



## **Workshop Manual Engine Management Systems**

### **Rolls-Royce & Bentley motor cars**

**Rolls-Royce Silver Spirit**

**Rolls-Royce Silver Spur**

**Rolls-Royce Corniche**

**Rolls-Royce Corniche II**

**Bentley Eight**

**Bentley Mulsanne**

**Bentley Mulsanne S**

**Bentley Turbo R**

**Bentley Continental**

**1987, 1988, and 1989  
model year cars**

**TSD 4737**

**September 1989**



# Introduction

This manual is written specifically for skilled service personnel and it is therefore assumed that the workshop safety and repair procedures generally accepted by the motor trade are appreciated, understood, and carried out.

Information relating to any subsequent modification will be circulated by the issue of amended or additional pages.

Each chapter incorporates an issue record sheet. Reference must be made to these sheets when determining either the current issue date for a particular page, or the number of pages contained within a chapter/section.

Throughout the manual reference is made to the right-hand and left-hand side of the car, this is determined when sitting in the driver's seat.

In order to identify the two banks of engine cylinders, it should be noted that 'A' bank of cylinders is on the right-hand side and 'B' bank on the left-hand side when viewed from the driver's seat.

Service personnel at Rolls-Royce Motor Cars Limited are always prepared to answer queries or give advice on individual servicing problems. When making an enquiry it is essential that the full vehicle identification number (VIN) is quoted.

## **Important**

When obtaining information for a particular model always refer to the appropriate Chapter and/or Section contents page.



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## General information

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## General information

### Health risk

#### Engine oils

Prolonged and repeated contact with mineral oil will result in the removal of natural fats from the skin, leading to dryness, irritation, and dermatitis. In addition, used engine oil contains potentially harmful contaminants which may cause skin cancer. Adequate means of skin protection and washing facilities should be provided.

#### Health protection precautions

1. Avoid prolonged and repeated contact with oils, particularly used engine oils.
2. Wear protective clothing, including impervious gloves where practicable.
3. Do not put oily rags in pockets.
4. Avoid contaminating clothes, particularly underpants, with oil.
5. Overalls must be cleaned regularly. Discard unwashable clothing and oil impregnated footwear.
6. First aid treatment should be obtained immediately for open cuts and wounds.
7. Use barrier creams, applying before each work period, to help the removal of oil from the skin.
8. Wash with soap and water to ensure all oil is removed (skin cleansers and nail brushes will help). Preparations containing lanolin replace the natural skin oils which have been removed.
9. Do not use fuel, kerosine, diesel fuel, gas oil, thinners, or solvents for washing skin.
10. If skin disorders develop, obtain medical advice.
11. Where practicable, degrease components prior to handling.
12. Where there is a risk of eye contact, eye protection should be worn, for example, chemical goggles or face shields; in addition an eye-wash facility should be provided.

See also UK Health and Safety Executive Cautionary Notice SHW 397 'Effects of Mineral Oil on the Skin'.

#### Environmental protection precautions

It is illegal to pour used oil onto the ground, down sewers or drains, or into water courses.

The burning of used engine oil in small space heaters or boilers is not recommended unless emission control equipment is fitted. In cases of doubt check with the Local Authority.

Dispose of used oil through authorized waste disposal contractors to licensed waste disposal sites, or to the waste oil reclamation trade. If in doubt, contact the Local Authority for advice or disposal facilities.

#### Exhaust gases

The exhaust gases contain carbon monoxide (CO), which is odourless and invisible but very poisonous.

Operating the air conditioning system in a confined space increases the danger of these gases entering the car.

Ideally, engines should be run in the open where the exhaust gases can discharge into the atmosphere. However, when running engines within an enclosed working area, the exhaust gases must always be removed safely.

Refer to further text within this manual regarding the use of exhaust gas extraction hoses and equipment.

#### Fuel

Fuel may contain up to 5% of benzene as an anti-knock additive. Benzene is extremely injurious to health (being carcinogenic) therefore, all contact should be kept to an absolute minimum, particularly inhalation.

Fuel has a sufficiently high vapour pressure to allow a hazardous build-up of vapour in poorly ventilated areas. Therefore, any work should be carried out in a well ventilated area.

Fuel vapour is an irritant to the eyes and lungs, and if high concentrations are inhaled it may cause nausea, headache, and depression.

Fuel liquid is an irritant to the eyes and skin and may cause dermatitis following prolonged or repeated contact.

When it becomes necessary to carry out work involving the risk of contact with fuel, particularly for prolonged periods, it is advisable to wear protective clothing including safety goggles, gloves, and aprons.

If there is contact with fuel the following emergency treatment is advised.

#### Ingestion (swallowing)

Do not induce vomiting. Give the patient milk to drink (if none is available water can be given). The main hazard after swallowing fuel is that some of the liquid may get into the lungs. Send the patient to hospital immediately.

#### Eyes

Wash with a good supply of clean water for at least 10 minutes.

#### Skin contact

Immediately drench the affected parts of the skin with water. Remove contaminated clothing and then wash all contaminated skin with soap and water.

#### Inhalation (breathing in vapour)

Move the patient into the fresh air. Keep the patient warm and at rest. If there is loss of consciousness give artificial respiration. Send the patient to hospital.

#### High voltage levels

Dangerously high voltage levels are present in an electronic ignition system. These levels are not only



present in individual components, but also in the wiring looms, plugs, sockets, and test connections.

Both primary and secondary circuits are subject to these high voltages.

Therefore, whenever the system is switched on do not touch any components/circuits contained within the ignition system.

Always wear thick rubber gloves and use insulated tools when working on the system with the ignition switched on.

## Workshop precautions

### Electrical

Always ensure that the battery master switch is turned to the OFF position or the battery is disconnected, before disconnecting or connecting any electrical components. In addition, note the following.

Never disconnect the battery or switch off the battery master switch when the engine is running.

Always ensure correct polarity when making cable connections.

It is recommended that when carrying out tests on the car wiring, a good quality multi-meter is used.

Never use generator type meters.

Do not use a test lamp on circuitry that contains electronic components, such as the ignition system.

Before using test equipment always read the manufacturer's instructions.

Do not pierce any electrical leads or looms with test probes, etc.

Do not remove the high tension lead situated between the ignition coil and distributor when the engine is running.

