TECHNICAL INFORMATION

Operation of a Typical EFI Fuel System

"This Fuel Pump Makes Too Much Pressure!!" –
Modern EFI fuel systems circulate as much as 200 litres per hour (~ 3 litres/min) of fuel at pressures between 2.5 & 3.5 bar (250 – 350 kpa). The diagnosis of these systems is a simple exercise provided the operation of the EFI fuel system is clearly understood.
Modern electric fuel pumps are "Positive Displacement" type pumps, simply this means that the pump cannot produce pressure unless it is acting upon a restriction. The only "restriction" in the system should be the fuel pressure regulator. This regulator controls the system pressure; the pressure ability or flow volume capacity of the fuel pump will not alter the system pressure.
The fuel pressure regulator is designed to maintain a constant pressure differential across the fuel injector under all engine operating conditions, this value is the regulators "set" pressure and is often marked on the regulator body.
The diagram below shows a typical fuel system arrangement, the cycle of fuel movement can be summarised as follows –

1. Fuel flows from the fuel tank to the main high-pressure pump. A sufficient volume is critical, typically 60 – 100 l/hour.
2. The main high-pressure pump then pressurises this fuel through the lines and filter up to the fuel rail where typically the pressure regulator will be located.
3. The pressure regulator will allow pressure to build until the set pressure is reached, at this point the regulator valve will open and allow the excess fuel to travel back to the fuel tank via the return line.

Suggested procedures on how to check fuel system operation can be located in the article "EFI Fuel Pressure Testing Procedures".

Cleaning & Servicing of K & KE -Jetronic Fuel Injectors

The cleaning of electronic fuel injectors has been a common practice for many years. The process of removing chemical build up and foreign material from the surface of the injector pintle has been quite successful with the use of various machines, chemicals and processes.
Whilst this is seen as a successful alternative to costly replacement of fuel injectors, the cleaning process is generally not successful however with K & KE-Jetronic mechanical type injection valves. The simple reason for this is related to the fact that unlike electronic fuel injectors, these valves are completely mechanical in their operation and simply wear out. The malfunction of K-Jetronic type injectors is generally caused by wear and tear of the valve mechanism and not due to contaminants, hence cleaning is generally not an alternative, nor is it successful in the long term.
Testing of these injectors can be easily and thoroughly carried out using Bosch mechanical injector valve tester # KDJE-P400. This tester allows not only the atomisation of the injector to be observed but also the "break pressure" of the injector, to be sure it will operate as per system requirements. More details of this tester can be found in the "Technical Spare Parts" section of this catalogue.\

Engine Overheating & Coolant Temperature Sensors

When repairing a vehicle that has been severely overheated, consider replacing the Coolant Temperature Sensor. These sensors are designed to operate in liquid temperatures ranging from -30°C to +130°C, however in an engine overheat situation the sensor may be damaged. It is suggested that the sensor is physically and electrically inspected prior to reassembly for heat stress, corrosion of the terminals, physical splitting around the joints and electrical malfunction, if in doubt replace the sensor.
Remember that modern engine management systems commonly utilise one sensor to supply various vehicle systems with engine temperature information, hence a faulty Coolant Temperature Sensor may cause various vehicle faults that are not necessarily related to the repairs undertaken.

Splitting Injector Bodies - 'JECS" Injectors.

Beware of fuel leakage at the body joints of certain types of fuel injectors fitted to early Nissan and some Isuzu engines. The injector body splits where the plastic connector housing meets the metal injector body and can "spray" fuel across the engine causing an extreme fire hazard. This leakage may only occur at higher fuel pressures such as those experienced at high load and/or turbo boost conditions. It is likely that thermal stress of these injectors may have contributed to this problem. Rectification of this problem will require replacement of the fuel injector, it is advisable to replace all injectors in this situation.

Noisy External Fuel Pumps

Many fuel pump noise issues are related to cavitation caused by insufficient fuel flow to the pump from the fuel tank. Keep in mind that external "Roller Cell" design fuel pumps are not designed to "draw" fuel from the tank. Vehicle design usually ensures that either the fuel pump is mounted low enough to be gravity fed, or a "Pre-Pump" or "Lift Pump" is fitted into the fuel tank of the vehicle.

When a fuel pump is to be replaced it is important to ensure adequate supply of fuel to the main pump exists. Details on how to check this is detailed in the article "EFI Fuel Pressure Testing Procedures"

Important Note – Fuel pumps that fail due to cavitation/fuel starvation caused by insufficient clean fuel supply are not covered by Bosch warranty

Porsche Turbo K-Jetronic Fuel Injectors

K-Jetronic fuel injector part numbers 0 437 502 009, 017 & 057 as applied to Porsche 911 & 924 Turbo must not be substituted by other fuel injectors. Whilst technically & physically appearing identical to earlier 004 & 012 injectors, these injectors have a fine thread near the gland nut. This thread is designed to secure these injectors into their unique holders avoiding any possibility of the fuel injectors becoming dislodged under boost conditions. The use of other fuel injectors may result in the injector being loosened or dislodged causing engine performance issues and possible fire.

