PETROL FUEL INJECTORS

FROM WHAT THEY'RE MADE UP OF TO WHETHER HAVING EIGHT IS BETTER THAN FOUR, STU GIVES YOU THE LOWDOWN.

Words: Stewart Sanderson

THE EXPERT STEWART SANDERSON

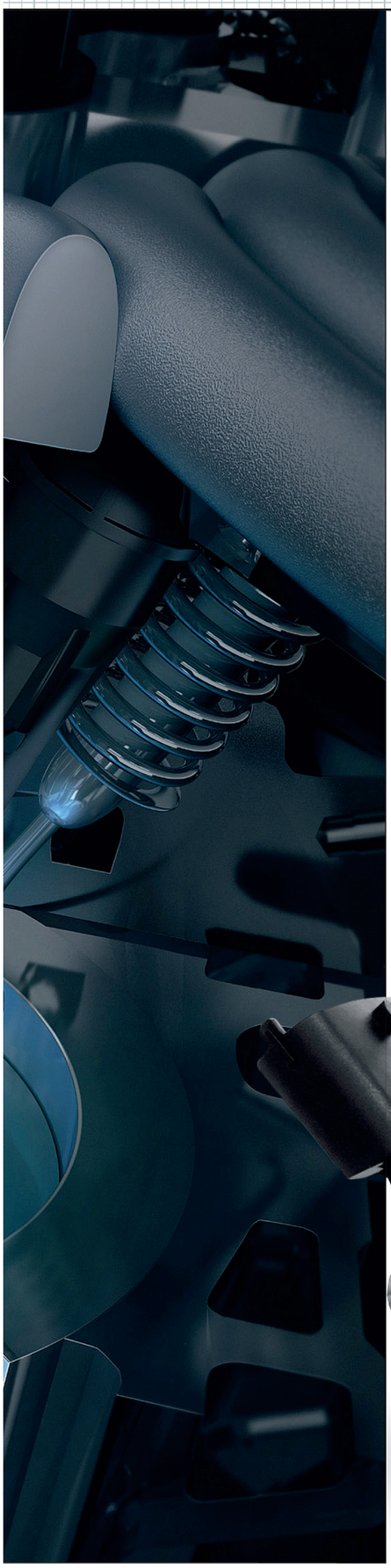
Having worked as a tuner for 17 years, Stewart 'Stu' Sanderson is one of the most-respected names in the business.

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

Eight 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 is the creator and administrator of **www.passionford.com**, which he started in 2003. It has grown rapidly from a few friends contributing, to one of the biggest Ford communities on the web.

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.



The humble fuel injector has been in use for years and most cars on the road today have a set of them, usually 4, but often 6, 8, 12 or 16. But what do you actually know about them? It's time to take a serious look at the petrol fuel injector.

WHAT IS A FUEL INJECTOR?

A fuel injector is a solenoid valve that is operated by the ECU to release a controlled amount of pressurised fuel into the engine. In virtually all cases, the injector is fed a constant supply of power and the ECU provides a 'negative trigger' to turn it on at the required time and for the required interval.

HOW AN INJECTOR IS CONSTRUCTED

A fuel injector is made up of many parts. Below are some of the main components of the most common type, known as the pintle-style injector:

- O-rings: fitted at the top and bottom of the injector to seal the injector into the fuel rail and inlet manifold. (Normally made from Viton rubber.)
- Basket: a very fine fuel filter that is designed to be serviceable. It is used to prevent damage to the pintle and seat inside the injector should dirt be introduced to the fuel system.

