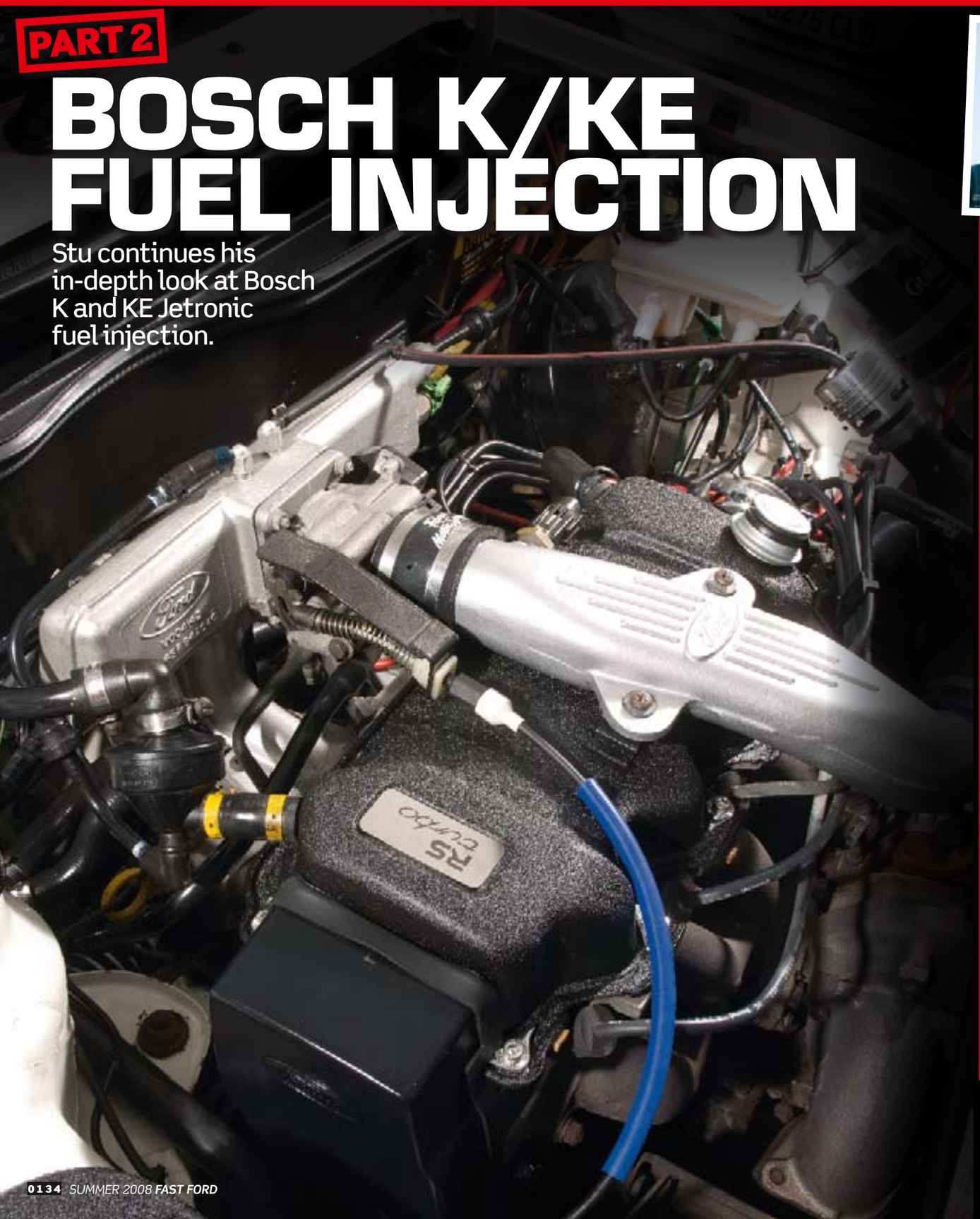
PART 2

BOSCH K/KE FUEL INJECTION

Stu continues his in-depth look at Bosch K and 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.fordrsforums.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 importantly how they can be improved.

