



# Service Product Training

## ELECTRONIC FUEL INJECTION 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 unburnt fuel being exhausted from the engine.

The desire for performance was still there, 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 Range Rover EFI, combines state-of-the-art technology with the legendary reputation for the ruggedness and reliability of our V8 engine. At first glance under the bonnet it is not surprising that one can be 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 Range Rover EFI contains three different systems, all interlinked to produce the correct fuelling under all driving conditions. These are:

Fuel system  
Air system  
Electronics

### DESCRIPTION

#### Fuel System

The submerged electric pump (P) draws fuel from the fuel tank (see fig.1). The pump passes the fuel along the fuel supply pipe (S), 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.

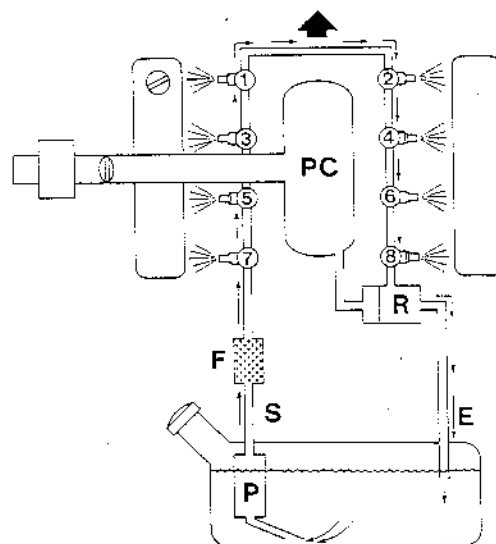


Fig.1 Fuel System

- P Submerged fuel pump
- 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.

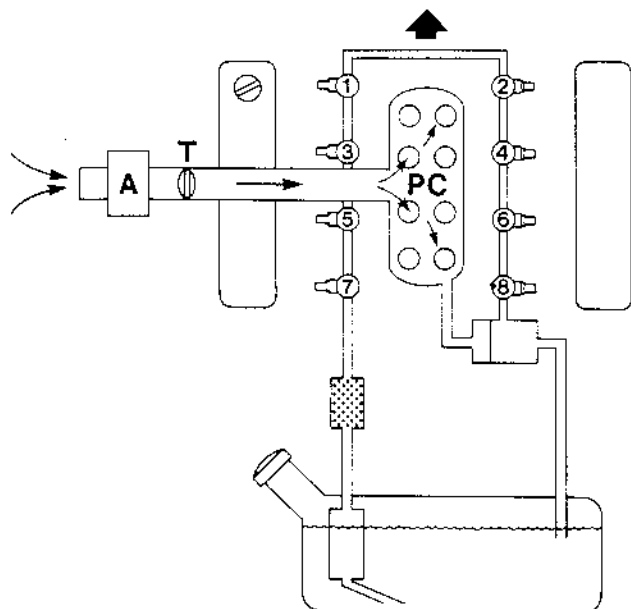


Fig.2 Air System

- A Air flow meter
- T Throttle butterfly
- PC Plenum chamber

The driver's accelerator pedal operates a throttle butterfly (T), as seen in fig.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 injector 'open' time (duration) is controlled by the Electronic Control Unit (ECU) illustrated in fig.3.

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

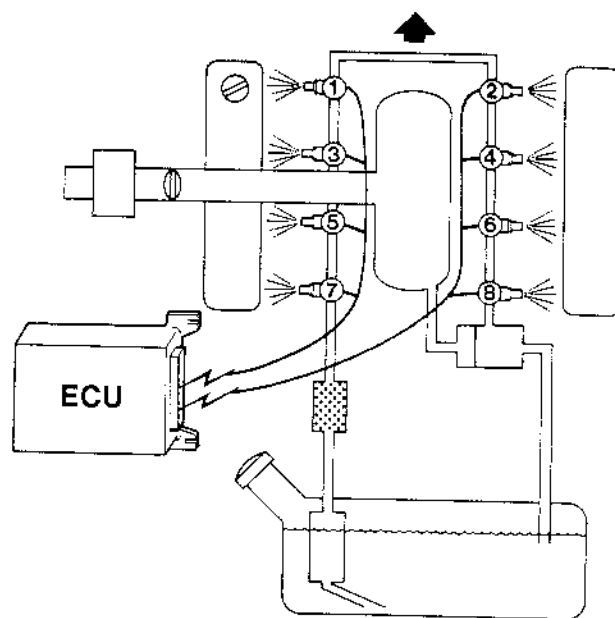


Fig.3 Electronics System

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.



### FUEL SYSTEM OPERATION

#### Fuel Pump

The electric fuel pump is located in the fuel tank; it is operated by a permanent magnet motor which is designed to operate in a submerged state. This means the armature and bearings are cooled and lubricated by the fuel. There is no risk of combustion because the pump never contains an ignitable mixture.

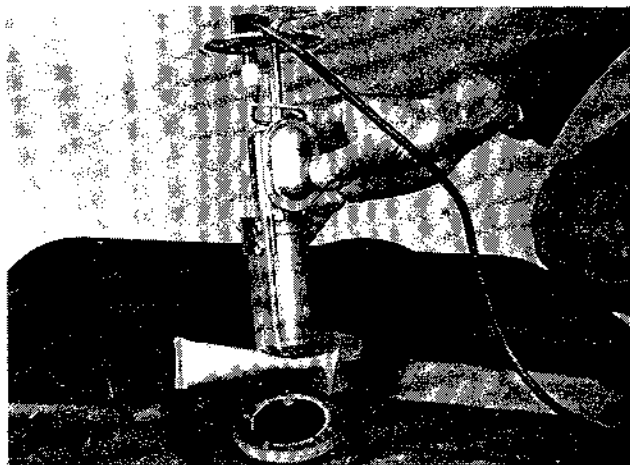


Fig.1 Fuel Pump

The pump has two pumping elements - a low pressure vane type pump (LP) and a high pressure roller type pump (HP). They are both located near the inlet port as shown in fig 2.

An excess pressure relief valve (PR) is located on the outlet side of the armature 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 is drawn through a filter at the pump inlet and into the vane pump (LP). The vane pump delivers fuel to the inlet of the roller pump (HP) at low pressure, thus ensuring that the system is primed. The roller pump boosts the fuel pressure to feed the injection system; excess pressure opens the relief valve allowing fuel circulation through the pump to ensure lubrication and cooling of the motor.

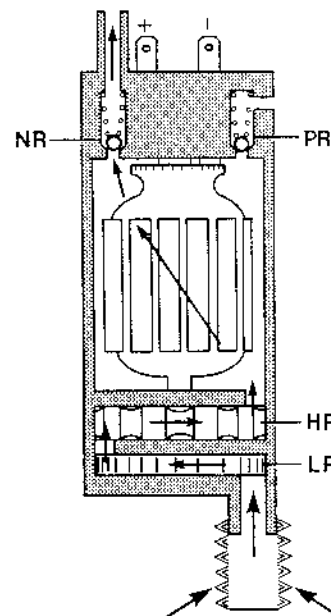


Fig.2 Fuel Pump

- LP Low pressure vane pump
- HP High pressure roller pump
- PR Pressure relief valve
- 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.

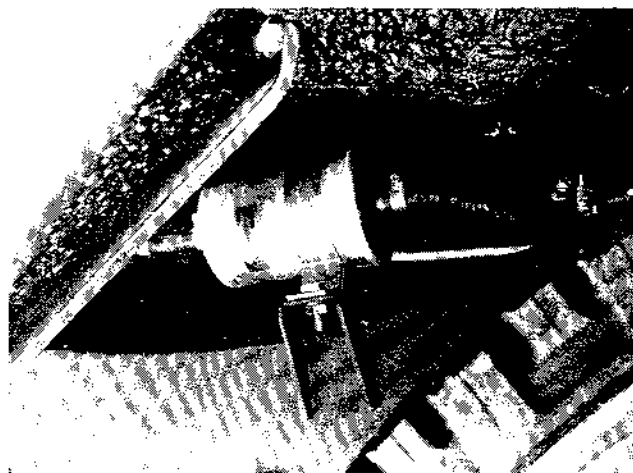


Fig.3 Fuel Filter

The fuel filter is mounted on the chassis, forward of the fuel tank; it is a 2 micron, fine mesh unit which 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 it is 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'.

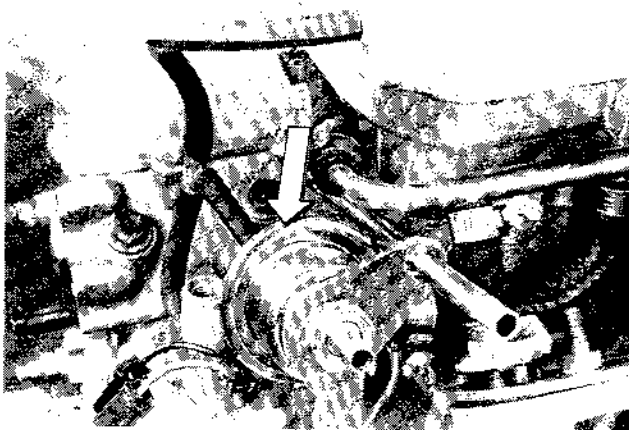


Fig.4 Fuel Pressure Regulator

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.5. 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.

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

Under conditions of low manifold depression, eg. full throttle (Fig.5A), the spring continues to hold the diaphragm on its fuel return pipe seat. In these circumstances, pump pressure must reach approximately 2.5 kgf/cm<sup>2</sup>. (36 lbf/in<sup>2</sup>) to move the diaphragm valve against spring pressure and allow excess fuel to return to the tank.

When manifold depression is high, eg. idle and overrun (Fig.5B), the diaphragm valve is drawn against spring pressure. The fuel return is opened and the fuel pressure falls to 1.8 kgf/cm<sup>2</sup> (26 lbf/cm<sup>2</sup>). 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'.

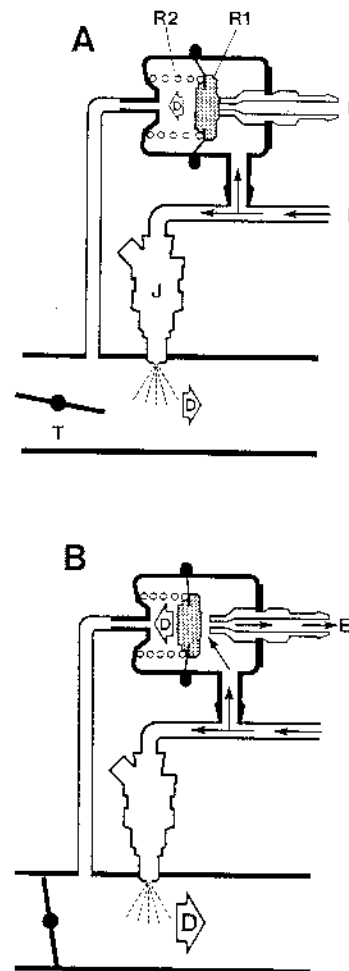


Fig.5 Fuel Pressure regulator

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

When manifold depression is low (Fig.5A), 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.5B), 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 cc 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.

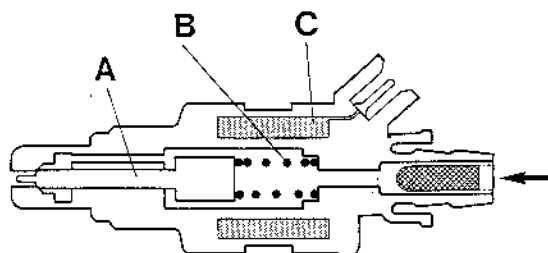


Fig. 6.

Each injector contains a needle valve (A) as seen in fig. 6, 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.

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.7. 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.

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, so let us see how this operates next.

