



**THE EXPERT
STEWART
SANDERSON**

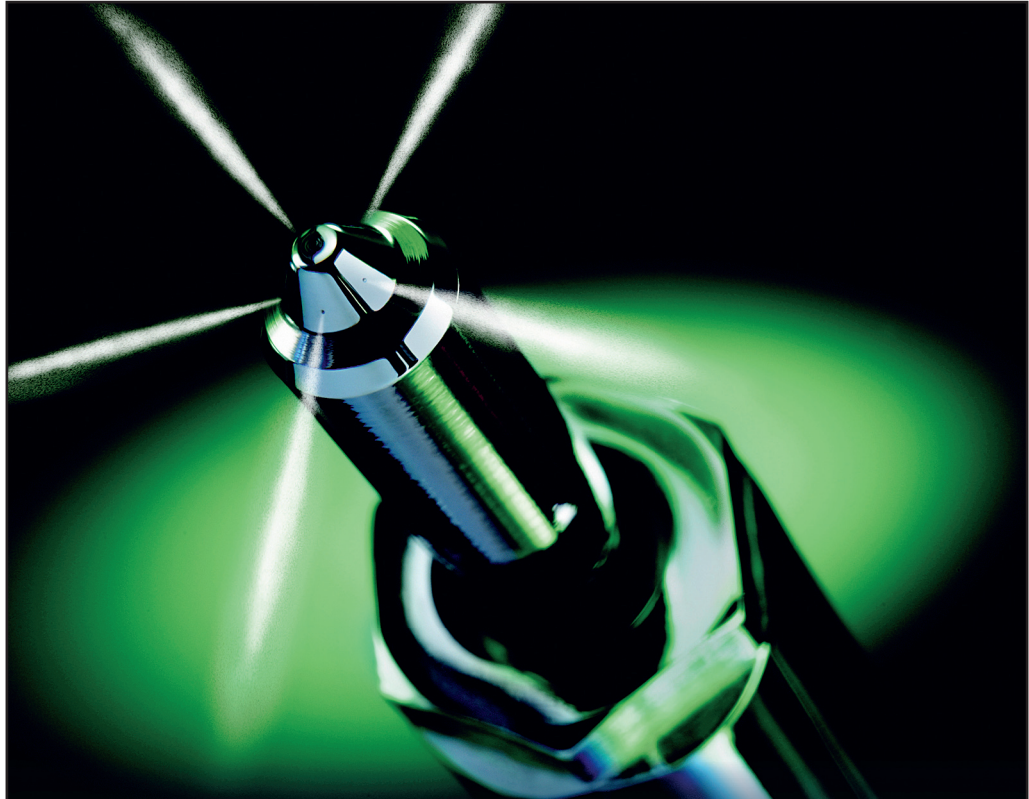
Having worked as a tuner for 18 years, Stewart 'Stu' Sanderson is one of the most-respected names in the business.

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.

Over 10 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.



Words: Stewart Sanderson and James Wills

COMMON RAIL DIESEL INJECTION

WHAT IS IT? AND WHY IS IT DIFFERENT?

As most of you are no doubt aware diesel powered vehicles always used to be known for their terribly poor performance and smoky emissions, but these problems really are things of the past now because diesel fuel injection technology has moved on in leaps and bounds over the last ten years or so.

Technology has been progressing at a rapid rate with diesel engines but the introduction of the common rail injection system certainly was a huge breakthrough in the Ford diesel world. These systems allow the diesel injectors to be controlled electronically, just like the petrol systems we all know and love. The term 'Common Rail' comes

from the simple fact that the injectors are all fed from a single high pressure fuel rail or accumulator. The fuel rail itself is fed by a high pressure fuel pump, and the fuel system also contains fuel coolers, filters and various sensors which we will look at in more detail in the next article.

There are many benefits to these new systems, the main ones being that they require little or no pre-heat time on cold start, and they are incredibly controllable, resulting in great power, great performance, very clean emissions, and reduced engine noise. The four main production companies making the majority of systems found

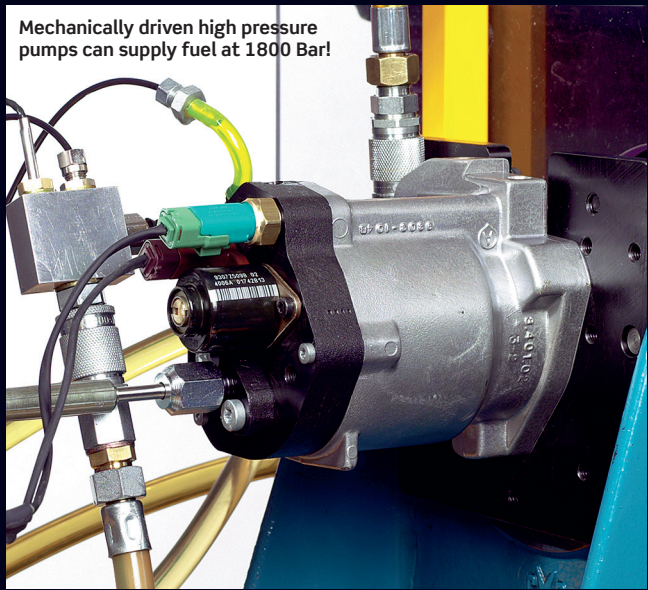
in our cars today are Bosch, Delphi, Siemens and Zexel.