Ensure that no arcing takes place between electrical connections.

Do not supply more than 16 volts direct current to the ignition system.

### Fire

Fuel is highly flammable, therefore great care must be exercised whenever the fuel system is opened (i.e. pipes or unions disturbed) or the fuel is removed from the system. Always ensure that 'no smoking' signs and CO<sub>2</sub> (carbon dioxide) fire extinguishers are placed in the vicinity of the vehicle.

Always ensure that the battery is disconnected before opening any fuel lines.

If the fuel is to be removed from the tank, ensure that it is siphoned into a suitable covered container.

### Fuel

#### Pressure

The fuel system contains fuel that may be under high pressure. Therefore, to reduce the risk of possible injury and fire, always ensure that the system is depressurized by one of the following methods before commencing any work that necessitates opening the system.

1. Allow the pressure to fall naturally by switching off the engine and allowing the vehicle to stand for a minimum of four hours before opening the system.
2. Clean the inlet connection to the fuel filter. Wrap an

absorbent cloth around the joint and carefully slacken the pipe nut to release any pressurized fuel from the system. Tighten the pipe nut. Always dispose of the cloth carefully, in accordance with the prevailing Health and Safety regulations.

### Cleanliness

It is extremely important to ensure maximum cleanliness whenever work is carried out on the system.

The main points are.

1. In order to prevent the ingress of dirt, always clean the area around a connection before dismantling a joint.
2. Having disconnected a joint (either fuel or air) always blank off any open connections as soon as possible.
3. Any components that require cleaning should be washed in white spirit and dried, using compressed air.
4. If it is necessary to use a cloth when working on the system, ensure that it is lint-free.

### General

Before working on the car, always ensure that the parking brake is firmly applied, the gear range selector level is in the park position, and fuse A6 is removed from fuse panel F2 on the main fuseboard.

A number of the nuts, bolts, and setscrews used in the fuel injection system are dimensioned to the metric system, it is important therefore, that when new parts become necessary the correct replacements are obtained and fitted.

### Terminology

It should be noted that not all of the components listed are fitted to any one particular model or model year of car. This section merely explains the abbreviation and operation of the specialist components used in the systems.

#### Air flow sensor plate

Balances the air flow entering the induction system with fuel pressure acting on the control piston.

#### Air flow sensor potentiometer

Monitors the quantity of air flowing into the engine.

The information is conveyed to the ECU as a measure of engine load and is one of the elements used in the calculation of ignition timing and fuelling requirements.

#### Air pressure transducer (APT)

The air pressure transducer monitors induction manifold pressure. It passes this information to the relevant ECU so that the necessary electrical corrections can be made to the relevant control system.

On cars fitted with one APT the unit provides instantaneous boost pressure information for the fuel injection and ignition control systems. It also supplies the information to the boost control system.

On cars fitted with two APTs one assembly is connected to the fuel injection system and the second unit is connected to the boost control system.



#### **Air pump clutched pulley**

The air injection system is de-activated whenever the coolant temperature is above 33°C (91°F) or engine speed exceeds 3000 + 100 rev/min. This is achieved by dis-engaging the air pump clutch.

#### **Air switching valve**

The air switching valve comprises a vacuum operated valve with an integral control solenoid.

At coolant temperatures below 33°C (91°F) the solenoid is energized. The resulting vacuum then applied to the diaphragm chamber opens the valve and allows injected air to pass to the exhaust manifold.

At coolant temperatures above 33°C (91°F) the solenoid is de-energized, the vacuum signal is inhibited and the injected air is re-routed to the engine air intake system.

#### **Auxiliary air valve**

Allows calibrated increases in idle circuit air flow and hence engine speed, with closed throttle plates. This provides the correct mixture strength during cold starting and warm-up periods.

#### **Check valves**

A check valve is fitted into the air injection pipe to each exhaust manifold. The valves prevent the back flow of exhaust gas.

#### **Cold start injector**

Sprays finely atomized fuel during engine cranking (cold engine) into the induction manifold. The amount and duration of cold start injector operation are dependent upon the coolant temperature.

#### **Control piston**

Cylindrical plunger type of valve that moves vertically in the fuel distributor. A precision machined edge on the piston opens the metering slits in the fuel distributor.

#### **Coolant temperature sensor**

The coolant temperature sensor is located in the thermostat housing. The internal resistance of the sensor changes with the engine coolant temperature.

To achieve the correct starting and warm-up characteristics at low operating temperatures, the ECU uses the signal it receives from the coolant temperature sensor to compute the correction factors for the ignition timing and the fuel injection system electro-hydraulic actuator.

#### **Crankshaft reference sensor**

Initiation of A1 ignition and subsequent engine firing order occurs when the front damper mounted reference pin passes the crankshaft reference sensor.

#### **Differential pressure valves**

One for each cylinder, maintains the correct pressure of fuel at the metering slits.

#### **Dump valve**

Allows compressed air to recirculate back through the

air intake. Closure of the dump valve allows induction manifold pressure (boost) to build-up during increasing engine load, to values predetermined by the boost control system.

The dump valve also acts as a relief valve if the boost pressure exceeds a preset level.

#### **Electro-hydraulic actuator (EHA)**

Mounted on the fuel distributor, the electro-hydraulic actuator replaces the warm-up regulator used on K-Jetronic systems. A positive increase in current (mA) supply to the EHA results in a corresponding increase in fuel flow and hence fuel mixture strength.

On 1989 model year cars fitted with the KE3-Jetronic fuel injection system, it is also possible to have a negative increase in the supply to the EHA which will 'lean off' the mixture.

#### **Engine running sensor**

Inhibits the supply of power to the fuel pump unless the engine is running. The only exception being one by-pass to the circuit, which allows the fuel pump to operate when the engine is being 'cranked' by the starter motor.

#### **Engine speed sensor**

The signal generated by the rotation of the four segment timing wheel is sensed by the engine speed sensor. The information is then conveyed to the K-Motronic ECU for calculation of the engine speed.

#### **Exhaust gas recirculation valve (EGR)**

The operation of this valve is vacuum controlled.

A proportion of exhaust gas is recirculated from the exhaust system, through the EGR valve, into the induction manifold where it mixes with intake air.