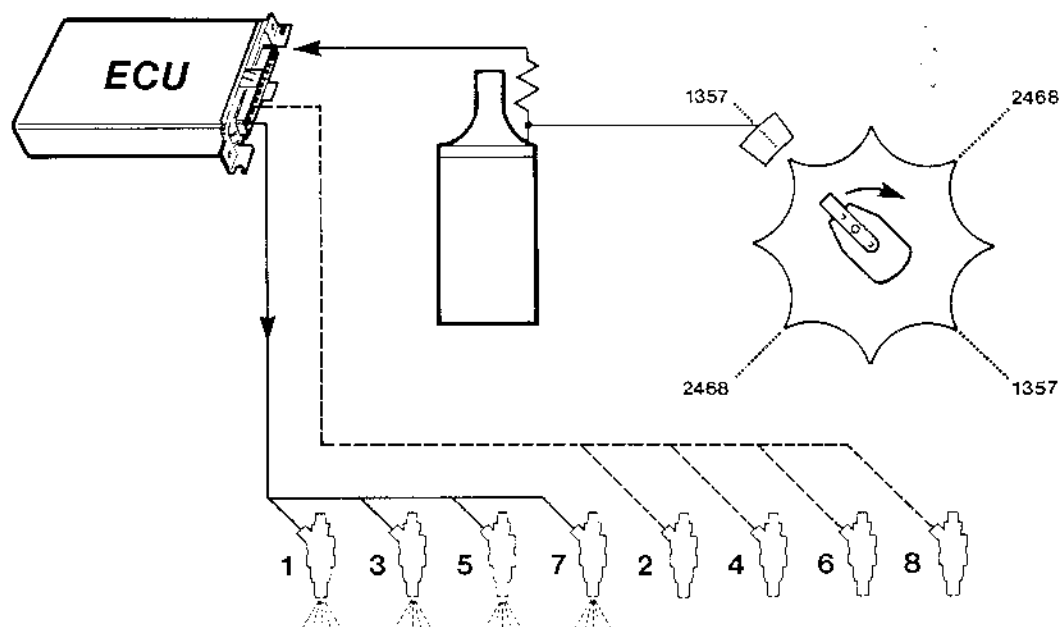


Fig. 7

## 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.

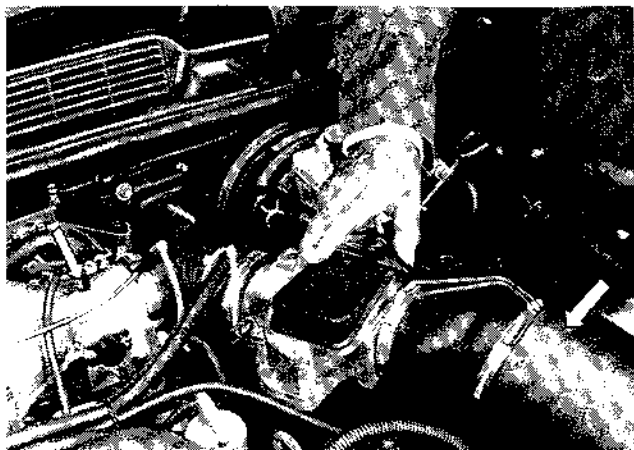


Fig.8 Air flow meter

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

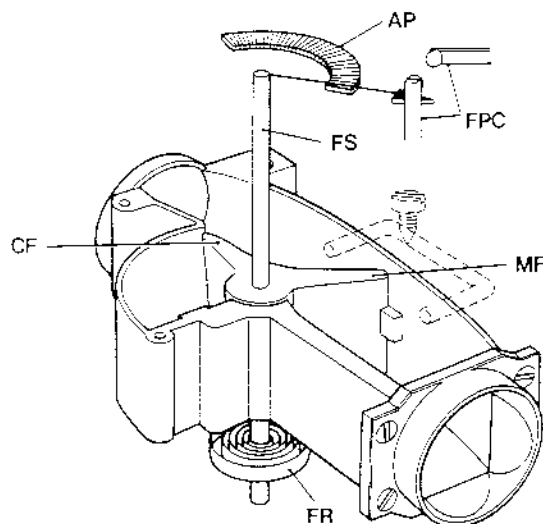


Fig.9 Air flow meter (sectioned)

- MF Measuring flap
- CF Compensating flap
- FS Flap spindle
- FR 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.9 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.10. This movement allows the contacts (FPC) to close and switch the fuel pump into operation.

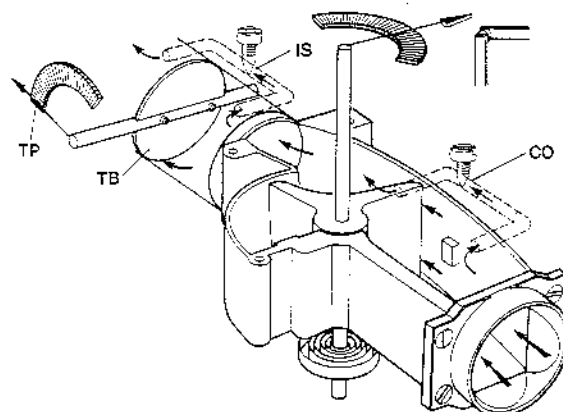


Fig.10

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

It can also be seen in fig.10 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 air flow 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 most of the air is passing the throttle butterfly, the idle screw can be adjusted to finely tune 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 stabilized throughout the engine speed range. When the throttle is opened as seen in fig.11, 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.

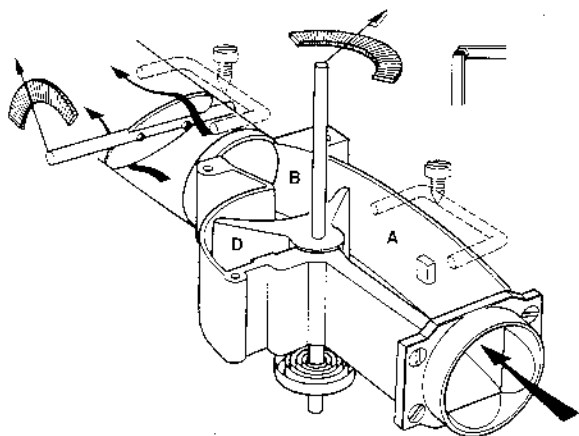


Fig.11

If the throttle is now held steady, the air pressure in chamber D 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.

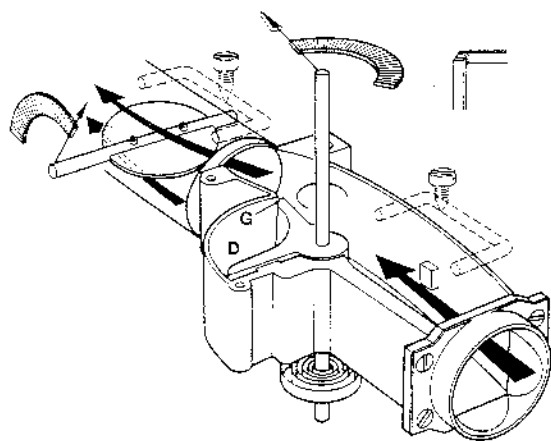


Fig.12

At maximum throttle opening as shown in fig.12, the flap unit will be resting against the full open stop; here depression is maintained in chamber D 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 D and smooth movement of the flap unit when opening or closing.

### Throttle Butterfly

The throttle butterfly (seen in figs.13 & 14) is mounted in between the plenum chamber and the air flow meter; it is linked directly to the driver's accelerator pedal.

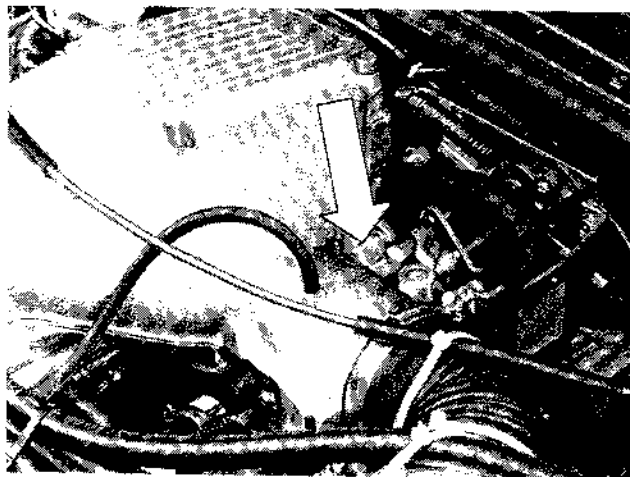


Fig.13

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

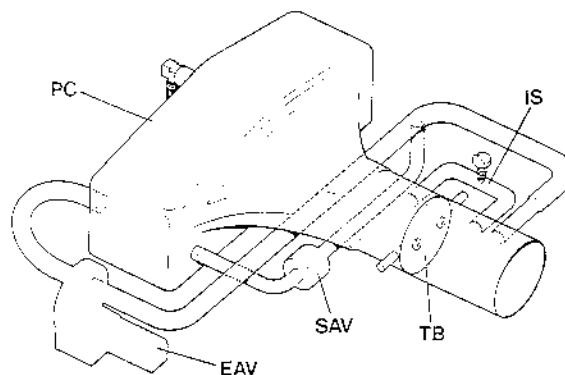


Fig.14

- PC Plenum chamber
- TB Throttle butterfly
- IS Throttle by-pass port & 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 by-passes 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, and is therefore sensitive to coolant temperature.

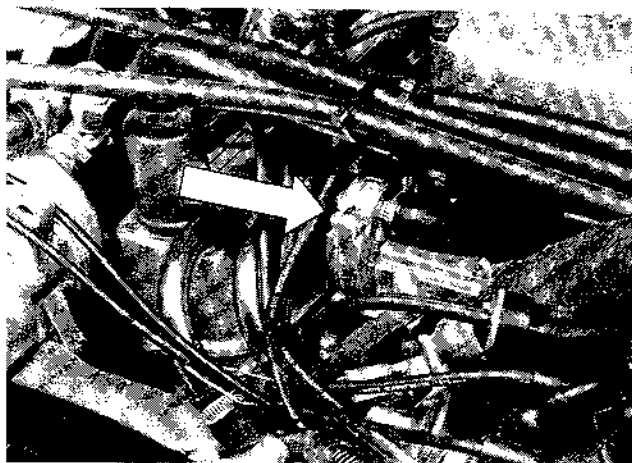


Fig.15 Extra air valve

The extra air valve contains a disc valve (D) as seen in fig.16A, 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.

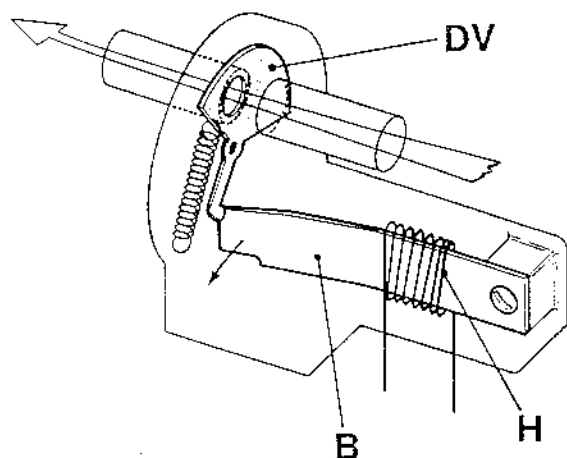


Fig.16A Extra air valve (cold)

- DV Disc valve
- B Bi-metal
- H Heating wire

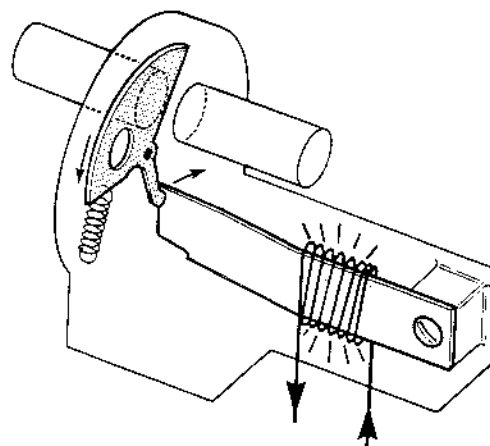


Fig.16B Extra air valve (hot)

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.16B).

Once the engine is running, the combined effect of the heater coil and engine temperature closes the extra air valve at temperatures between 60 - 70°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 is positioned in the plenum chamber and sprays directly against the incoming air to give the best atomisation of the additional fuel it supplies.

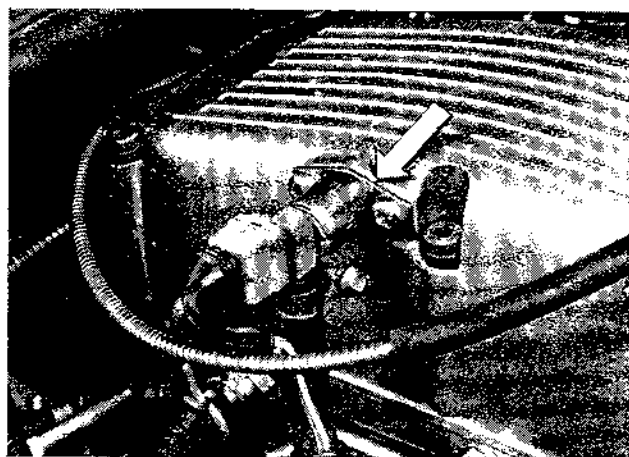
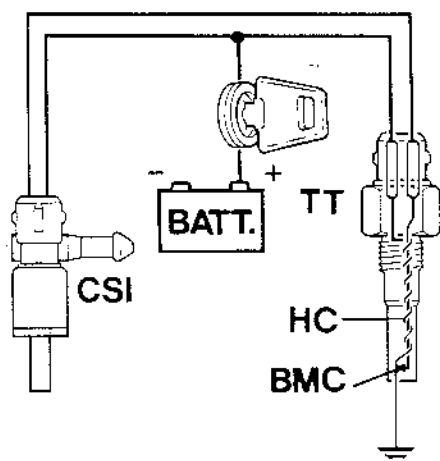


Fig.17 Cold start fuel injector

The injector is controlled by a 'thermotime switch' located in the coolant gallery in the inlet manifold. This unit contains a heater coil around bi-metal operated contact points, and works as follows.





**Fig.18 Cold start injector circuit**

CSI	Cold start injector
BATT	Battery supply (when engine is cranking)
TT	Thermotime switch
HC	Heater coil
BMC	Bi-metal contacts

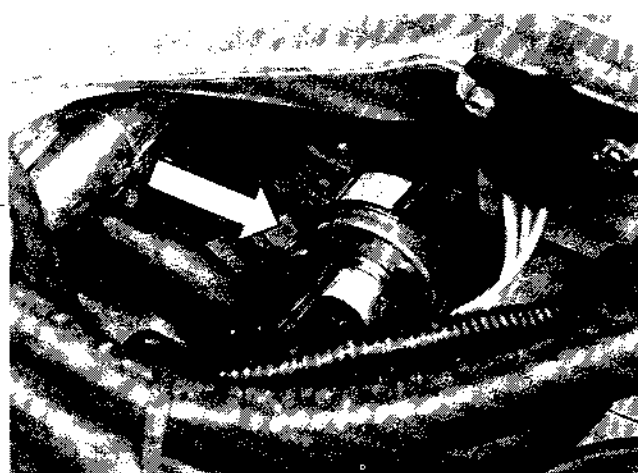
During cranking in cold conditions current can pass through the closed contact points of the thermotime switch and cause the injector to operate. At the same time current is passing through the heater coil to warm the bi-metal. After a maximum of 12 seconds the expansion of the bi-metal will open the 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, up to temperatures above 35°C approximately, when the thermotime switch contact points remain open and the cold start injector will not operate.

