Back to Basics

With

Auto-Solve

Topic 9

Emissions Related Components and Actuators

In this months topic we will be looking at the actuators and components that effect the vehicles exhaust emissions when the electronically controlled fuel injection system is found to be over fuelling.

There are predominantly two reasons for *excessive* fuelling: increased fuel pressure or extended injector duration.

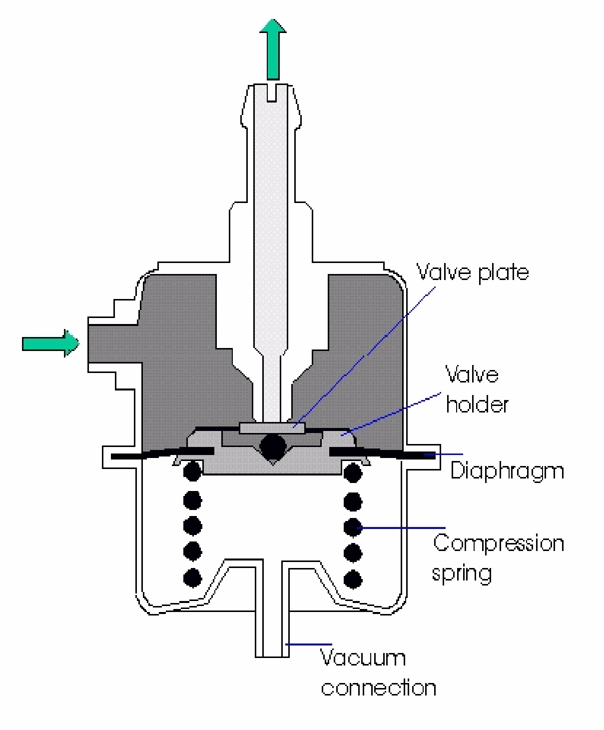


Fig 1.0

The Fuel pressure should be tested using an accurate pressure testing kit and the results compared against the manufacturers specification. The system pressure on the majority of multi-point injection systems is usually around 2.0 bar, increasing to 2.5 bars under acceleration conditions. The fuel pressure regulator (**Fig 1.0**) is separated into two halves, these being divided by a diaphragm. The lower part has an internal spring and a vacuum take off point, the upper half receives the fuel from the fuel rail. When the fuel pressure rises above that of the spring tension, the diaphragm is depressed and the excess pressure escapes back to the fuel tank via the return pipe. If the spring inside the pressure regulator becomes weakened, the pressure reduces accordingly.

The vacuum hose that is connected to the lower chamber allows the effective pressure exerted onto the diaphragm to change with different engine loads. Excessive fuelling will occur if the rubber diaphragm inside the pressure regulator is perforated as this will allow fuel to pass into the inlet manifold via the vacuum pipe.

The emissions produced by the combustion process have never before been under more scrutiny from both ecological movements and government legislation; it is therefore important that the vehicle runs efficiently, helping to minimise harmful emissions from the exhaust tail pipe. An engine can, in theory run at such a point where the emissions produced will be no more than harmless oxygen, carbon dioxide, nitrogen and water. The theory may be correct, but with the combination of moving parts, varying engine speed, temperature change and different timing and fuel mapping, the final output is often less than perfect.

At a certain Air / Fuel ratio (AFR) the emissions from the exhaust will be minimised and with the introduction of the catalytic converter and lambda sensor, the outputs can be reduced to satisfy the current construction and use regulations. If the engine should suffer from an ignition misfire or an electronic component failure the combustion process will be greatly compromised, causing both an unacceptable increase in exhaust emissions and the possibility of damage to the catalytic converter. Most vehicles registered after 1992 will be equipped with a three way catalytic converter and more often than not, will have 'closed loop' control.

'Closed loop' means that when the expended exhaust gasses pass through the exhaust pipe, the lambda (or oxygen) sensor will report the condition of the mixture to the Electronic Control Module (ECM) and can adjust the fueling accordingly. A sensor that is switching correctly will alter the fueling about once per second and the speed of this switching can be seen on an oscilloscope. An ideal Air/Fuel ratio from complete combustion will result in the lambda sensor having the ability to ‘fine tune’ the fuelling.