"Dual Element" Coolant Temperature Sensor - 0 280 130 032

Many European vehicles utilise the combination of Bosch LH-Jetronic (LH 2.3/4) and EZK/F ignition management systems. As both of these systems require coolant temperature information, these vehicles use a "Dual Element" Coolant Temperature Sensor, part number 0 280 130 032. This sensor [often identified by its black connector plug] is unique in that not only does it contain two independent NTC sensing elements, but is actually earthed through its body. Due to this fact it is important that the mounting area is always clean and free from corrosion and foreign matter to avoid earthing problems. Due to its design principle, this sensor must not be substituted with, or for any other sensor.

Fuel Injector Triggering Methods.

Whilst there are many different designs and manufacturers of engine management systems with varying levels of complexity and control, certain fundamental design principles remain constant. One of these principles is the method in which the fuel injectors are controlled or "triggered". As technology has improved over time and emission control legislation has tightened, the selected methods of injector control have become more critical. Essentially there are three different methods used in the majority of engine management systems, these methods include,

Simultaneous Injection
All fuel injectors are triggered together every crankshaft rotation or twice per engine cycle. Whilst simultaneous injection is the simpler and lower cost option, due to the timing of the injector pulses it does not deliver the most efficient fuel control. Due to some cylinders "storing" fuel in the inlet, and others injecting whilst the inlet valve is open, combustion control is not optimised and excessive emissions may result under certain operating conditions.

Group Injection
Injectors are triggered in groups of 2 or 3 [4 or 6 cylinder engine] alternately to one another. Generally these groups contain odd and even cylinders [cylinders 1, 3 & 5 in one group, cylinders 2, 4 & 6 in the other]. Each individual group of injectors are therefore only triggered once per engine cycle [every second crankshaft rotation]. Group injection has been used as far back as the 1960's, with D-Jetronic using a pair of contact points to control the triggering of each separate "group" of fuel injectors. Group injection has similar fuel control issues to the simultaneous triggering method in relation to "storage" and overlap injection. This method is not widely used in modern management systems but has an advantage over the simultaneous method in that due to the individual injectors only being triggered once per engine cycle, the amount of "dead time" that occurs in the opening and closing of the fuel injector is halved. Due to the fact that the injector is triggered at half the frequency, this also allows the available "on-time" of the fuel injector to be maximised. This may be a controlling factor in higher speed engine applications.

Sequential Injection
Each fuel injector is controlled and triggered individually in a selected firing order. Sequential injection provides optimal fuel control in that not only is the "on-time" controllable but also the exact timing of the injector pulse. Sequential injection methods only differ in the actual injection point, the sequence follows the ignition firing order of the cylinders. Injectors may be triggered when the inlet valve is closed or open. The choice of either method is dependent upon various engine design and emission requirements. The main effect, apart from perceived performance issues, is exhaust emissions. A system that triggers the injector when the inlet valve is open [during the camshaft overlap period] tends to produce higher Hydrocarbon emissions and less NoX, as combustion temperatures are generally lower. Whereas, a system that triggers the injector on a closed inlet valve tends to be the reverse, higher NoX emissions and less Hydrocarbon emissions because there is less transient fuel to go out through the exhaust.

Whilst fuel injector triggering is primarily about combustion control, other impacts of injector triggering method include fuel pulsation. The opening of all fuel injectors at once obviously creates a much more noticeable pressure variation than a system that operate only half or one fuel injector at a time.

What is Fuel Injector "Duty Cycle"?

In order to properly explain fuel injector "Duty Cycle", an understanding of the concept and measurement of Frequency (HZ) and Duty Cycle (%) is essential.

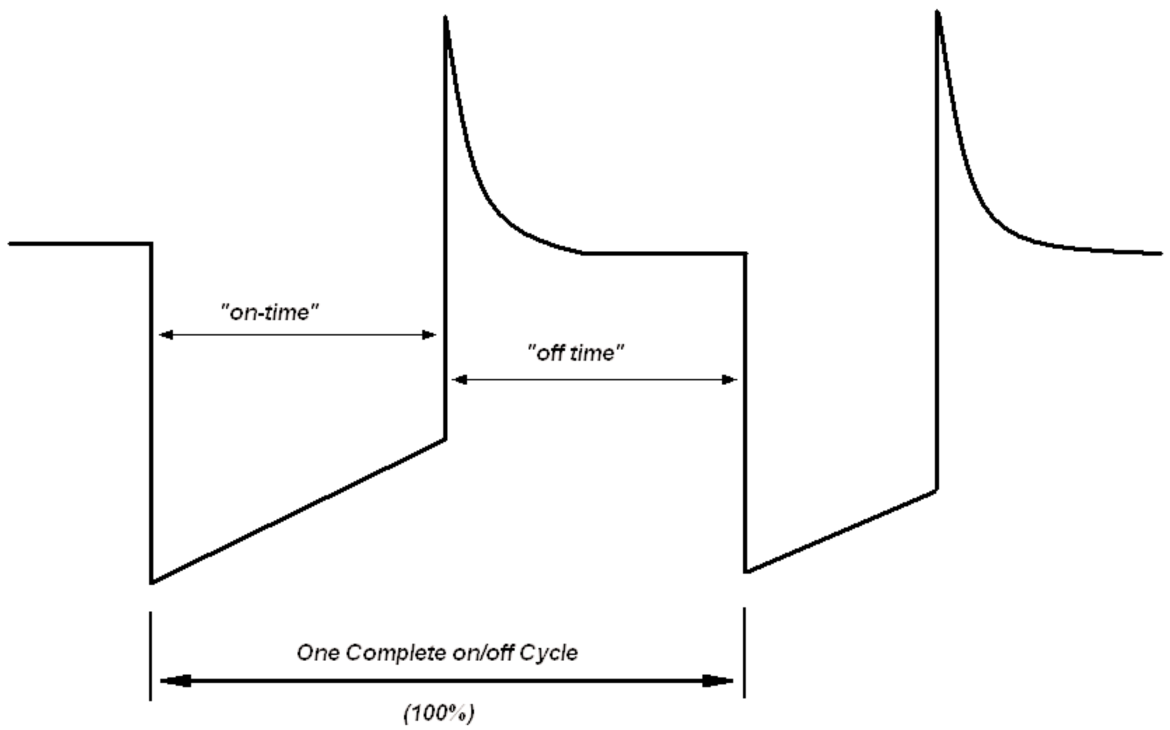
Frequency is a measure of specific "cycles" of over a period of "time". For many years the automotive industry has referred to RPM [engine revolutions per minute] this is of course a measurement of frequency. In this application, engine crankshaft rotations equal the "cycle" and the period of "time" equals one minute, hence "cycles per minute".

