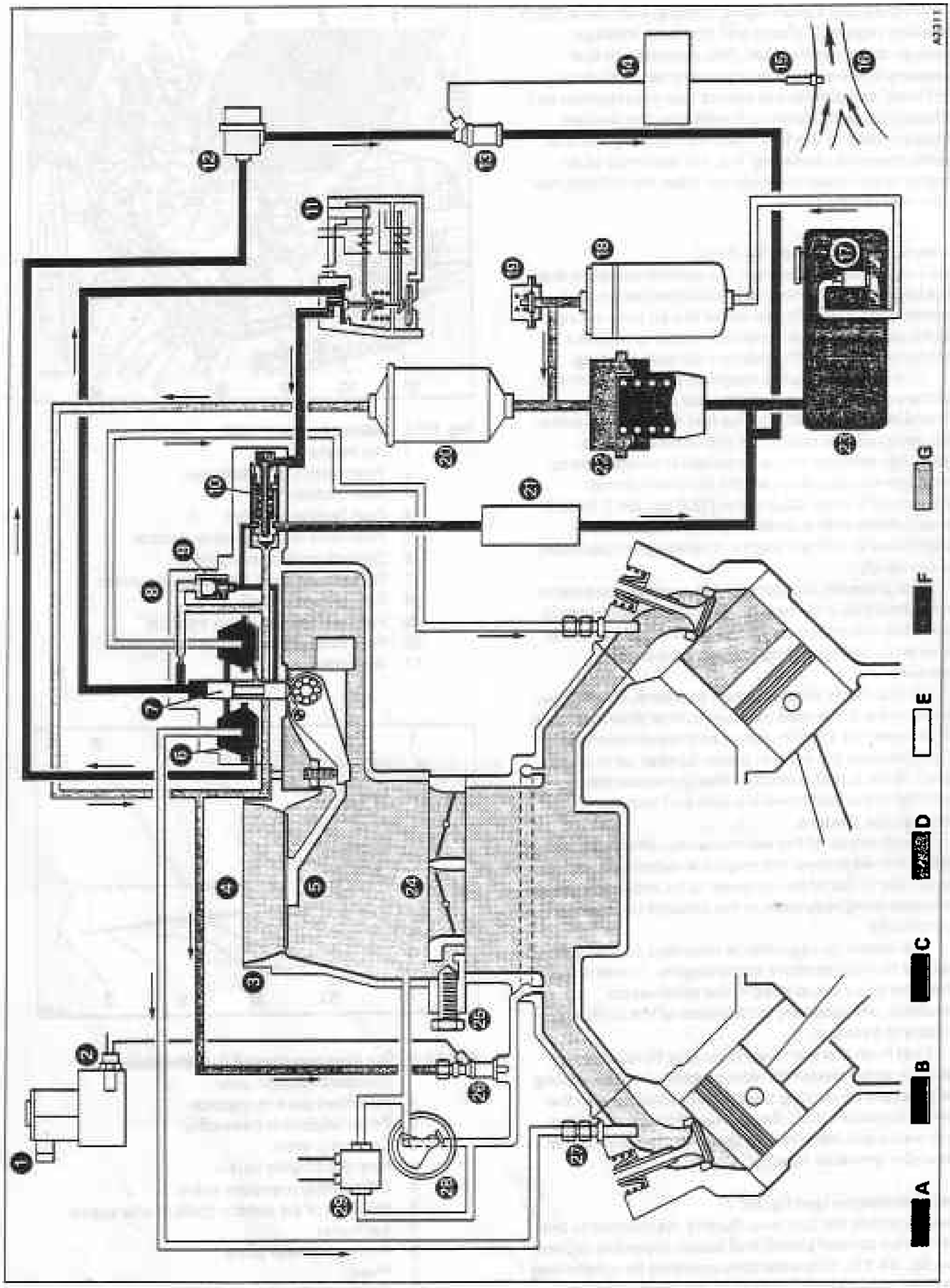


Fig. B2-4 Fuel injection system

Key to fig. B2-4 Fuel injection system

1 Thermostat housing
2 Thermal time switch
3 Air cone
4 Air meter
5 Air sensor plate
6 Differential pressure valve
7 Control piston
8 Fuel distributor
9 Anti-suction valve
10 System pressure regulator
11 Warm-up regulator
12 Fuel damper
13 Pressure control valve
14 Electronic control unit (ECU)
15 Oxygen sensor
16 Exhaust system
17 Fuel pre-pump
18 Fuel pump
19 Fuel pressure damper
20 Fuel filter
21 Fuel cooler
22 Fuel accumulator
23 Fuel tank
24 Throttle body
25 Idle speed adjusting screw
26 Cold start injector
27 Injector
28 Auxiliary air valve
29 Idle speed control solenoid
A Upper chamber pressure
B Lower chamber pressure
C Control pressure
D Primary circuit pressure
E Injection pressure
F Unpressurized return line
G Pre-pump to main pump supply pressure

