LUCAS L ELECTRONIC FUEL INJECTION

AS FITTED TO THE 3528cc V8 ENGINE INSTALLED IN THE ROVER SD1 VITESSE AND EFI VDP

Contents

IMPORTANT

This Rover SD1 EFI manual has been compiled using material originally made available for Range Rover Dealer technician training. Where appropriate, it has been modified to take account of different components used on the Rover SD1 Vitesse and EFI Vdp system.

Please read/review in its entirety to enable complete understanding of the system rather than use Individual sections as a quick reference for solving specific problems.

PART 1

INTRODUCTION

In the days when fuel was cheap, mans desire for performance from his car far outweighed any thought of economy.

Then two things happened; the price of fuel soared, and people became conscious of air pollution caused by unburned fuel being exhausted from the engine.

The desire for performance remained but now everyone became aware of the amount of fuel being consumed.
Suddenly design engineers had to pay much more attention to detail - cylinder head design, manifolding and valve gear efficiency and so on.

An essential part of the new thinking was attention to the fuel system. No longer was it good enough simply to ensure fuel reached the combustion chambers in a form that allowed it to burn and produce power. No longer was an air/fuel ratio of 14:1 under most conditions considered adequate.

Now the engineers had to design an efficient system, which burned all the fuel introduced into the engine. As a result, carburettors have become much more sophisticated, incorporating devices to vary the amount of fuel entering under a variety of conditions - ambient temperature, overrun etc.

14: 1 is no longer the air/fuel ratio to be aimed at; today it is expected to be flexible - around 15.5: 1 for most operating conditions and 12.5: 1 under full load.
In this search for efficiency a radical departure from traditional carburettor fuel systems was the introduction of electronic fuel injection on petrol engines. First developed in the 1950's these units were large and heavy, and proved to be very unreliable electronically.
However, since that time technology has transformed the mass production of transistors and other solid-state components, which has opened the way to a practical and reliable electronic fuel injection system (EFI).
Today's Rover SD1 EFI, combines state-of-the-art technology with the legendary reputation for the ruggedness and reliability of the VB engine. At first glance under the bonnet it is not surprising that one can he overwhelmed by the apparent maze of pipes, ducts, valves, sensors and electronics. However, when broken down into their component parts the system becomes easier to understand and therefore easier to adjust or diagnose problems when they occur.

The Rover SD1 EFI contains three different systems, all interlinked to produce the correct fuelling under all driving conditions. These are:

Fuel ˍstem
Air system
Electronics

DESCRIPTION

Fuel System

The electric pump (P) draws fuel from the fuel tank (see fig.1.1). The pump passes the fuel along the fuel supply pipe (8), through a fine mesh (2 micron) in-line filter (F) to the injector rail and injectors (1 - 8). Fuel pressure is controlled by the regulator (R) and excess fuel returns to the fuel tank via the return pipe (E).
Fuel enters the engine via eight injectors, one for each cylinder, and the fuel is injected indirectly. This means that fuel is not injected directly into the' combustion chambers.

The amount of fuel delivered by the injectors is governed by the period of time they are open - the longer the 'open' time, the greater the amount of fuel delivered.

The injectors operate in two banks of four; each bank operates alternately, with both banks operating twice per working cycle.

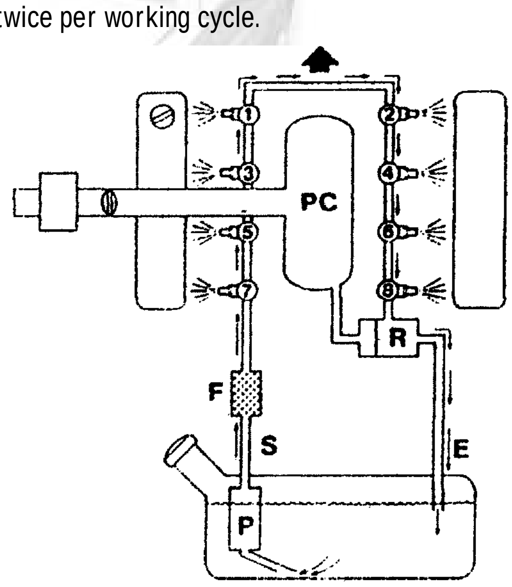


Fig.1.1 Fuel System

P	Fuel pump (not submerged on SD1)
F	Filter
S	Fuel supply pipe
E	Excess fuel return pipe
R	Fuel pressure regulator
PC	Plenum chamber
1-8	Injectors

Air System

Without air in the correct volume, the fuel will not burn efficiently; therefore a sophisticated air control system is also necessary.

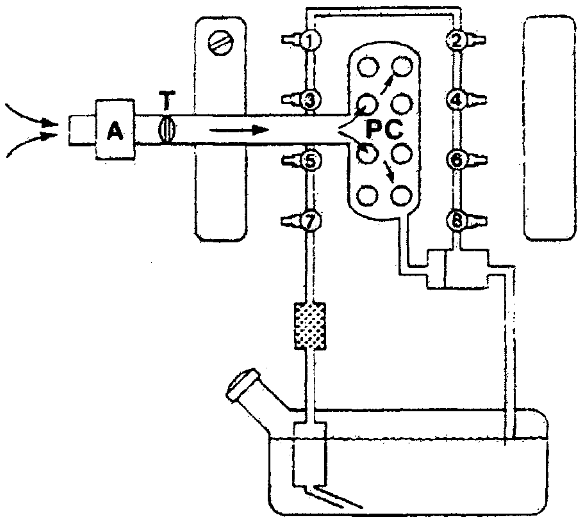


Fig.1.2 Air System
A Air flow meter
T Throttle butterfly
PC Plenum chamber

The driver's accelerator pedal operates a throttle butterfly (T), as seen in fig.1.2, located in the air intake tract. From there the air passes to a plenum chamber (PC) located centrally over the engine and from which the air is drawn through ram pipes into the inlet manifold itself.

However, before the air reaches the throttle butterfly it is drawn through the air flow meter (A). The air flow meter is a vital part of the EFI system; it measures the volume and mass of air being drawn into the engine, and takes into account the air temperature.

Electronics System

The Electronic Control Unit (ECU) illustrated in fig.1.3 controls the injector 'open' time (duration).

The ECU is a solid state computer; it receives information from a number of sensor sources - engine speed, engine temperature, ambient temperature, throttle position, air flow etc. It compares this information with data already programmed into it, to inject the correct amount of fuel by controlling the injector 'open' time.

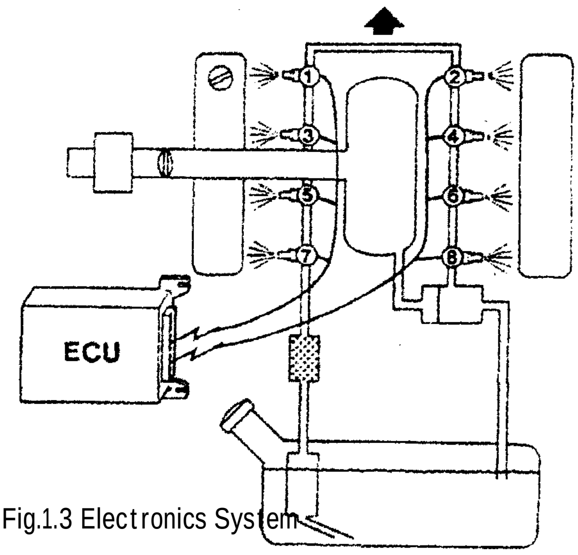


Fig.1.3 Electronics System

Now let us look at the function of the components within each system, and see how they contribute to the overall operation of 'Electronic Fuel Injection'; we will start with the fuel system.

PART 2

FUEL SYSTEM OPERATION

Fuel Pump

The electric fuel pump, located in front of the fuel tank, is a roller type pump operated by a permanent magnet motor. The armature and bearings are cooled and lubricated by the fuel flowing through the pump with no risk of combustion because the pump never contains an ignitable mixture, even when the tank empties.

Fig.2.1 shows an eccentric rotor (RT) mounted on the armature shaft with rollers (RO) in pockets rotating within a housing (H). When the motor is energised centrifugal force acting on the rollers forces them outward to act as seals. The fuel between the rollers is forced to the high-pressure side of the system (HP).

A pressure relief valve (PR) is located within the roller pump (RP) prior to the armature (A) and protects the pump from over -pressurising. A non-return valve (NR) is located in the pump outlet to the filter and injectors; it prevents fuel draining from the injector supply pipe.

Fuel gravitates through a filter in the tank to the pump inlet and into the roller pump ensuring that the system is primed. The roller pump generates the necessary fuel pressure to feed the injection system. Excess pressure opens the relief valve allowing fuel to recirculate to the pump input.

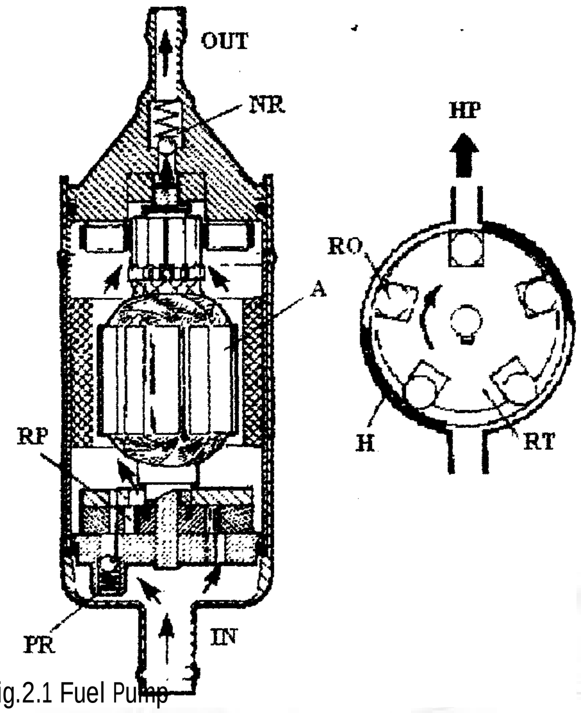


Fig.2.1 Fuel Pump

RT	Rotor
RO	Roller
H	Housing
HP	High pressure side
RP	Roller pump
PR	Pressure relief valve
A	Armature
NR	Non return valve

Fuel Filter

Injector components are machined to close tolerances, and therefore thorough fuel filtering is essential to their efficient operation and long life.

The fuel filter is mounted on the *n/s* inner wing forward of the bulkhead. It is a 2 micron, fine mesh unit that must be changed at stipulated service intervals. It must be fitted the correct way round; the arrow on the filter body shows the direction of fuel flow, when installed.

Fuel Pressure Regulator

The fuel pressure regulator is fitted to control the pressure of fuel delivered at the injectors by sensing variations in manifold depression; this is to ensure that the actual quantity of fuel released by the injectors is governed by one factor only - injector 'open time'.

The pressure regulator is fitted in the excess fuel return pipe (E), close to the injector fuel rail with its fuel supply (F) as seen in Fig.2.2. It has two chambers separated by a diaphragm (R1); one chamber contains fuel from the supply line (F), the other is linked by a pipe to the engine side of the throttle butterfly to sense manifold depression.

b. In the rest position the spring (R2) holds the, diaphragm valve against the fuel return pipe.

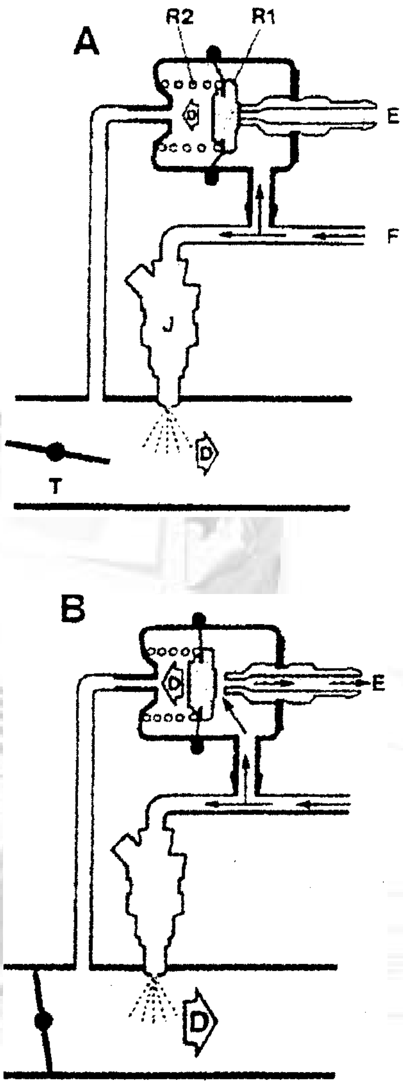


Fig.2.2 Fuel Pressure Regulator

T	Throttle butterfly
D	Manifold depression
E	Excess fuel return
J	Injector
R1	Regulator diaphragm valve
R2	Regulator spring
F	Fuel rail (pump supply)

Under conditions of low manifold depression, e.g. full throttle (Fig.2.2A), the spring continues to hold the diaphragm on its fuel return pipe seat. In these circumstances, pump pressure must reach approximately 36lb/sq.in to move the diaphragm valve against spring pressure and allow excess fuel to return to the tank.

When manifold depression is high, e.g. idle and overrun (Fig.2.2B), the diaphragm valve is drawn against spring pressure. The fuel return is opened and the fuel pressure falls to 26 Ib/sq.in. Any intermediate depression will regulate fuel pressure between the minimum and maximum.

In this way fuel pressure varies according to manifold depression and ensures the amount of fuel delivered by the injectors is governed only by the injector 'open time

me.

When manifold depression is low (Fig.2.2A), fuel pressure needs to be high to ensure sufficient fuel is forced through the injector for a given injector 'open time', say 0.003 cc of fuel per 10 millisecond period.

When manifold depression is high (Fig.2.2B), the depression will try to 'suck' fuel from the injector nozzle. Therefore the fuel pressure needs to be reduced by the action of the regulator to ensure the same 0.003 co of fuel will pass through the injector in the same 10 millisecond period.

Injectors

Although the injectors are non-serviceable items, it is useful to have some knowledge of how they operate for diagnostic purposes.

Each injector contains a needle valve (A) as seen in fig.2.3, which is held closed in the rest position by a coil spring (B). When the electrical solenoid (C) is energised, it lifts the needle valve to allow the fuel to pass; and when the solenoid is de-energised, the spring snaps the needle valve closed to cut off the fuel flow.

The tip of the needle is ground to a pintle shape to ensure efficient atomisation of the fuel spray into the inlet manifold.

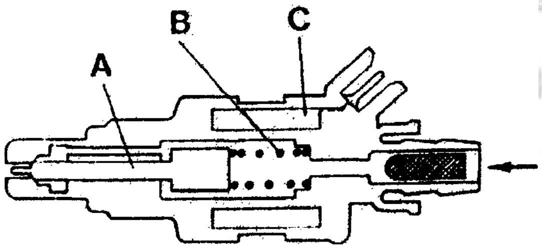


Fig. 2.3 Injector

- A Needle valve
- B Coil spring
- C Electrical solenoid

The injector needle valve is opened when signalled by the ignition system via the ECU.

The signal to inject comes from the ignition distributor reluctor as shown fig.2.4. Only four of the reluctor gaps are used to signal 'inject'; the ECU ignores every other signal. It is the ECU, which dictates the injector 'open time' and therefore the amount. Of fuel that is injected.

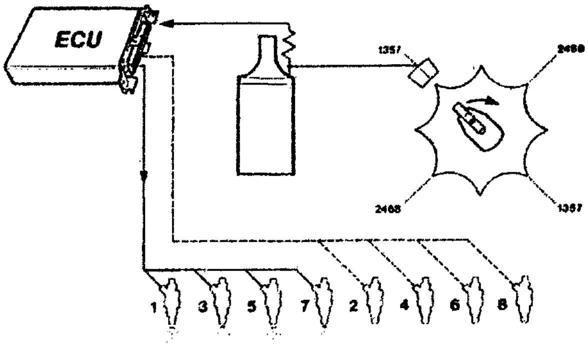


Fig.2.4 Injector Signal

A separate resistor pack is fitted in the circuit to reduce the 12 volt supply down to 3 volts at the injector; this is shown in the electrical section.

Obviously if the incorrect quantity of fuel is injected, emissions, performance, economy and the customer, soon become upset.

The principal sensor in the EFI system is the intake air flow meter. And we see how this operates in the next section.

AIR SYSTEM OPERATION

Air Flow Meter

The air flow meter is located between the air filter and the throttle butterfly housing. Air flowing to the engine is monitored by the air flow meter and information is sent to the ECU.

Incorporated in the airflow meter is an adjustment screw to set the mixture and CO levels.