As the speed of signals has increased, the required measurement definition has also increased. The most commonly used and accurate frequency measurement for electronic signals is Hertz (HZ), or "cycles per second". One complete cycle can be stated as 100%. So, frequency is a measurement of how many on/off cycles occur in one second, and duty cycle is a measurement of the percentage of "on-time" or "off-time" over that period.

In relation to fuel injectors, the frequency is directly related to engine speed. As the engine speed increases, so does the injector pulse frequency, this also means that the "real time" between injector pulses reduces as engine speed rises and therefore the available "on-time". In simple terms, the amount of time taken for the crankshaft to complete one rotation at 1000 rpm is much more than the time it takes to complete one rotation at 5000 rpm.

The Duty Cycle of the fuel injector is therefore a measurement of the percentage of time the fuel injector is switched on for across one complete on/off cycle.

When designing an engine management system, engineers take into account various factors that will influence injector on time including fuel system pressure and fuel injector flow capacity. Insufficient fuel pressure or fuel injectors that are too small for their application may cause excessive injector duty cycle. Excessive fuel pressure and/or injectors that are too large for their application can cause duty cycles that are too small. It is important that there is sufficient on time for the injector to be able to establish a useable atomised spray. Systems with minute duty cycles at low engine speeds will generally have fuel control issues; this is commonly caused by fuel injectors that are too large. Problems may also arise when a large fuel injector is required to supply correct volume of fuel at heavy load/high speed, and yet these are too big to control at low speed/low load conditions. Alternative fuel system management processes may be required under these conditions.



Evolution of Engine Load Measurement Devices

Overview

The evolution of engine load measurement devices has been driven by improvements in materials, manufacturing and technology. The two most critical pieces of data required by the modern engine management system is engine speed/crankshaft position and engine load. As engine load input has the largest effect on injector pulse time of all engine sensors, accuracy of measurement is of prime overall importance to deliver premium system performance.

Since the use of electronic fuel injection systems commenced as far back as the early 1950's, certain critical factors of engine operation have been required to be monitored. There are several key pieces of engine data required by the electronic control unit [ECU] to control even the simplest of systems. These include,

- Engine Speed [RPM]
- Engine Load
- Coolant Temperature
- Air Temperature
- Throttle Position

Whilst the sensors that generate these signals have evolved with technology to allow the ECU to support more functions with greater clarity, the methods for measuring engine load have gone through many interesting phases to provide more accuracy, less complexity and increased reliability. The engine load signal has the biggest effect on fuel injector "on time" of any of the signal inputs to the ECU, hence its accuracy is critical for fuel control.
Essentially there are two operating strategies that are used in the design of an engine management system in reference to how engine load is measured. These two methods are,

- **Manifold Pressure Control [MPC] or Speed/Density** – uses a Manifold Absolute Pressure or MAP Sensor.
- **Air Flow Controlled [AFC] – uses an air flow or air mass sensor.**

There are various advantages and disadvantages of both of these strategies that we will discuss. It must be understood in all systems, the ECU must finally arrive at a calculation of the mass of air inducted by the engine in order to calculate the correct volume of fuel to be injected. As manufacturing processes and technology has improved, this has allowed us to improve on some design issues.

MAP Sensor versus Air Flow Sensor.

There is no rule to say whether MPC systems are better than AFC or vice-versa, manufacturers choice relates to many factors including performance, cost and reliability. Some of the issues are,

- MPC systems solely utilise manifold vacuum as an indication of engine load. Normal engine wear causes manifold vacuum to reduce, the system will interpret this as an increase in engine load and therefore increase the amount of fuel injected. The basic result is that as the engine wears the mixture becomes richer and richer over time.

- MPC systems are less affected by air leaks and generally have less complex inlet ducting.

- MPC systems are re-active to throttle movement due to the fact that manifold vacuum changes after the throttle has moved. AFC systems however have immediate reaction to changes in incoming air flow.

- As the engine wears and manifold vacuum drops, so does air flow. Hence the output from the air flow sensor reduces with the result that AFC type systems tend to maintain a serviceable air/fuel ratio over the entire life of the engine.

- Air flow sensors tend to be more expensive and complex than MAP sensors, they are also more susceptible to backfire damage and external tampering.

Manifold Absolute Pressure [MAP] Sensors.