Note Items 12, 13, 14 and 15 are fitted to cars with a lambda control system (closed loop mixture control).

The barrel has one slot shaped opening (the rectangular metering slit) for each cylinder. Each metering slit has a differential pressure valve to hold the drop in pressure at the metering slits constant at the various flow rates. As a result, effects of variations in the primary system pressure and differences in the opening pressure of the injector valves are eliminated.

With a constant drop in pressure at the metering slits, the amount of fuel flowing to the injector valves depends solely upon the open cross sectional area of the slits.

Differential pressure valves (see figs. B2-4 and B2-7)
There is a differential pressure valve for each engine cylinder. The valve is a diaphragm type consisting of an upper and lower chamber with the diaphragm separating the two halves (see fig. B2-7). The basic principle of operation is that the fuel pressure in the upper chamber is at approximately 0,1 bar (1.5 lbf/in²) less than the pressure in the lower chamber. The

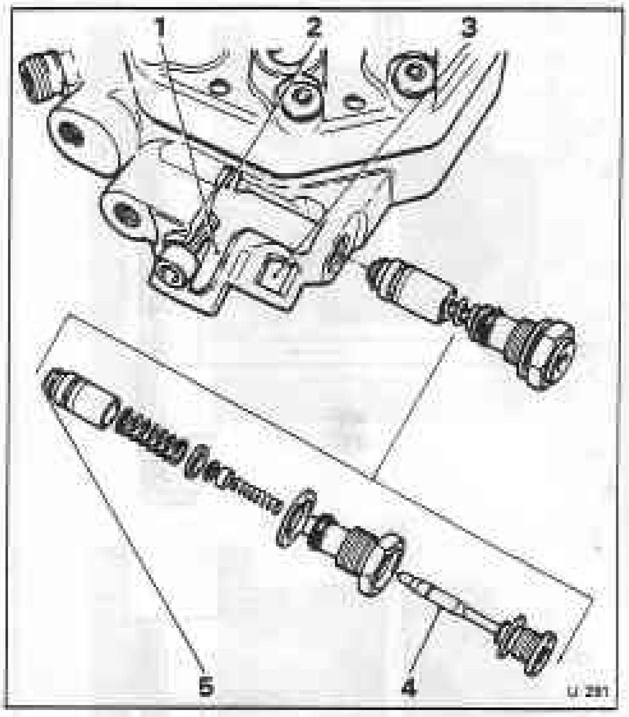


Fig. B2-5 System pressure regulator
1 Fuel return to tank
2 System pressure line
3 Fuel return from warm-up regulator
4 Push valve
5 Regulator valve sealing face

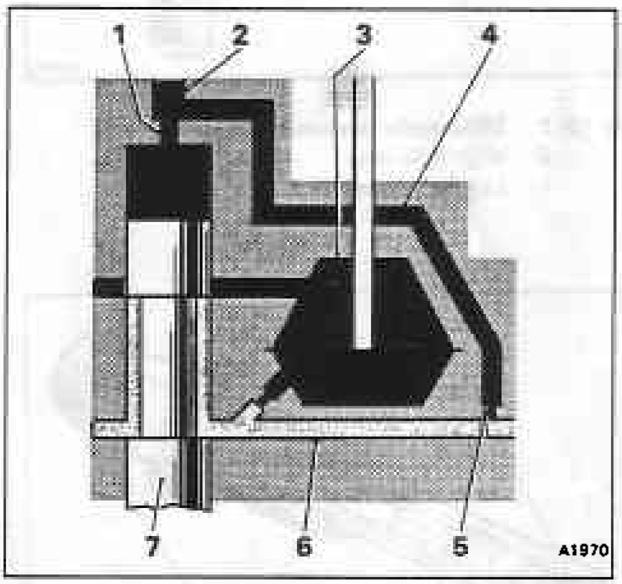


Fig. B2-6 Relationship between primary circuit pressure and control pressure
1 Damping restrictor
2 Fuel feed to warm-up regulator
3 Differential pressure valve
4 Control circuit pressure
5 Control circuit restrictor
6 Primary circuit pressure
7 Control piston