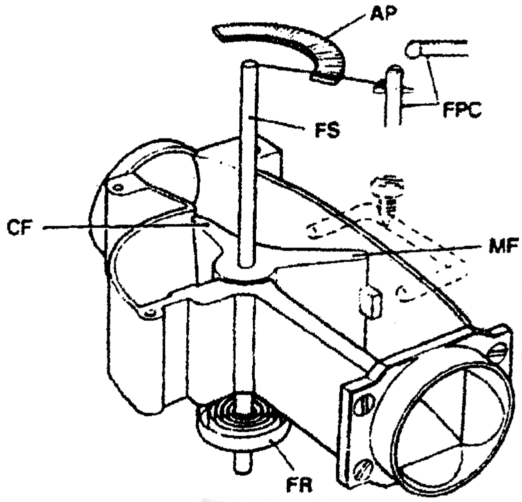


Fig.2.5 Air flow meter (sectioned)

MF Measuring flap
CF Compensating flap
FS Flap spindle
FP Flap return spring
AP Air flow meter potentiometer
FPC Fuel pump switch contacts

The air flow meter contains a double flap unit, which pivots on a spindle (FS) mounted in the housing. The measuring flap (MF) is closed on to its stop by a light spring (FR), and is opened by the air being drawn into the engine; as the measuring flap opens, the compensating flap (CF) moves into the damper chamber.

A potentiometer (variable resistor) *(AP)* is connected to the flap spindle; movement of the flap alters the value of the resistance which is signalled to the ECU. The ECU compares this signal value with its memory and, together with information from other sensors, computes the duration of the injector 'open' time.

There is one further electrical connection at the flap spindle, which is to the switch contacts (FPC) in the circuit to the fuel pump.

Operation

In fig.2.5 the flap is shown at rest (engine not running); here it can be seen that the measuring flap is closed by the spiral spring against the stop. At this stage the fuel pump contacts are open to prevent operation of the pump.

During cranking and when the engine is idling sufficient air is drawn into the engine to open the flap unit approximately 5° as seen in fig.2.6. This movement allows the contacts (FPC) to close and switch the fuel pump into operation.

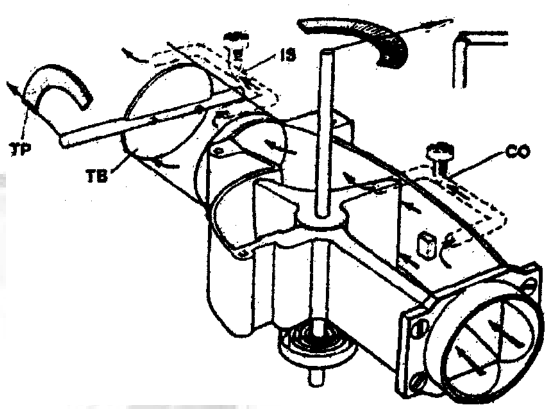


Fig.2.6

CO Air by-pass port and CO adjustment screw
TB Throttle butterfly
TP Throttle potentiometer
IS Throttle by-pass port and idle Screw

It can also be seen in fig.2.6 that whilst the bulk of air enters the engine via the measuring flap, a by-pass port and adjustment screw (CO) is also provided. This adjustment screw enables fine adjustment of the actual airflow and thereby controls the mixture strength (CO) at idle speeds.

The throttle butterfly (TB), which controls the speed of the engine, is also equipped with a potentiometer (TP) to provide the ECU with information on throttle position.

Also shown is the throttle butterfly by-pass port and idle speed adjustment screw (IS). This screw operates in much the same way as the mixture screw, in that while some air is passing the throttle butterfly, the idle screw can be adjusted to alter the total volume of air entering the engine, in order to control the idle speed.

Let us now just concentrate on how the measuring flap is stabilised throughout the engine speed range. When the throttle is opened as seen in fig.2.7, pressure at 'B' falls due to the depression in the manifold, and atmospheric pressure 'A' moves the measuring flap to allow more air to enter the engine. At the same time the air in chamber D is momentarily compressed, thus damping the rate of movement of both flaps.

c.

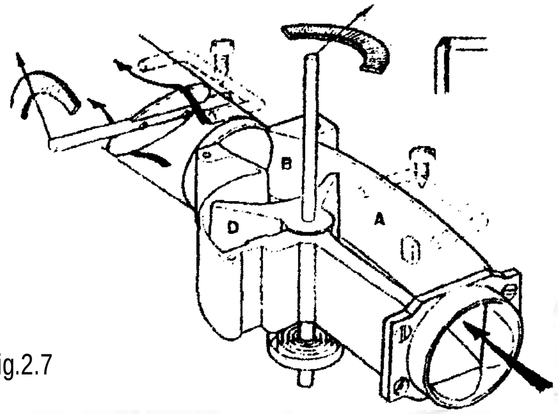


Fig.2.7

If the throttle is now held steady, the air pressure in chamber '0' will also fall until it is equal to the pressure at 'B'. This balance of pressure on each side of the damper flap ensures that the flap unit remains stable at any throttle opening.

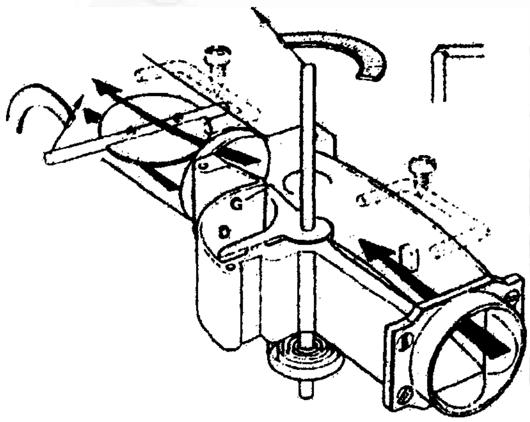


Fig .2.8

At maximum throttle opening as shown in fig.2.8, the flap unit will be resting against the full open stop; here depression is maintained, in chamber '0' by the rush of air passing the small gap shown at 'G.

Both flaps are in fact slightly twisted in opposite directions to the pivot spindle axis; this is to ensure progressive pressure changes within chamber '0' and smooth movement of the flap unit when opening or closing.

Throttle Butterfly

The throttle butterfly (seen in fig.2.9) is mounted in between the plenum chamber and the air flow meter; it is linked directly to the driver's accelerator pedal.

As mentioned previously, a throttle potentiometer is mounted on the butterfly spindle similar to the potentiometer on the air flow meter spindle.

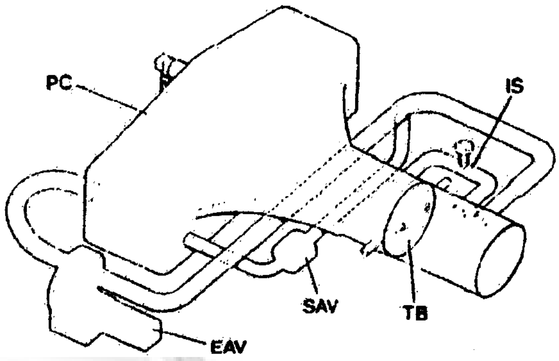


Fig.2.9

PC Plenum chamber TB Throttle butterfly
IS Throttle by-pass port and idle adjustment screw
EAV Extra air valve
SAV Solenoid operated air valve (fitted Only to vehicles with air conditioning)

The varying resistance signals from the air flow meter and throttle potentiometers are fed to the ECU for analysis and for computation of the injector 'open' time.
The information from these two potentiometers is computed by the ECU to give a very accurate fuel/air ratio supply to the engine.

The required ratio varies dependant on a number of factors, and therefore additional devices are fitted to ensure the correct air/fuel ratio under a variety of conditions; for example, an 'extra air valve' and Injector provide a richer mixture for cold starting.

COLD START OPERATION.

During cold starts, additional air and fuel is required to provide a combustible mixture. The air is supplied to the plenum chamber via the extra air valve, which bypasses the throttle butterfly and operates in conjunction with a cold start injector to supply the additional fuel.

Extra Air Valve

The extra air valve is mounted on the inlet manifold coolant gallery in front of and to the right of the plenum chamber, and is therefore sensitive to coolant temperature.

The extra air valve contains a disc valve (DV) as seen in fig. 2.10A. and its basic design is quite simple. When cold, an aperture in the disc and an aperture in the body of the valve are in alignment, allowing air to pass through. When the temperature rises, the disc turns about its central spindle progressively eclipsing the aperture through which the air can pass.

d.

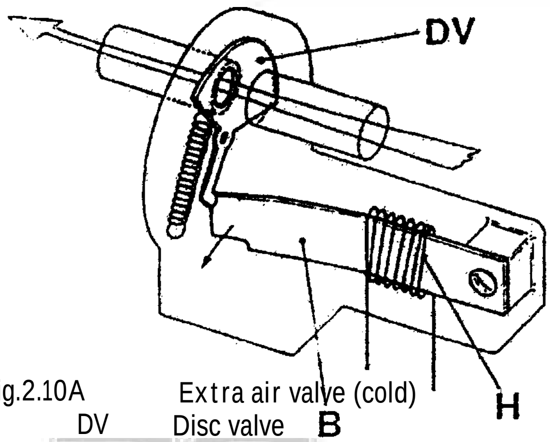


Fig.2.10A Extra air valve (cold)
DV Disc valve
B Bi-metal
H Heating wire

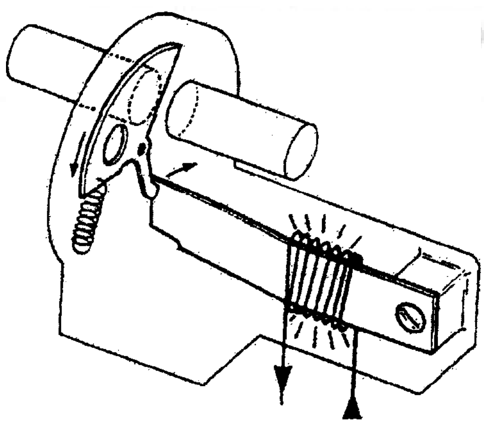


Fig.2.10B Extra air valve (hot)

The disc is turned by a bi-metal (B), which responds to both ambient temperature (i.e. the coolant temperature) or to the heating wire (H) coiled around it This coil is connected to the fuel pump electrical circuit; therefore the coil starts to heat the bi-metal and begins to close the valve as soon as the engine cranks and runs (see fig. 2.10B).

Once the engine is running, the combined effect of the heater coil and engine temperature closes the extra air valve at temperatures between 60 - lO°C.

Cold Start Fuel Injector

During cold starts an electrical supply into the ECU from the starter circuit ensures an increased 'open' time for all the injectors during cranking. However, to achieve a satisfactory start in particularly adverse conditions, a· cold start injector mounted on the R/H side of the plenum chamber is positioned to spray directly against the incoming air to give the best atomisation of the additional fuel it supplies.

The cold start injector (CSI) (see fig.2.11) is controlled by a 'thermo time switch' (TT) located in the coolant gallery in the inlet manifold. This unit contains a heater coil (HC) around bi-metal operated contact points (BMC), and works as follows.

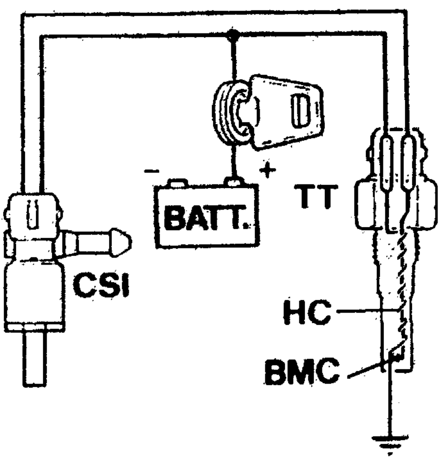


Fig.2.11 Cold start Injector circuit
CSI Cold start injector
BATT Battery supply (when engine is cranking)
TT Thermo time switch
HC Heater coil
BMC Bi-metal contacts

During cranking in cold conditions current can pass through the closed contact points of the thermo time switch and cause the injector to operate. At the same time current is passing through the heater coil to warm the bi-metal. After a maximum of 12 seconds the expansion of the bi-metal will open the contact points; the injector will then cease to operate to avoid an over fuelling condition.

In any case the injector will cease to operate as soon as the engine fires because it is only connected to the ignition system during cranking, and when correctly tuned, the engine will fire and run before the maximum 12 second limit is reached. At higher ambient temperatures the operating time progressively lessens, until 35°C approximately, when the thermo time switch contact points remain open and the cold start injector will not operate.

SOLENOID AIR VALVE OPERATION
(Only fitted to vehicles with air conditioning)

On vehicles fitted with air conditioning, an air supply is taken from the extra air valve pipe; this supply feeds an air valve (fig.2.12), which increases the idle speed when the air conditioning compressor cuts in. It is a sealed unit containing a solenoid-operated valve.

The solenoid is connected electrically to the compressor control circuit, and as soon as the compressor cuts in, the solenoid opens the valve to allow additional air into the engine. This causes a slight fall in manifold depression - enough to affect the fuel pressure regulator and increase the fuel pressure. The increased air/fuel mixture is sufficient to step up the idle speed and counteract the loading on the engine imposed by the compressor.

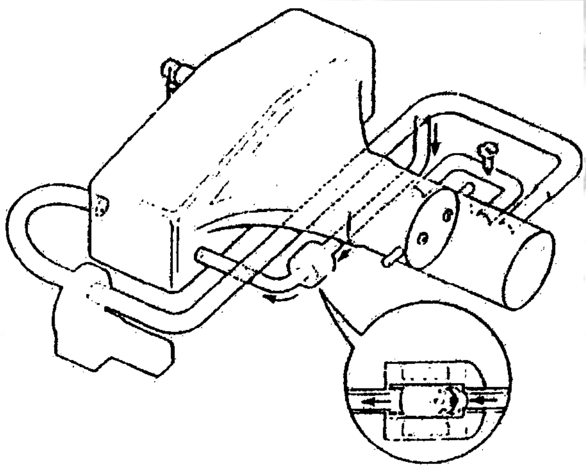


Fig.2.12

VENTILATION SYSTEM VACUUM SUPPLY (Only fitted to vehicles with air conditioning)

On vehicles fitted with air conditioning some of the flaps on the heater/air conditioning unit are operated by Vacuum actuators controlled from a vacuum diverter unit linked to the heater/aircon controls on the centre console.

This vacuum comes from a connection to the rear of the plenum chamber and is stored in a reservoir (VR) fig.2.13, mounted ON the N/S bulkhead.

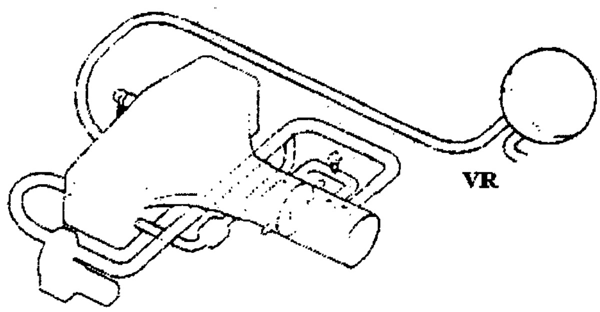


Fig.2.13 Ventilation system vacuum supply
VR Vacuum reservoir

COOLANT CONNECTIONS

For quick warm-up, a manifold hot spot (MH) fig.2.14 is fitted under the plenum chamber intake in the area of the throttle butterfly; the hot spot is heated by coolant passing through hoses (CH) from the engine.

It is important to ensure that the ·hot spot· gasket and bolt threads are smeared with silicone sealant during assembly to ensure coolant cannot leak to the outside, or indeed past the bolt hole threads which break through into the plenum chamber throat.

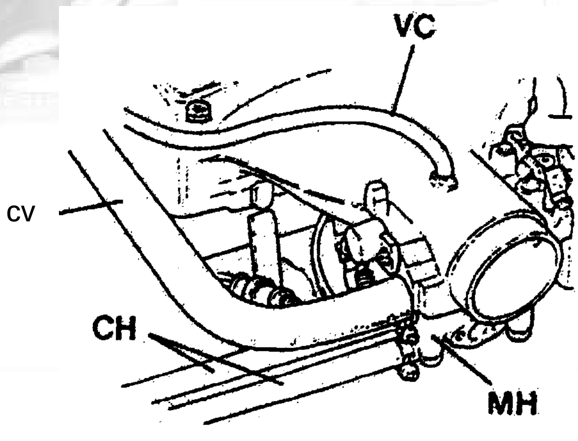


Fig.2.14 Throttle butterfly housing
VC Vacuum advance pipe
CV Crankcase vent pipe
MH Manifold hot spot
CH Coolant hoses

The illustration also shows the vacuum advance pipe connection (VC) on the manifold side of the butterfly and the crankcase vent pipe (CV) on the intake side.

Correct Functioning of the Crankcase Ventilation System is important to the operation of EFI. It is explained next.

