

PART 1

BOSCH FUEL INJECTION

This month Stu starts his series looking at Bosch K/KE Jetronic fuel injection.



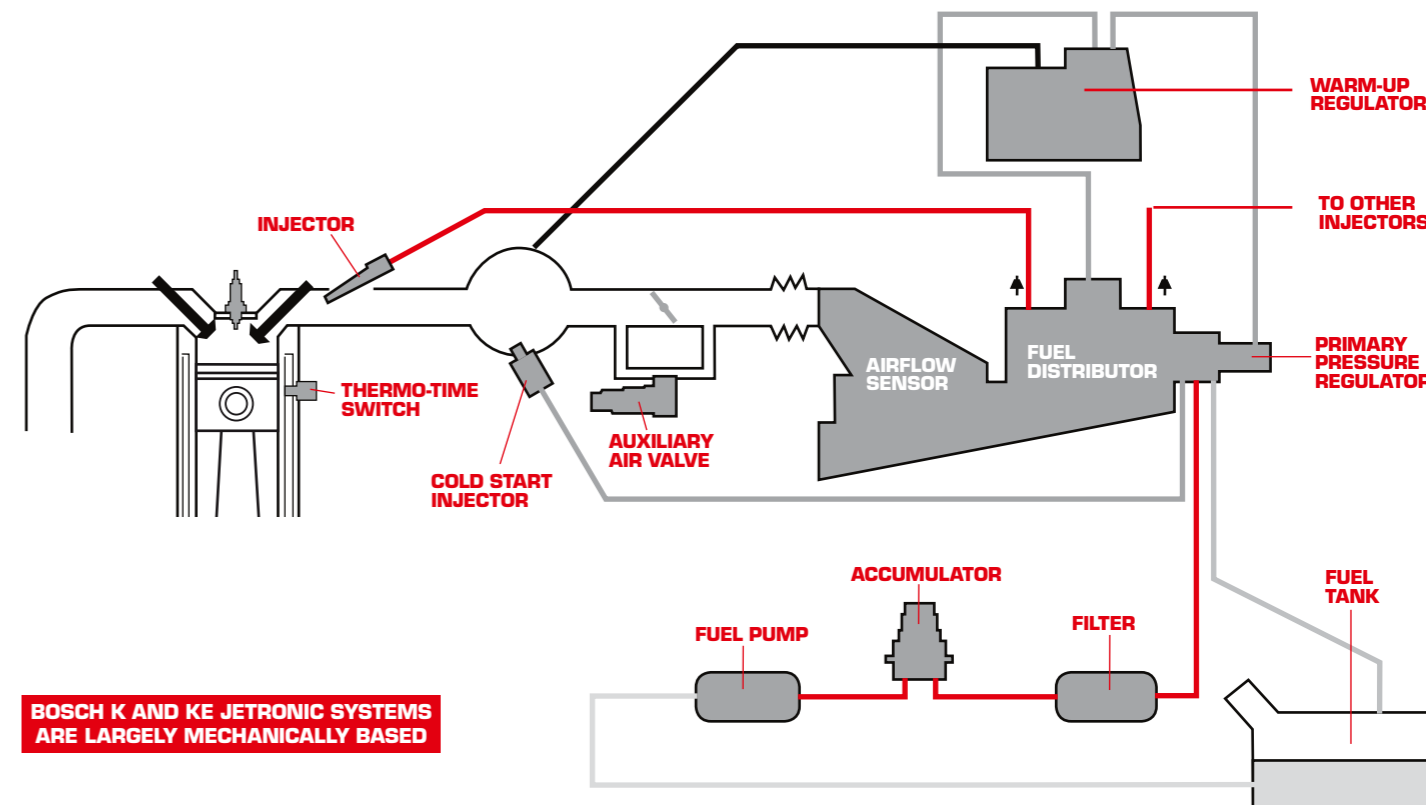
Having worked as a tuner for 17 years, Stewart 'Stu' Sanderson is one of the most-respected names in the business.