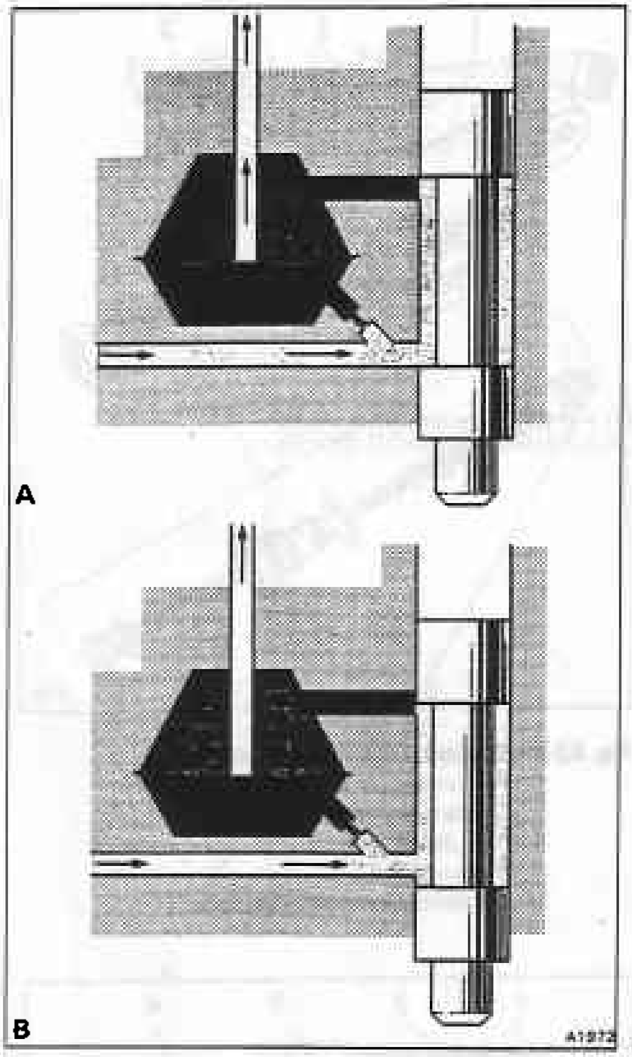


Fig. B2-7 Differential pressure valve
A High flow rate
B Low flow rate

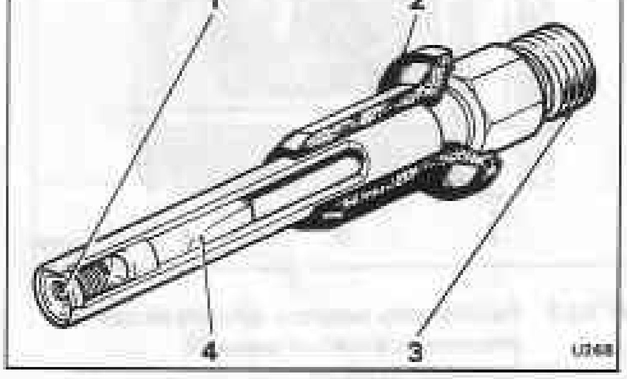


Fig. B2-8 Injector
1 Nozzle
2 Insulating sleeve
3 Fuel supply connection
4 Filter

pressure differential is produced by the helical spring built into the upper chamber. Under these conditions equilibrium of forces exists at the diaphragm.

If additional fuel flows through the metering slit into the upper chamber, the pressure rises temporarily. This increase in pressure will force the diaphragm downwards until a differential pressure of 0,1 bar (1.5 lbf/in²) again prevails at the metering slit.

At higher rates of fuel flow, the diaphragm opens a larger annular cross section, so that the pressure differential remains constant. If the rate of fuel flow decreases, the diaphragm reduces the amount of fuel flowing into the injector line.

The total travel of the diaphragm is only a few hundredths of a millimetre.

Note The fuel pressure in the lower system and therefore, the pressure differential between the two halves of the chamber is affected slightly by the operation of the lambda control system.

'Closed loop' mixture control system (Lambda control system)

Cars fitted with a catalytic converter also have a 'closed loop' lambda control system.