#### **Exhaust gas wastegate**

Regulates the flow of exhaust gas to the turbocharger turbine when either boost pressure or engine detonation reach predetermined levels. The boost control system actuates wastegate control.

#### **Four segment timing wheel**

The four segment timing wheel has four equal length segments and gaps. Angular relationship of segment to gap is 54° and 36° respectively, and produces a 60:40 ratio signal for engine speed calculation.

#### **Fuel accumulator**

When the engine is stopped, the small volume of fuel held in the accumulator (under pressure from the accumulator spring) maintains pressure in the primary fuel circuit to ensure good starting response during the engine 'cranking' operation (i.e. fuel is immediately available).

#### **Fuel cooler**

The fuel cooler is located in the left-hand side of the engine compartment. It uses air conditioning system refrigerant to cool the fuel prior to its return to the tank.



#### **Fuel distributor**

Apportions the fuel equally to the injectors adjacent to each engine cylinder.

#### **Fuel pressure regulator**

Maintains a constant primary circuit fuel pressure. When the engine is stopped, the fuel pressure regulator allows the system pressure to drop rapidly to a value preset by the fuel accumulator (i.e. just below the injector valve operating pressure). It also seals the return line from the lower chambers of the differential pressure valve.

#### **Heated oxygen sensor**

Measures the oxygen content (which is directly related to the air/fuel ratio) in the exhaust gas and by means of an electrical signal transmits the information to the electronic control unit.

#### **Idle speed actuator**

The idle speed actuator contains a stepping motor, the armature of which is connected to a rotating slide. This adjusts the cross sectional area of the by-pass passage.

The duty cycle from the K-Motronic ECU produces a torque at the rotating armature which acts against a return spring.

The by-pass opening is continually adjusted to maintain the correct engine idle speed under all potential engine load conditions.

#### **injector**

One injector is used for each engine cylinder and sprays finely atomized fuel under all running conditions into the induction system.

#### **Intercooler**

A charge air intercooler is fitted below the air cleaner assembly. It is situated in the ambient air stream behind the air dam and beneath the front bumper. The intercooler reduces compressed air temperature, this enables recovery of charge air density and maintains optimum engine power output.

#### **KE2-Jetronic electronic control unit (ECU)**

Processes input from a chain of engine mounted sensors and provides the necessary electronic fuel corrections in terms of DC mA to the electro-hydraulic actuator. This includes start, post start, warm-up, acceleration enrichment, and positive induction manifold pressure compensation.

#### **K-Motronic digital ECU**

The K-Motronic ECU is mounted in the ECU compartment in the rear right-hand corner of the engine compartment.

The K-Motronic system brings together the benefits of digital fuel injection (KE3-Jetronic) and ignition control (EZ 58F) systems into a single electronic control unit (ECU). Other features of the system include cold start and warm-up enrichment, idle speed regulation, and automatic correction of any long term

mixture strength deviations.

On cars fitted with catalytic converters the K-Motronic system also provides an 'on-board' self diagnostic facility.

The engine is equipped with several sensors that continuously monitor operating parameters such as engine speed, coolant temperature, and load. The sensors are connected to the digital ECU which is programmed with characteristic data for the following functions, mixture strength control, ignition timing, idle speed control, and purging of the evaporative emission control canister.

#### **Knock sensors**

Sense crankcase vibration and then produce an output signal which is processed by the boost electronic control unit. If knock is present the ECU signals the boost control valve to divert the compressor pressure signal more towards the wastegate than atmosphere.

#### **'On board' self diagnostic ability**

A fascia mounted warning panel illuminates to alert the driver to a number of possible engine related faults. The lamp displays the message 'Check Engine' and is illuminated when the engine is running and a failure is identified.

When the 'Check Engine' lamp is illuminated a fault message (in the form of a four digit code) is stored within the K-Motronic ECU and can be subsequently used to inform workshop personnel of the faulty components or system.

#### **Pressure control valve**

Operating from an electrical signal received from the electronic control unit, the valve varies the fuel pressure in the lower chambers of the differential pressure valves.

#### **Pressure damper**

Dampens the pressure pulses caused by the operation of the pressure control valve.

#### **Purge control valve**

This valve is connected into the purge line of the fuel evaporative emission control system. It regulates the purge flow rate depending upon engine load and mode of operation. The valve receives a duty cycle signal from the engine management system ECU.

#### **Thermal time switch**

Situated in the thermostat housing. Depending upon the temperature of the coolant, it controls the operation of the cold start injector.

#### **Throttle position switch (TPS)**

Identifies the engine operating mode (i.e. idle, part load, or full load).

Part load occurs when the switch contacts are broken between idle and full load.

#### **Turbocharger**

Increases the power and torque of the engine by utilizing energy from the exhaust gas.



Figure A2-1

## Vehicle specification



Specification	UK and all countries not listed		Norway and Sweden	
	Naturally Aspirated	Turbocharged	Naturally Aspirated	Turbocharged
<b>Engine</b>				
L 410 I	87/88/89	—	87/88/89	—
L 410 IT	—	87/88	—	87/88
L 410 ITI	—	89	—	89
<b>Fuel injection system</b>				
Bosch K-Jetronic	87/88/89	—	87/88/89	—
Bosch KE2-Jetronic	—	87/88	—	87/88
Bosch KE3-Jetronic (electronically controlled by K-Motronic engine management system)	—	89	—	89
<b>Fuel system</b>				
Recirculatory with in-tank and main pumps	87/88	87/88	87/88	87/88
With fuel cooler	89	89	89	89
<b>Turbocharging system</b>				
Boost pressure control system regulating exhaust gas by-passing turbocharger via a wastegate	—	87/88/89	—	87/88/89
<b>Ignition control system</b>				
Constant energy type. Lucas 35 DM 8 distributor conventional vacuum and centrifugal advance	87/88/89	—	87/88/89	—
Digital non-adjustable EZ 58F. Twin 2 x 4 cylinder distributor	—	87/88	—	87/88
Digital non-adjustable EZ 58F (electronically controlled by K-Motronic engine management system). Twin 2 x 4 cylinder distributor.	—	89	—	89
<b>Exhaust emission control system</b>				
Air injection system	—	—	89	89
EGR system	—	—	89	—
Catalytic converter system with closed-loop	—	—	**89	**89
<b>Fuel evaporative emission control system</b>				
Standard purge control system	—	—	88/89	—
Programmed purge control system	—	—	—	89
<b>Crankcase emission control system</b>				
Recirculatory closed breather type	87/88/89	87/88/89	87/88/89	87/88/89
<b>Air intake system</b>				
Filter mounted on right-hand inner wing valance	87/88/89	87/88	87/88/89	87/88
With charge air intercooler	—	89	—	89
<b>Throttle intake</b>				
Rod and lever system	87/88/89	87/88/89	87/88/89	87/88/89