### SOLENOID AIR VALVE OPERATION

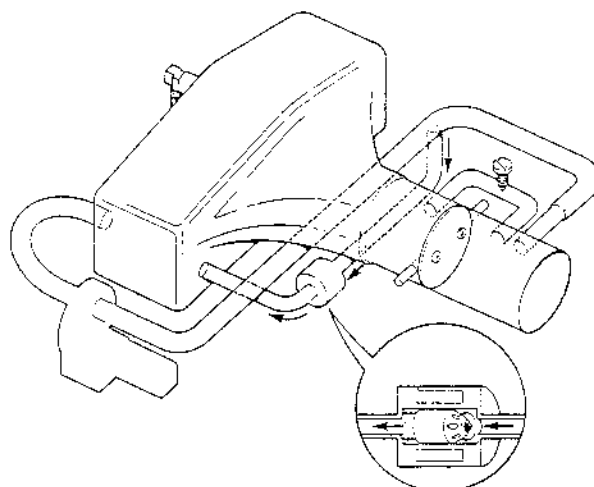
(Only fitted to vehicles with air conditioning)

On vehicles fitted with air conditioning, an air supply is taken from the extra air valve pipe; this pipe contains an air valve (fig.20), which increases the idle speed when the air conditioning compressor cuts in. It is a sealed unit containing a solenoid operated valve.



**Fig.19 Solenoid operated air valve.**

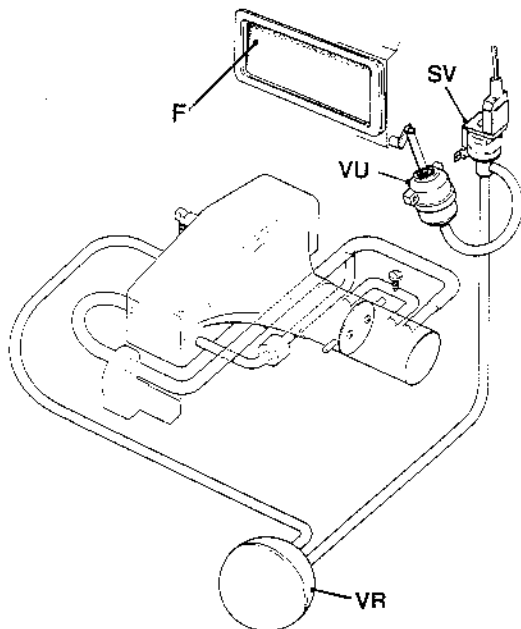
The solenoid is connected electrically to the compressor control circuit, and as soon as the compressor cuts in, the solenoid opens the valve to allow additional air into the engine. This causes a slight fall in manifold depression - enough to affect the fuel pressure regulator and increase the fuel 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.20**

## VENTILATION SYSTEM FRESH AIR FLAP

The flap on the heater/air conditioning unit which makes the change between fresh air and recirculating air is controlled by a solenoid operated valve and a vacuum servo unit. This vacuum comes from a connection to the plenum chamber.



**Fig.21 Fresh air flap control.**

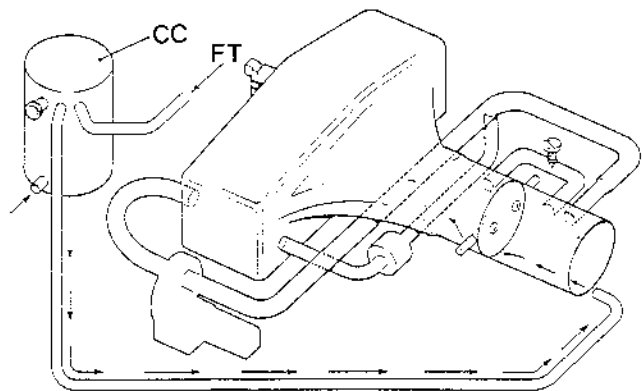
- VR Vacuum reservoir
- SV Solenoid valve
- VU Vacuum servo unit
- F Fresh air flap

Vacuum is stored in the reservoir (VR) fig.21, and is sensed at the solenoid valve (SV) attached to the side of the heater or air conditioning unit. When the driver moves the appropriate lever on the control panel, the solenoid valve is energised and vacuum is now applied at the vacuum servo unit (VU) to open the fresh air flap (F).

## FUEL EVAPORATIVE LOSS SYSTEM

The specification for certain countries requires the recycling of fuel evaporating from the fuel tank. For these countries only, a charcoal canister is mounted on the right front wing valence.

Any fuel vapourising in the fuel tank (FT) fig.22, will pass to the charcoal canister. Thus when the engine is running, air entering the engine will also draw the fumes from the canister.



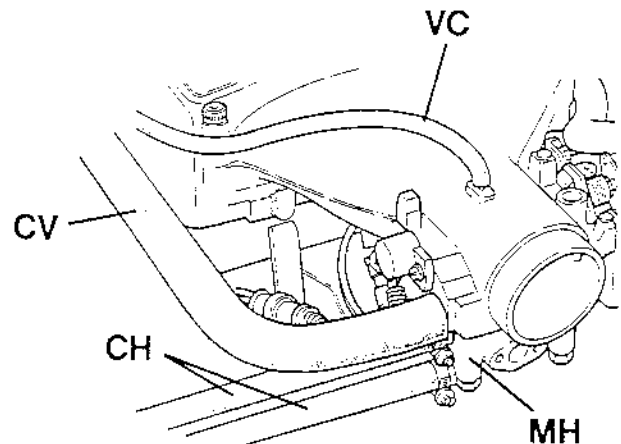
**Fig.22 Evaporative loss system.**

- CC Charcoal canister
- FT Fuel tank connection

## COOLANT CONNECTIONS

For quick warm-up a manifold hot spot (MH) fig.23 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.23 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, and 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.

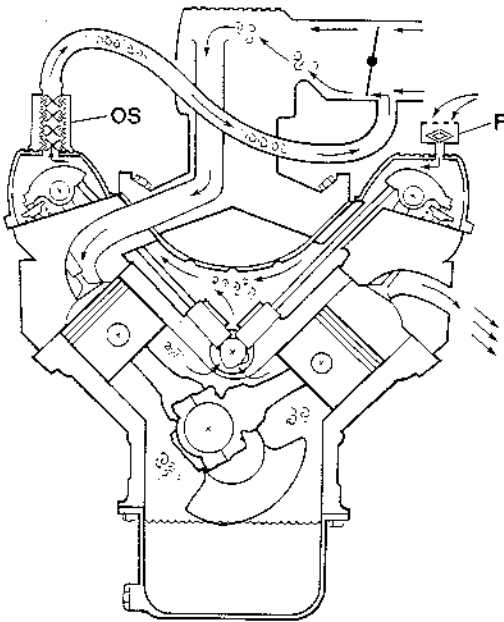


Fig.24 Crankcase ventilation system

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.

The volume of air taken into the engine in this way by-passes 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.

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

### ELECTRICAL COMPONENT FUNCTION AND 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 (E.C.U.)

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

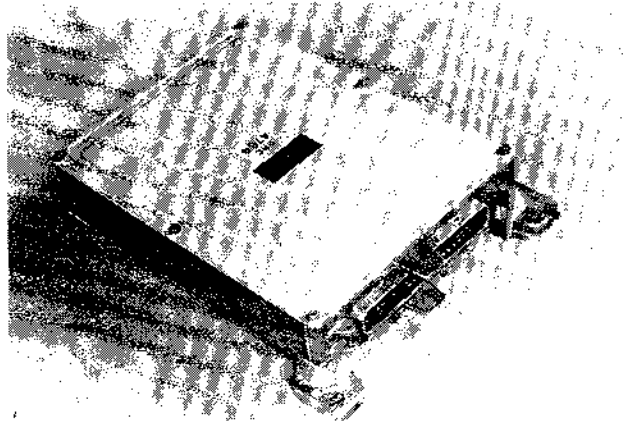


Fig.1 Electronic Control Unit

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.

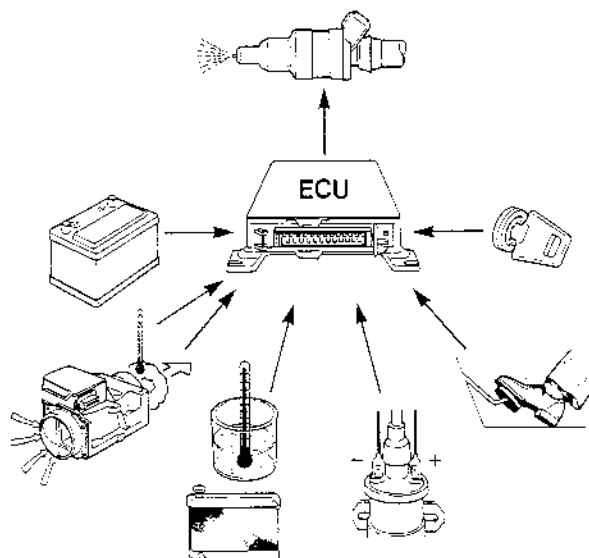


Fig.2 Electronic Control System

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 air flow - to calculate volume of air entering engine
- Battery voltage.

#### Air Flow Meter

The air flow meter contains three separate electrical systems.

##### 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.

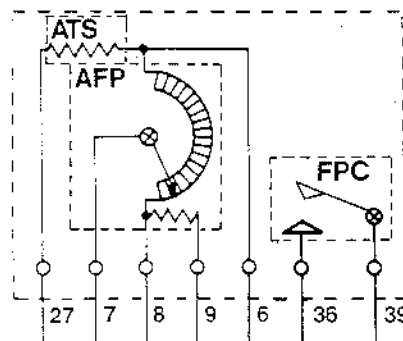


Fig.3 Air flow meter (AFM)

- ATS Air temperature sensor
- AFP Air flow 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 fig.12.

## Throttle Potentiometer

The throttle potentiometer is connected to the spindle of the throttle butterfly. Its purpose is to advise the ECU of the driver's accelerator pedal position and it works in the same way as the air flow meter potentiometer.

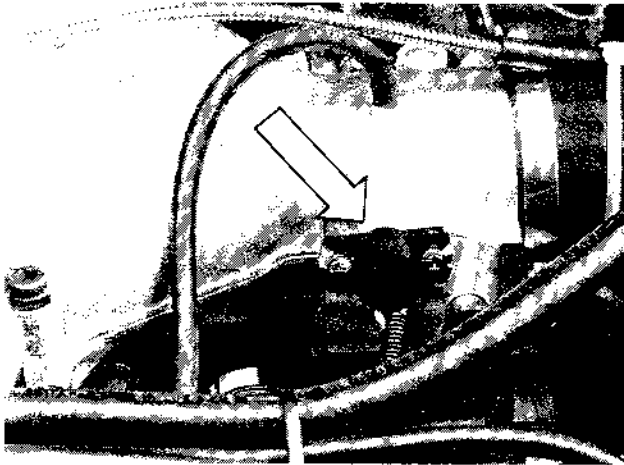


Fig.4 Throttle potentiometer

When the throttle is operated, the wiper moves over the resistance to vary the voltage.

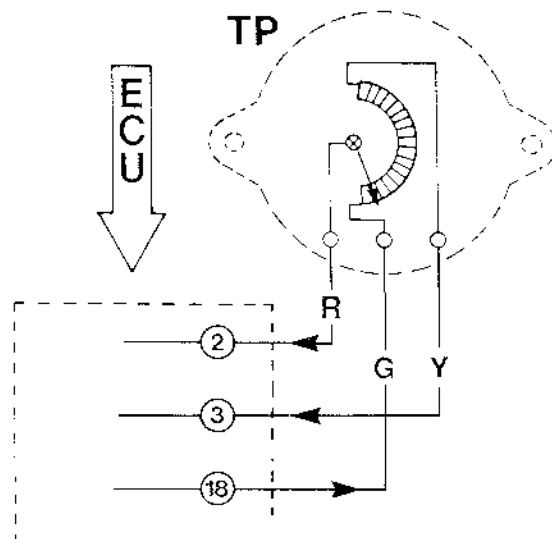


Fig.5

The ECU detects the changing voltage across the potentiometer connections (pins 2, 3 & 18), and 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).

## Thermotime Switch

The thermotime switch is fitted to time the operation of the cold start injector; it is located in the coolant gallery at the front of the inlet manifold. It must not be confused with the coolant temperature sensor fitted alongside it.