A fuel injector is basically an ECU-controlled solenoid valve which opens and closes to allow fuel to pass through it

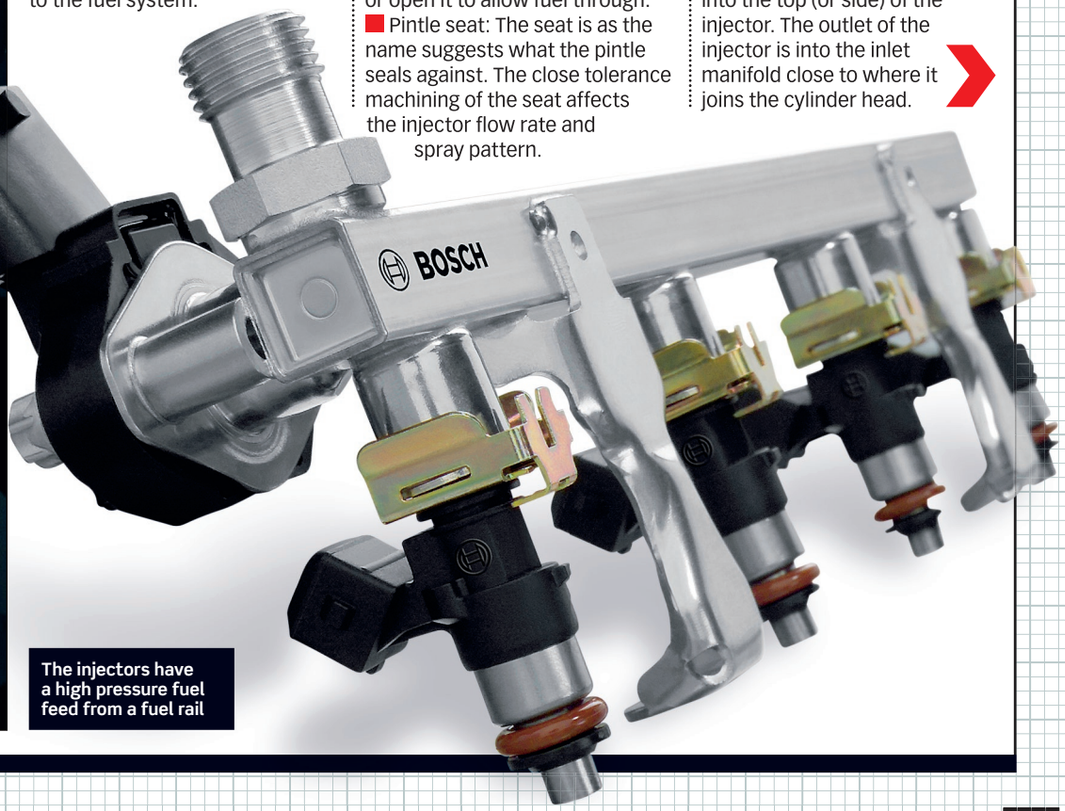
- Multi-plug connector: where the wiring loom connects to allow the power supply and the output from the ECU to be received by the injector.
- Injector body: normally constructed from metal – steel on older injectors and alloys on more modern items. Some injectors utilise a coloured plastic construction at the top to aid in identification.
- Coil winding: this is energised by the ECU output and lifts the pintle from its seat to allow fuel to flow through the injector.
- Pintle: a needle-like component machined to very fine tolerances. It moves only fractionally, (less than a hundredth of a millimetre) to either seal the injector closed or open it to allow fuel through.
- Pintle seat: The seat is as the name suggests what the pintle seals against. The close tolerance machining of the seat affects the injector flow rate and spray pattern.

ALTERNATIVES TO PINTLE-STYLE INJECTORS

There are other options to the pintle-style injectors that have been introduced in recent years. These include disc-style and ball-style injectors which revolve around the same principle as the pintle style injector by using an ECU controlled electromagnet to vary the fuel flow through the injector.

HOW A FUEL INJECTOR WORKS

The fuel injector works by having a high pressure (usually 3bar minimum) fuel feed from the fuel rail feeding into the top (or side) of the injector. The outlet of the injector is into the inlet manifold close to where it joins the cylinder head.