BOSCH K

Hopefully you all read last month's feature on Bosch K and KE and are ready for part 2. If you didn't, you should probably grab a back issue, as some of this may not make sense without reading the first part.

Firstly, I need to clarify some points from last month's feature. I specifically had in mind the Escort XR3is and RS Turbos when I wrote it, and mentioned a couple of things that related only to them and not Bosch K as whole. Those things were:

1) Bosch K and KE use conventional ignition. While it does in those cases, it can also use other configurations as proven by the Escort RS1600i in the feature's main pictures; I just forgot to mention it.

2) The air metering flap moving up on Bosch K and down on KE was intended to illustrate the difference between K & KE when used on the Escorts. The RST was unique in having both KE and the downward flow to the metering head, but the system can operate in either direction depending on packaging and installation requirements at the time of design. Apologies if I suggested otherwise.

Also, I mentioned that modified cars flow more fuel through the filters, when it should of course have read more fuel pressure as the fuel flow is the same regardless.

This month we will cover the last few remaining items of K and then look at the various items that were introduced with Bosch KE. Let's crack on...

BOSCH K THERMO TIME SWITCH

This provides the earth path for the cold start injector via a heated bimetallic strip. The heater is activated by voltage from the starter motor. As the strip heats, over a period of 8-10secs (when cranking), the legs on the bimetallic strip separate and the earth path is lost.

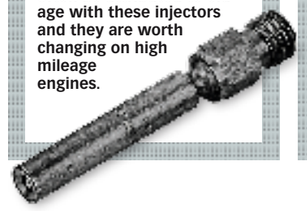
A warm engine will perhaps only require 2secs before the circuit is broken, and a hot engine will already show an open circuit. This simple circuit is to avoid the engine being flooded when cranking and the additional enrichment only given when essential.

BOSCH K FUEL INJECTORS

Fuel injectors fitted to the Bosch K and KE system open at a predetermined pressure in much the same way a pressure relief valve operates. If pressure drops below the opening limit, they close. When open they spray a fine atomised mist of fuel behind the inlet valve, which simply waits there until it is drawn in on the induction stroke.

The fuel is delivered in a continuous spray and isn't timed or pulsed as on most fuel injection systems. When the injector pintle opens this causes the pressure to drop, closing the injector. This causes the pressure to rise again and will open the injector. This pintle vibration is called chatter and helps to atomise the fuel before its induction. When the engine is switched off the fuel pressure drops below 3.3bar and the injector closes forming a fuel tight seal, helping to avoid fuel dripping into the inlet manifold.

The spray pattern should be a conical shape and when clean and working efficiently, should emit a high frequency noise: this is the sound of the pintle chatter and is perfectly normal. Poor running, fuel economy and power can often be attributed to old age with these injectors and they are worth changing on high mileage engines.



BOSCH K AUXILIARY AIR VALVE

The purpose of the auxiliary air valve is to help the engine with smooth idling when it is cold. It does this via a facility to open up a small port that will bypass a controlled amount of air past the throttle body in order to increase the engine idle speed.

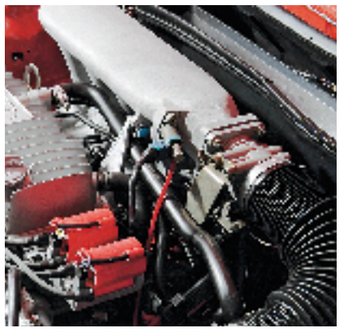
The bypass port locations are pretty typical of this type of design, ie the air goes through a port located before the throttle body and enters the plenum via a port somewhere behind the throttle body.