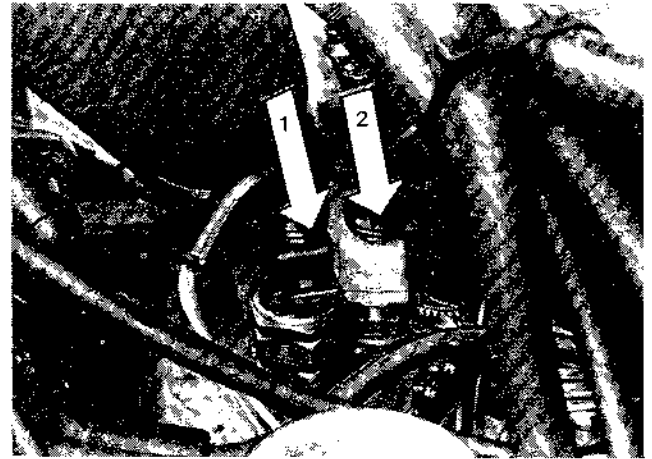


Fig.6

1. Thermotime switch
2. Coolant temperature sensor

The thermotime switch (TT) seen in fig.7 contains a pair of contact points, one of which is mounted on a bi-metal strip. A heater coil is fitted around the bi-metal strip.

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

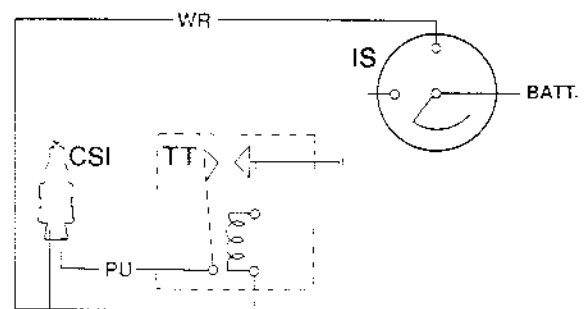


Fig.7 Thermotime switch

- CSI Cold start injector  
TT Thermotime switch  
IS Ignition switch

When it can operate, the thermotime 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.



# Service Product Training

## ELECTRONIC FUEL INJECTION

PART 3

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 thermotime switch to earth, and the injector will operate. The bi-metal strip is sensitive to ambient temperature, and if the ambient is already above 35°C the contacts will be open and the injector will 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.

### Overrun Fuel Shut-off Relay & Vacuum Switch

The overrun fuel shut-off relay is attached to the air flow meter mounting bracket and works in conjunction with the vacuum switch mounted on the right hand side of the plenum chamber. Their purpose is to shut-off the injector operation during very high manifold depression (24 in.Hg  $\pm$  1) eg. decelerating with a closed throttle from high speed or down a hill to improve exhaust emissions and economy. The system works as follows:

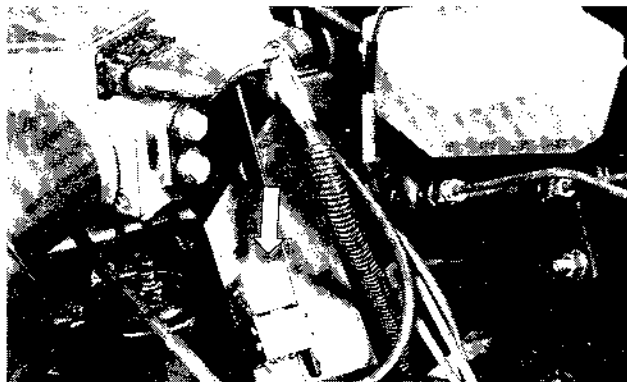


Fig.8 Overrun fuel shut-off relay location

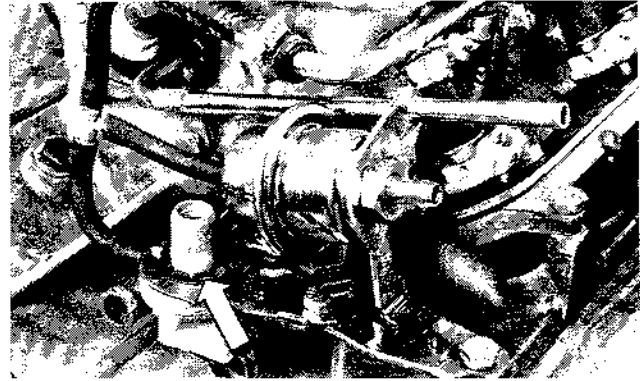


Fig.9 Vacuum switch location

Fig.10 shows the system in the rest position with the ignition switched off; the vacuum switch is closed and the points in the relay are open. When the ignition is turned on, current passes through the vacuum switch to earth via the relay windings and terminals 85 - 86 of the overrun fuel shut-off relay. This closes the relay contact points, and distributor/ignition pulses can pass to the ECU pin 1 to ensure the injectors operate.

The vacuum switch is connected into the plenum chamber where it senses manifold depression; it is preset to open at a depression of 24  $\pm$  1 in. Hg. Whenever this high manifold depression occurs, the vacuum switch opens, current no longer passes to the relay and the contact points open to cut off the injector operation, because the ECU no longer receives a signal from the electronic ignition system (coil).

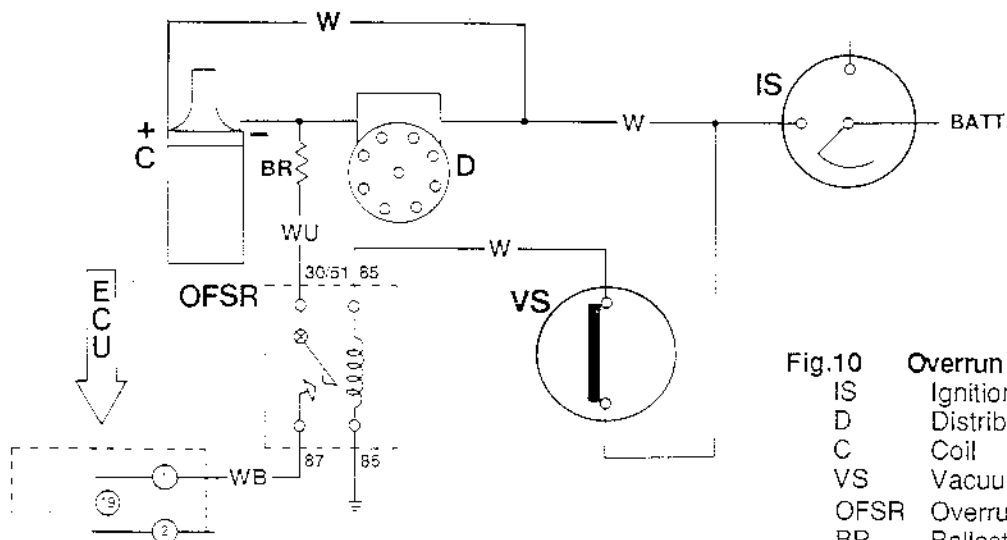


Fig.10 Overrun fuel shut-off circuit

IS	Ignition switch
D	Distributor
C	Coil
VS	Vacuum switch
OFSR	Overrun fuel shut-off relay
BR	Ballast Resistor

## Steering Module (Diode Pack) Main Relay Fuel Pump Relay

These three components are located together inside the vehicle beneath the front right hand seat as seen in fig.11; they all work in conjunction with one another.

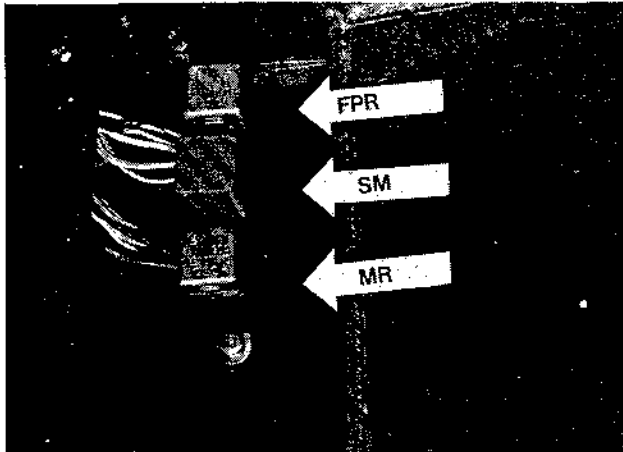


Fig.11

SM Steering module  
MR Main relay  
FPR Fuel pump relay

A white wire from the ignition switch takes current through the right diode in the steering module (terminals 4 to 1) seen in fig.12. 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.

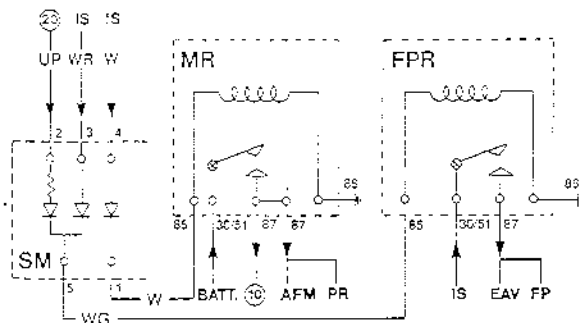


Fig.12

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 contains a heating coil which, when heated, causes a bi-metal to close off the air valve progressively.

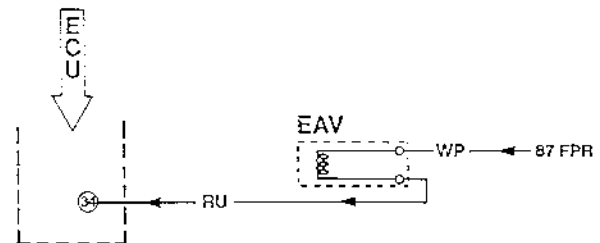


Fig.13

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 front of the inlet manifold; it must not be confused with the cold start thermotime switch fitted alongside it (see Part 3, fig.6). Its function is to advise the ECU of coolant temperature changes.

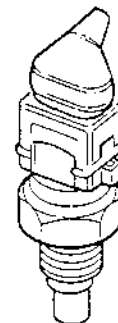


Fig.14 Coolant temperature sensor

The coolant temperature sensor (CTS) seen in fig.15 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".

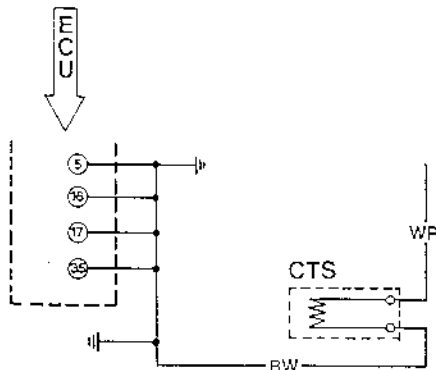


Fig.15 Coolant temperature sensor (CTS)

### Power Resistor Pack

This pack is attached to the air flow meter mounting bracket and its purpose is to reduce voltage to the injectors from 12 volts to 3 volts when open.



Fig.16 Power resistor pack

### Injectors

The injectors which inject fuel into the engine are opened by internal solenoids. Current to the injectors comes from the ignition switch and Main Relay (MR) terminal 87 to two Power Resistor packs (PR) as seen in fig.17. This current is available when the ignition is turned on.

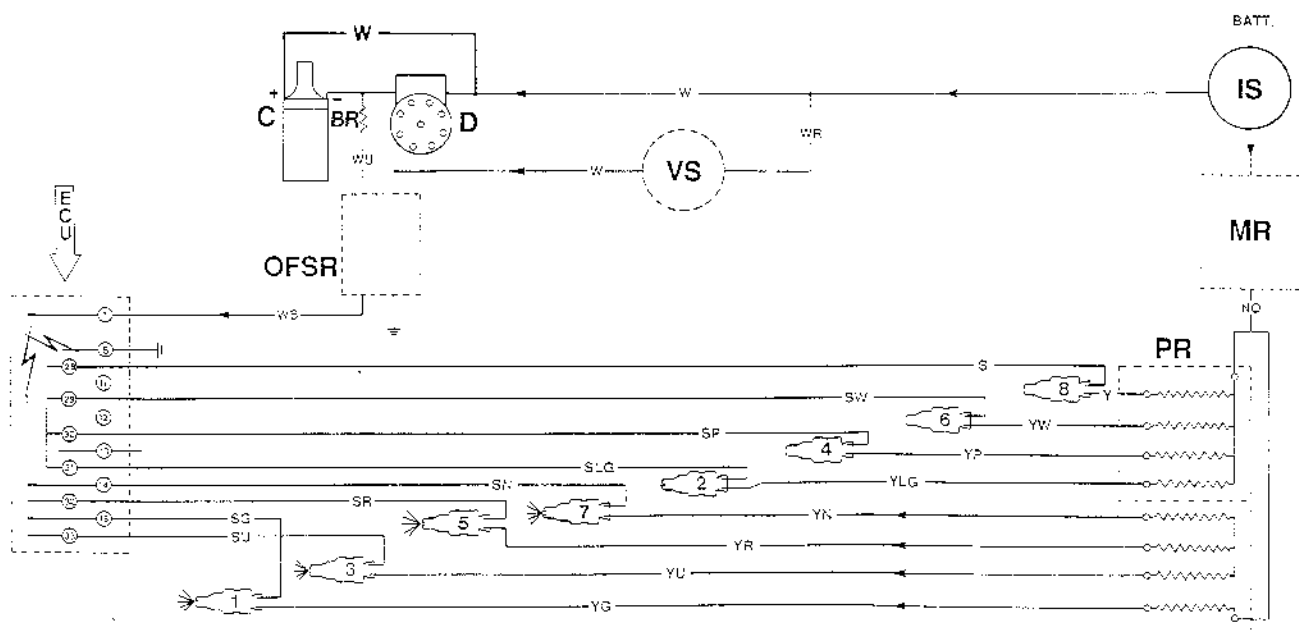
However the circuitry is not complete until the current is earthed by the ECU. To achieve this the engine must be either cranking or running, and then current flows from the ignition switch along the white (W) wire to the windings of the overrun fuel shut off relay via the vacuum switch, to close the contact points and connect the engine speed signal input to pin 1 on the ECU white/black (WB) wire.