CRANKCASE VENTILATION

The crankcase ventilation system is an integral part of the air supply system to the engine, but it is often overlooked when diagnosing problems. An air leak or a blocked pipe in the ventilation system will noticeably affect engine performance.

e.

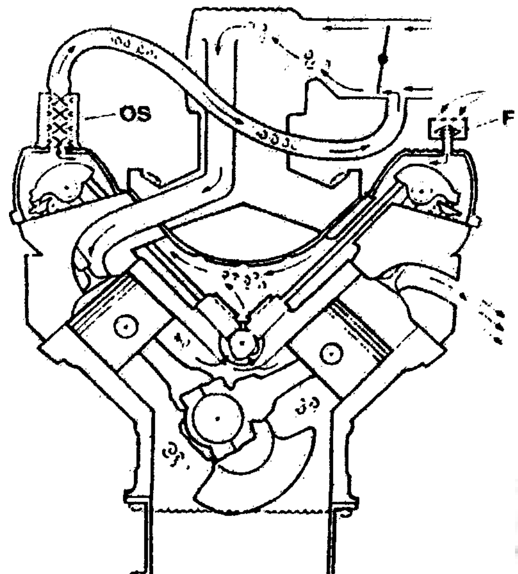


Fig.2.15 Crankcase ventilation system
OS Oil separator
F Filter

The system works as follows:

Air is drawn out of the crankcase by depression felt at the pipe connected to the plenum chamber in the butterfly housing. This pipe connects to the front of the right rocker cover via an oil separator (OS) which is fitted to ensure that lubricating oil is not drawn into the engine inlet. As the impure air is being drawn out to be burnt in the combustion chambers, it is replaced by fresh air drawn in through the filter (F) located on the rear of the left rocker cover (see fig.2.15)

The volume of air taken into the engine in this way bypasses the air flow meter, and therefore must remain a 'constant' amount to maintain the programmed air fuel ratio. Any faults that occur within the crankcase ventilation system will affect the running of the engine. These include:

Air restriction due to blocked filter, oil separator, external pipe etc.

Excess air due to leaking gaskets etc.

OVERRUN VALVE.

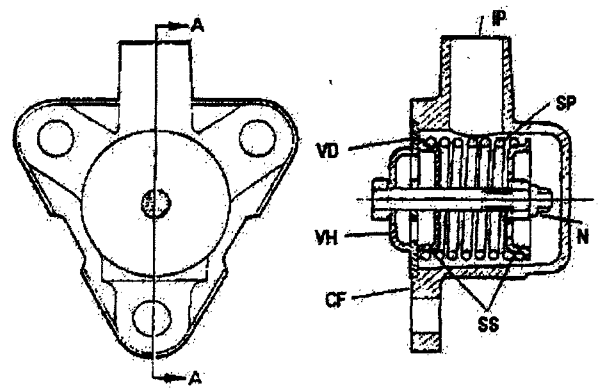


Fig.2.16 Overrun valve
VH Valve head
VD Valve disc
SP Spring
SS Spring seat
N Nut
IP Inlet pipe
CF Connection face to plenum chamber

Mounted on the side of the plenum chamber at the rear of the engine, the connection face (CF) must be airtight.

Sufficient air is provided by this valve during engine-overrun conditions to ensure good combustion.

This is necessary because the very nigh vacuum during rapid deceleration of the engine causes any residual fuel condensed on the inlet manifold and plenum chamber walls to evaporate and create an over rich mixture.

The pressure differential acting on the valve head (VH) compresses the spring (SP) centralised by the spring seats (SS). Thus, the head moves away from the valve disc (VD) which is trapped by the connection faces.

This allows air to pass from the air rail into the inlet pipe (IP) and through the valve into the plenum chamber to optimise the combustible mixture (see fig.2.16).

A nut (N) adjustment controls the spring tension, which is preset during manufacture and should not be altered. However if it has been disturbed, acceptable conditions can be restored with the nut approximately 5 turns out from fully closed.

Having explained the fuel air and crankcase ventilation systems, we now look at the operation of the electrical sensors, which provide the information by which components carry out the commands of the ECU.

PART 3

ELECTRICAL FUNCTION & CIRCUIT OPERATION

Before examining the operation of the electrical system in the various modes, the following is a brief description of the components.

Electronic Control Unit (ECU)

The ECU is of course the 'brains' of the EFI system, it is located inside the vehicle, under the carpet in the front passenger footwall and its principal function is to determine how much fuel should be injected for any given set of circumstances and conditions.

These circumstances and conditions are monitored by the various sensors, which provide the ECU with information so that it can compute the injector 'open time' and thus the quantity of fuel injected.

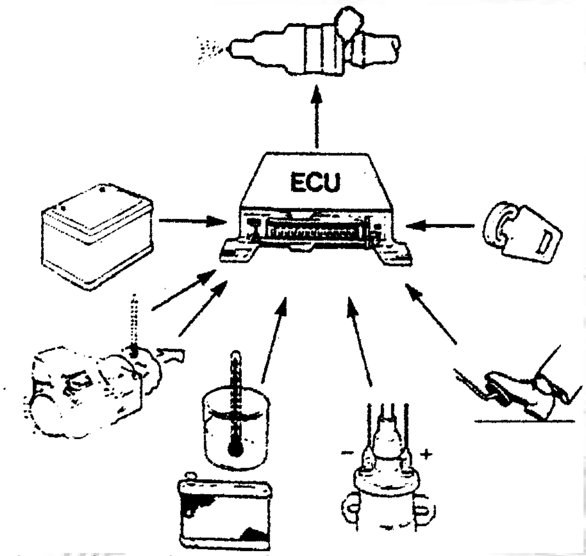


Fig.3.1 Electronic Control System

Clockwise in flg.3.1, Information is supplied to the ECU from:

- Ignition key position - to detect engine-cranking duration.
- Throttle position. to interpret driver's accelerator movement.
- Distributor. to give engine speed.
- Coolant temperature sensor. to calculate cold start and warm up fuelling requirements
- Air temperature sensor. located in air flow meter.
- Inlet airflow. to calculate volume of air entering engine
- Battery voltage.

Air Flow Meter

The air flow meter contains three separate electrical systems as seen in fig.3.2.

ATS Air temperature sensor

This air temperature sensor employs a silicon element to detect changes in temperature, and is located in the intake air stream. Current passing through the element causes it to be warmed and, as the temperature rises, the resistance of the element decreases. The volume of air entering the intake will cool the element and the change in resistance value is fed to pin 27 of the ECU.

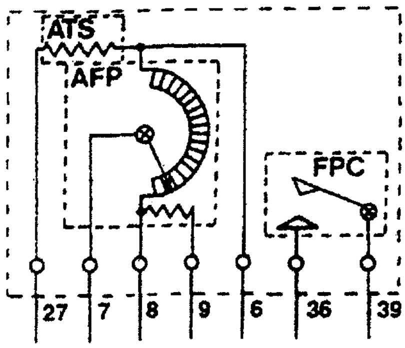


Fig.3.2 Air flow meter (AFM)
ATS Air temperature sensor
AFP Airflow potentiometer
FPC Fuel pump contacts

AFP Air flow Potentiometer

The potentiometer wiper is connected to the flap spindle in the air flow meter. When the spindle turns, the wiper moves across the resistor to vary the voltage. In this way flap movement is sensed and the appropriate voltage signal sent to pin 7 of the ECU.

FPC Fuel Pump contacts

The contact points are closed mechanically by a 5° movement of the flap during cranking.

This allows current to flow from the main relay, through terminals 39 and 36 of the air flow meter via the closed contact points, through. the left hand diode of the steering module to the fuel pump relay windings shown in flg.3.5

Throttle Potentiometer

The throttle potentiometer (TP) is connected to the spindle of the throttle butterfly. Its purpose is to advise the ECU of the driver's accelerator pedal position and its rate of change. It works in the same way as the air flow meter potentiometer.

When the throttle is operated, the wiper moves over the resistance to vary the voltage (see fig.3.3).

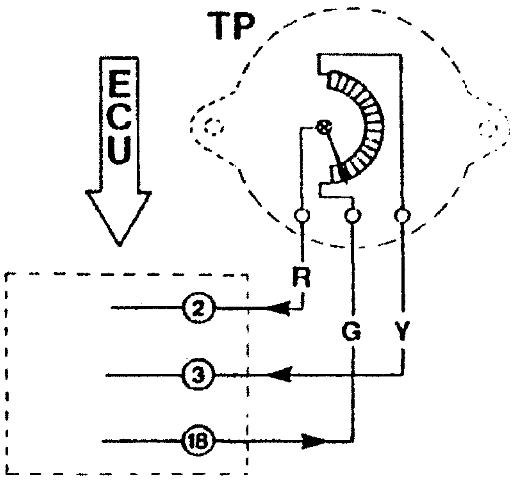


Fig.3.3

The ECU detects the rate of change of the voltage across the potentiometer connections (pins 2, 3 & 18), and when appropriate, triggers the acceleration enrichment circuits. At full throttle the ECU detects the appropriate signal to provide full load fuel enrichment.

The position of the throttle potentiometer is adjustable (see part 4).

Thermo time Switch

The thermo time switch is fitted to time the operation of the cold start injector (CSI); it is located in the coolant gallery at the left front of the inlet manifold. It must not be confused with the coolant temperature sensor fitted alongside it, but slightly to the rear.

The thermo time switch (TT) seen in fig.3.4 contains a pair of contact points; one of which is mounted on a bimetal strip. A heater coil is fitted around the bi-metal strip.

This cold start system is under the control of the ignition switch (1S) it can only operate when the ignition is in the 'crank' position.

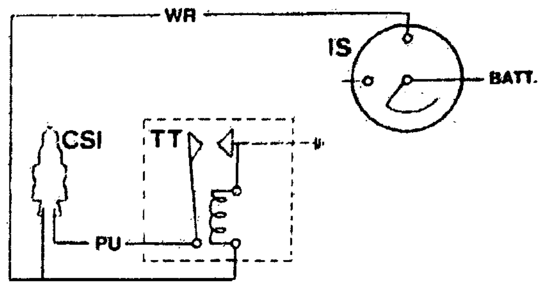


Fig.3.4 Thermo time switch
CSI Cold start injector
TT Thermo time switch
IS Ignition switch

When it can operate, the thermo time switch ensures that:

a. The injector does not operate at all if the coolant temperature is greater than 35°C.

b. The injector operates only up to a maximum of 12 seconds to avoid flooding, and the time depends on coolant temperature. In other words the injector only operates for the maximum 12 second period in temperatures of - 20°C; warmer than this and the operating time gets proportionally less.

In the cold condition the contacts are closed; current is fed from the white/red wire through the injector, and then through the bi-metal strip and contacts of the thermo time switch to earth, thus, the injector will operate. The bi-metal strip is sensitive to ambient temperature, and if the ambient is already above 35°C the contacts wilt be open and the injector win not operate.

The other connection from the white/red wire passes current through the heater element of the switch; it raises the temperature of the bi-metal strip until after a maximum of 12 seconds· it will break the contact and the injector will cease to function.

Steering Module (Diode Pack)
Main Relay
Fuel Pump Relay

These three components are located together inside the vehicle behind the front passenger glove box; they all work in conjunction with one another.

A white wire from the ignition switch takes current through the right diode in the steering module (terminals 4 to 1) seen in fig.3.5. From there it connects to terminal 85 of the main relay, through the relay windings to close the contacts. Current can now pass to the air flow meter, the ECU pin 10, and to the power resistors to supply the injectors.

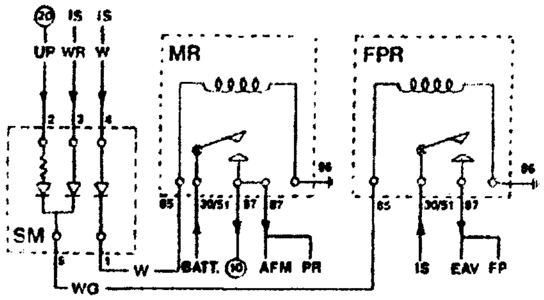


Fig.3.5

SM	Steering module (Diode Pack)
MR	Main relay
FPR	Fuel pump relay
BATT	Battery
IS	Ignition switch
FP	Fuel pump
EAV	Extra air valve
AFM	Air flow meter
PR	Power resistors

Similarly the fuel pump relay is activated by the steering module. In the cranking mode current reaches the steering module terminal 3 via a red/white wire and, in the run mode, to terminal 2 via a blue/purple wire. This current passes out of the steering module at terminal 5 to the fuel pump relay terminal 85; the relay windings are energised to close the points and operate the fuel pump.

Extra Air Valve

The extra air valve (EAV) contains a heating coil (see fig.3.6) which, when heated, causes a bi-metal to close off the air valve progressively

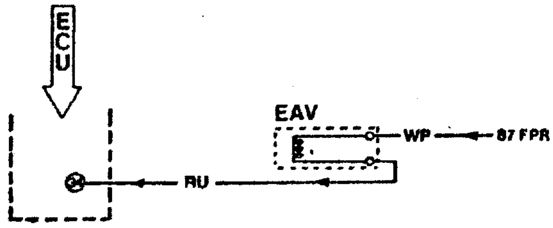


Fig.3.6

The heating coil is connected between terminal 87 of the fuel pump relay and pin 34 of the ECU. Therefore when the fuel pump is operating, current is also passing through the heating coil and, once the valve has closed after warm-up, the heat will continue to ensure that it does not open again until it has cooled.

Coolant Temperature Sensor

This sensor is located in the coolant gallery at the left front of the inlet manifold; it must not be confused with the cold start thermo time switch fitted alongside, but slightly to the front. Its function is to advise the ECU of coolant temperature changes.

The coolant temperature sensor (CTS) seen in fig.3.7 is connected to pin 13 and earth pin 35 of the ECU. It operates in a similar way to the air temperature sensor in the air flow meter, using a silicon element to signal the ECU of changes in resistance, and therefore temperature, so that the ECU can compute the correct injector 'open time'.

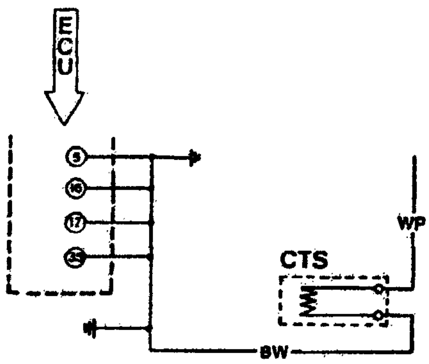


Fig.3.7 Coolant temperature sensor (CTS)

Power Resistor Pack

This pack is attached to a bracket on the NIS inner wing forward of the suspension turret and its purpose is to reduce voltage to the injectors from 12 volts to 3 volts when open.

Injectors

The injectors that inject fuel into the engine are opened by internal solenoids. Current comes from the ignition switch and Main Relay (MR) terminal 87 via two resistor modules inside the Power Resistor pack (PR) (fig.3.8). Current is available when the ignition is turned on.

However the circuitry is not complete until the current is earthed by the ECU. To achieve this the engine must be either cranking or running and the engine speed signalled via the (WB) wire and ballast resistor (BR) to Pin 1 of the ECU, which is programmed to operate each cylinder bank of injectors twice per cycle by providing an earth for the circuits.