\* Middle East has revised ignition timing \*\* Remote CO tapping \*\*\* Other than Australia

† Japan has excessive exhaust temperature warning †† With mods for boost system

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## Fuel injection system

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# Issue record sheet

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19		10/87	2/90	2/89						
20			10/87	10/88						
21		10/87	10/87	4/89						
22		10/87	10/87							
23		10/87	11/87	7/88						
24		2/90	11/87	7/88						
25		11/87	10/87	7/88						
26		11/87	10/87	7/88						
27		10/87	10/87	2/89						
28		10/87	10/87	2/89						
29		2/90	10/87	5/89						
30		10/87	10/87							
31		10/87	10/87	2/89						
32		10/88	11/87							
33		10/88	11/87	4/89						
34		10/87								
35		10/87		2/89						
36		10/87		7/88						
37		10/87		2/89						
38		10/88		7/88						
39		1/89		7/88						
40		10/88		7/88						
41				7/88						
42				7/88						
43				7/88						
44				7/88						
45				7/88						
46				7/88						
47				2/89						
48				7/88						
49				7/88						
50				10/88						
51				10/88						
52				10/88						
53				1/89						
54										



## 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/in <sup>2</sup> to 84.1 lbf/in <sup>2</sup> )
Differential pressure valves (upper chambers)	4,6 bar (67.0 lbf/in <sup>2</sup> )
Differential pressure valves (lower chambers)	4,7 bar (68.1 lbf/in <sup>2</sup> ) nominal
Control circuit (variable dependent upon engine temperature)	0,5 bar to 3,6 bar (7.25 lbf/in <sup>2</sup> to 52.2 lbf/in <sup>2</sup> )
Fuel injector pressure	3,6 bar (52.2 lbf/in <sup>2</sup> )

#### 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/in<sup>2</sup> to 84.1 lbf/in<sup>2</sup>).

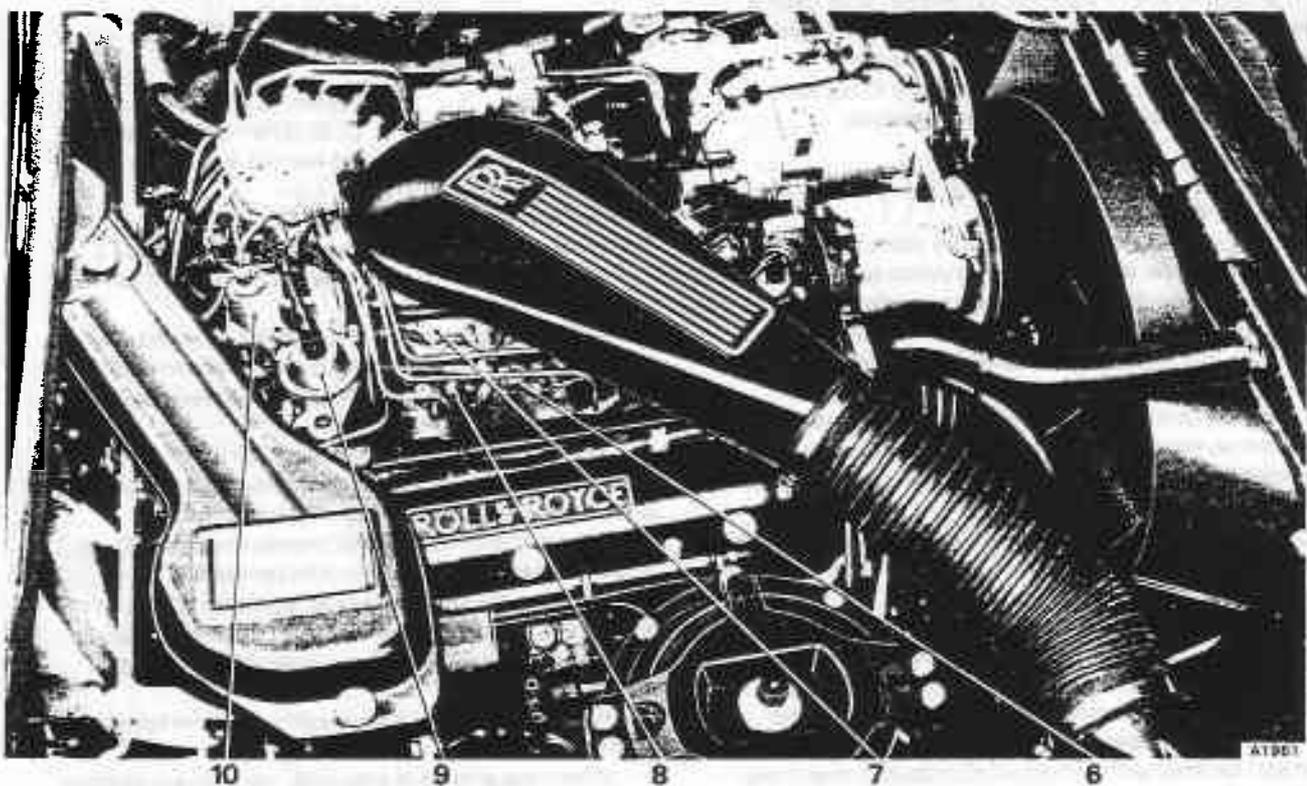
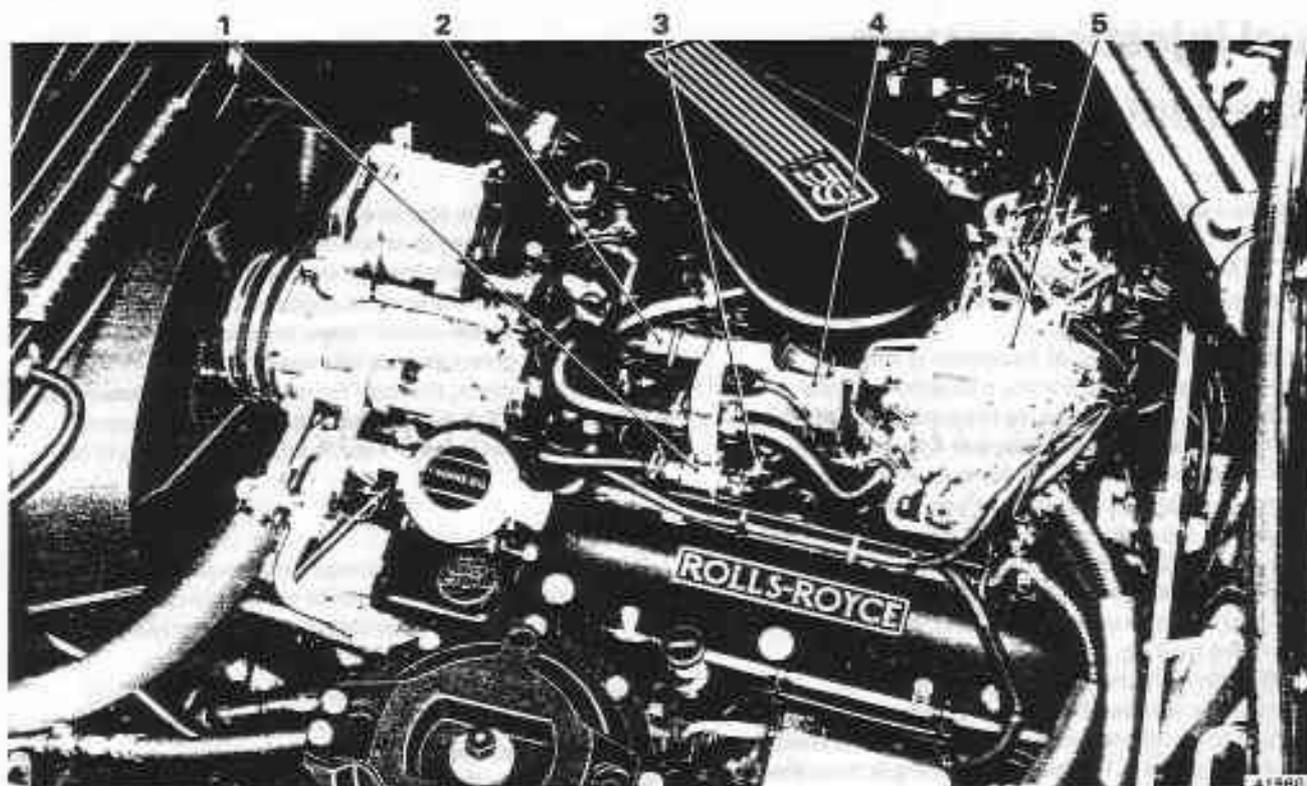
In the fuel distributor the fuel initially enters a passage which joins with the lower chambers of the differential pressure valves via a small fixed orifice (see fig. B2-7).