Released in 1967, the Bosch D-Jetronic ["D" standing for the German word "Druck", meaning pressure] fuel injection system utilised the first "MAP" sensor, a sophisticated mechanical device. Referred to simply as a pressure sensor or aneroid, this device contains a brass diaphragm attached to a metal "slug" that moves in and out of two electrical coils affecting their inductance. As the engine load changes so manifold vacuum alters, the diaphragm within the sensor moves, and the electrical output to the ECU changes giving it a variable "load" signal. Due to the mechanical nature of this device, it is inherently slow. To aid in overcoming any flat spotting issues, D-Jetronic uses a sophisticated throttle position switch assembly that causes the ECU to provide multiple injection pulses on rapid throttle opening.

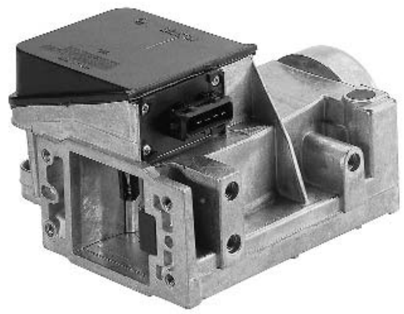
Evolution of Engine Load Measurement Devices - cont.

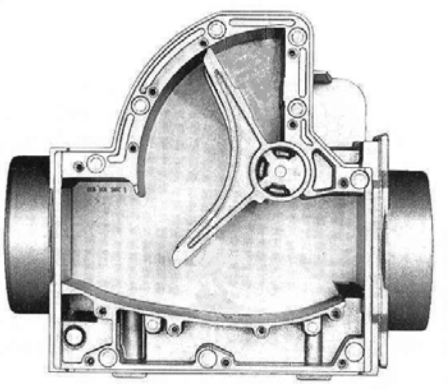
Although certain vehicle manufacturers utilised D-Jetronic up until the early 1980's, MPC type systems were not the system of choice of most manufacturers. MAP Sensor technology changed dramatically during the mid 1980's with the introduction of a piezo-crystal type sensor. Simply a piezo-crystal will produce a small voltage as it is subjected to pressure. By connecting a sensing chamber to the inlet manifold via a hose, changes in manifold vacuum will distort the piezo-crystal causing it to produce an output. This signal is then amplified and transmitted to ECU as a load signal. These sensors are much faster, cheaper and more reliable than the old mechanical D-Jetronic version. It is interesting to note however that the design problem related to flatspotting with MPC type systems still exists. Modern engine management systems using a MAP sensor use an injection mode referred to as "Asynchronous" injection to resolve flatspotting. This design feature allows the ECU to provide multiple injector pulses irrespective of crankshaft position and normal injection frequency.

Continual development and investment in this technology by Bosch has seen MAP Sensor design take a further evolutionary step with the creation of the ***"T-MAP Sensor",*** an integrated temperature and MAP sensor. These sensors allow the engine management system to accurately detect both manifold pressure and inlet air temperature within one sensor at one point in order to make an accurate assessment of the weight or mass of air being inducted by the engine.

Air Flow & Air Mass Sensors.

It is important to clarify the difference between an Air ***"Flow"*** Sensor and an Air ***"Mass"*** Sensor. An air flow sensor measures incoming air flow only. As the density or weight of air alters with temperature, the ECU utilises a separate air temperature sensor with an independent input to make its calculation of air mass. This sensor may well be located within the air flow sensor but is evaluated by the ECU independently.
An air mass sensor uses technology to be able to generate an output to the ECU related to total air mass, not flow.
Introduced in 1974, the Bosch L-Jetronic ["L" standing for the German word "Luft", meaning air] was the first system produced by Bosch to use a mechanical "Flap" or "Vane" type air flow sensor. Although these mechanical sensors appear simple in construction, they are in fact an extremely complex device, balancing precise mechanical movement with a variable rate spring and a laser calibrated potentiometer.
It is important to understand that these devices do not control the amount of air inducted into the engine as is often thought, but act purely as a measuring device.
Important design features of the flap or vane type air flow sensor are summarised below,





- Body contoured to suit airflow characteristics of individual engines. Clearance between body and measuring flap varies according to pivotal position of flap.

- Variable rate spring ensures correct body to flap position relationship across entire air flow range. Also allows altering spring force against incoming air flow rate at certain points.

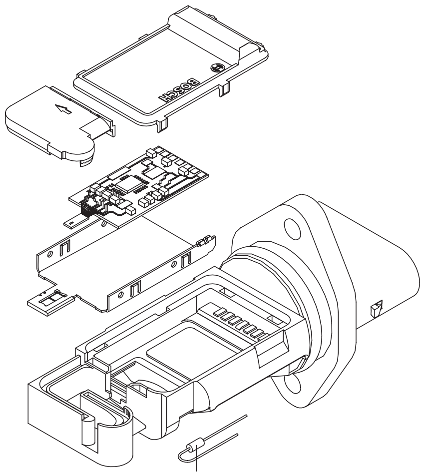
- Final calibration with a known quantity of air concentrates on three major factors, flap position to body, spring variable force against air flow and correct positioning of potentiometer wiper contact. Final laser trimming of the potentiometer resistive track completes the calibration of each unit.

Flap type air flow sensors can be found on the majority of European and Japanese engine management systems manufactured from the mid 1970's and up to as late as the late 1990's on certain systems.
Although flap style air flow sensors have served their purpose well for many years, some considered them not the most ideal device for this purpose. Issues such as mechanical failure, cost and the possibility of external tampering with the potentiometer settings lead to the requirement for development of superior technology.