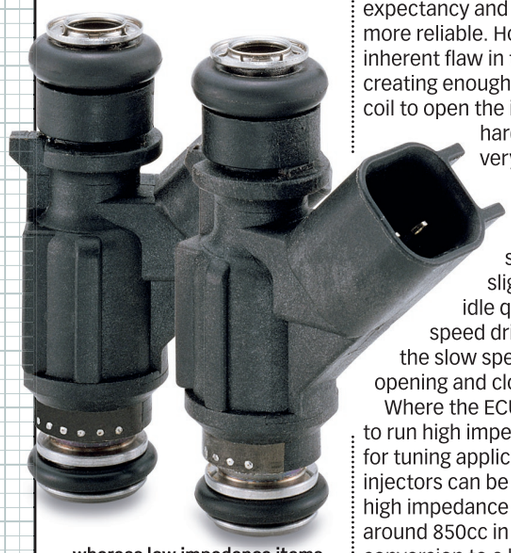


The injectors have a high pressure fuel feed from a fuel rail


Large high impedance injectors can sometimes cause idle and slow engine speed problems...

The injector is fed with a +5 or +12 volt ignition live feed and the ECU gives a negative trigger output to it. This negative trigger completes the circuit to the coil windings and creates an electromagnet. The electromagnet then moves the pintle/disc/ball to allow fuel to flow through and out of the injector.

How long the fuel is allowed to flow out of the injector is controlled by the ECU and the calibration file within it. When the engine is mapped, the fuelling table will be set with a value which when referenced will give an output to the injector for a demanded duty cycle. It is this duty cycle, normally measured in milliseconds (ms), that dictates how long the injector flows for. A spring is used to return the pintle/disc/ball to the closed position after it has been opened.


...whereas low impedance items operate much faster, but are more costly to run

DIFFERENCES BETWEEN HIGH AND LOW IMPEDANCE

When we talk about injectors, we hear a lot about high and low impedance. Here are some of the differences and benefits.

HIGH IMPEDANCE INJECTORS

Also known as 'Saturated Coil' injectors, they have an impedance rating in excess of 8 ohms, normally between 10 and 16 ohms.

By design a high impedance injector rarely draws more than 1 amp of current and are designed this way because they consume less current and run considerably cooler. As such they have a much longer life expectancy and are deemed more reliable. However, the inherent flaw in this design is that creating enough energy in the coil to open the injector is quite hard work. As such, very large flowing high impedance injectors can sometimes suffer from slightly reduced idle quality and low speed driveability due to the slow speed of the injector opening and closing.

Where the ECU is configured to run high impedance injectors, for tuning applications the injectors can be replaced with high impedance units up to around 850cc in size. After that a conversion to a low impedance set-up is strongly advised if

SPRAY PATTERN

We hear a lot of talk about how fuel injector spray patterns affect performance, so let's have a look at why that is.

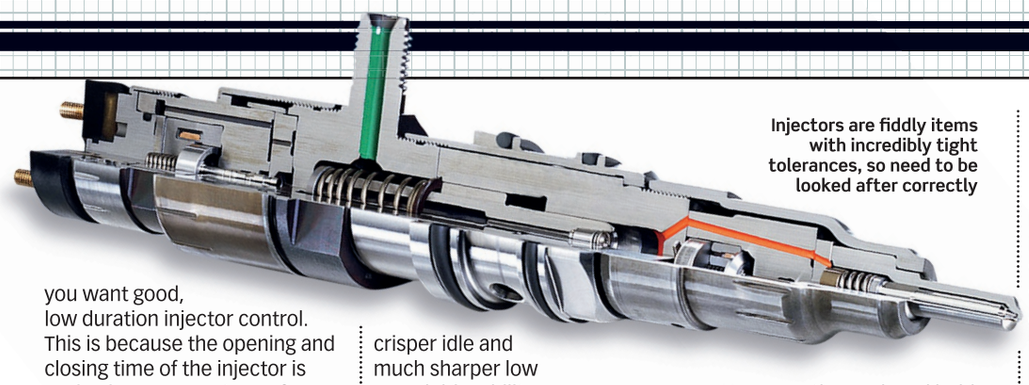
Most of us know that the power created by the engine comes from the mixture of air and fuel being compressed and ignited in the cylinder and driving our piston down with the energy released from the burn. Right? Well, to create the most energy from this burn we need the fuel and air to mix very thoroughly and as evenly as possible. We therefore need the fuel to 'atomise' when it is injected into the inlet port of the cylinder head.

The spray pattern out of the fuel injector itself has a great effect on how well the fuel atomises. In an ideal scenario the spray pattern would be as wide as possible but without spraying onto the inlet manifold walls.