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/in<sup>2</sup>) 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/in<sup>2</sup>) [3,5 bar (50.7 lbf/in<sup>2</sup>) 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.

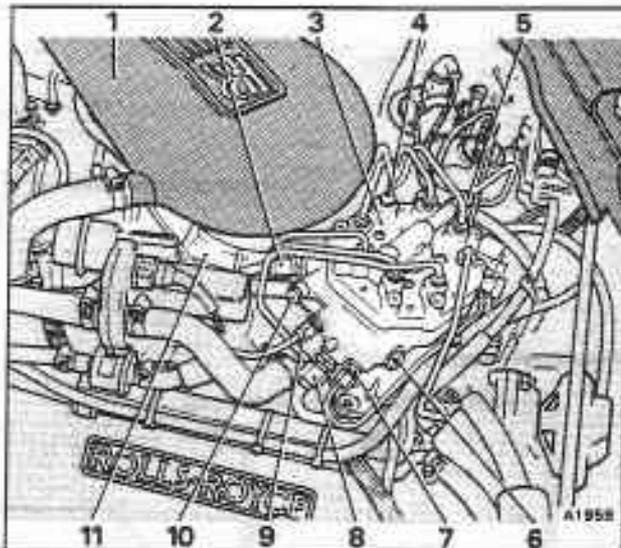
The bi-metal of the warm-up regulator is heated electrically whenever the engine is running. This causes the effect of the bi-metal to be reduced with a corresponding reduction in the amount of mixture enrichment.

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).

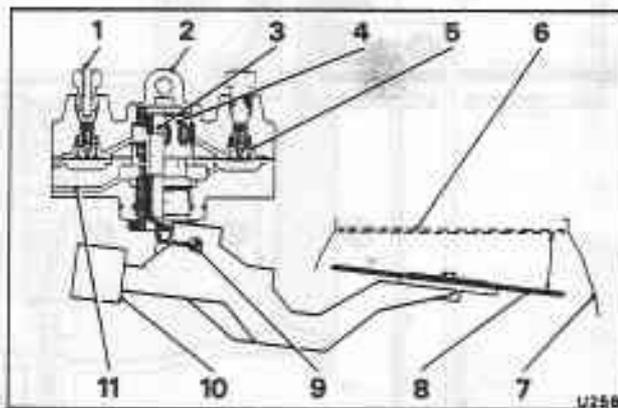
#### Fuel distribution (see fig. B2-4)