Bosch's pursuit of continual technological advancement saw the introduction in the mid 1980's of the ***"Hot Wire" Air Mass Sensor.*** This highly efficient sensor used technology not seen in a motor vehicle before. It was considerably smaller, lighter, more tamper proof and much faster to react than its predecessor. It also had the advantage of producing a signal related to total air mass without any further processing.
Although a complex electronic device in practice, the theory of operation is quite simple. The sensor contains a 70 micron platinum wire suspended in a measuring venturi controlled by a hybrid control circuit located in the top of the unit. The platinum wire is held at a constant temperature of ~ 100° C above ambient temperature [measured by an internal air temperature sensor]. As incoming air flows over the platinum wire it dissipates heat from it, the hybrid control circuit then alters the amount of current that flows through the wire to stabilise its temperature, these changes are processed into an output voltage signal to the ECU reflecting incoming air mass.

Evolution of Engine Load Measurement Devices - cont.

As the platinum wire is exposed to all incoming air, a build up of minute contaminates will naturally occur over time. To reduce this build up, these units go through a “Self Cleaning” process each time the engine is shut down and certain parameters have been met. The cleaning process is in fact a function of the ECU with a signal being sent to the air mass sensor to increase the temperature of the platinum wire to 1000° C above ambient temperature for 1 second to clean the platinum wire. This process is often referred to as the “Burn Off” process.
Continual development and improvement of this technology has seen the evolution of the “Hot Film” Air Mass Sensor which uses the same principle as described above but with a “Hot Film Sensing Element” rather than a platinum wire. Due to their design, these units suffer less contamination issues and are simpler in operation requiring no circuitry for “Burn Off” or mixture adjustment. This technology is also better suited to the sensitivity requirements of engine air flow.
Current “State of the Art” in air mass sensor technology from Bosch is the “HFM 5” air mass sensor with reverse flow detection. This unit has the unique ability to detect the “reverse airflow” created by inlet pulsations naturally created by an engine during operation. By filtering these pulsations out the output signal accuracy is optimised.



Other Designs of Load Measurement Device.
Whilst many vehicle and component manufacturers broadly use the technology and methods described above for load measurement alike, there are other methods that have been used.
The ***“Karmen Vortex” Air Flow Sensor*** utilises a complex air flow measurement principle used generally in the commercial air conditioning industry for measurement of large air flows in building ventilation systems. The *“Karmen Vortex”* principle, involves the use of a *“vortex generating rod”* to create “*vortices”* within a measuring chamber. Positioned on either side of this measuring chamber are a transmitter and a receiver for passing either ultrasonic waves or infra-red light through the chamber. These “vortices” will distort the sensing sources, the rate of distortion will indicate the volume of air flow. These units require some complex electronics to operate and manage them, but are generally low maintenance and quite reliable.

The demands placed upon modern engine management systems to deliver better performance, functionality and driveability, whilst improving vehicle emissions can only be done with constant development and evolution of the ECU’s, sensing devices and management strategies used. The evolution process of load measurement devices has been a constant process and will continue to be so, this is due not only to material and manufacturing improvements over time, but also Bosch’s desire to improve on the technology that monitors one of the most critical engine parameters.

Cold Start Systems

Overview

Improved technology has allowed better control of fuel management across the entire engine operating range, situations such as engine cold start are now managed more effectively by the modern EFI system. Many of the functions of a carburettor obviously carried over to the fuel injection system. The carburettor often had components that appeared to carry out multiple functions during cold start, early EFI systems often used separate components to meet these needs.

The cold starting process sees the requirement for both enrichment of the air/fuel ratio and an increase in engine idle speed. This situation must be accurately controlled during and after start in order to provide good driveability.

The carburettor serviced these needs with a choke butterfly and fast idle cam. Early fuel injection systems used a dedicated “Cold Start Injector” system and an “Auxiliary Air Valve”.

Components of a “Cold Start Injector” Circuit

It is important to understand that a “Cold Start Injector” circuit is exactly that, a circuit that only operates when the engine is “Cold” [under a certain temperature], and only whilst “Starting” or cranking the engine. The cold start circuit is only responsible for supplying extra fuel to “Start” the engine, once the engine has started it is no longer in operation.

The traditional “Cold Start Injector” circuit consists of a **Cold Start Injector** and a **Thermo-Time Switch** and may be summarised as follows;

- The Cold Start Injector is a solenoid-operated valve designed to spray fuel into the manifold at a central point allowing distribution to all cylinders.
  The Thermo-Time Switch is connected directly to the Cold Start Injector and controls its earth, acting as an anti-flooding device.
- The Thermo-Time Switch consists of a set of contacts, one of which is attached to a bi-metal strip and a heating element. One terminal of the switch is connected to the cold start injector and the other directly to a voltage supply present only during cranking.
- The Thermo-Time Switch is affected by both temperature and time and will often be marked with a specification such as “35°C/15sec” or “15°C/8sec” on the body. These markings are often mis-understood, the specification means that for instance a 35°C/15sec switch will not close above 35°C and the longest time it would ever be closed would be 15 seconds.
- It is important to note that the “Cold Start Circuit” is generally not connected to the ECU and that Thermo-Time Switch is purely an electrical switch and not a temperature sensor.