By diffusing the fuel into the air stream we can ensure that the mixture burns cleanly in the cylinder. However, any fuel that has sprayed onto the inlet manifold wall is likely to 'pool', and on entry to the cylinder will not burn as cleanly, so we need to avoid spraying fuel on the inlet manifold walls if possible so our injector spray angle will usually be dictated by this fact.

On most modern engines the fuel injector is located in the centre of the runner to each cylinder of the engine; it is normally close to the cylinder head and angled to fire at the inlet port directly. These injectors normally operate between a 15 and 30-degree spray pattern to ensure good atomisation with no wall contact.


The spray pattern of an injector is crucial to the performance it offers



Injectors are fiddly items with incredibly tight tolerances, so need to be looked after correctly

you want good, low duration injector control. This is because the opening and closing time of the injector is such a large percentage of an injector's actual fuel delivery time when we are talking about low durations such as 1 millisecond. (A thousandth of a second)

For example, if we want the injector to be open and delivering fuel for only 1.5ms in total, but it takes 1ms to open and another 1ms to close, our minimum open time is going to be around 2-2.5ms. However, as the injector is spraying fuel during both the opening and closing stages the amount of fuel delivered would be too much and cause the fuel mixture to become rich. Therefore this type of injector would be deemed too large for our required use. The only alternative here is to use a smaller injector, or a faster responding one, such as a low impedance version.

LOW IMPEDANCE INJECTORS

Also known as 'peak and hold' injectors. They have an impedance rating of less than 3 ohms, normally around 2 ohms.

Low impedance injectors get their 'peak and hold' name through the fact that their design means they draw a much larger current of around 3 amps to open the injector and then reduce the current draw down to around 1 amp to hold it open.

This design is considerably different to the high impedance unit. The powerful coils used result in a much more powerful solenoid, which has a higher initial current draw but allows the injector to open much quicker. This makes for better injector response at low durations and so often a crisper idle and much sharper low speed driveability.

Also, with the lower coil resistance the internal spring pressure that holds the pintle closed can be increased. This means the injector can close much faster, which in turn allows both faster opening and closing times making tuning large injectors considerably easier.

WE'VE SEEN ENORMOUS ADVANCES IN ECU AND INJECTOR TECHNOLOGY OVER THE LAST TWO DECADES.

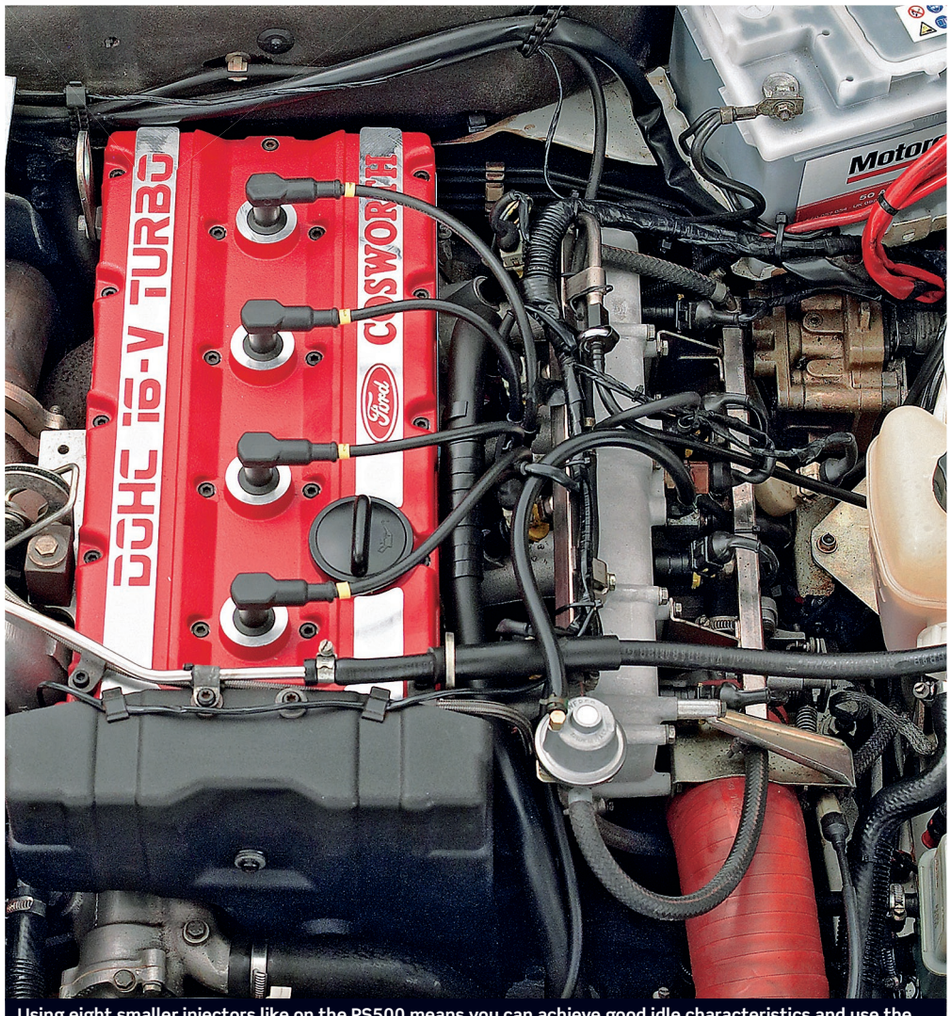
However, the peak and hold circuitry used in low impedance injectors is more expensive than the simple logic circuitry used in high impedance injectors. Therefore there is a price premium on low impedance units, which is why most cheap aftermarket ECUs cannot drive them.