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

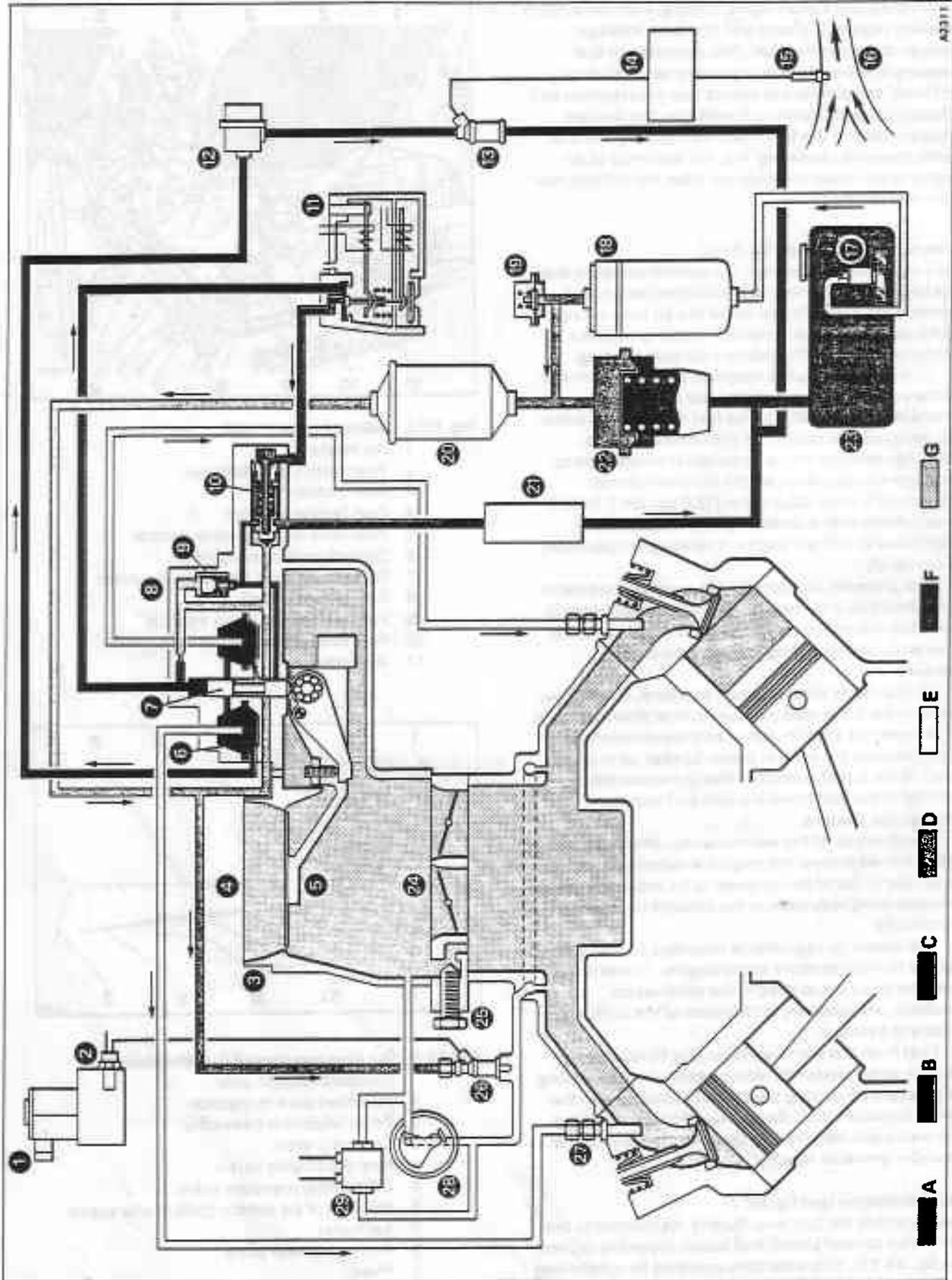


Fig. B2-4 Fuel injection system

**Key to fig. B2-4 Fuel injection system**

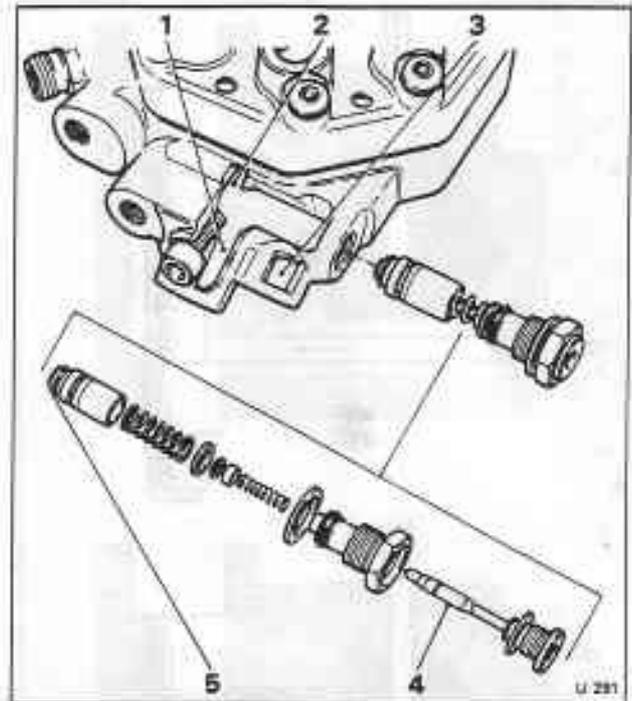
- 1 Thermostat housing
- 2 Thermal time switch
- 3 Air cone
- 4 Air meter
- 5 Air sensor plate
- 6 Differential pressure valve
- 7 Control piston
- 8 Fuel distributor
- 9 Anti-suction valve
- 10 System pressure regulator
- 11 Warm-up regulator
- 12 Fuel damper
- 13 Pressure control valve
- 14 Electronic 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.

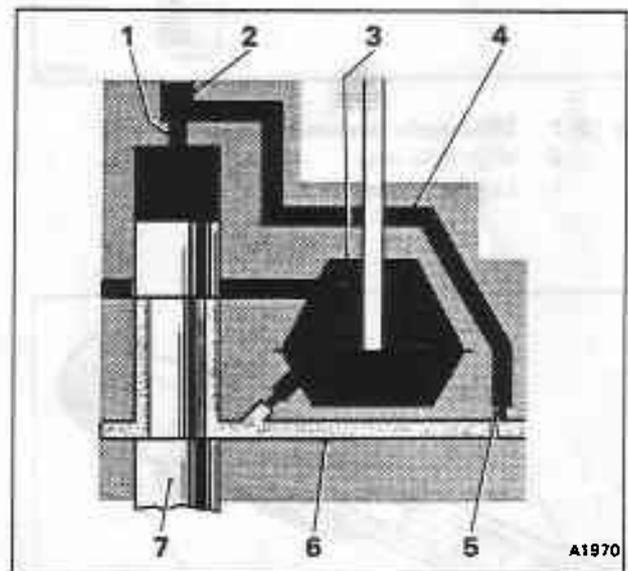
With a constant drop in pressure at the metering slits, the amount of fuel flowing to the injector valves depends solely upon the open cross sectional area of the slits.