A Level 5-trained fuel-injection technician, in the past Stu has worked for a Ford Rallye Sport dealer, a well-known fuel-injection specialist and various tuning companies.

Then seven years ago he joined forces with Kenny Walker and opened up Motorsport Developments near Blackpool (01253 508400, www.remapping.co.uk), specialising in engine management live remapping, as well as developing a range of Evolution chips which are now sold all over the world.

He's also jointly responsible with Webmaster, Petrucci for www.passionford.com. Started in 2003, it's grown rapidly from a few friends contributing, to one of the biggest Ford communities on the web. His new forum, www.fordrforums.co.uk, is also up and running.

Stu's enviable knowledge of the workings of modern-day Ford performance engines means that every month he's just the man to explain how and why things work, and most importantly how they can be improved.



BOSCH K AND KE JETRONIC SYSTEMS ARE LARGELY MECHANICALLY BASED

This month I'm starting my multi-part Bosch K and KE Jetronic article. Bosch K is fitted to Escort RS1600is, XR3is, Sierra XR4is and 2.8i XR4x4s, whereas the Bosch KE system is fitted to all Escort RS Turbos. That's a whole generation of fast Fords, and there are still a great many of them in operation today.

The system is unique in its operation and leaves many garage technicians and performance specialists baffled when it goes wrong, as they have been trained in normal EFI. We have cars brought to us on a trailer quite regularly from garages and sometimes even Ford main dealers when they can't get to the bottom of a problem with an aging Bosch KE system.

Applying normal EFI practices to Bosch K and KE will often make the system run worse than it did before you tried to repair it. If you're willing to blank your mind of conventional fuel injection practices, I will attempt to educate you as to how the system works and what its common problems are.

DIFFERENCES FROM CONVENTIONAL EFI SYSTEMS?

The biggest difference with Bosch K and KE compared to today's electronic fuel injection systems is that it's largely mechanical in operation. The distribution

unit handles fuel distribution mechanically, and the injectors open under pressure and stay open, injecting fuel constantly. Modern counterparts use mechanical solenoids as injectors that can be switched on and off at will by a computer that contains maps for such operations.

UNDERSTANDING BOSCH K AND KE

As with all fuel injection systems, I believe that the only way to understand them properly is to start breaking them down into component form and look at what each item does and what effect it has on the system's operation as a whole.

The easiest way to understand Bosch K and KE is to look at Bosch K components in depth first and then see what differences were brought in to make it essentially Bosch KE. The Bosch K section will be of most use to XR owners but will also benefit the RS Turbo owners. The KE section will be of more interest to those with Escort RS Turbos as your cars needed the electronic enrichment system specific to KE, mainly to cater for forced induction.

BOSCH K JETRONIC

With these systems, the fuel is delivered in a conventional manner from the fuel tank, via a rear mounted fuel pump, up to

the fuel distribution unit (often known as the metering head) in the engine bay. It is delivered at a regulated pressure and any excess fuel is returned to the tank. Depending on the engine's coolant temperature, the correct amount of fuel is delivered via the injectors to the engine.

The injectors on this system spray fuel continuously (the K in Bosch K and KE means Konstant) in a fine atomised spray into the inlet manifold. A cold start

injector caters for extreme cold start. Any fuelling adjustments required for normal cold start and warm-up periods are dealt with by adjusting the control pressure within the metering head. The auxiliary air valve increases the idle speed if necessary and the ignition system is the conventional distributor and rotor arm system. Let's break it down into component form now and see how each piece actually works.

FUEL PUMP

The fuel pumps used are of the high-pressure roller cell type. The fuel enters the pump at one end and is compressed by a number of rotating cells that force it through the pump at very high pressure. They are capable of producing a pressure in excess of 8bar (115psi) with a delivery rate of around 4-5 litres per minute.

Within this type of pump there is always

a pressure relief valve that lifts off its seat at around 8bar to release the pressure should the filter, the fuel lines or any other foreign body cause an obstruction.