The circuits for injectors 1, ~, 5 & 7 are earthed by the ECU via pins 15, 33, 32 & 14, whilst Ine· circuits for injectors 2,4,6 & 8 are earthed via pins 31,30,29 & 28

Fig.8 Injector circuit
IS Ignition switch
D Distributor
C Coil
MR Main relay
PR Power resistor packs
BR Ballast Resistor
1- 8 Injectors 1- 8

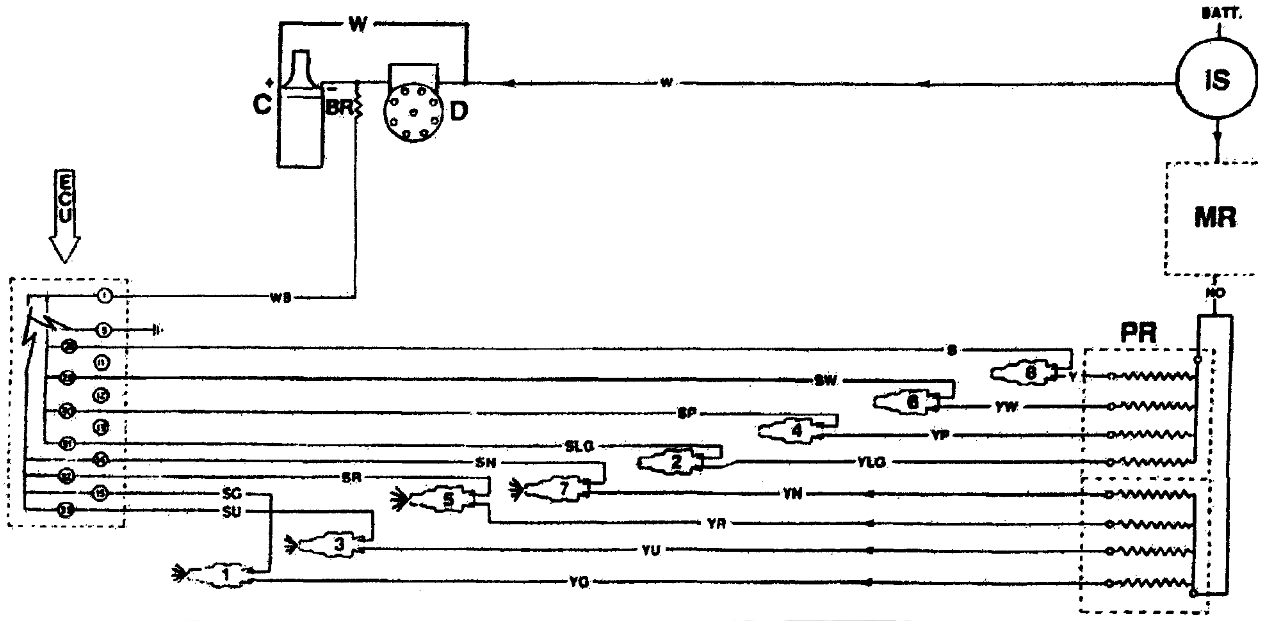


Fig.3.8

ELECTRICAL CIRCUIT OPERATION

Key to all the following circuits - figs. 8 through 13

BATT	Battery
IS	Ignition switch
D	Distributor
C	Coil
FP	Fuel pump
TT	Thermo time switch
CSI	Cold start injector
AFM	Air flow meter
TP	Throttle potentiometer
ECU	Electronic control unit
SM	Steering module
MR	Main relay
FPR	Fuel pump relay
1-8	Injectors
CTS	Coolant temperature sensor
EAV	Extra air valve
PR	Power resistors
BR	Ballast Resistor

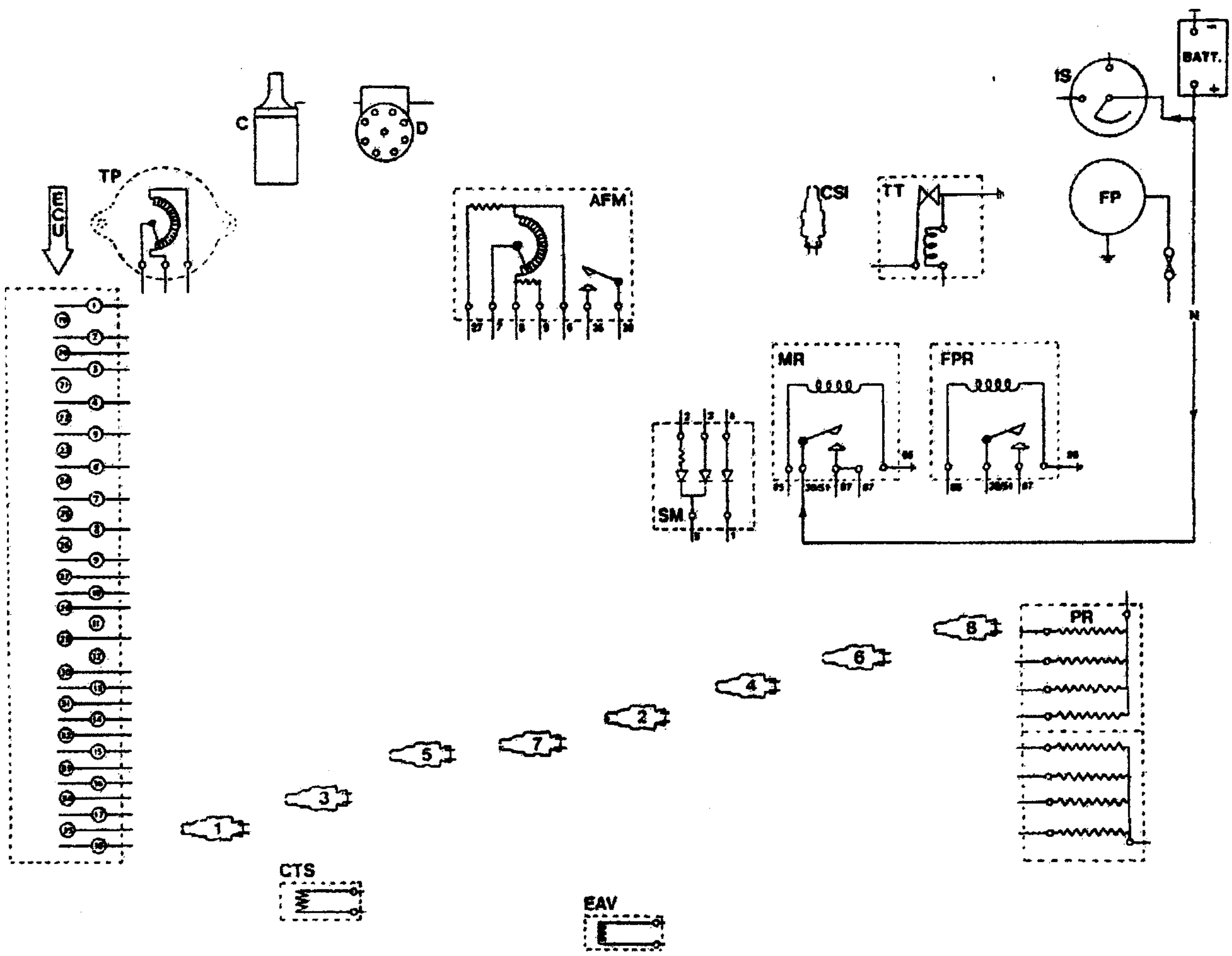
Wiring colour codes

B	Black
U	Blue
N	Brown
G	Green
O	Orange
P	Purple
R	Red
W	White
Y	Yellow
S	Slate
P	Pink
LG	Light green

The last letter of a colour denotes the tracer

Ignition off (fig.3.9)

b.



In the mode shown in Fig.3.9 the ignition is turned off and the engine is cold.

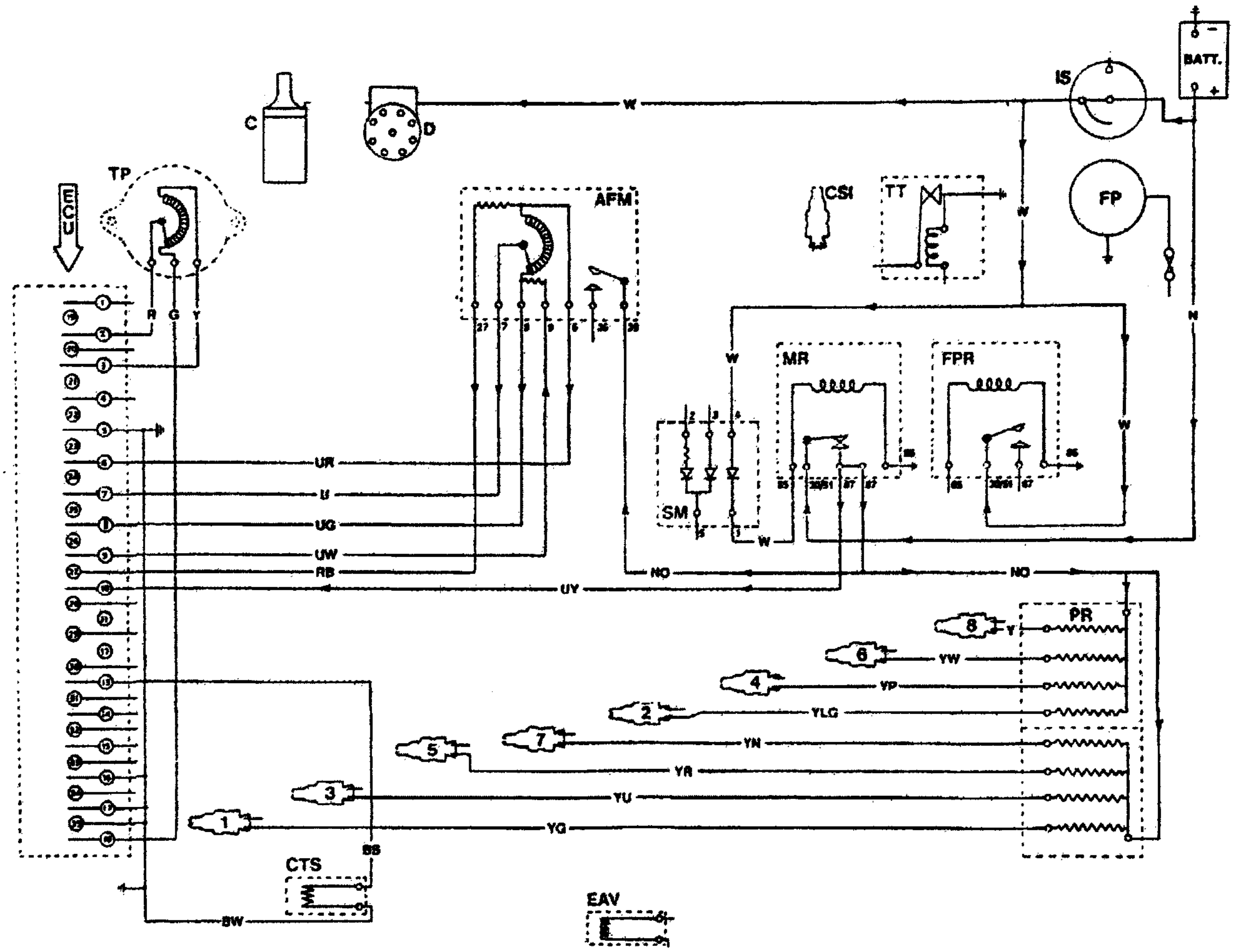
It can be seen that voltage is supplied to the brown wires (N) from the battery to the ignition switch and to the main relay (MR) terminal 30/51.

At this stage the mechanical contacts that are open are:

Air flow meter (AFM) Main relay (MR)
Fuel pump relay (FPR)

However thermo time switch contacts (IT) are closed (assuming the coolant temperature is below 35°C).

Ignition on fig.3.10)



In the mode shown in fig.3.10 the ignition has been turned on (cold engine) but cranking has not started.

There is now a feed through the white wire (W) to the distributor (D) but as the distributor is not turning there is no outward signal.

There are also supplies as follows:

White (W)
To the fuel pump relay (FPR) terminal 30/51. However the contacts are still open so the pump cannot operate.

White (W)
Through terminals 4 & 1 of the steering module (SM) to the windings of the main relay (MR) terminal 85/86 causing the contact points to close.

Because the main relay contacts are now closed, current can pass through the main relay to:

Blue yellow (UY)
To terminal 1 0 on the ECU. This is the main feed to the ECU to switch on the ECU circuits.

Brown/orange (NO)
To the two power resistors (PR) to alert the injectors.

Brown/orange (NO)
To the mechanical contacts on the air flow meter spindle (AFM).

The circuits through the ECU are:

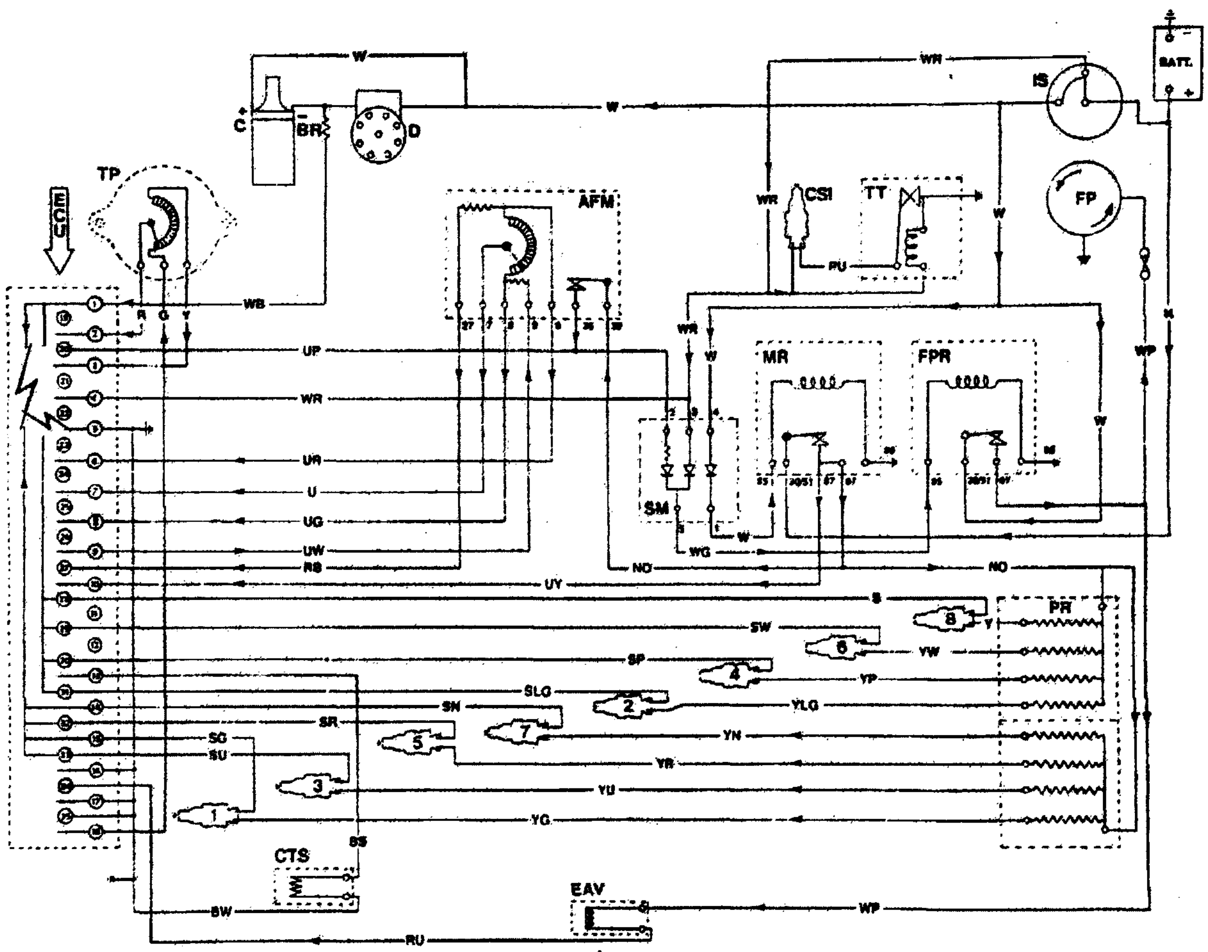
Pins 2 and 3. From the throttle potentiometer (TP).
Red (R) and yellow (Y) wires.

Pin 18. To the throttle potentiometer.
Green wire (G).

Pins 6, 7, 8, 9, and 27. To the air flow meter.
Blue/red (UR) to terminal 6.
Blue (U) to terminal 7.
Blue/green (UG) to terminal 8.
Blue/white (UW) to terminal 9.
Red/black (RB) to terminal 27.

Pin13. The coolant temperature sensor (CTS).
Black/slate (BS) to sensor.
Black/white (BW) to earth and pin 5.

Cranking (fig).3.11)



In the mode shown in fig 3. 11 the engine must be able to start. Therefore circuits become operational to the fuel pump, injectors, ignition, cold start injector and extra air valve.

A white/red wire (WR) supplies the following:

- Pin 4 of the ECU
- The thermo time switch (TT)
- The cold start injector (CSI)
- Terminal 3 of the steering module (SM)

Steering module terminals 3 - 5 actuates the following:

White/green (WG)
To the fuel pump relay (FPR) terminal 85.

White/purple (WP)
From the fuel pump relay terminal 87 to fuel pump; the fuel pump now operates.

White/purple (WP)
From the fuel pump relay terminal 87 to the extra air valve (EAV). The extra air valve signals the ECU terminal 34 via a red/blue wire (RU).

Because the engine is now cranking, the distributor will be turning; current will signal pin 1 of the ECU via the white/black wire (WB) from terminal 87. This signal provides the engine speed information.