Function of the “Cold Start Injection” System

The circuit derives its power from the “cranking” circuit of the ignition switch, often connected directly to the starter solenoid. Under cranking conditions, voltage will flow through the Cold Start Injector over to the Thermo-Time Switch. If the temperature of the switch was for instance 10 degrees, the Thermo-Time Switch contacts would be closed providing an earth and the Cold Start Injector would operate. The valve will continue to operate until either cranking of the engine ceases, or the heating element of the Thermo-Time Switch causes the bi-metal strip to heat up sufficiently to open the contacts and break the Cold Start Injector earth connection.

Once the engine has started, fuel enrichment is controlled by the ECU via the main fuel injectors in reference to information provided by the Coolant Temperature Sensor.

Purpose & Operation of an “Auxiliary Air Valve”

The purpose of an Auxiliary Air Valve is to allow an amount of measured air to bypass the closed throttle plate during starting and the engines warm-up phase in order to maintain a stable and smooth engine idle speed. The conventional electrical Auxiliary Air Valve is a fairly simple device comprising of an air control disc, return spring, heating element and a bi-metal strip. When the engine and valve is cold the valve will be open allowing air to pass through it. As the valve is heated via ambient engine temperature and its internal heating element, the valve will gradually close. Once the engine has reached normal operating temperature, the valve should be completely closed not effecting idle speed. Each valve is designed to compensate for the warm-up & cold idle load characteristics of the engine it is applied to.

It is important to note that there are major differences between an Auxiliary Air Valve and an Idle Speed Control Valve/Actuator. An Auxiliary Air Valve is not controlled by the ECU, in the majority of cases has no connection to the ECU whatsoever. The Auxiliary Air Valve is not a variable device, it purely operates during the engines warm-up phase in reaction to temperature change. An Idle Speed Actuator is controlled by the ECU and is an infinitely variable device allowing influence over idle speed for various engine load conditions not solely the warm-up process.

Modern engine management systems utilise simplified “Start Control” systems for cold start and warm-up processes removing the need for separate injectors and control circuits. Main fuel injectors are multiply pulsed during cranking to provide extra fuel and idle speed control devices manage the extra air required to provide efficient starting and idle quality.

EFI Fuel Pressure Testing Procedures

EFI Fuel Pressure Testing Procedures

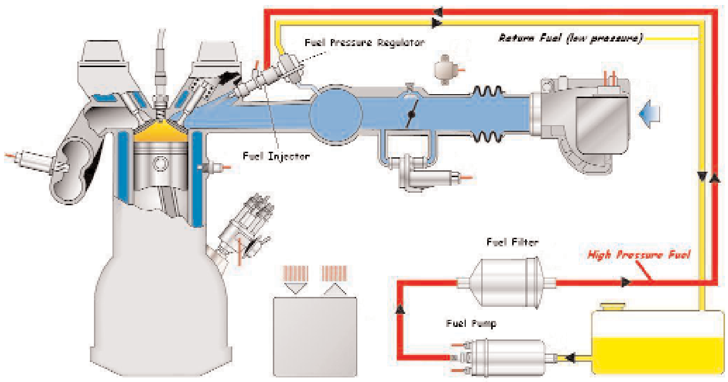
Correct fuel pressure is essential for the efficient operation of any EFI system. Incorrect fuel system pressure and/or flow can cause various problems including starting, idle and overall performance issues. Fuel pressure and flow testing is an important process in the diagnosis of any EFI system and in most cases is a simple process. Detailed here is a simplified, generic test procedure that can be used to test the majority of conventional EFI fuel systems. It is important that both fuel pressure and flow are tested. The broader use of "returnless" type fuel systems by vehicle manufacturers may require some different testing procedures. Vehicle manufacturer testing and service information should always be used when available.
Comprehensive fuel system testing should include analysis of,

- Fuel System *"Operating"* or *"Regulated" Pressure*
- Fuel System Flow
- Residual Fuel System Pressure retention

Traditionally, many EFI systems operated at pressures of 2.5 – 3.0 bar. Modern EFI systems now often operate at much higher pressures of 3.5 – 4.0 bar or higher due to various factors including higher engine temperatures and performance requirements. With this in mind, it is important to refer to the vehicle manufacturers information for correct system operating pressure. It is also worthwhile to note that many Bosch fuel pressure regulators have their operating or regulating pressure stamped on the side of the upper housing. This value will indicate the correct testing pressure.
The most accurate pressure test measurement is the "set" pressure of the fuel pressure regulator [pressure value without manifold vacuum applied]. Whilst fuel pressure is "reduced" by manifold vacuum [the regulator maintaining pressure differential across the fuel injectors constant at all times] the amount of fuel pressure measured with the manifold vacuum connection applied will vary.

WARNING – Testing should only be carried out by adequately qualified persons using test equipment designed for the purpose of pressure testing automotive fuel systems, and using containers suitable for the safe storage of liquid fuel.

IMPORTANT NOTE – *Always de-pressurise* the fuel system before opening any fuel lines or test connections.
Always ensure the vehicle has an adequate level of fuel in the fuel tank prior to any fuel pressure testing. Low fuel levels, less than 1/4 tank, may cause erratic and inaccurate test results.