The lambda control system is an addition to the K-Jetronic fuel injection system and is fitted to give accurate control of the air/fuel ratio about the stoichiometric value which is necessary to achieve efficient operation of the three-way catalytic converter.

The control principle is based on the fact that by means of the oxygen sensor the exhaust is continuously monitored and the amount of fuel fed to the engine is continuously corrected.

With an ideal (stoichiometric) air/fuel mixture the air factor is identified by the value * $\lambda = 1$. At this mixture ratio the output signal from the oxygen sensor develops a voltage jump which is processed by the electronic control unit. This voltage changes sharply for small deviations from the stoichiometric mixture (the air/fuel ratio for full combustion of the fuel). The electronic unit therefore, controls the injection system for 'closed loop' fuel metering by modulating the signal to the pressure control valve. This in turn, affects the pressure in the lower chambers of the differential pressure valves.

By responding to the unconsumed oxygen content of the exhaust gas, the sensor registers the extent of the complete combustion and regulates the air/fuel mixture to the ideal or stoichiometric ratio.

$$\lambda = \frac{\text{Actual intake air}}{\text{Theoretical requirement}}$$

Description of the components

Injector (see fig. B2-8)

An injector is fitted into the induction system just behind each inlet valve. The injector opens automatically when the fuel pressure in the injection lines reaches 3,6 bar (52.2 lbf/in²). It has no metering functions, its purpose being to continually spray finely atomized fuel under all running conditions. The injector is supported in a specially shaped moulded rubber sleeve, it is pressed (not screwed) into position. The hexagonal section is provided to hold the injector while the fuel line is attached. A retention plate is fitted over the injector and secured to the cylinder head by two small setscrews, each plate retains two injectors.

Cold start injector (see fig. B2-9)
In order to facilitate engine starting particularly from low ambient temperatures, a cold start injector is fitted into the induction manifold and sprays additional finely atomized fuel during engine cranking. A thermal time switch mounted in the thermostat housing controls the operation of the cold start injector. This injector ceases to operate when the ignition key is released from the START position.

In the cold start injector a helical spring presses the movable armature and seal against the valve seat, closing the fuel inlet. When the armature is energized (and therefore drawn upwards) the fuel port is opened and the pressurized fuel flows along the side of the armature to the swirl nozzle.

Idle speed adjustment screw (see fig. B2-10)
This adjustment screw is situated at the forward end of the throttle body and allows limited adjustment of the engine idle speed. During manufacture of the vehicle the engine idle speed is set using the throttle butterfly valve adjusting screws. These screws are situated on the side of the throttle body and sealed after the initial adjustment.

Afterwards, adjustment to the engine idle speed is by means of the idle air bleed screw situated at the forward end of the throttle body. This screw is the only means of limited adjustment to the engine idle speed.

Idle speed control solenoid (see fig. B2-10)
Moving the transmission selector from the neutral position causes the engine idle speed to decrease, due to the additional load of the transmission.

To compensate for this idle speed decrease a solenoid valve is opened (energized) when the transmission selector is moved from the neutral position into any forward gear. This allows more intake air to by-pass the throttles and effectively increase the idle speed to the optimum setting.

Air flow sensor plate (see fig. B2-3)
The sensor plate is housed in the air venturi of the air meter. Its function is described on page B2-1 under the heading of Air flow sensing.

Differential pressure valves (see fig. B2-7)
The differential pressure valves (one for each engine cylinder) are housed in the fuel distributor. Their function is described on page B2-5 under the heading Differential pressure valves.