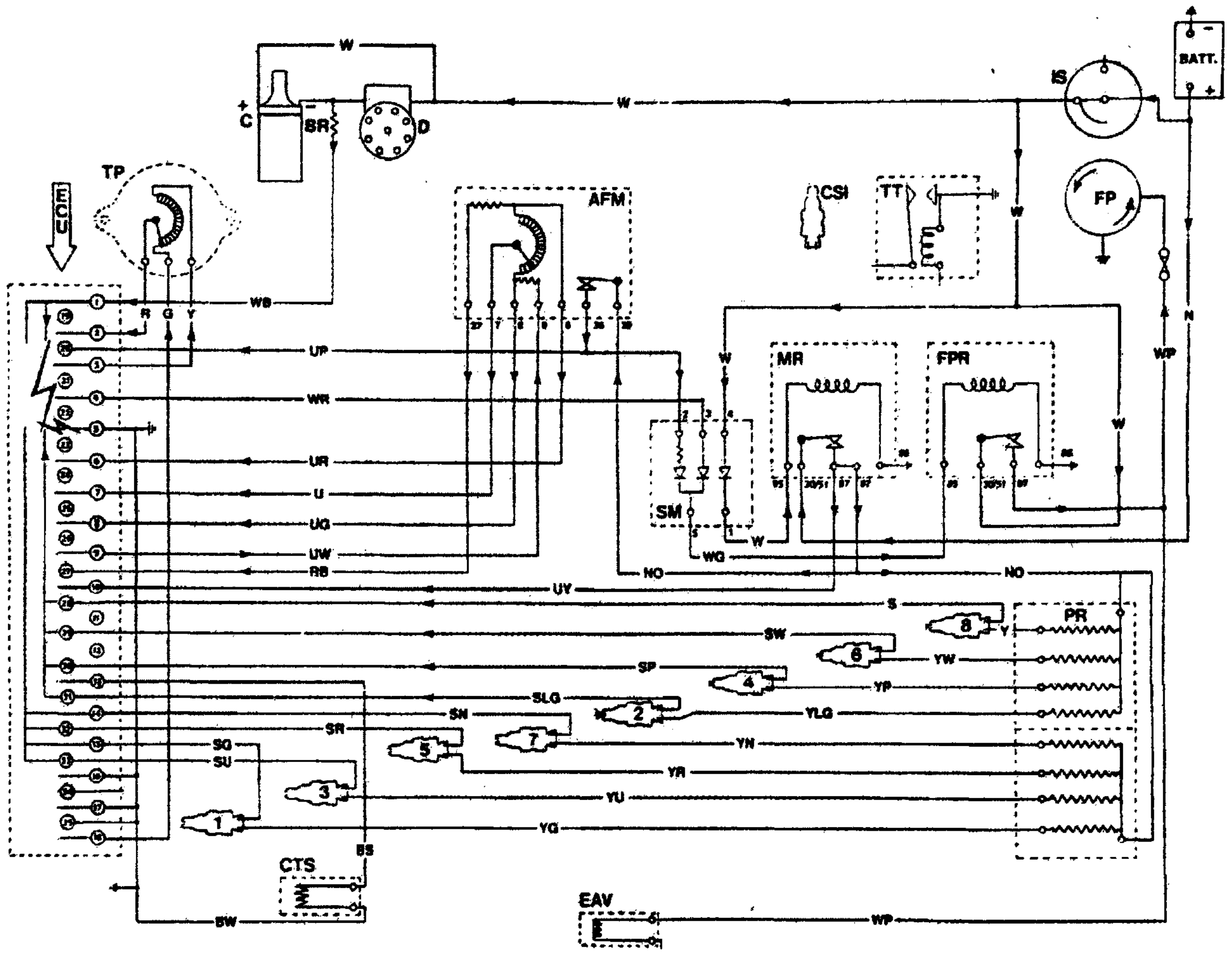
Pin 1 of the ECU triggers the injector circuits by providing an earth as previously described.

Air is now being drawn into the engine through the air flow meter (AFM) and therefore the air flow meter contacts (FPC) will close mechanically.

Current can now pass from the main relay terminal 87 via a brown/orange wire (NO), through the closed points of the air flow meter terminals 36 and 39 to the ECU pin 20 via a blue/purple wire (UP).

The same terminal (39) at the air flow meter provides a secondary feed to the steering module terminal 2, also via a blue/purple wire (UP).

Engine running (fig. 3.12)



In the mode shown in fig 3.12 the engine has started and therefore the ignition key switch has been released from the cranking position to the on/run position.

Current is no longer supplied to the centre terminal (3) of the steering module because there is no longer a feed via the white/red wire from the ignition switch.

Instead current is supplied from pin 36 of the AFM through the blue/purple wire (UP) via terminals 2 - 5 of the steering module.

This supply now keeps the pump relay closed and the pump supplied with current.

Because the engine is running the cold start circuit is no longer live.

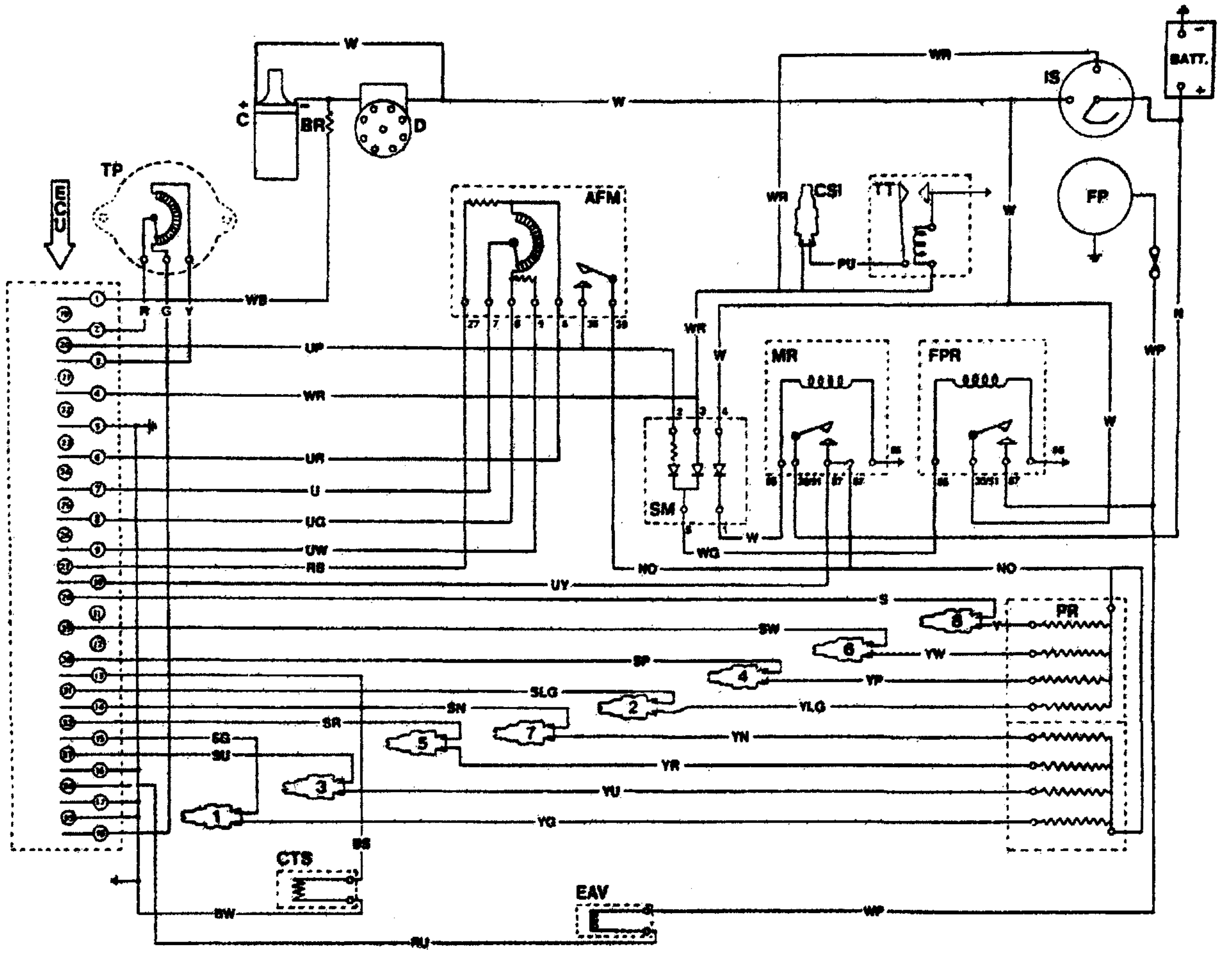
As the engine warms up, the extra air valve (EAV) will progressively close and reduce the supply of extra air to the manifold.

The coolant temperature sensor (CTS) informs the ECU via terminal 13 of the progressive increase in coolant temperature, and the ECU reduces the injector 'open' time accordingly.

When the engine has reached 60 - 70°C, the extra air valve will be closed and the injectors will be supplying a reduced fuel requirement for that condition.

The injectors will now supply fuel in quantities dictated by the ECU in response to signals from the throttle potentiometer (i.e. accelerator pedal position), and airflow and temperature as sensed by the air flow meter.

EFI Wiring Diagram (fig3.13)



Key to all the previous circuits - figs. 3.8 through 3.13.

BATT	Battery
IS	Ignition switch
D	Distributor
C	Coil
FP	Fuel pump
IT	Thermo time switch
CSI	Cold start injector
AFM	Air flow meter
TP	Throttle potentiometer
ECU	Electronic control unit
SM	Steering module
MR	Main relay
FPR	Fuel pump relay
1-9	Injectors
CTS	Coolant temperature sensor
EAV	Extra air valve
PR	Power resistors
BR	Ballast Resistor

Wiring colour codes

B	Black
U	Blue
N	Brown
G	Green
O	Orange
P	Purple
R	Red
W	White
Y	Yellow
S	Slate
P	Pink
LG	Light green

The last letter of a colour denotes the tracer

This completes the description of the electrical circuit operation and we now move on to study tune-up adjustments and diagnosis.

PART 4

APPROACHING A TUNE UP

There seem to be two ways in general that a tune up is approached.

Approach number 1 is to assume that plugs, air and fuel filters are OK, and all that is necessary is to connect one or two instruments, turn a few screws, adjust this that and the other and the job is done.

Approach number 2 is to clean or renew plugs, fuel, air, and crankcase ventilation filters, connect one or two instruments, turn a few screws, adjust this that and the other and the job is done.

Approach number 1 is likely to develop into a complete fiasco, as you discover one thing wrong after another, i.e. blocked filters, burned out plugs, etc.

Approach number 2 might work quite welt in some instances, but can still develop into a problem job, particularly if the operator has little knowledge of the systems he is dealing with.

Then there is the correct way to approach a tune up

In fact it is often very difficult to decide where a 'problem job' ends and a 'tune up' begins. However, when you decide to carry out a tune up, you must first have a reasonable understanding of the operation of the systems involved. Without such knowledge it is impossible to diagnose what is wrong or how to put it right. It is also reasonable to assume that the reader is able to use basic workshop tools and instruments.

Thus the following instructions are designed to assist the user by adopting a systematic procedure to diagnose, and rectify the most commonly encountered problems associated with tuning, poor starting and poor performance.

Engine Tuning Preparation Procedure Including Preliminary Checks & Adjustments

The first checks are so obvious they are often overlooked; the following questions should be asked.

A Is there petrol in the tank?
B Is the tank ventilation system in order?
C Are the inlet air or fuel filters blocked?

Incidentally the above presupposes that the engine will crank.

If it will not crank refer to the section of the Workshop Manual, which deals with the starter motor and associated circuitry.

Assuming the engine attempts to start or run

- Is the battery fully charged (slow cranking)?
- Do all cylinders have good compressions (Refer to Workshop Manual for data)?
- Is the distributor timing reasonably accurately set?
- When NO.1 piston is at TDC compression stroke, does the distributor rotor arm point to No. 1 plug lead in the distributor cap as seen in Fig.4.01?
- Are the distributor leads connected in the correct sequence and correctly routed (Note the separation for Nos. 5 and 7 cylinders in particular, as these will cause cross firing if incorrectly routed)?

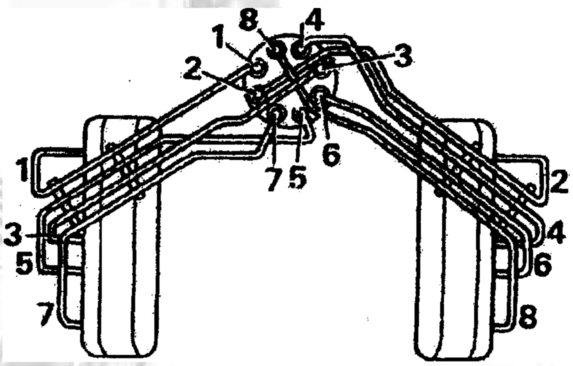


Fig.4.01 Plug lead routing.

- Is the crankcase ventilation system in good order? (See section on Crankcase Ventilation)
- Are all the inlet manifold joints and pipe connections to the plenum chamber secure?

<u>IF ALL THE ABOVE CHECKS APPEAR SATISFACTORY. DO NOT ASSUME THAT THE ELECTRONICS IS FAULTY AS IT IS EXTREMELY RELABLE. THE FAULT IS MOST LIKEL Y ELSEWHERE</u>

The next items to check are the throttle pedal/cable adjustments; throttle butterfly, throttle quadrant and levers, and throttle potentiometer.

Throttle Pedal and Cable

Before attempting any adjustments to the throttle system, first check that full movement of the throttle pedal is not restricted by:

a. Lack of lubrication of the cable.
b. Incorrect pedal adjustment.
c. Extra carpeting under the pedal.

Throttle Butterfly Seating

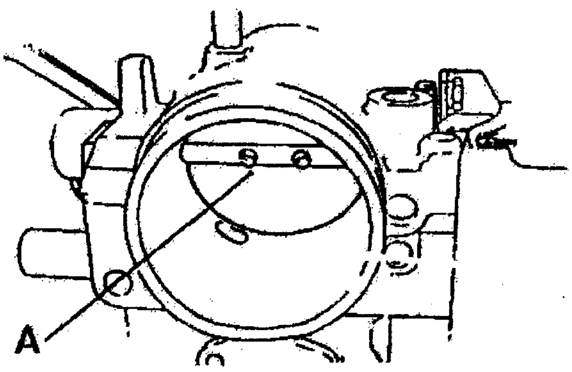


Fig.4.02
A Throttle disc retaining screws

Contrary to the adjustments specified on some other Rover vehicles, the adjustment of the butterfly disc on the Rover SD1 requires zero clearance between the disc and its housing. To ensure this is possible the disc must sit centrally within the housing without binding on either side.

To facilitate this alignment thoroughly clean the disc and housing, then slacken the adjustment screws (A) to allow the disc to centralise on its shaft.
For twin plenum air intake models refer to specific set-up instructions, peculiar to that system.

Carefully tighten the screws to secure the centralised position depress the throttle pedal fully and check that the butterfly opens fully but does not travel over centre.

Throttle quadrant and levers) adjustment

Depending upon whether the vehicle has single or twin plenum air intakes or whether it has a manual or automatic gearbox, or if cruise control is Present will determine exactly what type of throttle quadrants and levers are fitted.

Suffice to say that the quadrant and levers must be adjusted for minimum friction and no interference with adjacent components (refer to Workshop Manual for appropriate adjustments).

Thus when the throttle pedal is depressed and released, it must always allow the butterfly disc to seat itself in the same fully closed position.

Failure to attain this quality of adjustment will result in a condition called idle speed hang up·, whereby the idle speed differs each time the throttle pedal is released and would make many of these tests impossible to carry out.

Throttle Potentiometer

If either, the position of the throttle butterfly, or its linkages, have been disturbed, the throttle potentiometer must also be checked and, if necessary, adjusted as described below.

CAUTION: When making the following adjustment, the meter must be set to volts.

WARNING: The potentiometer may be irreparably damaged if the meter is set to ohms.

To check the adjustment, switch on the ignition, connect the voltmeter between the red and green leads at the potentiometer electrical plug and note the voltmeter reading. It should read 325 ± 25Mv.

If the reading is incorrect, slacken the potentiometer securing screws and rotate the potentiometer one way or the other until the reading is correct. Tighten the securing screws and re-check the voltmeter reading.

At this stage it is assumed that the engine will run. If all the above checks have been carried out correctly, but the engine fails to start easily from a hot or cold condition, it is possibly due to a faulty coolant temperature sensor. In this case it would be necessary to jump to the sensor checking procedure given later in the electrical test section of this guidebook. Other reasons would have to be pursued on their merit.

So, with the engine able to run, proceed as follows:

Check and adjust ignition timing

To check the timing, run the engine until it reaches normal running temperature. Connect a stroboscopic timing lamp and an accurate tachometer to the engine, and disconnect the vacuum pipe from the distributor. If air conditioning is fitted, isolate the compressor by switching the system off.

Start the engine and check the timing on the crankshaft pulley damper at idle. For timing purposes the idle speed must not exceed 600 RPM.

If the ignition timing is outside the tolerance for the model concerned (Refer to Workshop Manual for data) slacken the distributor clamp bolt and rotate clockwise to retard or anti-clockwise to advance to the correct setting. Tighten the clamp bolt and recheck.