**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/in<sup>2</sup>) less than the pressure in the lower chamber. The



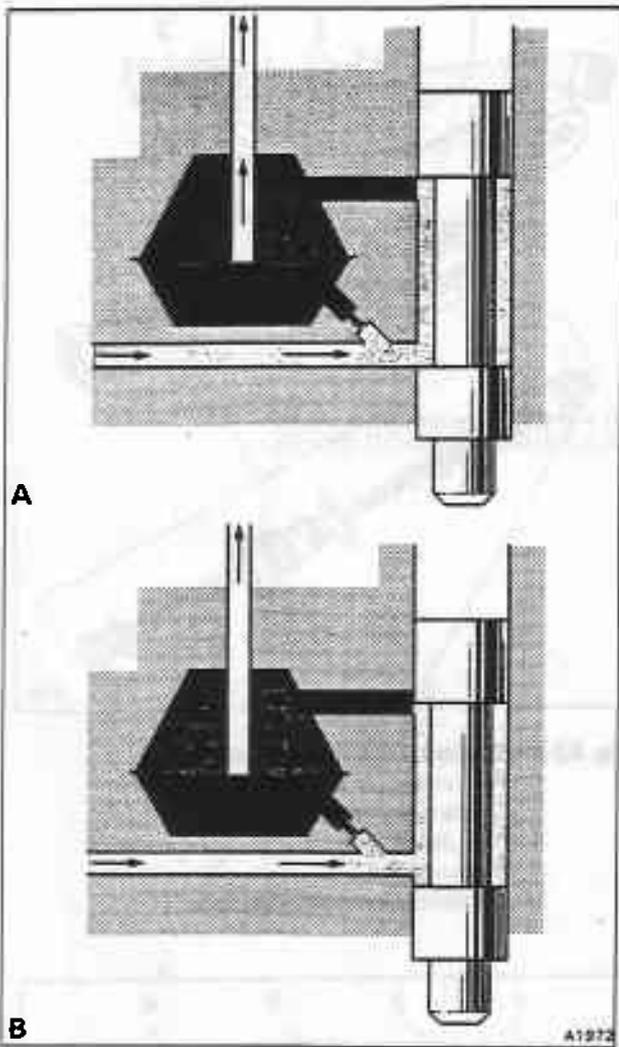
**Fig. B2-5 System pressure regulator**

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

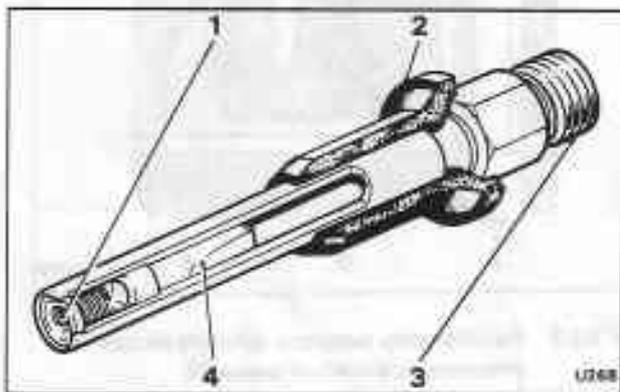


**Fig. B2-6 Relationship between primary circuit pressure and control pressure**

- 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/in<sup>2</sup>) 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)

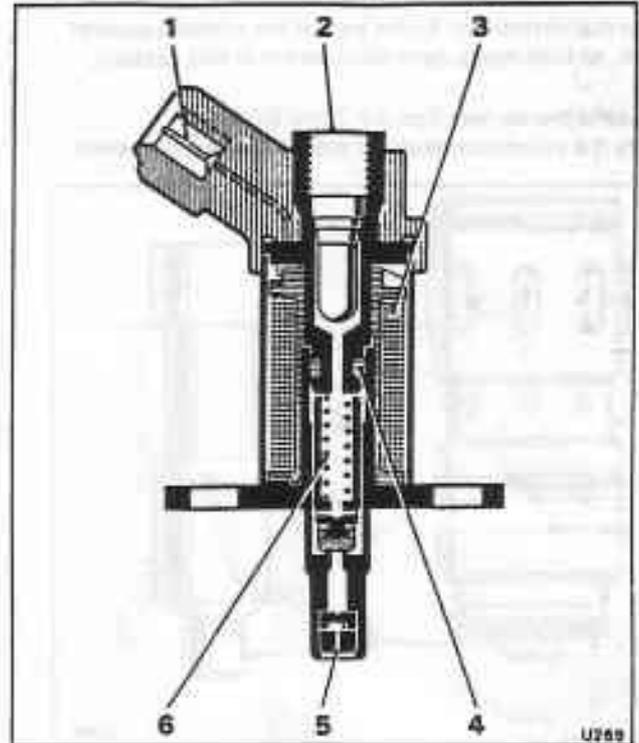
An injector is fitted into the induction system just behind each inlet valve. The injector opens automatically when the fuel pressure in the injection lines reaches 3,6 bar (52.2 lbf/in<sup>2</sup>). It has no metering functions, its purpose being to continually spray finely

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.



**Fig. B2-9 Cold start injector**

- 1 Electrical connection
- 2 Fuel inlet
- 3 Magnetic coil
- 4 Sealing ring
- 5 Swirl nozzle
- 6 Armature

#### 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.

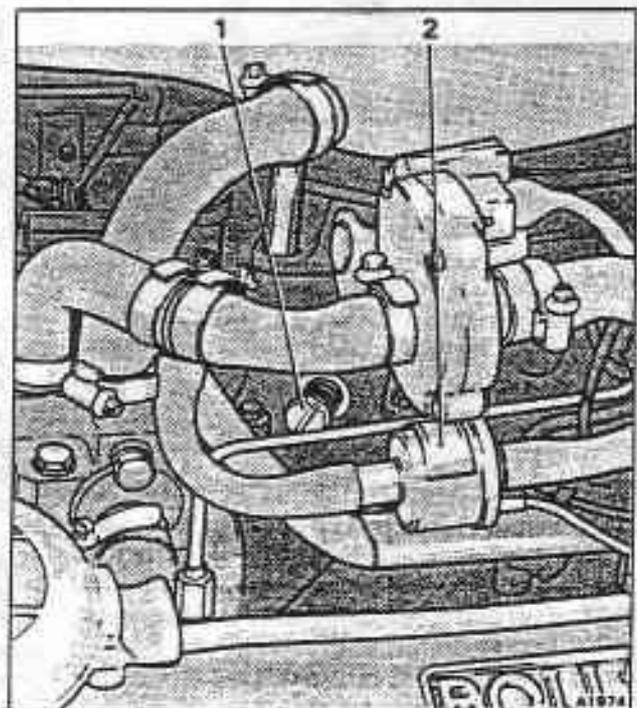
To compensate for this idle speed decrease a solenoid valve is opened (energized) when the transmission selector is moved from the neutral position into any forward gear. This allows more intake air to by-pass the throttles and effectively increase the idle speed to the optimum setting.