Once the fuel system has been de-pressurised, the fuel pressure gauge can be fitted anywhere between the outlet of the fuel pump and the inlet of the fuel pressure regulator, anywhere in the RED area on the diagram above. Many late model vehicles will have a dedicated test connection on the fuel rail for the purpose of fuel pressure testing. Professional fuel pressure test kits *[i.e.: Pressure Test Kit # 0 986 615 100]* contain specific fittings and test valves to allow simplified access to conduct accurate testing on EFI systems.

EFI Fuel Pressure Testing Procedures - cont.

Fuel System Operating or Regulated Pressure Testing [with 3.0 bar regulator]

1. With the fuel pressure gauge fitted, operate the fuel pump and note the system pressure with no vacuum applied to the regulator. This is the system operating pressure and should be 3.0 bar.
2. Connect manifold vacuum to the regulator, pressure should reduce by approximately 0.5 bar.
3. *If pressure is too low* – slowly restrict the fuel return line, if pressure rises replace the fuel pressure regulator. If pressure does not rise, check operating voltage and fuel supply to the fuel pump, if OK, replace the fuel pump.
4. *If fuel pressure is too high* – remove the fuel return line from the pressure regulator, if pressure does not reduce, replace the fuel pressure regulator. If pressure does reduce then there is a restriction in either the return line or the fuel tank. To establish the source of the fault, re-connect the return line to the pressure regulator and remove it at the fuel tank end. If pressure does not reduce, there is a restriction in the return line. If pressure does reduce then the restriction is within the fuel tank.

Fuel System Flow Testing

Remove the fuel return line from the pressure regulator and place it into an approved fuel measurement container. Safely operate the fuel pump for up to 30 seconds and observe the fuel flow rate and volume. Typical fuel system flow values will range from **~ 0.8 - 1.5 Litres/30sec** dependant upon the type of vehicle. If system flow rate is insufficient check and/or replace the fuel filter. If flow is still insufficient, check pump voltage and fuel supply volume, if both OK, replace the fuel pump.

Residual Fuel System Pressure

Retention of residual fuel system pressure is important in any EFI system. Loss of residual fuel pressure will result in fuel vapourisation.
If vapourisation occurs in the fuel supply lines, problems with hot start and idle quality will result.
Once the fuel pump has shut down the system pressure will settle. After 20 mins, system pressure should be no lower than 1.0 bar. Loss of residual pressure can be caused by many faults including,

- Leaking Fuel Pump Check Valve
- Leaking Fuel Pressure Regulator
- Leaking Fuel Injectors
- Leaking Cold Start Injector
- External Leakage *[hose connections, injector bodies etc]*

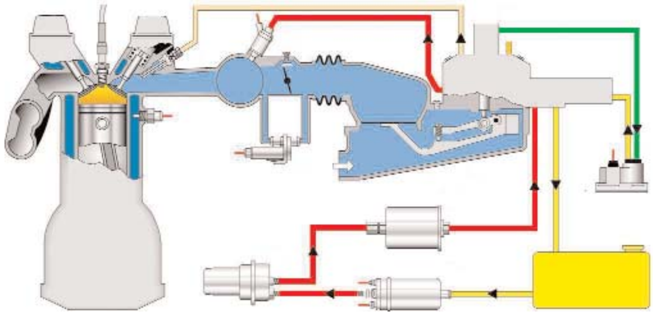
To isolate the area of leakage, run the fuel pump and then shut it down.
Clamp the fuel return line, if the pressure holds, replace the fuel pressure regulator. If the pressure does not hold, clamp the fuel supply line. If the pressure holds, the fuel pump check valve is leaking. If the pressure still does not hold with both the supply and return lines clamped, then the pressure loss is through the injectors and/or cold start injector.
As a general observation, rapid loss of residual fuel pressure is generally attributed to leakage through either the fuel pump check valve or fuel pressure regulator. Fuel injector leakage will normally cause slow loss of residual fuel pressure. Leaking fuel injectors however normally cause the most noticeable hot starting problems as not only does the fuel system need to be purged due to the vapourisation, but also the engine is essentially flooded due to the leakage.

There are many systematic checks and adjustments that need to be carried out to diagnose various EFI systems. Comprehensive information on the operation, testing and servicing of various EFI systems is available from the range of Bosch Technical Literature and Independent Workshop Training Courses. Details of available products are listed in the *"Test Equipment, Training and Technical Literature"* section of this catalogue.

K-Jetronic Fuel Pressure Testing Procedures

Although the K-Jetronic fuel injection system is no longer applied as original equipment to modern vehicles, there are still many vehicles on our roads fitted with this fuel injection system. An overview of the operation of the K-Jetronic system can be found under the *"Technical System Overviews"* section of this catalogue.

As with any fuel injection system diagnosis, all factors that may effect the operation of the K-Jetronic system including overall engine and ignition system condition, basic settings and service procedures should be checked and rectified prior to any servicing of the K-Jetronic. This information is only a generic overview of fuel pressure testing procedures for K-Jetronic, it does not replace vehicle manufacturers recommended testing processes, specifications or service information.