Before reconnecting the vacuum advance pipe check the distributor vacuum advance mechanism by sucking on the end of the tube and noting that the mechanism is free to move and that the diaphragm it holds a vacuum.

Check and adjust idle speed

Make sure the engine is fully warmed up before connecting an accurate tachometer to check the idle speed (Refer to Workshop Manual for data).

If the idle speed is incorrect, the idle speed adjustment screw is located in the plenum chamber adjacent to the throttle butterfly. A tamperproof plug may be present, if so, remove it to gain access to the idle speed screw.

Turn the idle speed adjustment screw clockwise to decrease the speed and anti-clockwise to increase it. If the screw makes little or no difference to the idle speed then the throttle by-pass port will be blocked with oil or carbon deposits and must be cleaned out.

Check and adjust Idle CO level

The idle CO level is checked with the engine at normal running temperature; the air cleaner must be fitted and there must be no leaks in the exhaust system.

Make sure the CO equipment is being operated to the manufacturers instructions and that the probe is correctly positioned in the exhaust pipe.

Check the CO level at idle and, if outside the limits specified (Refer to Workshop Manual for data), remove the tamperproof plug, if fitted, and adjust the mixture with the allen headed screw fitted in the air flow meter.

When checking/setting CO level do not allow the engine to idle for longer than 3 mins and give the engine a clear out burst of 30 sees at 2000 rpm, then re-check the CO. If necessary re-adjust the idle speed.

If access to a CO meter is not possible, then the screw can be adjusted to 2.5 turns out from fully home, for an acceptable approximate setting. Fit new tamperproof plugs to complete the job.

If at this stage a problem still exists with engine performance then the preliminary checks should be carefully carried out again before continuing.

DIAGNOSIS & PROBLEM SOLVING

The first task when attempting to diagnose a problem is to find evidence of the possible cause and the obvious place to start is with the spark plugs.

So, remove the plugs keeping them in strict cylinder order left bank 1357, right bank 2468. You will recall that the injectors operate in banks, so the colour of each cylinder bank of plugs should now be compared with following chart:

Condition	Plug colours	
	Left bank	Right bank
A	Grey	Grey
B	White	White
C	Black	Black
D	{Black	Grey}
	{Grey	Black}

A = No obvious problem with air or fuel systems.
B = Excessive air or insufficient fuel.
C = Excessive fuel or insufficient air.
D = Excessive fuelling one bank only.

Analysis

Condition A

Grey is good, so this indicates a fault elsewhere in the ignition system, plug lead condition or routing, timing, centrifugal or vacuum advance.

Condition B

Suggests that air is leaking into the inlet system due to a faulty air valve (air con. or cold start) or by way of one of the many connections to the manifold. Less likely is a fault with the air flow meter or electrical system.

Condition C

Given that the air filter and hose connections are sound, the obvious choice is the fuel regulator (high fuel pressure), or it may be the thermo time switch or coolant temperature sensor signalling engine cold, when the engine is in fact hot. The final possibility is that the air flow meter is faulty, giving the ECU incorrect information.

Condition D

Over-fuelling on one bank of cylinders is most certainly an electrical fault. This could simply be due to a poor connection, or chafing of the earth wires in the loom to one injector bank causing haphazard injection; or it might be a more serious problem with the ECU.

Rectification

Condition A (Ignition system)

Diagnosis and rectification should be possible by reference to the Workshop Manual or V8 Engine Tuning Training Manual. LSMOO94TM.

Condition B, C & D (EFI system)

Diagnosis and rectification is given in the following air leak, fuel pressure and electrical checks.

Air Leak Checking Procedure

Having carried out the checks/adjustments listed previously, if the engine performance is still not up to standard, then obviously there remains a fault as yet undiscovered. With so many pipe connections to the inlet manifold and plenum chamber it is possible that an air leak is occurring into the manifold, which was not discovered during the preliminary checks. The following procedure therefore is a method of diagnosing the exact location of the air leak, and will also prove if the extra air valve for cold start or the air valve for air conditioning (if fitted) are working correctly.

Begin by disconnecting at the plenum chamber the vacuum pipe to the fuel pressure regulator. Fit a vacuum pump to the pipe and operate the pump to approximately 15 in. Hg. If the vacuum does not hold this will indicate an air leak in either the regulator or the pipe. Rectify as necessary then reconnect to the plenum chamber.

If a Vacuum pump is not available, disconnect vacuum connection pipe from the regulator and examine the pipe to ensure it is totally sound. Then, a simple check for the integrity of the regulator is to refit one end of the good pipe to the regulator and to suck on the open end. If the vacuum generated by sucking does not hold, then the regulator is definitely faulty.

Now thoroughly check the hose connection between the air flow meter and the throttle butterfly housing, ensure that the laminations of the hose have not separated, that there are no holes in the hose and that the hose clips are secure.

Start the engine, allow it to come up to operating temperature and note and record the engine idle speed, using an accurate tachometer. Stop the engine.

Next all air/vacuum related systems connected to the plenum chamber, which could affect performance, must be disconnected, and their attachment pipes at the intake manifold/plenum chamber sealed off with patches of self-adhesive tape (badge tape?) as follows:

1. Disconnect the brake servo, and seal the union connection at the plenum chamber.

2. Disconnect the vacuum connection to the vehicle ventilation system and seal the plenum chamber.

3. Disconnect the extra air valve connection and seal the plenum chamber.

4. Disconnect the air supply to the extra air valve gallery from its connection near the throttle butterfly and seal the port.

5. Disconnect the crankcase ventilation pipe from its connection near the throttle butterfly, and seal the port

6. If fitted, disconnect the hose from the air conditioning air valve, and seal the plenum chamber

7. Disconnect the air supply to the overrun valve and seal the input to the valve.

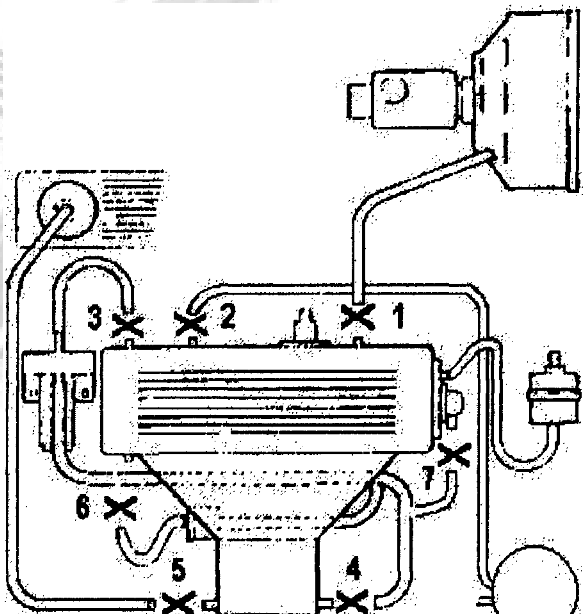


Fig.4.03 Air connections to plenum chamber sealed off.

With the exception of the pressure regulator connection, all the air/vacuum connections at the plenum chamber/inlet manifold have now been sealed off, as illustrated in Fig.4.03.

Start the engine (if necessary depress the throttle pedal to raise the engine RPM) and run it again until normal operating temperature is reached; then allow to idle and check and record the idle speed, and compare with that recorded at the start of these tests.

If there is no change, this proves that all the systems that have been disconnected were all sound originally.

If on the other hand the engine speed has altered significantly (more than 100 RPM), this indicates that one of those systems is faulty and, when reconnected, will cause the engine speed to alter again.

Excessive air leakage into the vacuum connections, or blockage of a permanent air bleed into the inlet system, can cause the engine speed to increase or decrease by as much as 200 RPM or as little as 10 RPM if, for example, the crankcase ventilation oil separator is blocked.

Faults, which cause small changes in engine speed are often overlooked, or are erroneously rectified by readjustment of the idle screw. Over time, these minor faults can build up and interact, so they must not be disregarded when they can be detected and analysed.

So if the RPM has altered, record the engine speeds at this and each subsequent stage. They are required for comparison to enable you to pinpoint which of the disconnected pipes or components is at fault, during the remainder of the tests, as follows:

Brake servo

Begin by unsealing and reconnecting the brake servo pipe (No.1 in fig.4.03), then start the engine and compare with the speed just recorded; if there is a change, a fault lies in the brake servo hose or in the brake servo unit itself. This area can now be investigated and the problem rectified.

Ventilation System

Before reconnecting the vacuum pipe (if air conditioning is fitted) to the ventilation system vacuum reservoir, set the controls to “ON”

Then unseal and reconnect the pipe to the ventilation system vacuum reservoir (No.2 in fig.4.03). Start the engine and check the engine speed; any change indicates an air leak into the vacuum control system.

To isolate the fault, first move the controls to 'OFF' and recheck the engine speed; if it is still affected, you have narrowed the fault down to the vacuum reservoir or the connecting pipes. If the engine speed has been restored to that previously recorded the fault must lie in the vacuum distribution unit or one of the associated vacuum servo units that operate the flaps or their associated pipes.

Extra air valve

The next step is to unseal and reconnect the extra air valve hose at the plenum chamber (No.3in fig.4.03) and check if there is a change in the engine speed.
Assuming that the hose itself is sound, and remember, the inlet hose is open at the throttle end, any change indicates that air is leaking through the extra air valve mechanism into the plenum chamber and therefore the fault lies in the extra air valve itself.

If when the hose is reconnected there is no change in the engine speed then the extra air valve is proved to be sound in respect to air leaks.

Overrun valve

Now unseal the input pipe to the overrun valve (No.7 in fig.4.03) and restart the engine once again. If there is no change in the idle speed then the valve is not leaking.

If the idle speed changes then there is a fault within the valve that must be corrected. A common cause is debris between the valve head and the valve disc preventing the valve from closing properly.

Air conditioning air valve and air rail hoses

Unseal both the air conditioning air valve connection at the plenum chamber (if fitted) and the air hose at the throttle butterfly (No.4 and No.6 in fig.4.03) and reconnect both pipes. Again start the engine and check for any change in engine speed.

If no change is detected this proves that the air hoses and the air conditioning air valve are sound.

If however the speed has changed it means that air is entering the plenum chamber either through the air conditioning air valve and it is this that is faulty, or its associated pipes.

Crankcase ventilation

Unseal and reconnect the crankcase vent (No.5 in fig.4.03) and check the engine speed again. Any change in engine speed will indicate a possible air leak in or around the oil separator or the pipe itself. However, the crankcase ventilation system is complex and interactive with several seals and gaskets, which should be carefully inspected if problems are indicated.

Plenum chamber joints. Injector seals etc

Having checked all the vacuum connections and components there still remains a number of other possible ways in which air can leak into the inlet manifold system. It could leak past the plenum chamber to trumpet housing joint and the trumpet housing to inlet manifold joint, the cold start injector, or indeed past any of the injector seals, or past the manifold gasket.

To check for leaks in any of these more inaccessible areas, start the engine and squirt thin oil (or even WD40) around the mentioned joints, cold start injector and gasket locations in turn; any ingress of oil sucked into the manifold can usually be heard or seen. Repeat the test around all the injectors to ensure each has an airtight seal.

Excessive amounts of oil ingress into the manifold system will be indicated by not only the noise of the oil being drawn in but also by the colour of the exhaust smoke which will change to blue.

As an alternative to using oil a propriety brand of Damp Start lacquer may be applied. It is used when the areas to be sealed are grease fee and dry, and is sprayed from an aerosol around the suspected areas of leakage; forming a plastic latex film which will seal the most inaccessible of leaks into the air inlet system. This form of sealant should be only used when the engine is switched off, as during application it gives off a flammable mixture.

Remember that the cause any air leak discovered using this method would still need to be permanently corrected.

After rectification of any air leaks into the inlet system the idle speed and CO level must be readjusted.

Fuel Pressure Checking

WARNING: Under operating conditions the fuel injection system is pressurised by a· high-pressure fuel pump, operating at 1.8 to 2.5 kg/sq.cm (26 to 36 Ib/sq.In.) When the engine is stationary this pressure is maintained within the system.

To prevent pressurised fuel escaping and to avoid personal injury it is necessary to depressurise the fuel Injection system before connection of the test gauge or any servicing is carried out.

Depressurising the Fuel System

Remove the fuel pump relay located behind the passenger glove box; this will immobilise the fuel pump. Start and run the engine. When sufficient fuel has been used up, the line pressure will drop, and the engine will stall. Switch the ignition off and disconnect the battery.

Fuel at low pressure will still remain in the system. This low pressure can be released by removing the cold start injector from the plenum chamber and then placing the injector with hose still attached into a suitable container. Release the hose clip and carefully remove the hose from the injector to release any remaining pressurised fuel.

Pressure gauge

Connect a suitable pressure gauge to the cold start injector hose. Refit the cold start injector and fuel pump relay, and re-connect the battery.

Testing the Fuel Pressure Regulator

Remove the air filter from the inlet side of the airflow meter, then switch the ignition on and operate the flap in the air flow meter by hand to energise the fuel pump and generate pressure.

Check that the pressure gauge reading is between 2.5 to 2.6 kg/sq.cm (35 to 37lb/sq.in).

Switch off the ignition. The fuel pressure should be maintained between 2.1 to 2.6 kg/sq.cm (30 to 37 lb/sq.in.)

The pressure reading may slowly drop through either the regulator valve or the fuel pump non-return valve. A slow steady drop is permissible; a rapid fall must be investigated.

If the pressure test is unsatisfactory, the most likely cause of the problem is the fuel pressure regulator, which should now be renewed or substituted.

If after fitting a known good regulator and re-testing the system, the pressure continues to fall rapidly the fuel injectors, fuel pump non-return valve, and fuel system pipe-work should all now be checked in turn for leaks until the cause of falling fuel pressure is located.

Depressurise the fuel system again before removing the test gauge.

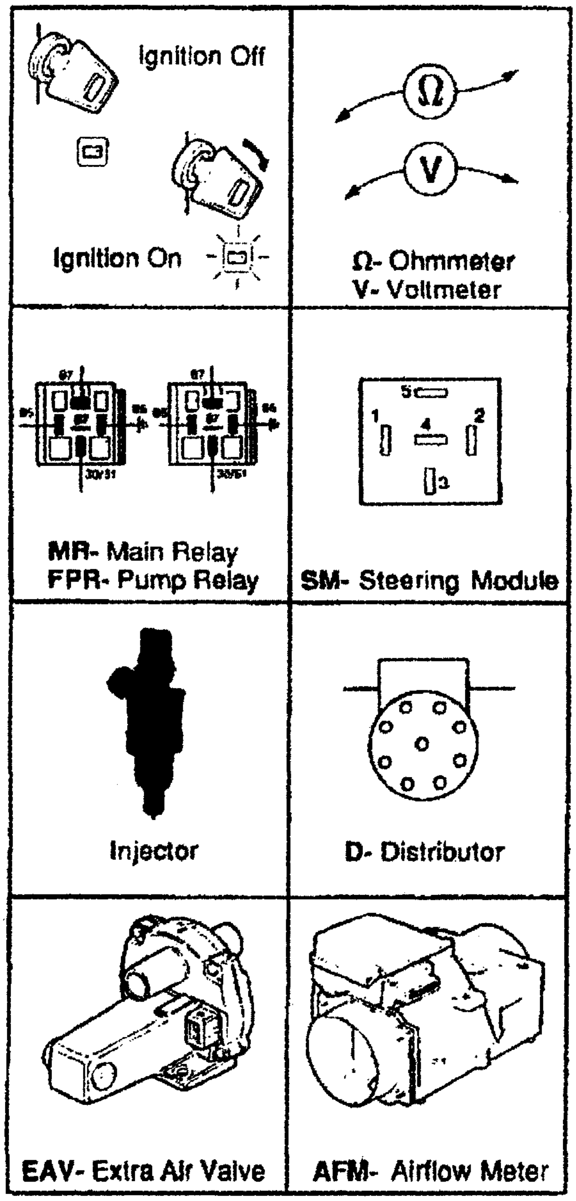
After final reconnection of the pipes recheck for leaks.