There is a non-return valve located on the other end of the pump where the fuel comes out, which stops the system pressure from dropping too quickly when the pump is stopped.



FUEL PRESSURE AND PUMP POWER SUPPLY

The normal operating pressure within the fuel system is approximately 5bar. At this pressure the current draw on the fuel pump is between 5 and 8amps. Interestingly, the fuel passing across the fuel pump's armature will be subjected to

sparks and arcing at this pressure but, while this sounds quite dangerous, the absence of oxygen means that there won't be an explosion! The supply voltage to the pump is 13volts fed directly to the pump via the fuel pump relay.



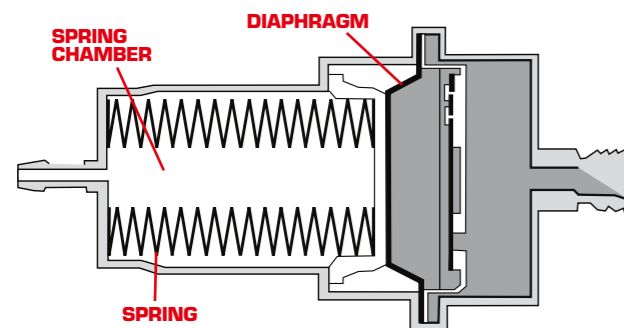
Fuel pump has direct 13volt feed and supplies 5bar of pressure

FUEL ACCUMULATOR

This is the first of the components in the fuel system after the pump. This unit has an important role in the operation of the Bosch K and KE Jetronic system. Its first job is to help smooth out any pulses in the flow of the fuel. This is achieved by passing the fuel through a series of baffles and into a chamber giving it slight capacitance and a much smoother flow.

Its other, and possibly more important, role is to maintain pressure within the system when the fuel pump has been switched off. This is achieved by the accumulator spring and diaphragm pushing against the fuel. For the

duration that the engine is running, the diaphragm will be against its stop within the spring's chamber. When the engine is stopped and all of the non-return valves close, the spring pressure against the diaphragm will maintain fuel pressure and overcome any slight seepage. After a journey, when the engine is switched off, the underbonnet temp increases causing the fuel in the lines to heat and it attempts to evaporate. Maintaining the pressure eliminates this problem and ensures a clean start when the vehicle has been standing with a hot engine.



AIRFLOW SENSOR

The fuel goes to the metering unit next, but we will discuss that part later. Let's instead move onto the airflow sensor. This is one of the most crucial parts of the system. The airflow sensor is located under the air filter housing and this unit is directly responsible for measuring the air going into our engine and helping the metering unit decide how much fuel needs to be injected.

The sensor housing is conical in shape and has an airflow plate fitted into it, which is drawn downwards (Bosch KE) or upwards (Bosch K) as air demand is increased. The amount it moves is directly proportional to the amount of airflow entering the engine.

The shape and angle of the conical area of the housing determines the amount of lift per pound of air. The resting position of this plate is approximately level with the bottom of the cone; this is adjustable by bending a small clip/spring that acts as a stop at the bottom of the unit. The purpose of this spring is to allow the flap to move beyond its neutral position to allow excessive pressure to escape if the engine was to backfire, passing a large volume of air back into the air filter housing. If the system did not have this facility the pressure could split

hoses or blow them off, resulting in an engine that will not start.

The airflow sensor plate is mechanically hinged and the other side of it is connected to the metering unit's control plunger. As the airflow moves the sensor plate this subsequently moves the metering unit's control plunger, which is situated directly in the centre of the metering unit. The higher the lift of the plunger, the greater the amount of fuel will be delivered to the fuel injectors. (You will read more about the plunger operation in the section below.)

To allow fine adjustment of the fuel mixture a 3mm Allen screw is located within the airflow sensor. This screw alters the relationship between the airflow sensor arm and the control plunger. Turning the screw clockwise enriches the mixture and anti-clockwise weakens it. It should be noted that the screw should be turned in very small increments and the Allen key should always be removed before the engine speed is raised or damage may result to the unit.