Assuming that the fuel pressure is correct, the excess fuel must therefore be emanating from an increase in injector duration. This can be caused by any of the following sensors and actuators.

- Coolant temperature
- Throttle position sensor
- Lambda sensor
- Mass airflow meter
- Weak or ‘dribbling’ injector
- ECM fault
- MAP sensor
- Air temperature sensor

Coolant Temperature Sensor

The sensor itself has the ability to alter its resistance with engine temperature change. The majority of sensors have a Negative Temperature Coefficient (NTC) which results in the resistance of the component decreasing as the temperature increases. The resistance change will therefore alter the voltage seen at the sensor and can be monitored for any discrepancies across its operational range. By selecting a time scale of 500 seconds, connect the oscilloscope to the sensor and observe the output voltage. Start the engine and in the majority of cases the voltage will start in the region of 3 to 4 volts; however this voltage will depend on the temperature of the engine - as the temperature increases the resistance decreases and the voltage will also be seen to drop. If the resistance of the sensor is higher than anticipated this will cause the ECM to be ‘fooled’ into thinking that the engine is colder than it actually is, thus giving additional fuelling. The same effect will be seen if there is a poor conductivity at either the sensors two pin connector or at the ECM. This will give the equivalent to another resistance in series, increasing the overall resistance.

Mass airflow meter (Air Vane)

The voltage output from the internal track of the Air Flow Meter (AFM) should be linear to flap movement; this can be measured on an oscilloscope and should look similar to the example shown. The waveform should show approximately 1.0 volt when the engine is at idle, this voltage will rise as the engine is accelerated and will produce an initial peak. This peak is due to the natural inertia of the air vane and drops momentarily before the voltage is seen to rise again to a peak of approximately 4.0 to 4.5 volts. The initial voltage seen at idle will vary between motor manufacturers and should therefore be compared against the relevant data.

Mass airflow meter (Hot Wire)

This particular form of air flow meter is, in many ways, advantageous over the conventional air vane meter as it offers very little resistance to the flow of incoming air. The mass air flow is measured by the cooling effect on a heated wire that is suspended in the air passage, and it is the air flow's cooling effect on the wire that signals to the ECM the quantity of incoming air.

Inside the component are two wires, one of which is used to convey the temperature of the incoming air and the other wire is heated to a high temperature (approximately 120°C) by passing a small current through it. As the air flows across the heated wire, it will have a cooling effect on it causing a temperature change; a small circuit inside the component will increase the current passing through the wire to maintain the temperature, and it is the recognition of this current that signals to the ECM the mass air flow.

The current supplied to the heated wire will alter proportionately to the air flow - any wire that is constantly heated will form an oxide coating. To clean the wire after each journey, a current is passed through the wire heating it to approximately 1000°C, burning off any build up, ensuring a clean wire for the next time the vehicle is started.

MAP Sensor (Analogue)

This particular component can be either an integral part to the electronic control unit or an individual component. The output from the analogue version will show a rise and fall voltage depending upon the vacuum seen. When the engine is stationary or the throttle is wide open, zero vacuum will be recorded and a voltage approaching 5 volts will be seen, as a vacuum is applied the voltage will reduce. With this particular form of engine load recognition, the condition of the vacuum pipes and connections are vital as any air leak will fool the ECM into over fuelling.

MAP Sensor (Digital)

A digital MAP sensor will produce a square wave signal to the engine management ECM; this square wave will change frequency with varying engine vacuum readings. This output waveform can also be monitored on an oscilloscope, or the frequency measured on a certain multimeters that have the appropriate setting (Hz). The frequency seen at idle should match the frequency seen in the manufacturer's data. Air leaks also effect this digital form of monitoring the engines vacuum.

With both forms of MAP sensor, the engines fueling will increase if the exhaust system has a restriction that impedes the flow of the spent gasses.