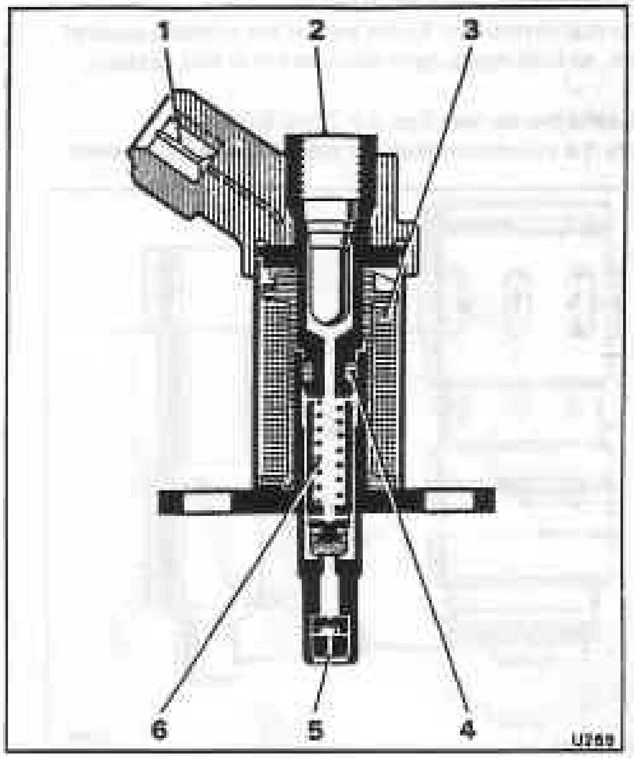


Fig. B2-9 Cold start injector
1 Electrical connection
2 Fuel inlet
3 Magnetic coil
4 Sealing ring
5 Swirl nozzle
6 Armature

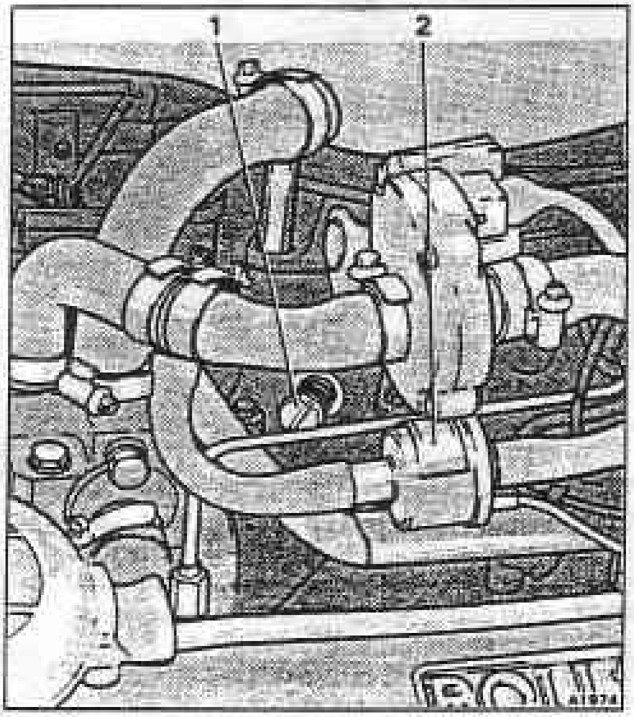


Fig. B2-10 Idle speed control
1 Idle speed adjustment screw
2 Idle speed control solenoid

Fuel distributor (see fig. B2-3)
The fuel distributor forms part of the mixture control unit. Its function is described earlier in this section.

Control piston (see figs. B2-3 and B2-11)
This is a cylindrical plunger type of valve that moves

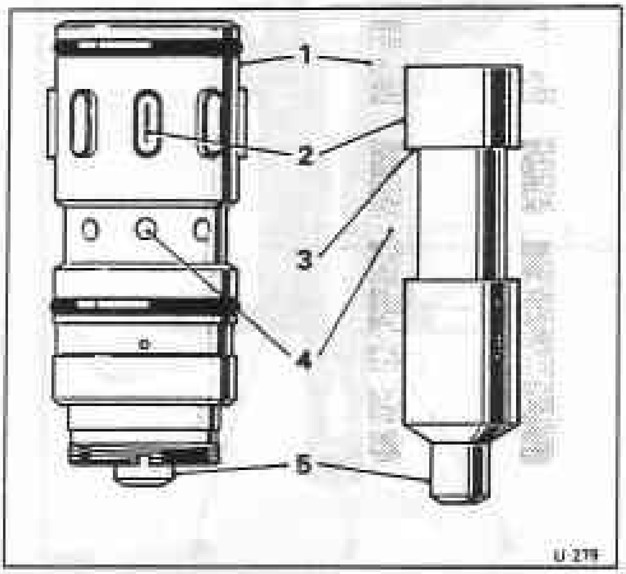


Fig. B2-11 **Fuel distributor barrel and control piston**
1 Fuel distributor barrel
2 Fuel metering slits
3 Piston control edge
4 Fuel inlet ports
5 Control piston