Airflow sensor is one of the most crucial parts of the system



ENRICHMENT

The lift on the plunger in the fuel distribution unit is proportionate to the volume of air passing into the engine via the airflow flap. However, the amount of fuel required when the engine is cold is different to when hot, and so we have a system that can exaggerate the fuel delivery by adjusting the pressure acting on the top of the plunger, allowing it to move further for less airflow.

Think of the pressure on top of the plunger as a spring. The more pressure we have there, the harder it will be to

move the plunger. The less pressure we have, the easier it will be. This is the case with cold starts. Bosch devised a way to make the air flap move further when cold for any given volume of air than it does when it's hot with the same volume of air using the warm up regulator.

It's worth noting that Bosch K and KE metering heads are different in how the pressure is regulated for enrichment and cold start, but the basic theory of operation is very much the same.



Spotting the difference between K and KE is quite easy. K has the air filter underneath the airflow sensor, and KE has it above

FUEL FILTER

This is next in line. It must be kept clean at all times as the extremely fine tolerances within the Bosch K and KE Jetronic system mean that damage can easily be done if dirt is allowed to enter the metering head. The filter is a large metal canister with different fittings at both ends to avoid the unit being installed incorrectly and compromising efficiency.

A visual inspection of the filter internals isn't possible so change it at the recommended intervals. Personally, I recommend high-power engines have these changed every 6000 miles. (Remember that standard power cars flow less fuel through these items so have higher service intervals.)

FUEL DISTRIBUTION

This is the heart of the Bosch K and KE Jetronic fuel injection systems. It is in charge of taking the fuel in from the fuel filter and delivering the correct amount to the fuel injectors. As the airflow sensor plate is lifted by the engine's inducted air, the control plunger is lifted proportionately, exposing small slits within the fuel distribution unit's barrel assembly. The barrel assembly has four small slits (6/8 on six and eight cylinder cars) that are machined into the

barrel, and it is through these openings that the fuel passes through to the injector lines and onwards to the injectors.

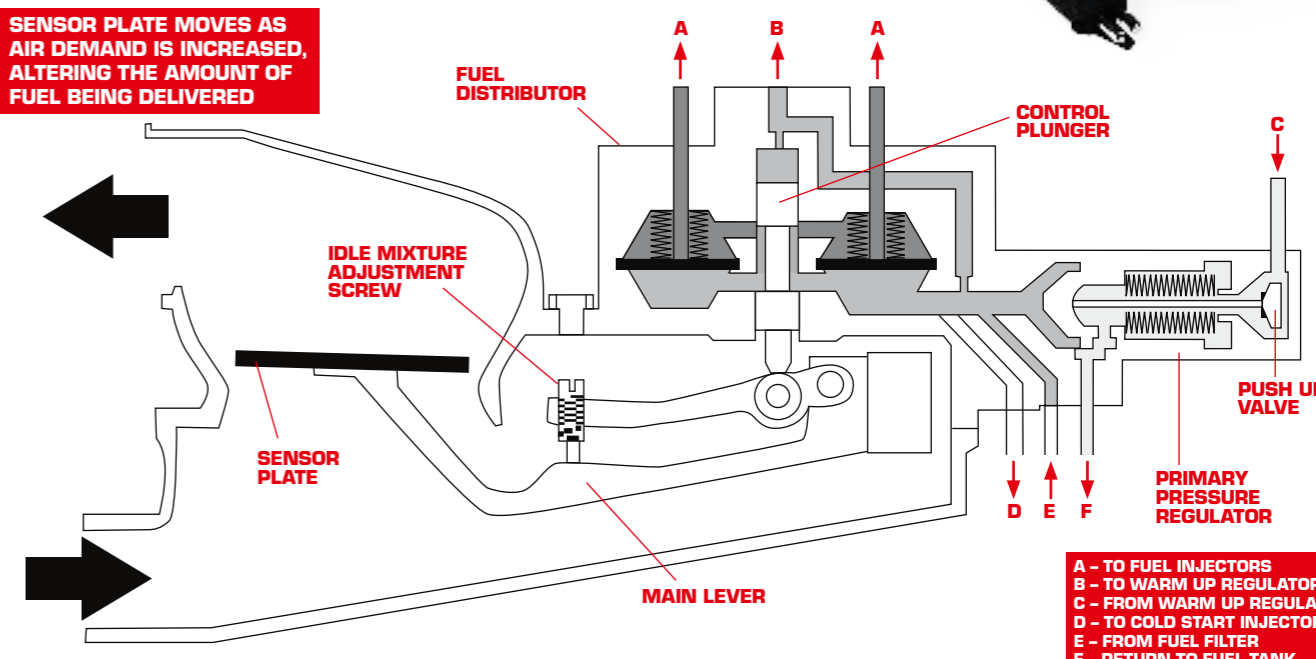
The width of these metered slits is only around 0.2mm across. This dimension, together with the plunger height itself, will determine how much fuel is delivered to the fuel injectors for supply into the engine. At low engine speeds the air drawn into the engine is likely to be minimal so this air flap will move only