Throttle Position Sensors

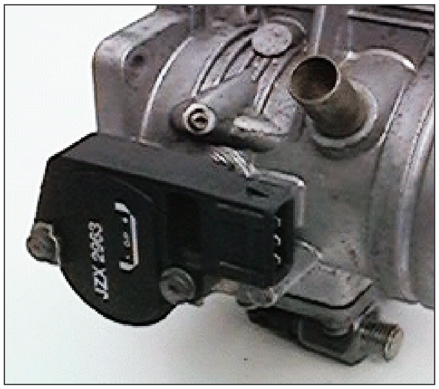


Fig 1.1

This throttle potentiometer (**Fig 1.1**) is able to indicate to the ECM the exact amount of throttle opening. A throttle switch is unable to give precise positions of opening; however a throttle pot will be able to give precise openings due to its linear output. The majority of modern engine management systems will employ this particular sensor, and like the throttle position switch it is located onto the butterfly spindle.

This is also a three wire device employing a 5 volt supply, an earth connection and a variable output from the centre pin. Some TPS's are attached to the throttle body via elongated locating holes, if this is the case, an initial voltage setting must be made as too high an initial voltage will suggest an open throttle and the ECM will over fuel.

Weak or 'Dribbling' Injectors

The injector consists of a solenoid operated valve which is held in the closed position by a spring until the earth circuit is completed by the ECM. When the electromagnetic field lifts the pintle off its seat, fuel is delivered to the engine. The total lift on the pintle is approximately 0.15 mm (6 thou) and has a reaction time around 1 millisecond.

Any dirt ingress around the pintle seating area will cause the injector to not seat properly, allowing fuel to escape into the inlet manifold. The same consequences will also occur if the internal spring is damaged or broken. The injectors can be tested for flow rate, reaction time and leakage in a specialised test unit. The leakage test can however be performed by removing the fuel rail, pressurising the system and observing the injectors for any leakage. Any faulty injectors should of course be replaced with another injector with a comparable flow rate. An example injector can be seen in **Fig 1.2**.

Fig 1.2

Air Temperature Sensor

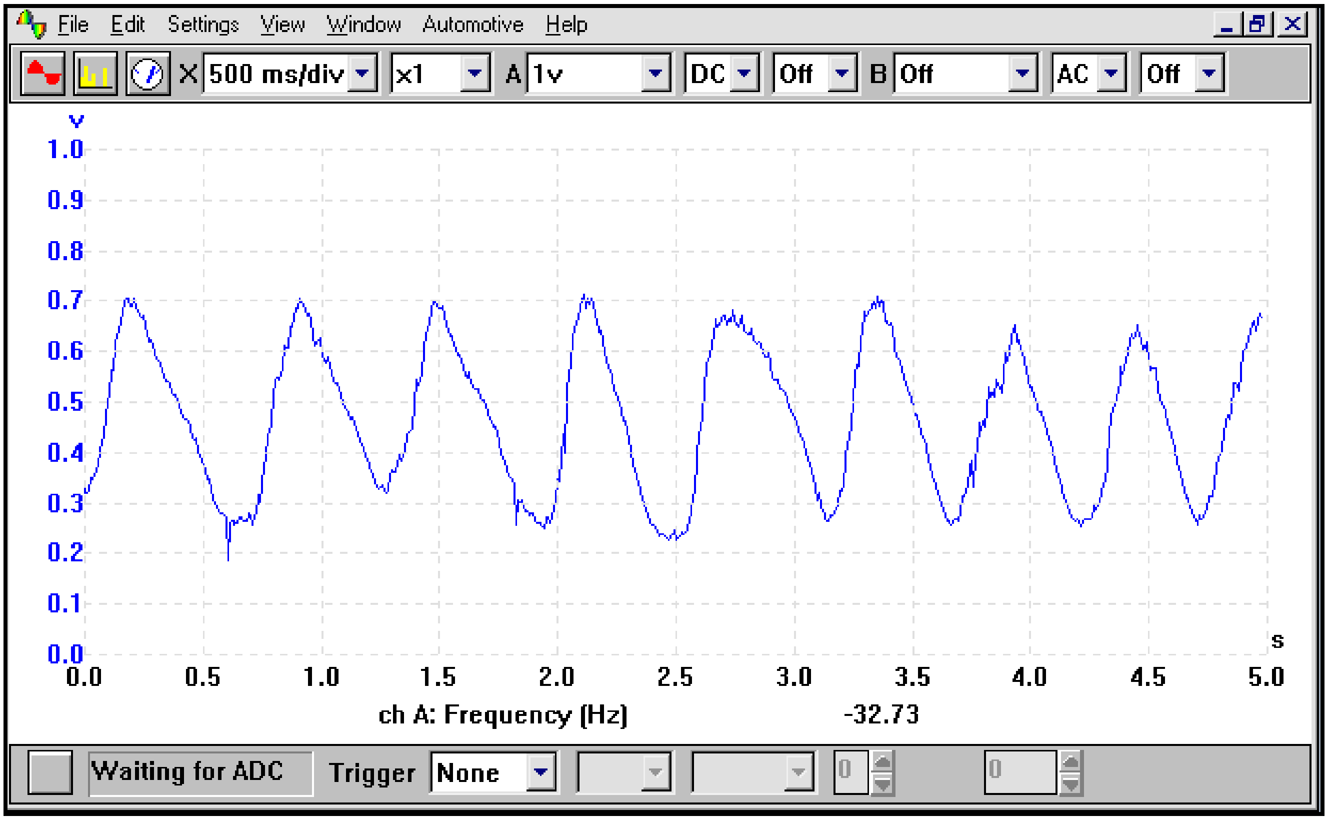
With the air temperature sensor only contributing 20% of the temperature compensation, the sensor would only have any discernable effect if it was open circuit.