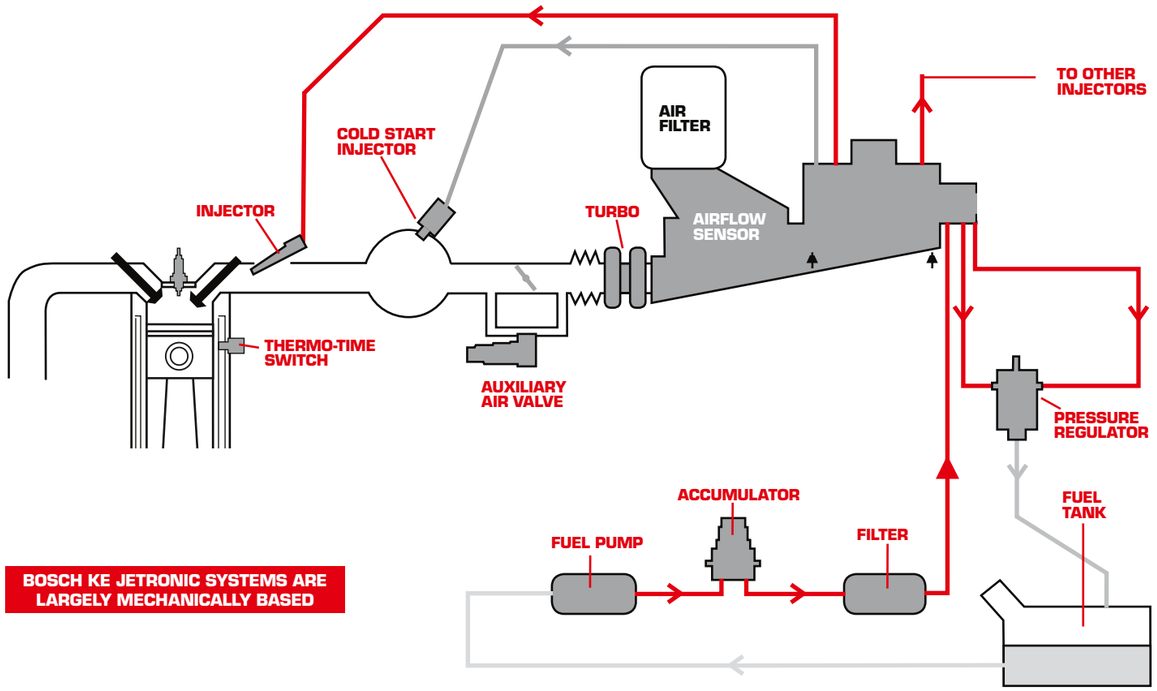
The auxiliary valve is placed in the middle of the pipe connecting these two ports so it can control how much air is allowed to leak past the closed throttle butterfly, increasing or decreasing the idle speed.

Internal operation is simple; the port in the auxiliary air valve is held open by a bimetallic strip and, as a consequence, whenever it is heated either by its own heater element or via natural heat soak from the engine, the port closes. This blocks off the air supply and lowers the engine's speed. The voltage supply to the air valve is via the same feed to the fuel pump and the warm-up-regulator.

BOSCH K COLD START INJECTOR

To help the engine start under extremely cold conditions, an additional fuel injector is located into the inlet manifold. This sprays fuel into the engine at full system pressure only when the engine temp is very cold and the starter motor is activated. The time that this additional injector sprays is determined by the engine's temp, which is monitored by the thermo time switch. It's worth noting that this injector is electronic in operation, not mechanical.





BOSCH KE JETRONIC SYSTEMS ARE LARGELY MECHANICALLY BASED

BOSCH KE DIFFERENCES

After the success of Bosch K, Bosch refined the system in a bid to get greater control of the fuel mixture. The Bosch KE system utilised a few different sensors and a special pressure control unit to allow it to control its fuel pressure electronically. Essentially, rpm, engine coolant and air temperature information is fed, along with expected load information from throttle and air position sensors, into the second ECU (known as the fuel ECU or black box).

The ECU then computes how much extra fuel is likely to be required over the standard operating pressure. It then adjusts the quantity injected using the Electro Hydraulic Pressure Actuator. Let's look at the various extra sensors first, then the changes introduced for the KE system.

BOSCH KE THROTTLE POSITION SENSOR

This mechanical sensor has two switches installed in such a way as to give the ECU feedback about three different throttle positions.