So, what would happen if you ran low impedance injectors in a car with an ECU designed to work with high impedance items? Quite simply, it would usually burn out the injector drivers in the ECU quite quickly. A common misconception is that resistors can be installed in the injector wiring to run low impedance injectors on a high impedance ECU. However, this won't always run correctly and won't offer the actual benefits of a low impedance peak and hold injector set-up, therefore pretty much negating the point of fitting them in the first place.

The correct way to do such a conversion is to install an aftermarket peak and hold injector driver. This replicates the standard high impedance injector signal in a low impedance peak and hold output.

1 OR 2 INJECTORS PER CYLINDER?

Many years ago it was common practise to run eight injectors on high



Using eight smaller injectors like on the RS500 means you can achieve good idle characteristics and use the extra four injectors to supply more fuel when the engine needs it

powered four cylinder performance cars. It allowed for four injectors to be used for start up, warm up, idle and low speed driving. When the throttle was pressed and the performance demanded, the additional four injectors would be brought in to provide the additional fuelling. This set-up worked very well and as the available technology at the time meant that very large capacity fuel injectors were not particularly controllable at idle or low speeds and that over fuelling was a problem with them, using eight smaller ones was the ideal solution.

Moving forward two decades, we have enormous advances in ECUs and injector technology. 1000cc injectors are now deemed 'normal' and 1600cc-2000cc injectors are available in standard fitment. So we can now have the same power potential, but with less injectors, fuel rails, wiring looms and hassle, so much cheaper and arguably more reliable too!

EIGHT INJECTOR SET-UPS V FOUR LARGE INJECTORS

The positioning of the extra four injectors can play a very crucial role in why some people continue to use eight injector set-ups. Inside most inlet manifolds there is a trumpet at the end of each cylinder runner where it enters the plenum chamber. If the injector is mounted to fire directly at the trumpet then it can give a significant gain in outright engine power due to the excellent atomisation time it provides and the very high speed of the fuel mixture.

As the additional four injectors will only activate when instructed to by the ECU under load, the engine will already be accelerating and drawing a lot of air in through the trumpet in the plenum when these additional injectors are activated. If the injector is of the correct specification and spray pattern it can fire at an angle closer to 15degrees without hitting the walls of the inlet manifold. This combination of fuel being fired in from such a distance while the engine is drawing in such a volume of high speed air makes for fantastic atomisation and tends to lend itself to creating slightly more power.