Lambda Sensor

The most popular lambda sensor used on European vehicles is the Zirconia type. This sensor is essentially two porous platinum electrodes. The outer electrode surface is exposed to the exhaust gasses and is coated in a porous ceramic with the inner coated surface exposed to fresh air. The sensor then produces a voltage when there is a difference in oxygen content between the two electrodes. This signal is then sent to the ECM and the mixture is adjusted accordingly.

The voltage range is normally 0.2 volts when lean and 0.8 volts when rich.

A constant high voltage output from the sensor shows that the engine is running constantly rich and is outside the ECM's adjusting range.



X 500 ms/div x1 A 1v DC Off B Off AC Off

ch A: Frequency (Hz) -32.73

Waiting for ADC Trigger None

Fig 1.3

Lambda sensors, when working correctly, will switch approximately once per second (1 Hz) and will only start to switch when at normal operating temperature. This switching can be monitored on an oscilloscope with the waveform looking similar to the one in **Fig 1.3**.

A conventional Zirconia sensor will display a high voltage while the engine is running with an excess of fuel, with a low voltage while running lean, the same principal also applies to the Titania variation but this time at a higher voltage of 0 – 5 volts.

ECM Fault

The ECM fitted to today's modern engine management system is responsible for the 'mapping' of the ignition timing and the fuel delivery. In order for the ECM to calculate the required ignition and fueling parameters, it must be fed with input signals from the engine's sensors. The ECM is pre-programmed with data that ensures the engine's performance and efficiency is maintained throughout the operational rev range and can be trimmed using a knock sensor to finely adjust the ignition timing and a lambda sensor to control the fueling when in closed loop.

The majority of ECM's will have a self diagnosis facility which is able to detect any problems from signals outside their normal operating range. Another facility that the ECM has is its ability to operate in 'limp home' or LOS mode (Limited Operation Strategy). This allows the ECM to operate from pre set parameters when the system encounters a failure, often illuminating the engine warning light.

If a faulty ECM is suspected, it can be tested to asses its condition before a substitute unit is fitted.

In next months topic we will be testing miscellaneous sensors and actuators and studying their resultant waveforms.