If switch one is closed, then the throttle is closed. In this position the ECU will run strategies for increased fuel economy, such as fuel pump shutdown on coasting. Switch two activates at wide-open throttle positions. This tells the ECU we need full load enrichment as the driver has put his foot to the floor. If neither switch one nor two are activated then the ECU knows you are at part throttle and thus activates neither of the above strategies. This switch not operating at wide-open throttle is a common cause of engine failure on highly-tuned CVH Turbos as the extra enrichment is critical on these engines. A wide-open throttle switch failure means the ECU does not provide the extra fuel for high load as it thinks the engine is in a cruising situation due to seeing neither switches in operation.

The throttle position sensor on the RS Turbo is located on the right-hand side of the throttle body.

BOSCH KE KNOCK SENSOR

Not all Bosch KE systems used a knock sensor, but later ones did. It is essentially a microphone tuned to monitor the exact frequency of detonation. Once it hears detonation, it relays this info back to the ECU, which is listening to the sensor output and reacts by retarding the timing and reducing boost pressure accordingly.

The system is not particularly effective on the CVH and is often fooled by a rattling camshaft and followers. As such we can end up with a really poor ignition curve on what is normally an engine that is still within tolerance. The knock sensor on the RS Turbo is located on the right-hand side of the inlet plenum.

1. BOSCH KE WASTEGATE CONTROL SOLENOID

The Bosch KE fuel injection system incorporated a wastegate control solenoid on all turbocharged models as a means of giving the ECU some control over the engine's boost pressure. This solenoid is a simple three-port device that takes one feed from the turbocharger's compressor and directs this feed according to the solenoid's on or off position.

When activated, the pressure signal from the compressor is bled away to both the wastegate actuator and the airbox so that the actuator sees less turbocharger pressure than really exists, thus causing the turbine to run faster, generating more (or full) boost. When it is deemed necessary, the solenoid can be closed which will direct all pressure from the compressor to the wastegate actuator and the boost will drop as a result, from 8 to around 4 on RS Turbos.

A couple of common reasons to drop the boost are excess air temperatures or detected detonation.

The wastegate control solenoid is bolted to a bracket on top of the gearbox, just underneath the distributor on the Escort RS Turbo.

2. BOSCH KE FUEL PRESSURE REGULATOR

The KE fuel pressure regulator differs from K systems, as the regulator isn't integrated into the fuel distributor but is mounted separately. The return line from the fuel distributor is connected to the primary system pressure regulator, from where a single return line to the tank carries both the excess from the distributor and the regulator. The regulator is located close to the fuel accumulator on Escort RSTs.

3. BOSCH KE COOLANT TEMP SENSOR

This keeps the ECU informed of the engine's coolant temp. This is very important to any fuel injection system, as all engines require mixture changes dependant on the temperature of the coolant. Generally, we require a rich mixture when cold, leaning progressively as it gets hot. The addition of this sensor gave Bosch KE the ability to enrich or lean the fuelling as required.

The coolant temperature sensor on the RS Turbo is located underneath the plenum between cylinder one and two inlet runners.

BOSCH KE RPM SIGNAL

Bosch KE has an rpm signal fed to it via the ignition system. This signal is also sent to the control relay on many installations as a means of stopping the fuel pump should you be involved in an accident that stops the engine.

BOSCH KE AIR PLATE POSITION SENSOR

Attached to the airflow meter, the air plate position sensor gives the ECU information on the position of the air flap and the ability to see rate of change as well as actual position. This gives even finer control of the mixture, as we can now see the rate of engine airflow increase.

The air plate position sensor on the RS Turbo is located on the turbo side of the airflow housing.

BOSCH KE AIR TEMPERATURE SENSOR

As we increase the temperature of air it loses oxygen content by weight and so is of less use to us in the combustion process, which means we will make less power for any given volume of hotter air. This is why we run intercoolers and chargecoolers to try and keep the air as cool as possible for the combustion process.

As the air temperature has such a substantial effect on the way the engine runs and develops bhp, the KE system incorporates an air temperature sensor and feeds information regarding this up to the ECU for processing. Generally speaking, the hotter the air, the less fuel and spark advance we will run, so a faulty one of these can at best be detrimental to the engine and at worst it can be terminal.