The engine speed is signalled 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, 3, 5 & 7 are earthed by the ECU via pins 15, 33, 32 & 14, whilst the circuits for injectors 2, 4, 6 & 8 are earthed via pins 31, 30, 29 & 28.

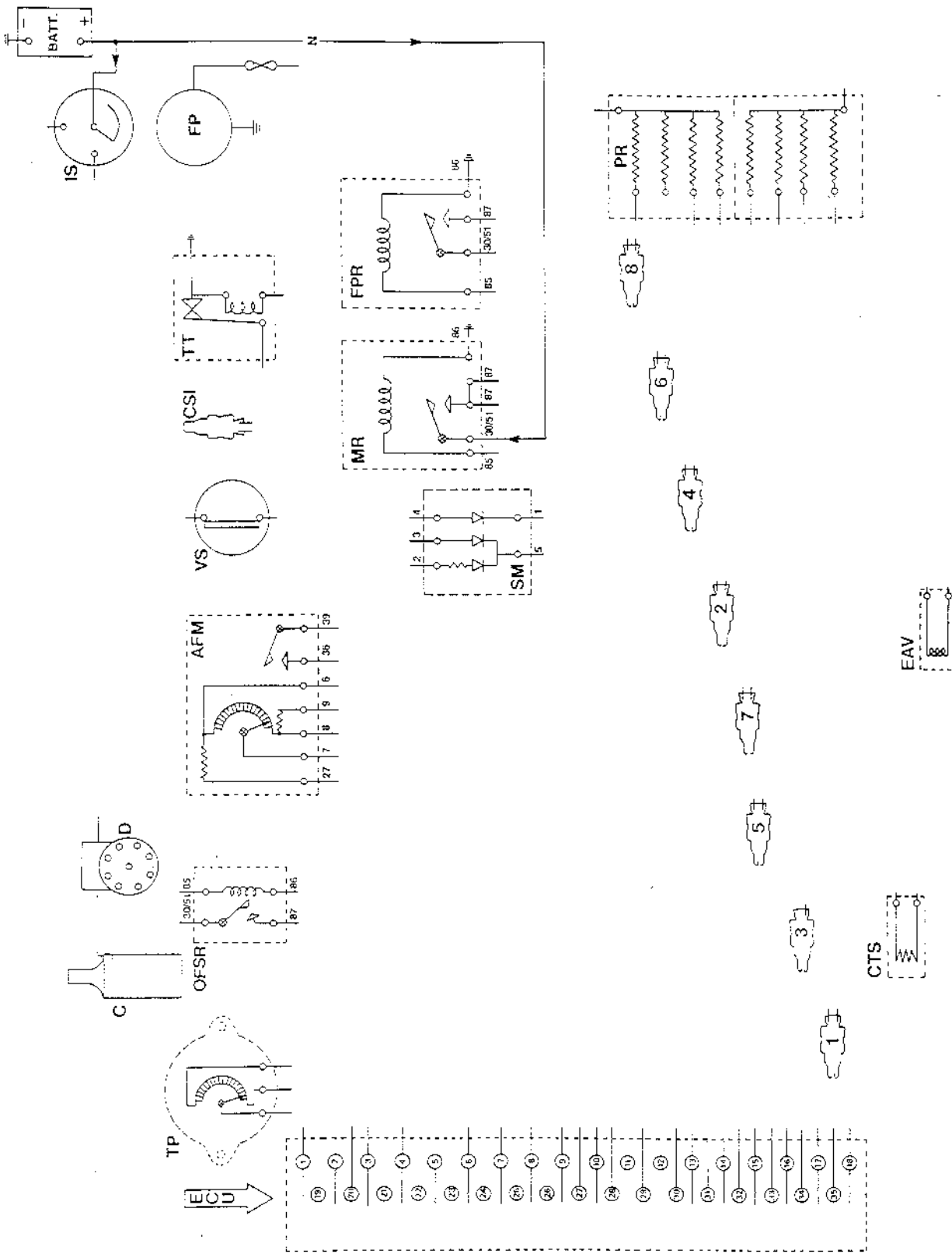
Fig.17 Injector circuit

- IS Ignition switch
- D Distributor
- C Coil
- VS Vacuum switch
- OFSR Overrun fuel shut-off relay
- MR Main relay
- PR Power resistor packs
- BR Ballast Resistor
- 1 - 8 Injectors 1 - 8





**Fig.18 Ignition off**



### ELECTRICAL CIRCUIT OPERATION

#### Ignition off (see fig. 18)

In the mode shown in Fig. 18 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 which are open are:-

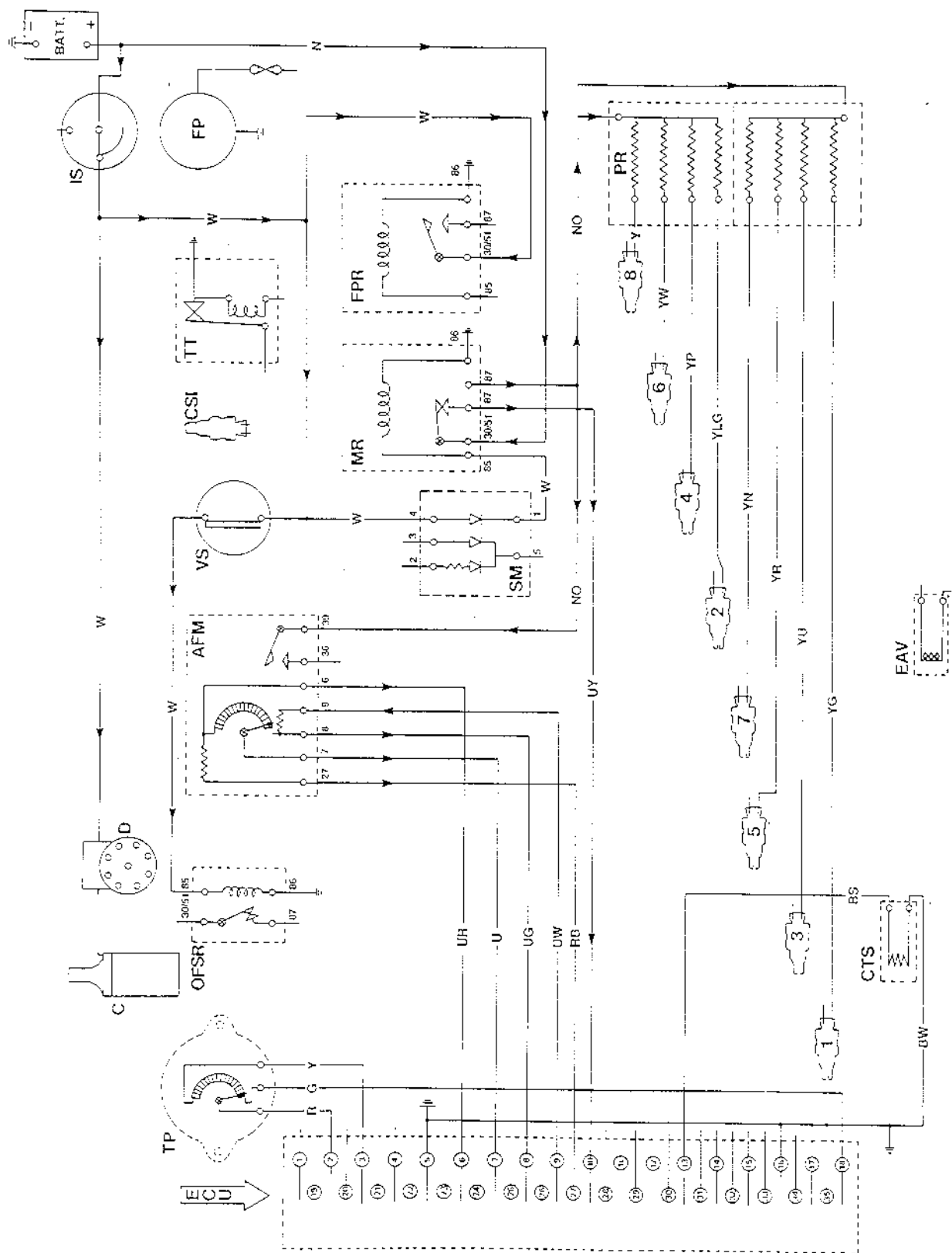
- air flow meter (AFM)
- overrun fuel shut-off relay (OFSR)
- main relay (MR)
- fuel pump relay (FPR)

However the vacuum switch contacts (VS) and thermotime switch contacts (TT) are closed (assuming the coolant temperature is below 35°C).

Key	
BATT	Battery
IS	Ignition switch
D	Distributor
C	Coil
FP	Fuel pump
TT	Thermotime switch
CS	Cold start injector
VS	Vacuum switch
AFM	Air flow meter
OFSR	Overrun fuel shut-off relay
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
Wiring colour codes	
B	Black
U	Blue
N	Brown
G	Green
O	Orange
P	Purple
R	Red
W	White
Y	Yellow
S	State
K	Pink
LG	Light green

The last letter of a colour code denotes the tracer.

Fig.19 Ignition on



#### Ignition on (see fig.19)

In this mode 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) - through the closed contacts of the vacuum switch (VS) to the overrun shut-off relay causing the relay contacts to close. The engine is not running therefore there is no current to pass through the relay from the distributor.

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 10 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, 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.

The final circuit to come into action in this mode is the coolant temperature sensor (CTS).

Pin13 - Black/slate (BS) to sensor, Black/white (BW) to earth and pin 5.

Key		Wiring colour codes
BATT	Battery	B Black
IS	Ignition switch	U Blue
D	Distributor	N Brown
C	Coil	G Green
FP	Fuel pump	O Orange
TT	Throttle switch	P Purple
CSI	Cold start injector	R Red
VS	Vacuum switch	W White
AFM	Air flow meter	Y Yellow
OFSR	Overrun fuel shut-off relay	S Slate
TP	Throttle potentiometer	K Pink
ECU	Electronic control unit	LG Light green
SM	Steering module	
MR	Main relay	
FPR	Fuel pump relay	
1-8	Injectors	
CTS	Coolant temperature sensor	
EAV	Extra air valve	
PR	Power resistors	

The last letter of a colour code denotes the tracer.

This is a detailed schematic diagram of a vehicle's electrical system. The diagram illustrates the power distribution from a battery (BATT.) through various components and relays. Key components include:

- Battery (BATT.):** The primary power source, connected to the system via a main line.
- Ignition Switch (IS):** Controls the flow of electricity to the ignition system.
- Relays and Solenoids:**
  - FPR (Fuel Pump Relay):** Controls the fuel pump (FP).
  - MR (Master Relay):** A central relay controlling multiple circuits.
  - SM (Signal Module):** Processes signals from various sensors.
  - AFM (Alternator Field Module):** Controls the alternator (A).
- Wiring Harness:** A complex network of wires connecting components, with terminals numbered 1 through 28. It includes a fuse block (F) and a battery disconnect switch (BDS).
- Other Components:**
  - Alternator (A):** Generates electricity to charge the battery.
  - Fuel Pump (FP):** Delivers fuel to the engine.
  - Sensors and Switches:** Various components like the alternator switch (AS), fuel pump switch (FWS), and master battery disconnect switch (MBDS) are shown.

The diagram uses standard electrical symbols for components like resistors, capacitors, and switches, and color-coded wire labels (e.g., W, Y, G, R) to identify different circuits.



# Service Product Training

## ELECTRONIC FUEL INJECTION

PART 3

### Cranking (see fig.20)

In this mode 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 thermostime switch (TT), the cold start injector (CSI) and terminal 3 of the steering module (SM).

The 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 pass via a white/blue wire (WU) to the overrun fuel shut-off relay terminal 30, and because the relay contacts are closed this 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).

### Key

BATT	Battery
IS	Ignition switch
D	Distributor
C	Coil
FP	Fuel pump
TT	Thermostime switch
CSI	Cold start injector
VS	Vacuum switch
AFM	Air flow meter
OFSR	Overrun fuel shut-off relay
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 Resistor
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
K	Pink
LG	Light green

The last letter of a colour code denotes the tracer.

The diagram illustrates a comprehensive vehicle electrical system. At the top left, a battery (BATT.) provides power to a network of wires. Key components include:

- Switches:** IS (Ignition Switch), FP (Fuel Pump), VS (Voltage Switch), TP (Throttle Position), TT (Throttle Throttle), ICSI (Ignition Control Switch), AFM (Automatic Fuel Meter), OFSR (Over Fuel Shut-Off Relay), and CTS (Circuit Test Switch).
- Relays and Solenoids:** MR (Master Relay), FPR (Fuel Pump Relay), SM (Solenoid Motor), and various solenoids numbered 1 through 8.
- Wiring Harness:** A complex arrangement of wires connecting various components, with terminals labeled with letters (A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z) and numbers (1 through 19).
- Other Components:** BS (Battery Switch), EAV (Electronic Valve Actuator), and various other electrical components.

The diagram shows the flow of electricity from the battery through various switches and relays to the components, with a focus on the wiring harness and its connections.