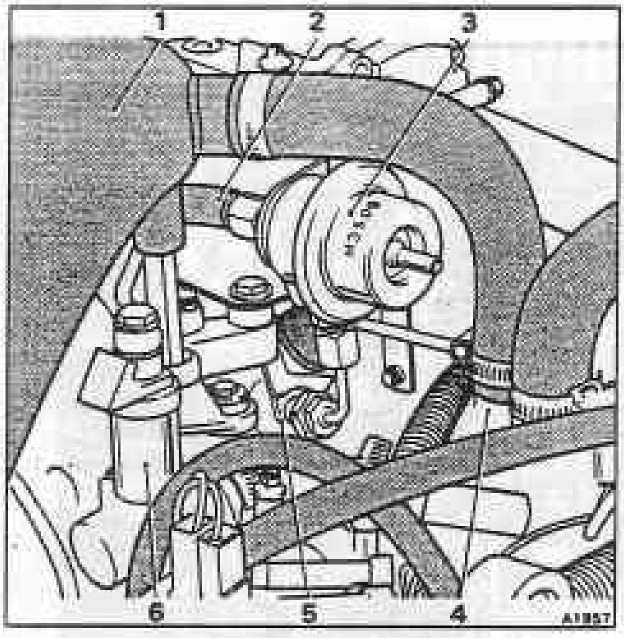


Fig. B2-12 **Fuel pressure control valve and damper**
1 Air intake elbow
2 Fuel feed from distributor
3 Pressure damper
4 Crankcase breather housing
5 Pressure control valve
6 Cold start injector

vertically in the fuel distributor. It is operated by a lever connected to the air flow sensor plate.

A precision machined edge on the control piston opens the fuel metering slits in the fuel distributor barrel and therefore, controls the amount of fuel injected into the engine cylinders.

System pressure regulator (see fig. B2-5)
When the engine is operating this regulator maintains a constant primary circuit fuel pressure. When the engine is stopped, the regulator valve allows the fuel pressure in the primary circuit to fall rapidly to just below the injector opening pressure. In addition, the push valve (the small valve on the outer end of the regulator) closes and prevents leakage from the control circuit.

Fuel pressure damper (see fig. B2-12)
Fitted to cars with a lambda control system.

This assembly is designed to 'damp' the pressure pulses caused by the operation of the pressure control valve.

Fuel pressure control valve (see fig. B2-12)
Fitted to cars with a lambda control system.

This valve is operated by an electrical signal received from the electronic control unit.

The pressure control valve receives square-wave pulses of constant frequency (70 cycles per second) but of variable width (i.e. the proportion of time that the valve remains open during any one cycle is variable, controlling the flow rate through the valve). This action varies the fuel pressure in the lower chambers of the differential pressure valves.

Electronic control unit (ECU) (see fig. B2-13)
Fitted to cars with a lambda control system.

The electronic control unit, converts the electrical signal from the oxygen sensor into a hydraulic correction of the fuel mixture. This is achieved by the signal it transmits to the pressure control valve.

The oxygen sensor reacts to a change from a weak to a rich mixture with a voltage jump which is processed by the electronic control unit.

As a result of this change to a richer mixture, the control unit changes the open-closed ratio of the pressure control valve smoothly towards a weaker mixture, until the oxygen sensor reacts to the resulting weaker mixture. This develops a voltage jump in the opposite direction, causing the open-closed ratio of the pressure control valve to be changed in the richer mixture direction.

To avoid driving continuously with a weak mixture if the oxygen sensor malfunctions, the control operation is periodically monitored within specified fixed time spans and, in the event of a defect, the control operation is switched to the 'internal-signal mode'. When in this operating mode the pressure control valve receives a constant pulse signal to control the on-off ratio. In addition a warning lamp situated on the facia will be illuminated to indicate that attention is necessary.

In addition to the basic function of the electronic control unit to evaluate the signal from the oxygen sensor, it also performs the following additional functions.

Until the oxygen sensor attains its operating temperature, a control function cannot take place. Therefore, during this warm-up period the electronic control unit is switched to the 'internal-signal mode' ('open loop control').

When it is necessary for the engine to operate under full load conditions it is also desirable to switch from the 'external-signal mode' or 'closed loop control'. This is achieved by a throttle position switch, situated on the side of the throttle housing activating a micro-switch and thereby, switching the electronic control unit into the 'internal-signal mode'.

Simultaneously, the electronic control unit modifies the signal to the pressure control valve to provide the additional enrichment required for satisfactory engine operation at full throttle.