small amounts, thus moving the plunger also by a very small amount, allowing only a small amount of fuel flow through the slits. As the throttle is opened further and the volume of fuel required is far higher, the airflow plate moves further, thus moving the metering plunger further and exposing more of the slits to allow more volume of fuel to flow to the injectors to keep the airflow ratio correct.

The K and KE metering heads differ in fitment and operation and are NOT interchangeable.



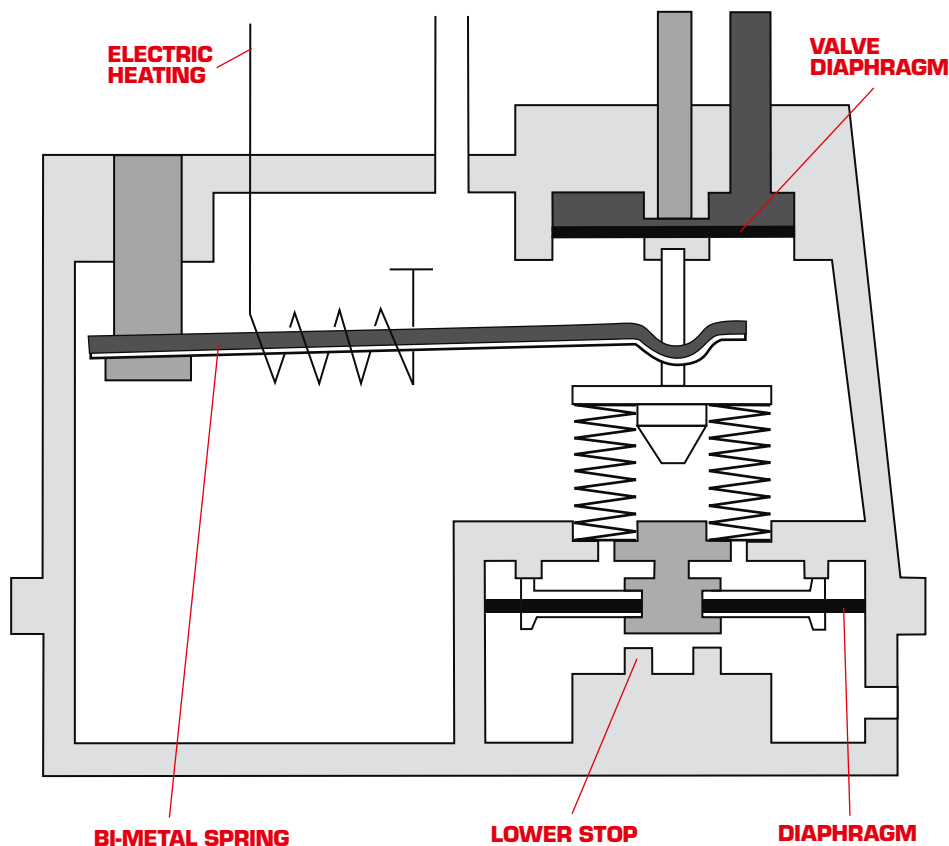
SENSOR PLATE MOVES AS AIR DEMAND IS INCREASED, ALTERING THE AMOUNT OF FUEL BEING DELIVERED