### HINTS AND TIPS

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

**Excessive fuel consumption and black smoke** - 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 of heavy fuel consumption is a broken connection inside the coolant temperature sensor, or for example, if the connections are pulled off the sensor whilst the engine is running. If this happens the ECU will immediately assume that the engine is cold, causing the injectors to overfuel to the extent that the engine will stall and, if hot, may not re-start.

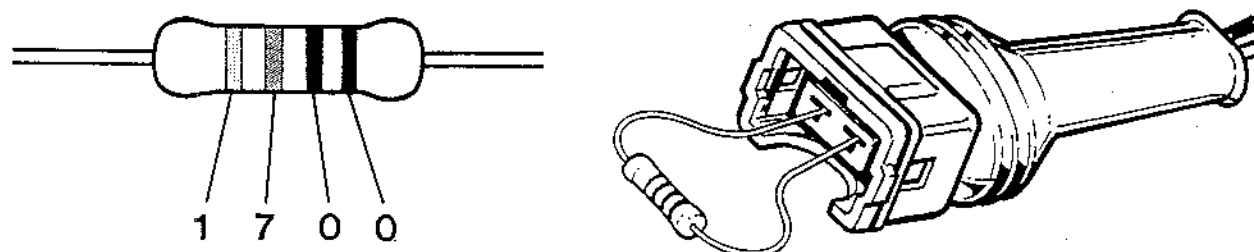


Fig.1

Therefore, should the sensor fail open circuit as described above, a very useful piece of equipment to have available is a 170 ohm resistor with the wire connectors bent as shown in fig. 1, 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 in fig.1, 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

#### Important warning

The main relay (MR) and the fuel pump relay (FPR) are identical components of Bosch manufacture, but the overrun fuel shut-off relay (OFSR) is a Lucas 28RA type which is not the same internally. Whilst the Bosch relay may be used in place of the Lucas unit, the Lucas 28RA 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.

### Air leaks (manifold system)

A suitable proprietary brand of damp start which may be used to seal suspected inlet manifold air leaks is 'Engine Lacquer', available from:

Nielsen Chemicals  
Church Gresley Industrial Estate  
Burton on Trent  
DE11 9NR  
England



If the throttle remains closed, only a relatively small amount of fuel will be injected because the throttle potentiometer will signal the ECU of the closed throttle condition.

### Key

BATT	Battery
IS	Ignition switch
D	Distributor
C	Coil
FP	Fuel pump
TT	Throttle switch
CSI	Cold start injector
VS	Vacuum switch
AFM	Air flow meter
OFSR	Overrun fuel shut-off relay
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 Resistor
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
K	Pink
LG	Light green

The last letter of a colour code denotes the tracer.

### Engine Running (see fig. 21)

In this mode 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 cut off the supply of extra air to the manifold.

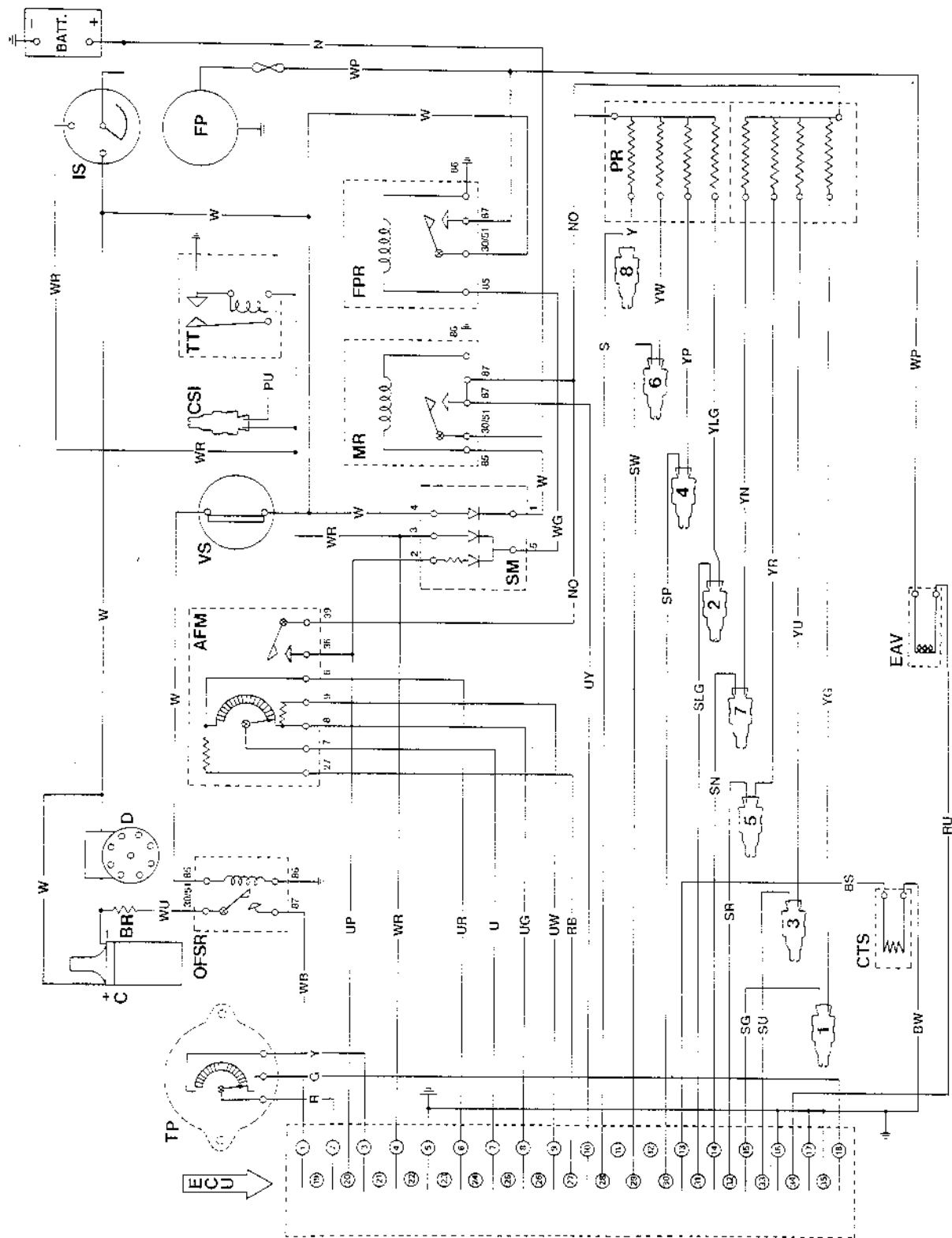
The coolant temperature sensor (CTS) informs the ECU via terminal 13 of the progressive increase in coolant temperature, and the ECU reduces the injector 'open' time.

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 (ie. accelerator pedal position), and air flow and temperature as sensed by the air flow meter.

The other component to affect fuelling is the vacuum switch (VS). In conditions of very high manifold vacuum ie. above 24 in. Hg, the vacuum switch will open; to interrupt the engine speed distributor signals and thus cause the injectors to cease operating until the vacuum falls below 24 in. Hg.

Fig 22 EFI Wiring diagram





# Service Product Training

## ELECTRONIC FUEL INJECTION

PART 3

### EFI WIRING DIAGRAM

Key to fig.22

Key	
BATT	Battery
IS	Ignition switch
D	Distributor
C	Coil
FP	Fuel pump
TT	Thermostatic switch
CSI	Cold start injector
VS	Vacuum switch
AFM	Air flow meter
OFSR	Overrun fuel shut-off relay
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 Resistor
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
K	Pink
LG	Light green

The last letter of a colour code denotes the tracer.

The next items to check are the throttle linkage adjustments; throttle butterfly, throttle lever and throttle potentiometer.

## Throttle Linkage

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

- Lack of lubrication of the cable.
- Incorrect adjustment.
- Extra carpeting under the pedal.

## Throttle Butterfly Clearance

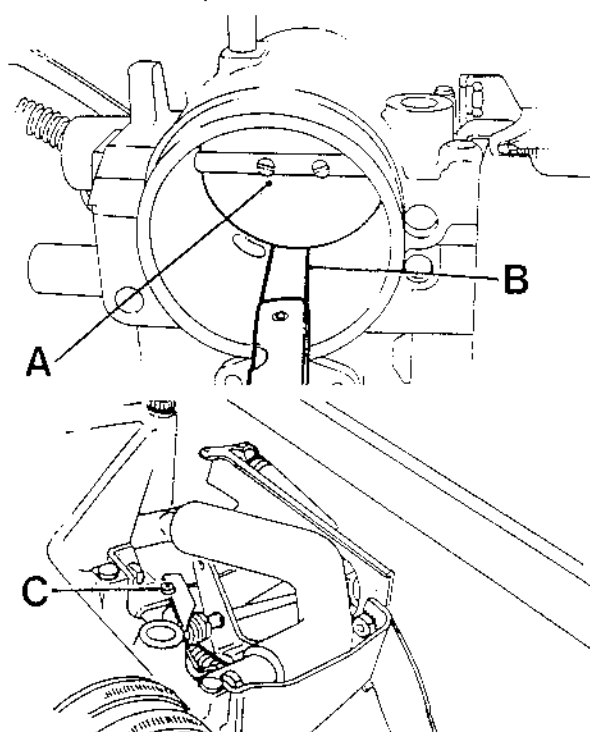


Fig.3 Adjusting butterfly linkage

- Throttle butterfly retaining screws
- Feeler gauge
- Adjustment Allen screw

An adjustment screw is provided to set the throttle butterfly to an initial 'open' position. Remove the tamperproof plug to gain access to the adjustment Allen screw, which should be adjusted to provide a minimum but definite clearance between the throttle butterfly and its housing of not more than 0,10mm (0.004 in.) measured at the top and bottom to ensure that the butterfly is central.

After making the adjustment, depress the throttle pedal fully and check that the butterfly opens fully but does not travel over centre. Then check the throttle lever adjustment as follows:

## Throttle Lever Adjustment

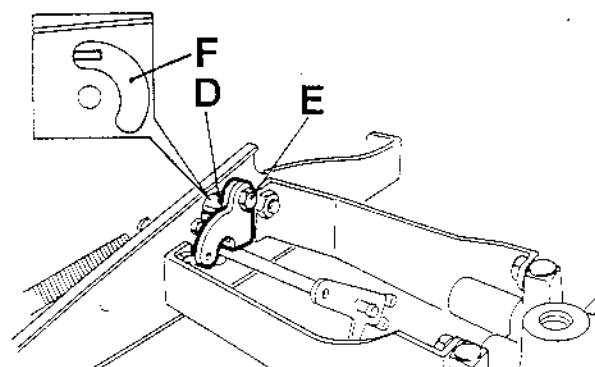


Fig.4 Throttle lever

- Throttle lever
- Throttle lever securing screw
- Lever mounting bracket

Release the throttle operating lever securing screw and adjust the lever until contact is made with the top end of the slot in the throttle lever mounting bracket. Retain the lever in this position whilst re-tightening the screw.

## Throttle Potentiometer

**NOTE:** If either of the two previous settings 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 will be irreparably damaged if the meter is set to ohms.

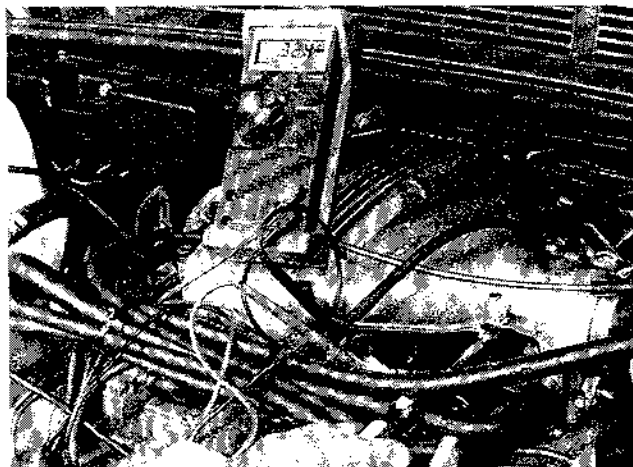


Fig.5 Throttle potentiometer adjustment.

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  $325 \pm 35\text{Mv}$ .

If the reading is incorrect, slacken the two 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. The checking procedure is given later in the electrical test section of this book.

### Check and adjust ignition timing

To check the timing, run the engine until it reaches normal running temperature. Then 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.

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 given in the tuning data section, 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.

Reconnect the vacuum advance pipe and the air conditioning compressor (if fitted).

### Check and adjust idle speed

Make sure the engine is fully warmed up before connecting an accurate tachometer to check the idle speed (see tuning data for correct idle speed).

If the idle speed is incorrect, the idle speed adjustment screw is located in the plenum chamber adjacent to the throttle butterfly.

NOTE: A tamperproof plug has to be removed to gain access to the idle speed screw.

Turn the idle speed adjustment screw clockwise to decrease the speed and anti-clockwise to increase.

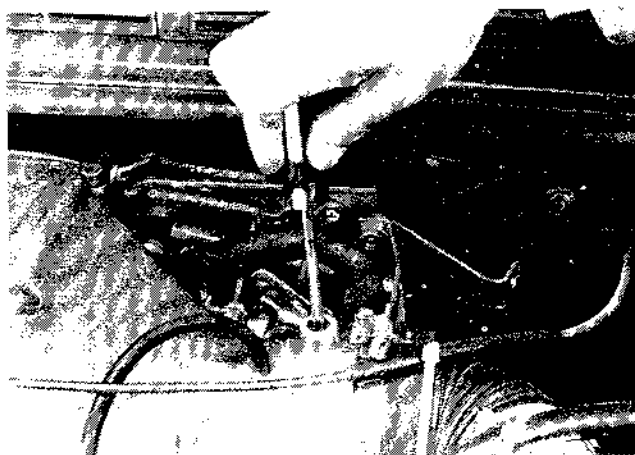


Fig.6 Adjusting idle speed

NOTE: Do not fit a new tamperproof plug at this stage as adjustment of the CO level will affect the idle speed.