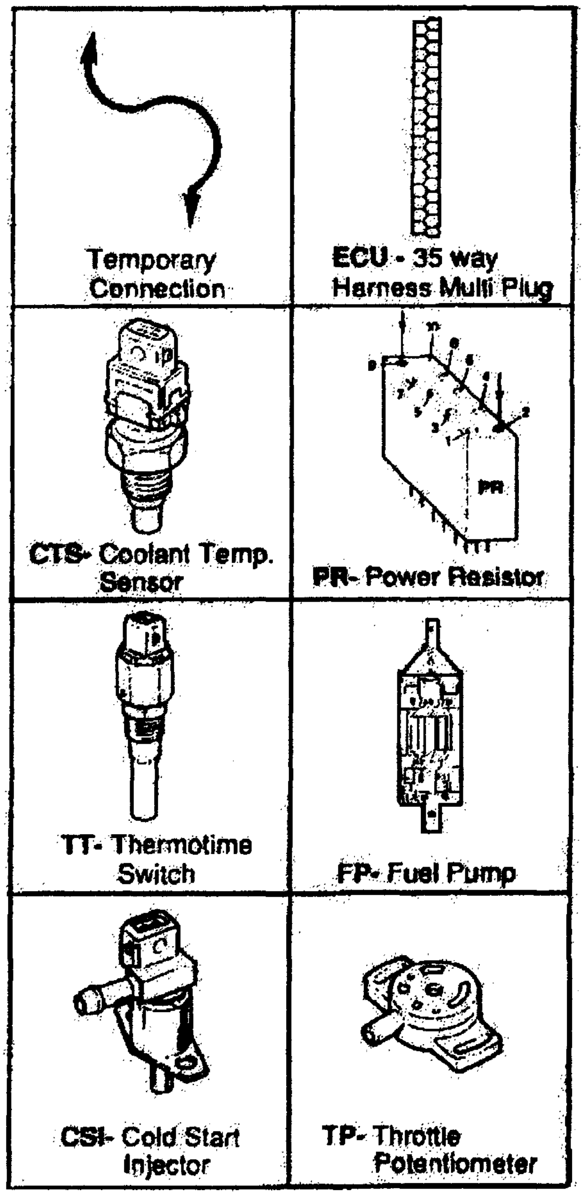
At this stage the problems of ignition and incorrect air fuel ratio and, therefore, plug conditions A, B, & C should be cured. However if problems still persist, gently check by hand that the air flow meter flap is perfectly free, and is fully closed by its return spring when the engine is at rest, before delving into the electrical tests, explained and specified in the next section.

PART 5

ELECTRICAL TESTS KEY TO

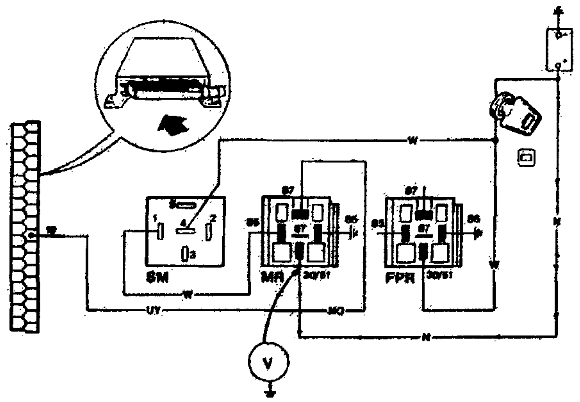
SYMBOLS





- All the following tests are designed to measure and, if necessary, re-establish the correct operating parameters for the individual components in the system
- They are best performed in the sequence shown and great care should be exercised when connecting to the various contacts with multimeter probes to avoid causing electrical short circuits
- The following instructions presume that the user is familiar with basic workshop measuring instruments such as voltmeter, ohmmeter and thermal probe for measuring temperature
- Further, it is presumed that when substitution of a faulty component is indicated in the instructions, then working spares are available for testing purpose rather than purchasing new items that may not subsequently be needed

TEST 1. To check the permanent voltage supply to the main relay



Conditions

- ECU multiplug connected
- Ignition OFF
- Connect voltmeter between terminal 3O/51 of the main relay and earth

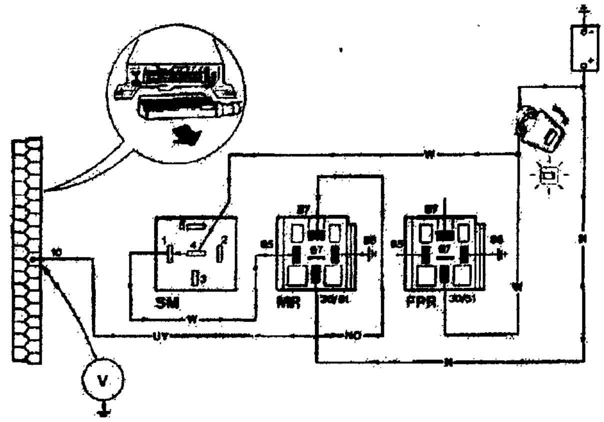
Reading should be 11 to 12.5 volts

If below 11 volts check the following

- Battery state of charge
- Earth connections
- Positive connection to the main relay via the brown wire (N)

If OK continue with Test 2

TEST 2. To check the voltage supply to the ECU via the steering module and main relay



Conditions

- ECU multiplug disconnected
- Ignition OFF
- Connect voltmeter between ECU multiplug terminal 10 and earth

Reading should be zero volts

If voltmeter reads a voltage

- Renew the main relay
- Turn the ignition ON (as shown in the above diagram)
- Main relay should be heard to operate

Reading should be 11 to 12.5 volts

If below 11 volts check the following

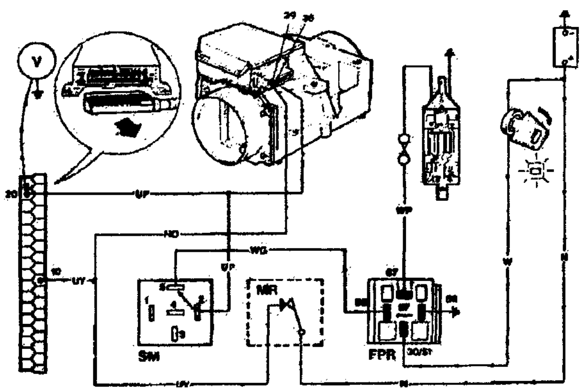
- All white wire (W) connections to the steering module and relays
- Good earth at terminal 86 on both relays
- Good connection of brown/orange wire (NO) at main relay terminal 87
- Good connection of blue/yellow wire (UY) at main relay terminal 87 and ECU pin 10

If still below 11 volts

- Substitute steering module and main relay

If OK continue with Test 3

TEST 3. To check the voltage to fuel pump via air flow meter switch. steering module and fuel Pump relay



Conditions

- ECU multiplug disconnected
- Connect voltmeter between ECU multiplug terminal 10 and earth
- Ignition ON
- Air flow meter flap closed

Reading should be zero volts

- Manually open air flow meter flap
- Listen for fuel pump relay and fuel pump operation
- Voltmeter should read 11 to 12.5 volts

If below 11 volts check

- All wiring and connections shown in Test 3 diagram

If still below 11 volts

- Substitute steering module

If voltmeter reads correctly but relay or pump are not heard to operate

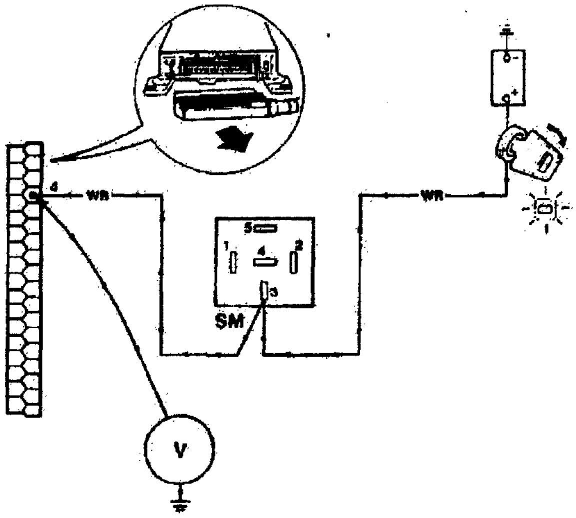
- Substitute steering module and then pump relay

If pump still fails to operate

- Suspect a faulty fuel pump

If OK, continue with Test 4

Test 4. To test cranking voltage and signal circuit to ECU Din 4



Conditions

- ECU multiplug disconnected
- Connect voltmeter between ECU multiplug terminal 4 and earth
- Ignition On and CRANKING

Reading should be 8 to 12 volts

If no reading but starter motor operates, check

- White/Red (WR) wiring
- Connections to ECU pin 4 via the steering module and wiring loom multiplug

If below 8 volts, check

- Battery and starter motor

If no reading and starter motor does not operate, check

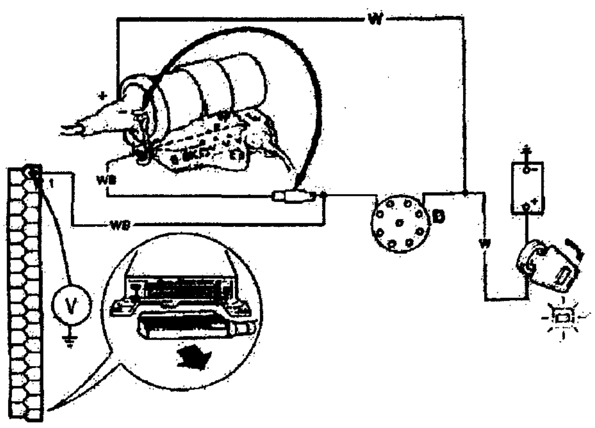
- Black/orange (BO) wiring connections and starter circuit

If OK, continue with Test 5

TEST 5. To check the speed signal circuit

This test varies dependent upon whether the ignition amplifier is fitted separately under the coil (5A) or is mounted on the distributor (5B).

5A - for separate amplifier installation



Conditions

- ECU multiplug disconnected
- Connect a jump lead between the coil negative terminal and the white/black (W/B) lucar connector adjacent to the coil
- Connect voltmeter between ECU multiplug
- terminal 1 and earth
- Ignition ON
- CRANK engine

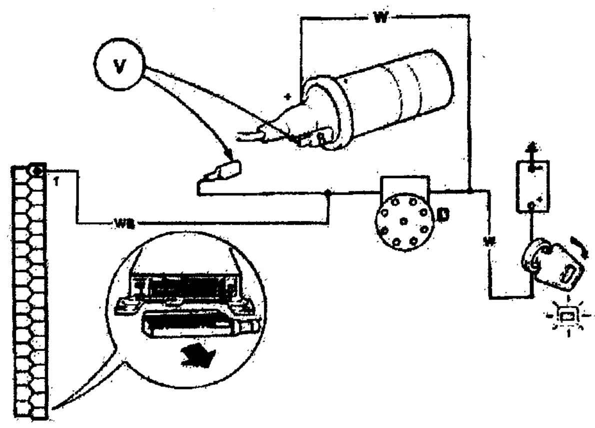
Voltage should fluctuate between 6 and 9 volts

If higher than 9 volts or lower than 6 volts, check

- Electronic ignition system

If OK, remove jump lead and continue with Test 6

5B - for integral amplifier installation



Conditions

- ECU multiplug disconnected
- Disconnect the lucar connector at the coil negative and connect a voltmeter between the resistor and the lucar connector
- Ignition ON
- CRANK engine

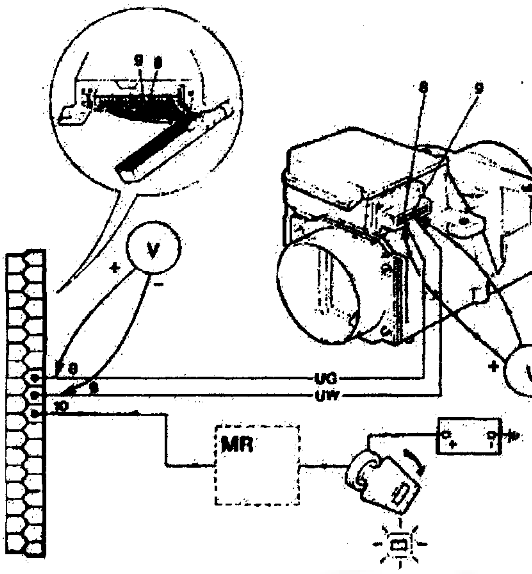
Voltage should fluctuate between 6 and 9 volts if

higher than 9 volts or lower than 6 volts, check

- Electronic ignition system

If OK, restore connections and continue with Test 6

Test 6. To check voltage across resistor wire in air flow meter Potentiometer



Conditions

- To gain access to the ECU terminals with the multiplug fitted, disconnect the multiplug, release its cover and refit the multi plug
- Ignition ON
- Connect voltmeter +ve to ECU multiplug pin 8 and -ve to pin 9
- Air flow meter flap closed

Reading should be 1.55 ± 0.1 volts

If reading is incorrect

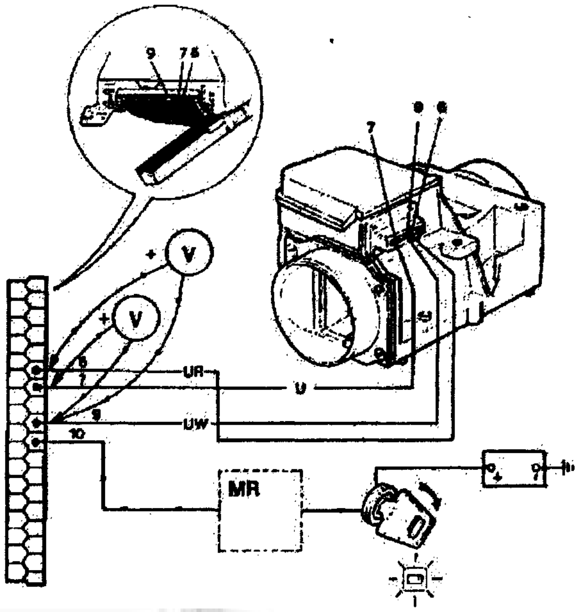
- Peel back rubber boot covering connections at air flow meter and connect voltmeter to terminals 8 and 9

If reading is still incorrect

- Substitute air flow meter

If OK, leave the ECU connections exposed and continue with Test 7

TEST 7. To check voltage through air flow meter Potentiometer and the wiring to the ECU



Conditions

- ECU multiplug connected (cover removed)
- Ignition ON
- Connect voltmeter +ve to ECU multiplug· pin 6 and -ve to pin 9

Reading should be 4.3 ± 0.2 volts

if voltmeter reads 0, check

- All wiring and connections seen in diagram above

Leave voltmeter -ve connected to pin 9 and move voltmeter +ve from pin 6 to pin 7

Reading should be 3.7 ± 0.1 volts

If voltmeter reads low, check

- Wiring for high resistance

With voltmeter still connected to pins 7 & 9, slowly open the air flap

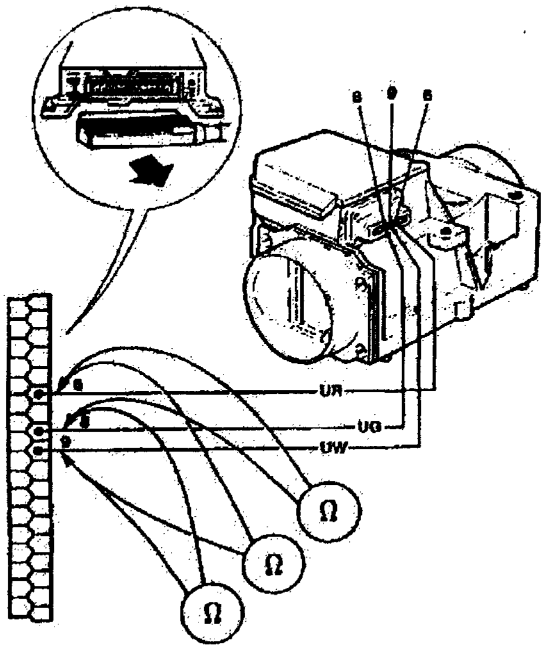
Reading should gradually decrease to 1.6 ± 0.1 volts

If results are not within those specified above

- Renew air flow meter

If OK, refit multiplug cover and continue with Test 8

TEST 8. To check internal resistance (ohms) of air flow meter and wiring to ECU



Conditions

- ECU multiplug disconnected.
- Ignition OFF
- Air flow meter flap closed
- Connect ohmmeter to ECU multi plug terminals

Readings as follows

PINS			OHMS	
• 6 and 8	should	be	360	± 10
• 6 and 9	should	be	560	± 10
• 8 and 9	should	be	200	± 10

(Not K OHMS as shown erroneously in RR Manual)