A - TO FUEL INJECTORS
B - TO WARM UP REGULATOR
C - FROM WARM UP REGULATOR
D - TO COLD START INJECTOR
E - FROM FUEL FILTER
F - RETURN TO FUEL TANK

WARM-UP REGULATOR WILL ENRICH AIR/FUEL MIXTURE WHEN THE ENGINE IS COLD

**A - VACUUM CONNECTION
B - RETURN TO FUEL TANK
C - CONTROL PRESSURE**



WARM-UP REGULATOR (BOSCH K ONLY)

This relatively simple device is responsible for controlling the amount of fuel delivered to the engine during its warm-up period.

This device, depending on the engine temperature, varies the pressure acting on the control plunger in the metering head. As such it provides a very effective method of fuel enrichment.

The control pressure within the metering unit is tapped off from the primary pressure circuit in the metering head's lower chamber through a tiny restrictive hole that gives it the ability to differentiate between the two pressures. A flexible pipe then connects the control plunger gallery to the warm-up-regulator and returns the fuel back to the metering head to a connection next to the primary pressure regulator's transfer valve.

The internals of the warm-up-regulator are quite simple. It

comprises of an inlet and outlet port, a stainless steel shim, a bi-metallic heated strip and a spring. The input to the warm-up-regulator flows into a small chamber in the top of the unit, its return is through a small drilling and back to the metering head. By controlling the flow of fuel back to the metering head it can directly control the pressure at the top of the metering plunger.

With a cold engine the flow must be fairly free giving a lower pressure on top of the plunger. This will allow a higher lift of the plunger by the air flap for any given volume of air passing through it, which consequently will enrich the mixture under these conditions.

The internal bi-metallic strip exerting a downward pressure on the spring decreases the pressure acting upon the shim to create the free flow; this lower force allows the fuel to flow

almost uninterrupted. As the bi-metallic strip is heated, by either its heater element or natural heat soak from the engine, the downward pressure acting on the spring is gradually decreased, increasing the force of the spring, which in turn increases the control pressure.

The voltage supply to the regulator is from the fuel pump relay. It is fuel system powered as opposed to ignition system powered for good reason. If the driver sat with the ignition on but without the engine running, all enrichment could be removed before the engine was ever actually started, as the bi-metallic strip would be heated prematurely and the driver would not benefit from the cold engine enrichment.

The two pipes that connect to the warm-up-regulator have different sized 'banjo unions' to avoid them being connected incorrectly.

SYSTEM PRESSURE

This is the pressure that is seen within the system between the fuel pump and the fuel metering head. The primary pressure regulator, situated within the metering head, determines this pressure. When the required pressure is obtained, the plunger within the regulator lifts off its seat and excess fuel is returned to the tank.

Due to the nature of its operation, this system will automatically compensate for different fuel demands under different conditions. If the fuel requirement is low at engine idle, the plunger will lift and return a greater volume of fuel back to the tank than when the demand is higher, when a smaller amount of fuel is returned.

On Bosch K systems, the system's pressure is determined by the tension of the spring reacting against the plunger. If a higher pressure is required, small shims can be placed behind the spring, changing its effective length and increasing the pressure. A shim of approximately 2mm will increase the pressure by about 10psi. Bosch KE has an electronic system to regulate pressure and we will discuss that later.



NEXT MONTH

More on the Bosch K, and how the system was improved with the KE version and its extra/different parts. Plus, how the electronics integrate in this mechanical system.