### 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 in the tuning data adjust the level at the idle mixture screw fitted in the air flow meter. The screw is accessed by removing a tamperproof blanking plug.

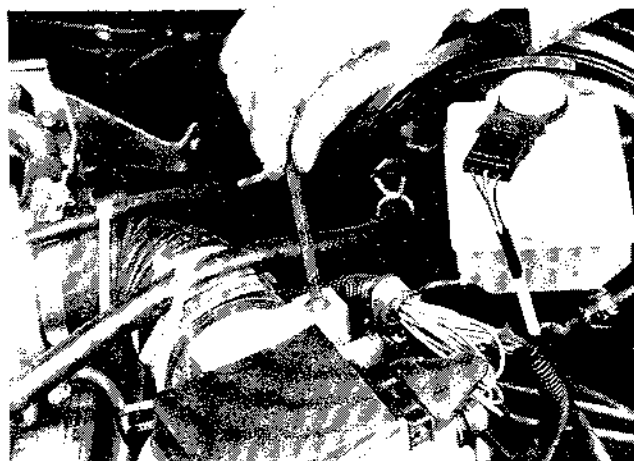


Fig.7 Adjusting idle CO level

NOTE: When checking/setting CO level do not allow the engine to idle for longer than a 3 minute period.

Give the engine a 'clear-out' burst of 30 seconds at 2000 RPM, then re-check the CO and if necessary re-adjust the idle speed.

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 i.e. 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 the chart below.

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, insufficient air.  
 D= Excessive fuelling one bank only.

### Analysis

#### Condition A

Indicates a possible fault 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 thermotime 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 grey 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 LSM0094TM.

#### 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.

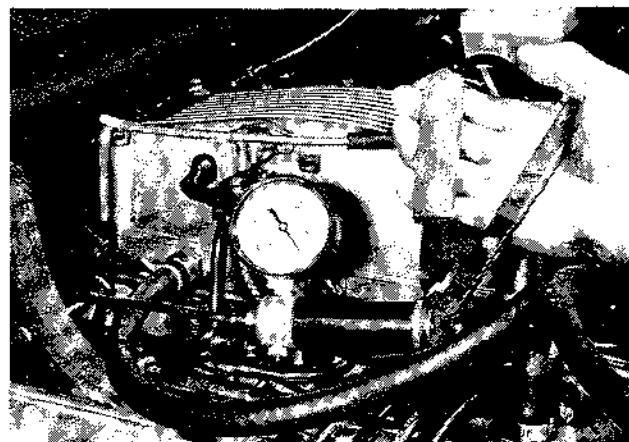


Fig.8

Begin by disconnecting at the plenum chamber the vacuum pipe to the fuel pressure regulator and the vacuum switch. Fit a vacuum pump (as shown in Fig.8) 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 switch, or in one of the connecting pipes. Rectify as necessary then reconnect to the plenum chamber.

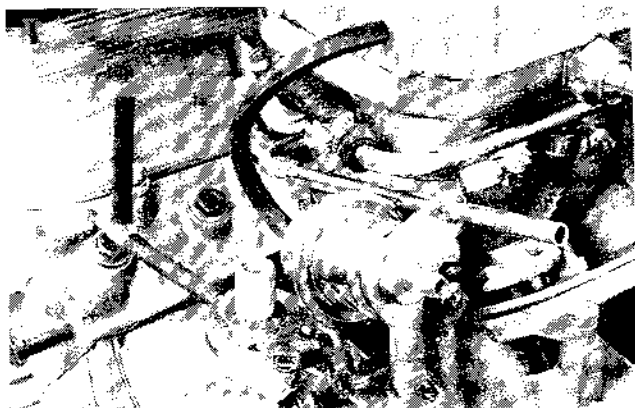


Fig.9

If a vacuum pump is not available, disconnect the fuel pressure regulator vacuum connection from the regulator and from the 'T' piece, and examine the pipe to ensure it is totally sound. Then refit the pipe directly between the fuel regulator and the plenum chamber as shown in Fig.9, leaving the vacuum pipe to the fuel shut-off relay vacuum switch hanging free.

Now thoroughly re-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 both clips are secure.

Start the engine and note the engine speed, using an accurate tachometer.

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 as follows:

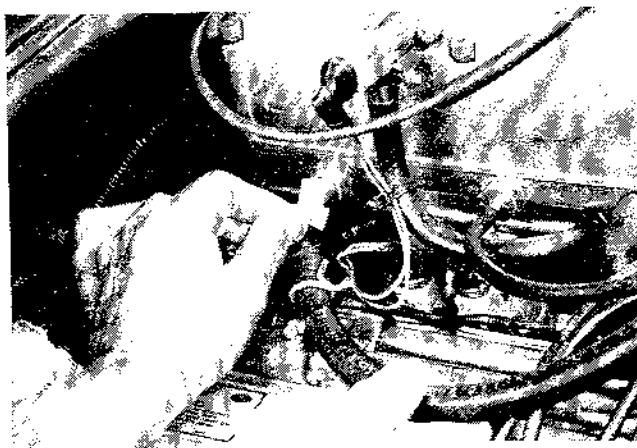


Fig.10

- 1 Disconnect the brake servo, and seal the union connection at the plenum chamber as shown in fig. 10.

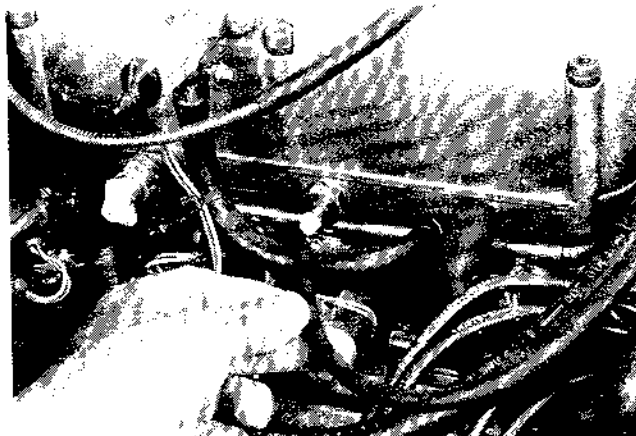


Fig.11

- 2 Disconnect the vacuum connection to the vehicle ventilation system and seal the plenum chamber (as fig 11)



Fig.12

- 3 Disconnect the extra air valve connection and seal the plenum chamber (as fig 12).

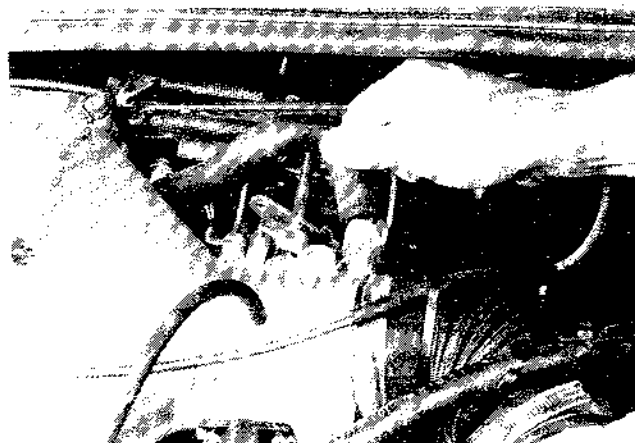


Fig.13

- 4 Disconnect the air supply to the extra air valve gallery from its connection near the throttle butterfly and seal the port (as Fig.13).

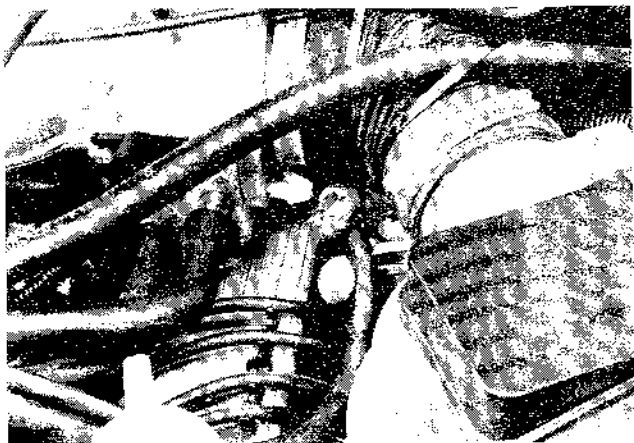


Fig.14

- 5 Disconnect the charcoal canister vacuum pipe (if fitted) and seal the port at the plenum chamber (as Fig.14).

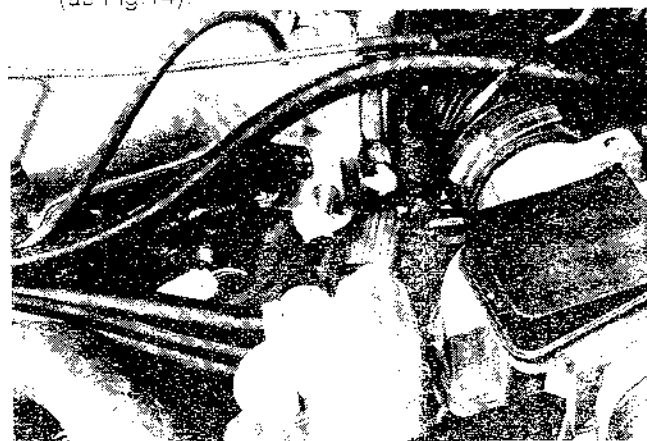


Fig.15

- 6 Disconnect the crankcase ventilation pipe from its connection near the throttle butterfly, and seal the port (as Fig.15).

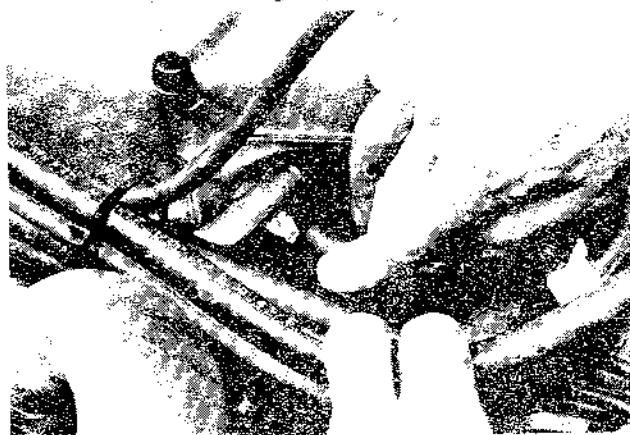


Fig.16

- 7 If fitted, disconnect the hose from the air conditioning air valve, and seal the plenum chamber (as Fig.16).

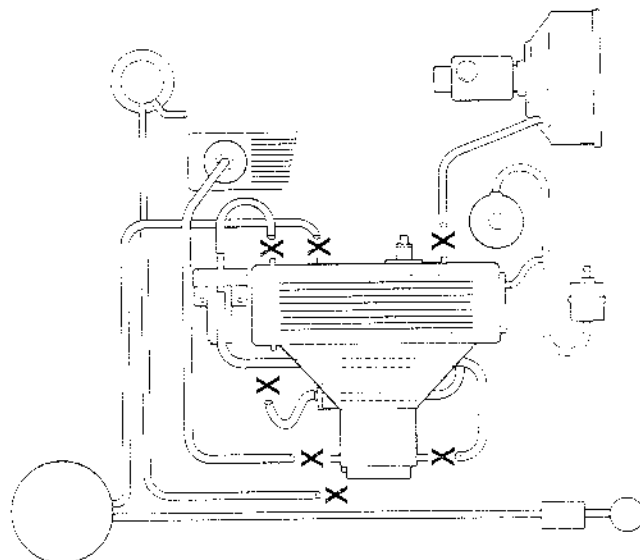


Fig.17 Air connections to the plenum chamber sealed off.

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.17.

- 8 Start the engine (if necessary depress the throttle pedal to raise the engine RPM) and run until normal operating temperature is reached; then allow to idle and check the idle speed, noting if it has changed, 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 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.

**NOTE:** 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 apparently rectified by readjustment of the idle screw.



- 9 So if the RPM has altered, record the engine speed at this stage; it is required for comparison to enable you to pinpoint which of the disconnected pipes or components is at fault, during the remainder of the tests.

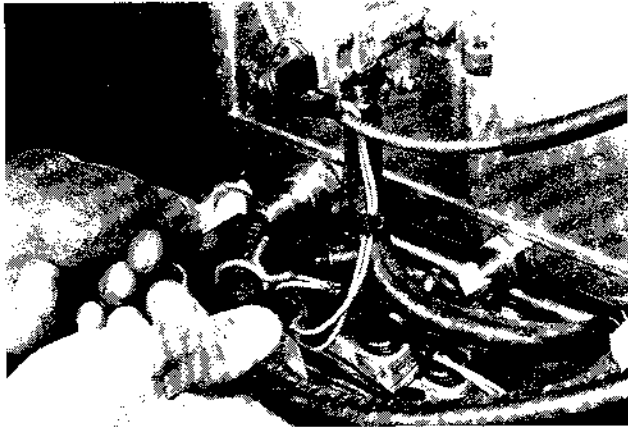


Fig.18

- 10 Begin by unsealing and reconnecting the brake servo pipe, seen in Fig.18, then start the engine and compare with the speed just recorded; if there is a change, the fault lies in the brake servo hose or in the brake servo unit itself. This area can now be investigated and the problem rectified.