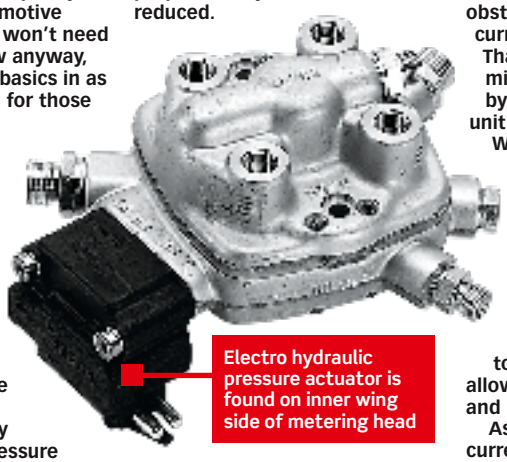
The air temperature sensor on the Escort RS Turbo is located on the right-hand side of the intake pipe (commonly known as the crossover pipe as it crosses over the rocker cover).

BOSCH KE ELECTRO HYDRAULIC PRESSURE ACTUATOR

Located on the inner wing side of the fuel metering head itself, this component is a marvellous piece of engineering in my opinion, and its actual operation is still massively misunderstood after all these years of service. As it's pretty much a piece of automotive history, you probably won't need to worry about it now anyway, but I will explain the basics in as simple a way as I can for those who are interested.

While the Bosch K system controls fuel quantity injected by starting with the fixed primary system pressure going into the lower chambers and then varying the resistance to fuel flowing out, the KE system inverts this procedure and imposes a fixed resistance on the way out and varies the pressure going in.

This controlled pressure variation is achieved by the integration of the electro hydraulic pressure actuator. This unit, made entirely of non-magnetic material, comprises mainly of a thin metal plate, a magnetic coil and two ports that allow the flow of fuel in and out. A thin metal plate obstructs the inlet port, and the extent of the obstruction to the fuel flow depends entirely on its position. When the plate is positioned very close to the supply port, it restricts fuel flow considerably. As a result the rate of fuel supplied to the lower chambers of the metering head is proportionally reduced.



Electro hydraulic pressure actuator is found on inner wing side of metering head

Because fuel is always flowing out from the lower chambers through the fixed restriction of a narrow orifice, any hindering of the inlet flow will drop the pressure in the lower chambers.

Because the upper chambers are always at lower chamber pressure minus the spring force, the pressure in the upper chambers will also drop. The pressure drop across the slits will increase and more fuel will flow for any given plunger position.

The movement of the metal plate in the pressure actuator is accomplished by an electro-magnet that pulls the plate towards the inlet to vary the obstruction according to the current supplied to the magnet. That current, and thus the mixture strength, is controlled by the electronic fuel control unit we discussed earlier.

With zero current flow, which only occurs with the engine stopped or if there is a component failure, the plate is at its most distant from the fuel inlet to the actuator, so the mixture will be at its leanest position. This position is normally set to the correct mixture to allow a warm engine to start and run properly.

As more fuel is required, more current is allowed to flow to the actuator, thus energising the magnet more and pulling the plate in against the flow of fuel. It is designed this way so that in the event of failure, the plate will return to rest position and the engine will be allowed to continue running, although it's worth noting a tuned engine would be left deadly lean when used hard on boost with a failed electro hydraulic pressure actuator circuit.

BOSCH KE FUEL ECU

The business end of Bosch KE. Located on the firewall below the windscreen on the Escort RS Turbo, this (black) box of tricks does all the calculations based on the inputs discussed previously. The ECU contains load v speed fuel maps as well as boost control tables in the turbocharged versions. The most complex function of the box is the way it controls the fuelling on what is essentially, still a mechanical system.

CONCLUSION

That's Bosch K and KE in a nutshell. I hope these articles have given a greater understanding of the systems on your cars, and that this knowledge will allow you to keep them in tip-top condition.