#### 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. B2-10 Idle speed control**

- 1 Idle speed adjustment screw
- 2 Idle speed control solenoid

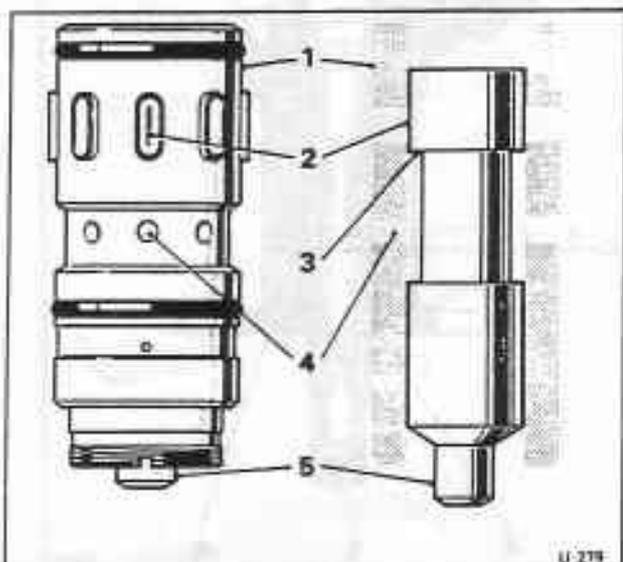


### Fuel distributor (see fig. B2-3)

The fuel distributor forms part of the mixture control unit. Its function is described earlier in this section.

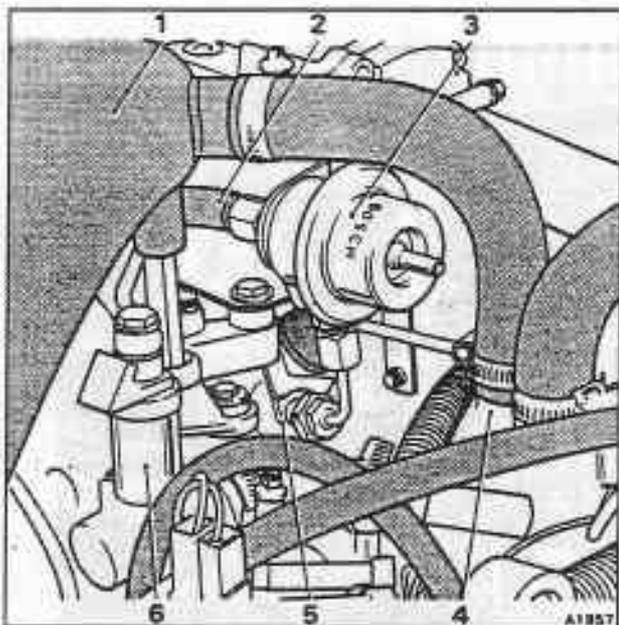
### Control piston (see figs. B2-3 and B2-11)

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 fascia 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.

#### 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.

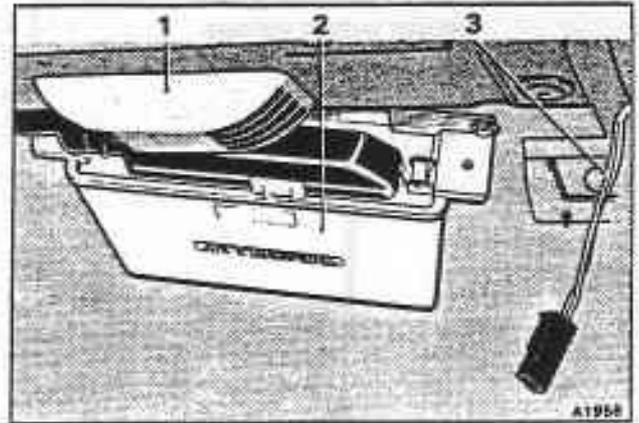
The assembly consists of a sintered zirconium dioxide ceramic, impregnated with certain metal oxides. The surfaces of the tube are coated with a thin layer of platinum. In addition, a porous ceramic layer is applied to the outer side which is exposed to the exhaust gas. The surface of the hollow inner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

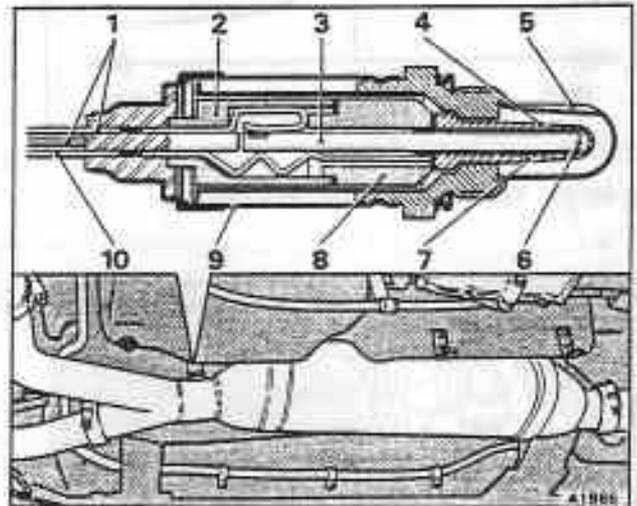
The ceramic sensor tube exhibits a steep change in signal output (approximately 1000 mV) when stoichiometric conditions are approached (see fig. B2-15).

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



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



**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

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 fascia.

#### 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.