The only way to establish the "Operational Status" of the K-Jetronic system is to *check the various fuel circuit pressure and flow specifications in a specified sequence.*

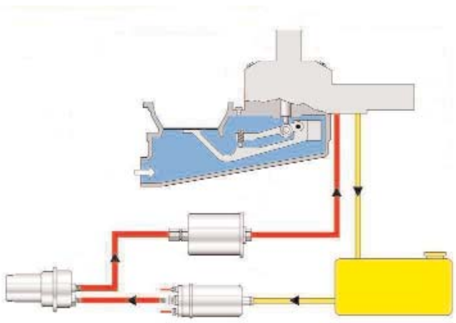
Essential system checks include,

- "System Pressure & Flow"
- "Control Pressure Circuit", cold & hot pressure values
- "Residual System Pressure" retained over time

Professional fuel pressure test kits [i.e.: Pressure Test Kit # 0 986 615 100] contain specific fittings and test valves to allow simplified access to conduct accurate testing on K-Jetronic systems. Whilst these test kits make testing much easier, they are not essential to test the fundamental pressures of K-Jetronic systems.

Always ensure the vehicle has an adequate level of fuel in the fuel tank prior to any fuel pressure testing. Low fuel levels, less than 1/4 full, may cause erratic and inaccurate test data.

WARNING – Testing should only be carried out by adequately qualified persons using test equipment designed for pressure testing of fuel systems and containers suitable for the safe storage of liquid fuel.



System Pressure

NOTE – *Always de-pressurise* the fuel system before opening any fuel lines or test connections.

The pressure gauge needs to be fitted between the fuel pump and system pressure regulator [fuel distributor], anywhere in the red area on the diagram. With the fuel pump running the system pressure should be approximately **5 bar (500 kpa).** Consult vehicle manufacturer for exact pressure specifications.

If system pressure is too low - slowly restrict the fuel return line, if pressure rises, adjust the system pressure regulator. If pressure does not rise, check pump voltage and fuel supply volume. If both are OK, replace the fuel pump.

If system pressure is too high - safely loosen the fuel return line, if pressure drops, check for a restriction in the fuel return line. If pressure does not drop, adjust the system pressure regulator.

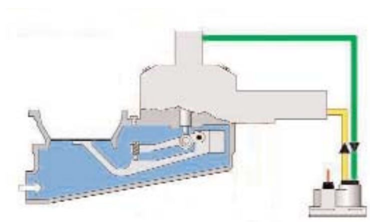
System Flow

Remove the fuel return line and place it into an approved fuel measurement container. Safely operate the fuel pump for up to 30 seconds and observe the fuel flow rate and volume. Typical fuel system flow values will range from **~1.0 -1.5 Litres/30sec** dependant upon the type of vehicle. If system flow rate is insufficient check and/or replace the fuel filter. If flow is still insufficient, check pump voltage and fuel supply volume, if both OK, replace the fuel pump.

Control Pressure Circuit Testing

IMPORTANT NOTE - You must have tested and rectified any issues with the "System Pressure & Flow" BEFORE carrying out control pressure circuit testing.

The pressure gauge must be fitted between the outlet at the top of the fuel distributor and the control pressure regulator. As the control pressure may be influenced by temperature, engine vacuum and even barometric pressure, the test values here are purely a guide, manufacturers information should always be used when available.



Typical **"COLD"** control pressure may be as low as **1.0 – 1.2 bar at ~ 15° C** gradually increasing as the engine warms up. Once the engine has warmed up, the **"HOT"** control pressure may be around **3.0 – 3.3 bar**. For control pressure regulators with wide open throttle enrichment, the typical values would be ~ 0.5 bar higher across the range with the vacuum line connected.

K-Jetronic Fuel Pressure Testing Procedures- cont.

If the control pressure is too high- safely loosen the return fitting at the control pressure regulator, if pressure reduces then there is a restriction in the return line and/or push valve assembly. If pressure is unchanged, check control pressure circuit flow by placing the control pressure outlet hose from the fuel distributor into a suitable container and running the fuel pump for 1 minute. Flow value over 1 minute should be between **160 – 240 cc**. If not within specification, replace the fuel distributor. If circuit flow is within specification, replace the control pressure regulator.
If the control pressure is too low- check the control pressure circuit flow as described above, if correct, replace the control pressure regulator.

Residual System Pressure
Retention of residual fuel system pressure is much more important with K-Jetronic than with any EFI system. As the system is basically “hydraulic” in its operation and control, its natural enemy is air in the system. If vapourisation occurs in the control and/or fuel supply lines, severe problems with system control will occur resulting in overall fuel control issues, idle quality and hot starting problems.
Once the fuel pump has shut down the system pressures will equalise and settle to a figure of approximately 2.0 – 3.0 bar. Importantly this pressure value should only fall by approximately 0.5 bar in the first 10 minutes from the initial reading. After 20 mins it should only have reduced by a further 0.2 – 0.3 bar. Loss of residual pressure can be caused by many faults including,

- Leaking Fuel Pump Check Valve
- Leaking System Pressure Regulator
- Leaking Accumulator Diaphragm
- Leaking Cold Start Injector
- Leakage past the fuel control plunger

Note that leaking fuel injectors will not cause loss of residual fuel pressure as the pressure differential valves within the fuel distributor should seal once the fuel pump has shut down. Leaking fuel injectors will certainly cause poor hot start and overall idle characteristics. Leaking fuel injectors are best tested by using Bosch Fuel Injector Tester # KDJE-P400 as detailed in the *“Technical Service Parts”* section of this catalogue.

There are many systematic checks and adjustments that should be carried out on the various K-Jetronic systems. Comprehensive information on the operation, testing and servicing of K-Jetronic systems is available from the range of Bosch Technical Literature and Independent Workshop Training Courses. Details of available products are listed in the *“Test Equipment, Training and Technical Literature”* section of this catalogue.