Unfortunately, while having the injectors far away from the cylinder head makes great power at the top end of the rev range, it would not be possible to get a car to start, idle and drive around normally at low speed if we just had four large injectors mounted there.

The vacuum created by the engine would be insufficient to draw the fuel in over such a distance and as a result most of the fuel would end up 'pooling' and not atomising. So, are there any advantages to using just four large capacity injectors in the standard location near the cylinder head? The answer is yes!

First of all, the cost! With high quality injectors costing up to £75 each, a saving of £300 can be made straight away by only using four instead of eight. There is also a saving on not having to purchase a new inlet manifold, plenum, second fuel rail, fuel lines and twin input fuel pressure regulator to accommodate the additional injectors.

The Engine Control Unit (ECU) cost will also be significantly reduced for a four injector capable ECU, so too will the cost of the wiring. The mapping tends to be somewhat easier as there are no switchover points, so this again will often lower costs and means that the vehicle is also smoother to drive as sometimes the injector crossover points tend to be a little jerky in activation on the cheaper ECUs.

With good mapping, there is no reason why a vehicle running four large fuel injectors cannot start, warm up and idle as well as a vehicle running four small fuel injectors. The four large fuel injector set-up will make very good power, usually within 1-2% of a fully optimised eight injector set-up and it is significantly easier and cheaper than using eight.

A SAVING OF £300 CAN BE MADE BY ONLY USING FOUR INJECTORS INSTEAD OF EIGHT.

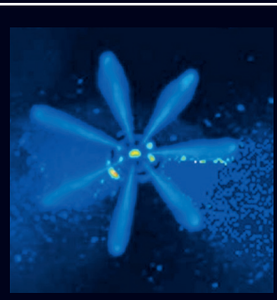
THE FUTURE OF FUEL INJECTORS

The future of petrol injection systems is set to follow in the footsteps of modern diesels, using a very high pressure direct injection set-up known as GDi (Gasoline Direct Injection).

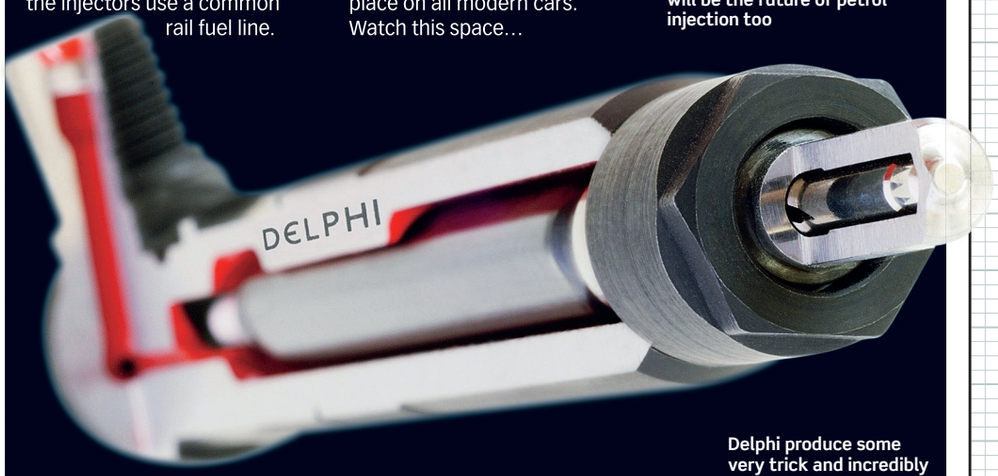
In these systems the injector is not mounted in an inlet manifold, but instead injects fuel directly into the combustion chamber. Like modern diesel systems the fuel pressure is incredibly high and the injectors use a common rail fuel line.

GDi offers a number of advantages over a conventional multi-point injection system, most of which are heavily focused around reducing emissions and improving fuel economy.

However, manufacturers such as Ferrari and BMW have already seen some very impressive power results from using GDi. It won't be long before the system is common place on all modern cars. Watch this space…



GDi is very similar to diesel common-rail technology, and will be the future of petrol injection too



Delphi produce some very trick and incredibly accurate injectors

NEXT MONTH
STU TAKES A LOOK AT ANTI-ROLL BARS