If readings are incorrect

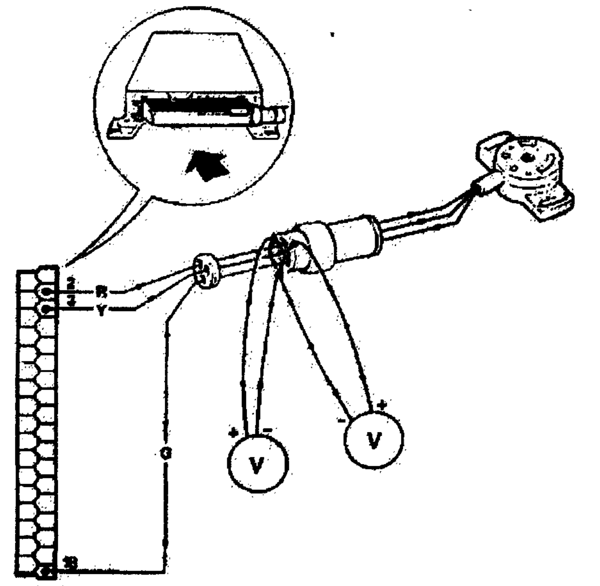
- Peel back rubber boot covering connections at air flow meter
- Repeat the tests at the air flow meter plug
- And then at the air flow meter socket

If readings are still incorrect

- Substitute air flow meter

If OK, continue with Test 9

TEST 9. To check voltage at throttle Potentiometer



Conditions

- ECU multiplug connected
- Ignition ON
- At throttle potentiometer multiplug, connect voltmeter +ve to yellow wire and -ve to green wire

Reading should be 4.3 ± 0.2 volts (ECU control voltage)

- Move voltmeter +ve to red wire

Reading should be 0.325 ± 0.025 volts. (0.30 to 0.35 V)

If zero or low reading, check

- Wiring and connections

If incorrect

Reset potentiometer as follows

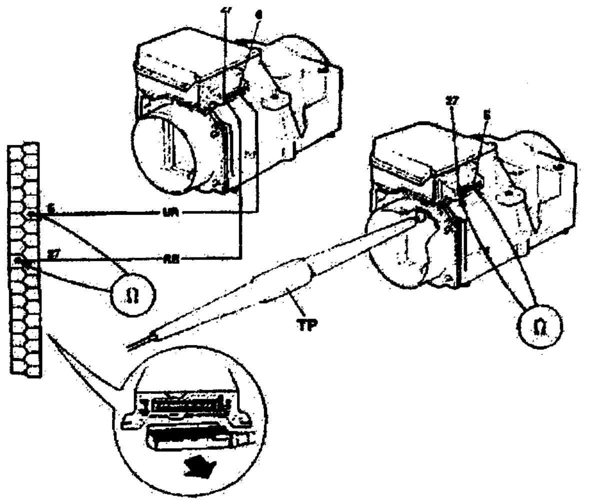
- Slacken potentiometer body retaining screws
- Rotate body in either direction until meter reads 0.325 ±O.025 volts and tighten screws
- Slowly open the throttle; the injectors should be heard to operate and the voltmeter should register a smooth increase up to 4.5 volts maximum

If the recommended voltages cannot be obtained or if the voltage reading is erratic when throttle is opened

- Renew throttle potentiometer

If OK, continue with Test 10

TEST 10. To check resistance of air temperature sensor



When performing this test, connect the ohmmeter for only a short period, as the meter battery may cause the sensor to heat up and give an incorrect reading

Conditions

- Disconnect ECU multiplug
- Ignition OFF
- Remove air filter to gain access to air flow meter inlet
- Check temperature of air sensor using suitable temperature probe (TP)
- Peel back rubber boot to gain access to air flow meter terminals and connect ohmmeter to terminals 6 & 27

Reading should be approximately as follows

TEMPERATURE	K OHMS
- 10°C ± 0.5°C	8.26 to 10.56
+ 20°C ± 0.5°C	2.28 to 2.72
+ 50°C ± 0.5°C	0.76 to 0.91

If readings are incorrect

- Substitute air flow meter and recheck

If the readings are correct

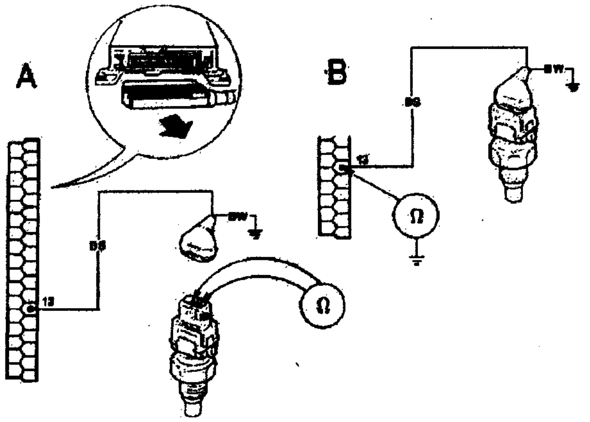
- Repeat the resistance check at the ECU harness pins 6 and 27 to verify continuity

If the readings are incorrect; check

- Red & brown wiring (RB) and connections
- Blue & red wiring (UR) and connections

If OK, continue with Tests 11A and 11 B

TEST 11A and 11B. To check resistance of coolant temperature sensor and continuity to ECU



When performing these tests, connect the ohmmeter for only a short period, as the meter battery may cause the sensor to heat up and give an incorrect reading

Conditions (for Test 11 A)

- ECU multiplug disconnected.
- Ignition OFF
- Measure coolant temperature with thermal probe
- Disconnect temperature sensor electrical socket and connect ohmmeter across sensor terminals

Readings should be approximately as follows

TEMP	OHMS	TEMP	OHMS
-10°C	9100 to 9300	60°C	500 to 700
O°C	5700 to 5900	80°C	300 to 400
20°C	2400 to 2600	100°C	150 to 200
40°C	1100 to 1300		

If the readings are incorrect

- Remove sensor and do controlled test. Suspend in water. Bring to boil. Compare readings to above

If the readings are still incorrect

- Substitute the temperature sensor and recheck

If the readings are correct (continue with Test 11 A)

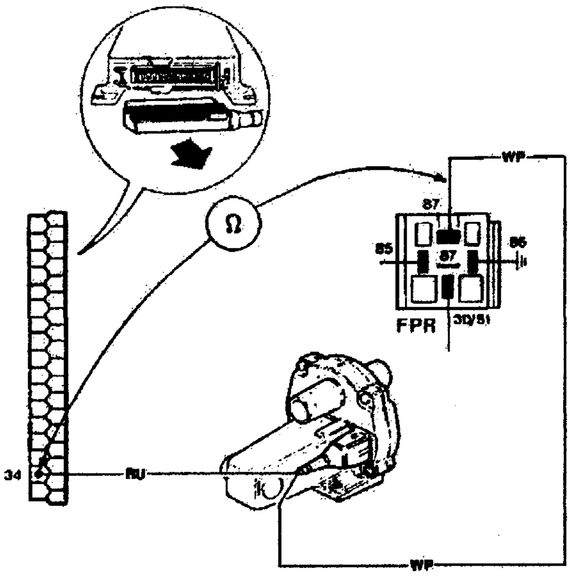
- Reconnect the sensor, and check continuity to the ECU pin 13 and earth

If this reading is incorrect, check

- Black & slate wiring (BS) and connections
- Black & white wiring (BW) and connections
- Pay particular attention to the earthing of the black & white wire (BW)

If OK, continue with Test 12

TEST 12 To check resistance of extra air valve



Conditions

- ECU multiplug disconnected
- Ignition OFF
- Connect ohmmeter between terminal 87 on fuel pump relay and pin 34 on ECU multiplug

Reading should be 30-40 ohms

If reading is outside these limits

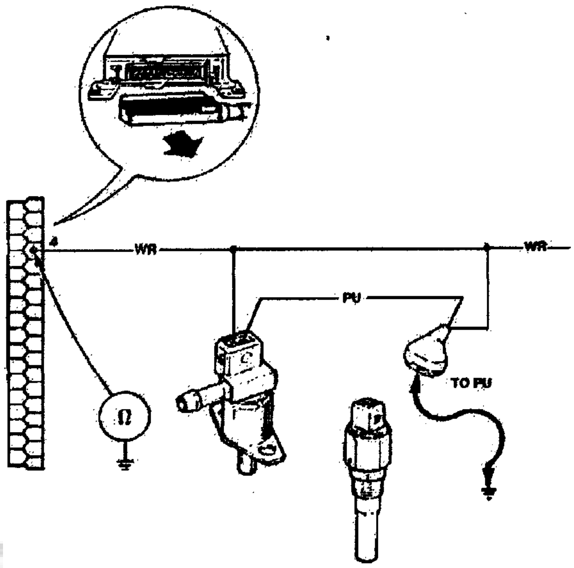
- Renew extra air valve

If meter shows infinity, check

- White & purple wiring (WP) and connections
- Red & blue wiring (RU) and connections
- If necessary connect a substitute extra air valve and recheck reading
- It is easier to connect a substitute air valve than to attempt to connect the ohmmeter to the original valve in situ where access to the terminals is restricted

If OK, continue with Test 13

TEST 13 To check resistance (ohms) of cold start Injector



Conditions

- ECU multiplug disconnected
- Ignition OFF
- Disconnect the thermo time switch, and temporarily connect the purple & blue wire (PU) to a good earth
- Measure the resistance between the ECU multiplug pin 4 and earth

Reading should be 0 to 5 ohms

If the reading is incorrect, check

- The temporary earth for good connections
- White & red wire (WR) and connections
- Purple & blue wire (PU) and connections

If reading is still incorrect

- Disconnect the cold start injector and check its resistance

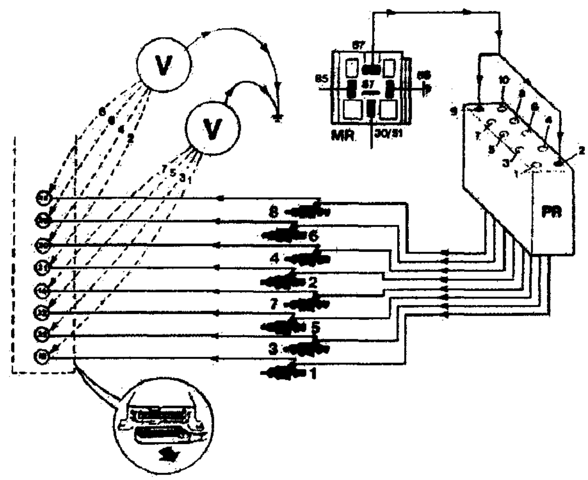
Reading should be 0 to 5 ohms.

If incorrect

- Renew the cold start injector

If OK, continue with Test 14

TEST 14 To check the integrity of the injector solenoids, resistor pack, wiring and ECU connections



Conditions

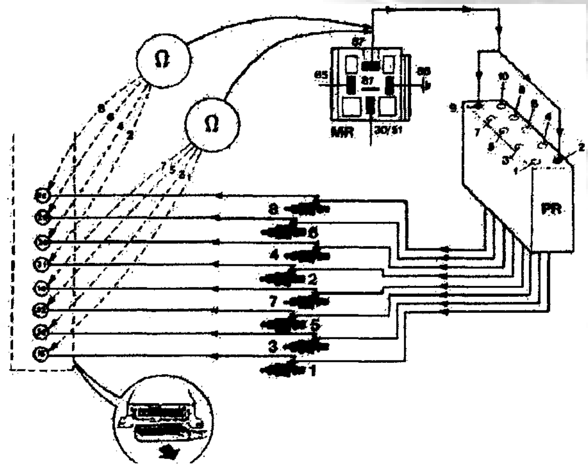
- ECU multi plug disconnected
- Ignition ON
- Connect voltmeter between a good earth (ECU pin 5) and each injector multiplug connector in turn

Readings should be within 0.5 volts of battery voltage

If variation is in excess of 0.5 volt

- Carry out continuity resistance Test 15

TEST 15 To check the continuity and resistance of each Injector and Its resistor



Conditions

- ECU multi plug disconnected
- Ignition OFF
- Connect the ohmmeter between terminal 87 or 87 A on the main relay and each injector multiplug terminal in turn

Reading of 7 to 10 ohms indicates

- No fault

Reading of infinity indicates

- A broken connection or component

Reading of high resistance indicates

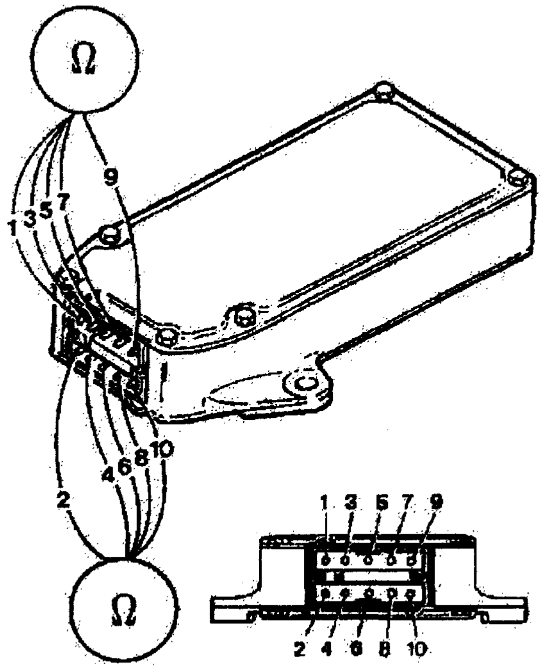
- A poor connection, faulty wiring or a faulty injector or resistor

If a faulty injector or resistor is suspected continue with Test 16

TEST 16 To check resistance of injectors and resistors

These checks are made separately - see Test 16A and Test 168

TEST 16A Resistor Pack test



Conditions

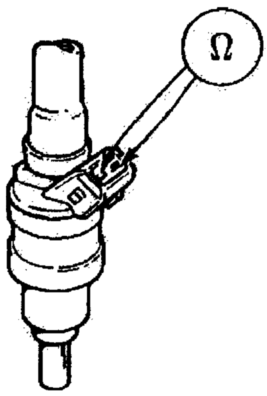
- Disconnect harness multiplug from resistor pack
- In turn, connect an ohmmeter between terminal 9 and terminals 1, 3, 5 & 7 to check the resistor values for injectors 1, 3, 5 & 7
- Similarly connect the ohmmeter between terminal 2 and terminals 4, 6, 8 & 10 to check the resistor values for injectors 2, 4, 6, & 8

Reading should be 6 ohms ± 1 ohm for each resistor

If any value is incorrect

- Renew the complete resistor pack

TEST 16B Injector test



Conditions

- ECU multiplug disconnected
- Ignition OFF
- Disconnect the wiring from each injector, and check its resistance value by connecting the ohmmeter to both terminals of the injector

Reading should be 2.4 ohms at 20°C ± 0.5 ohm

- Renew any injector outside this resistance value

PART 6

HINTS AND TIPS

In addition to the procedures already referred to in this manual, the following hints and tips may be useful.

Excessive fuel consumption and black smoke

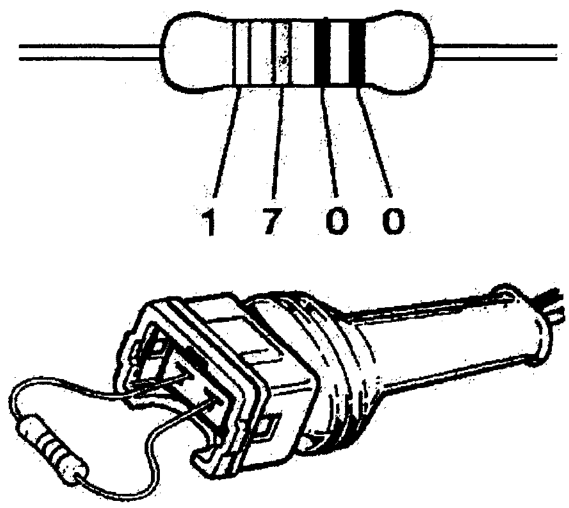
This condition may be caused by a perforated diaphragm in the pressure regulator. This fault can easily be checked as follows:

Pull off the vacuum pipe to the pressure regulator and check for a fuel leak from the pipe.

This would indicate a ruptured diaphragm in the regulator.

Another possible cause is a broken connection inside the coolant temperature sensor, or if the connections to the sensor become faulty whilst the engine is running.

If this happens the ECU will immediately assume that the engine is cold, causing the injectors to over fuel to the extent that the engine will stall and, if hot may not re-start.



Therefore, should the sensor fail as described above, a very useful item to have available is a 170 ohm resistor with the wire connectors bent as shown in the above diagram to use as a bridge across the sensor connections should the sensor be open circuit.

A 170 Ohm resistor is coloured as follows:

1 = Brown
7 = Violet
0= Black
0= Black

When fitted as shown the resistor will signal the ECU that the engine temperature is normal and temporarily restore 'engine hot performance until a new sensor can be fitted.

When starting the engine from cold, simply remove the resistor to obtain a rich mixture and refit the resistor after the engine is warm.

EFI electrical relays

The main relay (MR) and the fuel pump relay (FPR) are identical components of Bosch manufacture and as such are interchangeable.

However other relays used elsewhere on the car may be Lucas 28RA type are not the same internally and a Lucas unit must not be used to replace a Bosch main relay.

If a Lucas relay is fitted into the main relay socket the engine will not start.

END