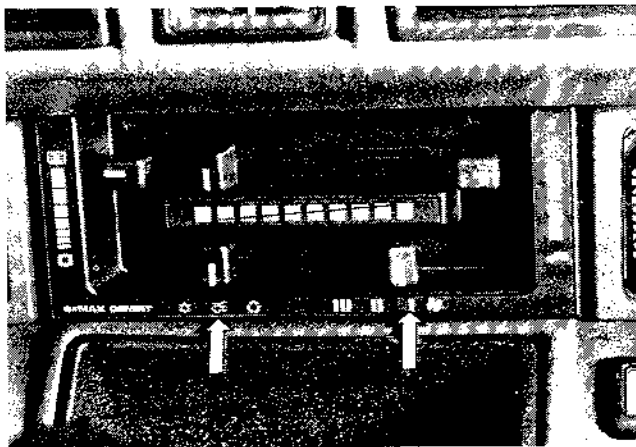


Fig.19

- 11 Before reconnecting the vacuum pipe to the ventilation system, set the two lower ventilation controls to 'Fresh Air' and 'Fan On' (see Fig. 19).



Fig.20

- 12 Then unseal and reconnect the ventilation vacuum pipe (see fig 20), and check the engine speed; any change indicates an air leak into the vacuum controls of the fresh air flap.

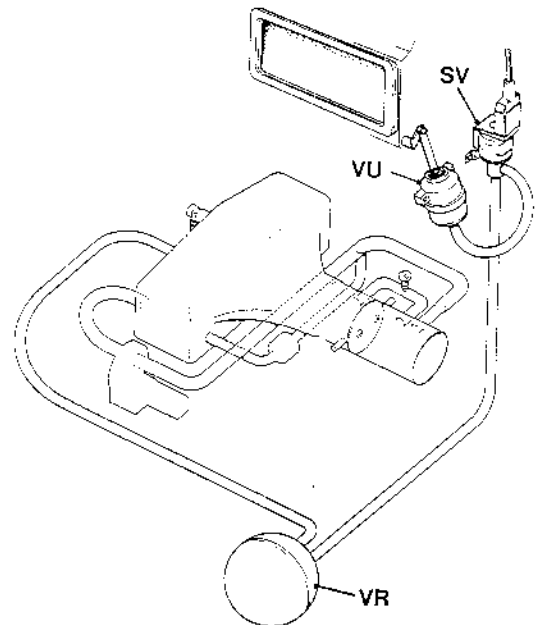


Fig.21 Vacuum connections to ventilation system.

- VR Vacuum reservoir
- SV Solenoid valve
- VU Vacuum servo unit

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, the solenoid valve or the connecting pipes. If the engine speed has been restored to that recorded at instruction 9, the fault must lie in the vacuum servo unit which operates the flap or the pipe between it and the solenoid valve.

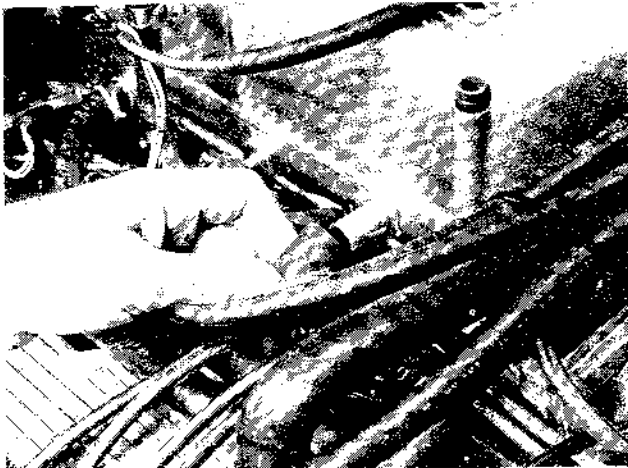


Fig.22

13 The next step is to unseal and reconnect the extra air valve hose at the plenum chamber, seen in Fig.22, and check if there is a change in the engine speed. Any change indicates that air is leaking through the extra air valve 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.

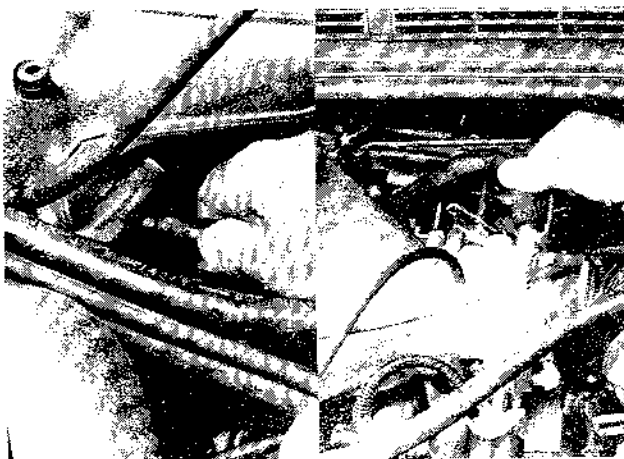


Fig.23

14 Unseal both the air conditioning air valve connection at the plenum chamber and the air hose at the throttle butterfly and reconnect both pipes shown in Fig. 23. 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 valve for the air conditioning unit are sound. If however the speed has changed it means that air is entering the plenum chamber through the air conditioning air valve and it is this that is faulty.

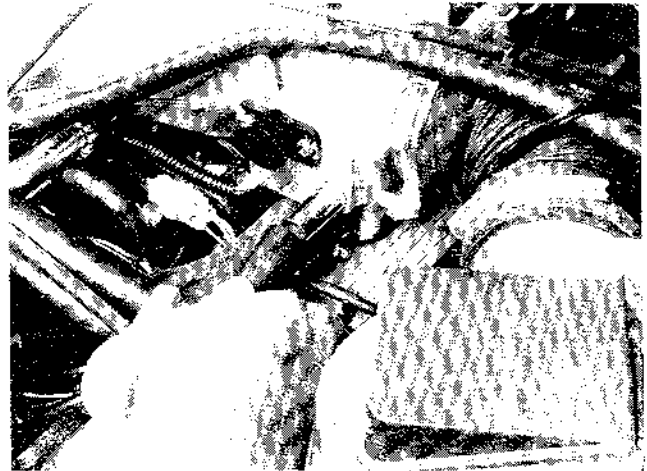


Fig.24

15 Unseal and reconnect the crankcase vent pipe (see fig 24), and check the engine speed.

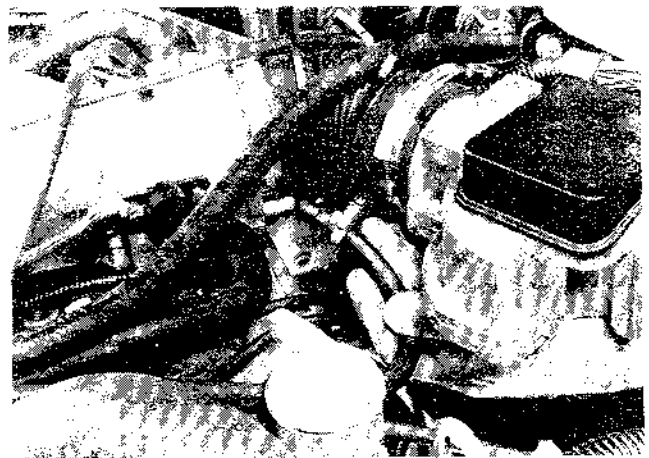


Fig.25

16 Unseal and reconnect the charcoal canister hose (see fig 25), and check the engine speed.

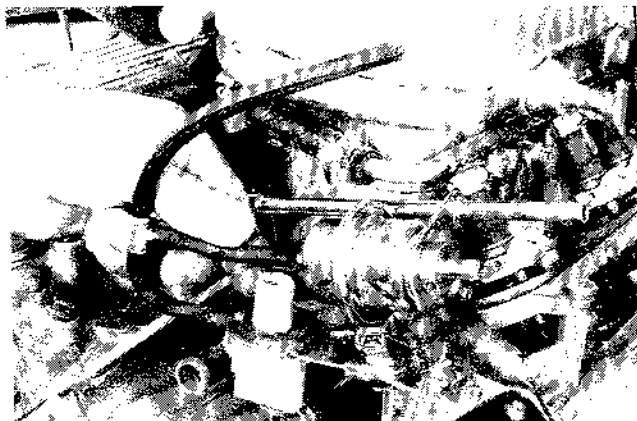


Fig. 26

17 Finally, if the vacuum switch was left disconnected as per fig.9, reconnect it now and check the engine speed. As with the preceding test a change in the engine speed would indicate a fault in the pipe or switch.

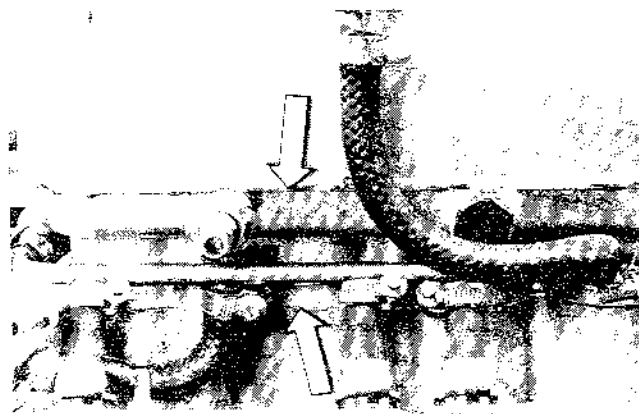


Fig. 27 Plenum chamber seals

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 two plenum chamber seals, the cold start injector, or indeed past any of the injector seals into the manifold, or past the manifold gasket.

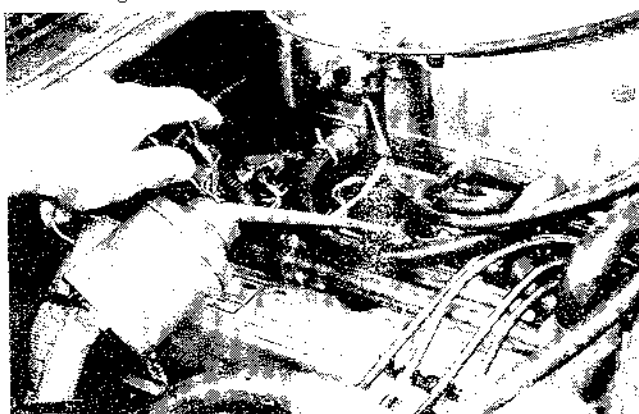


Fig. 28

To check for leaks in any of these areas, start the engine and squirt oil around each of the injector locations; 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 air tight seal.

The same exercise can be carried out on the inlet manifold joints by squirting oil around the suspected joint.

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 pipes to be sealed are 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.

**NOTE:** After rectification of any air leaks into the inlet system the idle speed and CO level must be adjusted.

### 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 kgf/cm<sup>2</sup> (26 to 36 lbf/in<sup>2</sup>). When the engine is stationary this pressure is maintained within the system.

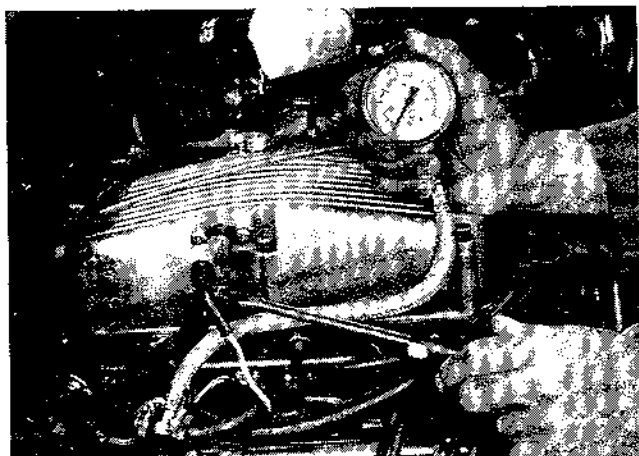
To prevent pressurised fuel escaping and to avoid personal injury it is necessary to depressurise the fuel injection system before connection of the test gauge or any servicing is carried out.

### Depressurising the Fuel System

Remove the ECU protective cover located under the front right hand seat, and pull the fuel pump relay off its multi-plug; this will immobilize 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.

**NOTE:** 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.



**Fig.29 Pressure gauge**

Connect the pressure gauge as seen in Fig. 29.

Refit the cold start injector and fuel pump relay, and re-connect the battery.

#### **Testing the Fuel Pressure Regulator**

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 kgf/cm<sup>2</sup> (35 to 37 lbf/in<sup>2</sup>)

Switch off the ignition. The fuel pressure should be maintained between 2.1 to 2.6 kgf/cm<sup>2</sup> (30 to 37 lbf/in<sup>2</sup>)

**NOTE:** 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 reading is unsatisfactory, renew the pressure regulator.

After fitting a new regulator re-test the system. If the pressure continues to drop off, the fuel injectors, fuel pump, non-return valve and fuel system pipework should be checked for leaks.

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 the problem still persists, 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.