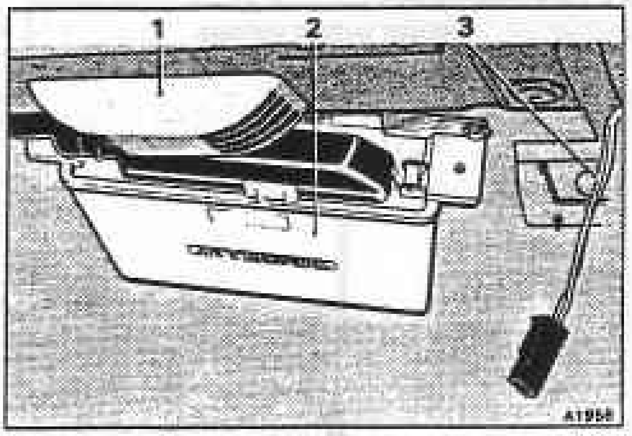


Fig. B2-13 Electronic control unit
1 Knee roll sensor (Auto ACU)
2 Electronic control unit
3 Test lead (black/slate)

Oxygen sensor (see fig. B2-14)
Fitted to cars with a lambda control system.

The oxygen sensor measures the oxygen content in the exhaust gas and by means of an electrical signal transmits the information to the electronic control unit.

The assembly consists of a sintered zirconium dioxide ceramic, impregnated with certain metal oxides. The surfaces of the tube are coated with a thin layer of platinum. In addition, a porous ceramic layer is applied to the outer side which is exposed to the exhaust gas. The surface of the hollow inner side of the ceramic tube is in contact with the ambient air.

When in position, the ceramic sensor tube is subjected to the exhaust gas on the outside, whilst ambient air is allowed to pass inside the sensing tube. If the oxygen concentration inside the sensor differs from the outside, a voltage is generated between the two boundary surfaces due to the characteristics of the material used. This voltage is a measure of the difference in the oxygen concentration inside and outside the sensor.

The ceramic sensor tube exhibits a steep change in signal output (approximately 1000 mV) when stoichiometric conditions are approached (see fig. B2-15).

The oxygen sensor will only exhibit this steep change in signal output when a certain pre-determined operating temperature is attained. Therefore, to reduce the oxygen sensor's dependency upon exhaust gas to maintain it at operating temperature, the sensor is heated electrically, using a ceramic heating rod fitted inside the zirconium dioxide tube.

When starting the engine, particularly from cold, satisfactory 'closed loop control' is not possible. During these conditions the electronic control unit supplies a fixed on-off ratio signal ('internal-signal mode') until the oxygen sensor attains its operating temperature, otherwise driveability would be impaired at this time without the regulating effect of control valve operation. If the oxygen sensor fails to function, this fixed on-off ratio signal is transmitted to the control valve in addition to illuminating a warning lamp on the facia.

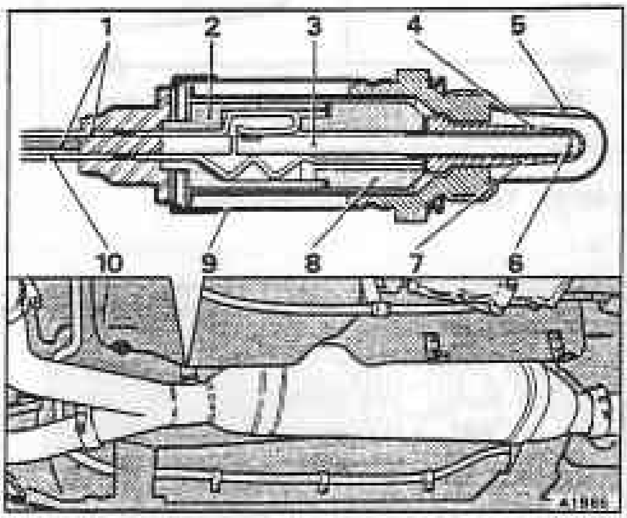


Fig. B2-14 Oxygen sensor
1 Two spring contacts for heater
2 Ceramic insulator
3 Heater
4 Ceramic sensor body
5 Protective tube
6 Air side
7 Exhaust gas side
8 Supporting ceramic
9 Protective sleeve
10 Contact for sensor

Anti-suction valve (see fig. B2-4)
When the engine is switched off it is possible for some fuel to vapourize and a depression can then occur above the control piston when the fuel condenses.

The depression would tend to lift the control piston and cause an excessively rich mixture when the engine is started.