As vehicle manufacturers spend billions of pounds developing new engines it is very important to have diesel injection systems that can make the most of these new engine designs and really make them perform as they were intended to.

As we have seen in recent years, diesel cars can now compete very well with their petrol powered equivalents. We have even seen diesels competing in several touring car race series, and of course winning the Le Mans 24hr.



Mechanically driven high pressure pumps can supply fuel at 1800 Bar!



THE PUMPS

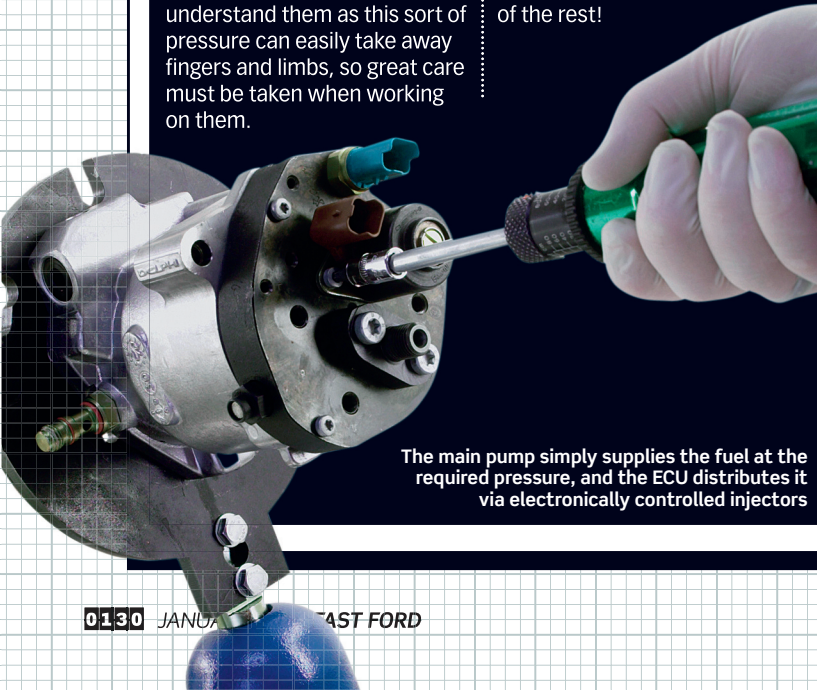
Most common rail systems will have two fuel pumps. The first pump is generally located in the fuel tank and is electronically powered. The function of this pump is simply to send the fuel up the fuel line, through the fuel filter and into the second pump. This pump is commonly called the 'lift pump'.

The second pump is mechanical, usually driven by the cam belt and is known as the pressure pump, which feeds the fuel rail at massive pressure. These pressures usually vary from around 1000-1800 Bar! (15,000-26,000 psi), and some systems run at even higher pressures!

It is quite easy to see why these systems can be dangerous if worked on by people who do not fully understand them as this sort of pressure can easily take away fingers and limbs, so great care must be taken when working on them.

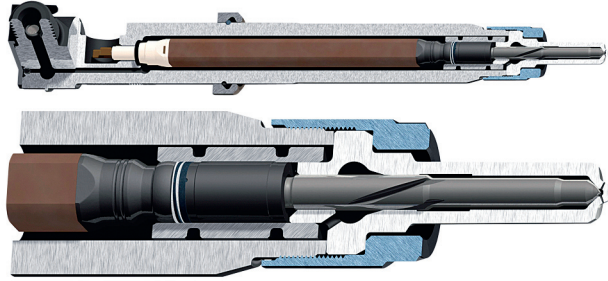
The fuel pump does not usually require timing or phasing as it only has a single job to do in these systems; raise fuel pressure and feed it to the fuel rail. Gone are the days where the injection pump controlled injection time, pressure and amount of fuel delivered to the cylinder. These other jobs are now much more accurately controlled by an ECU.

Another interesting aspect is that these pumps usually operate in a 'fly-by-wire' manner as there is not always a direct link from the throttle to the pump. This means throttle movement simply moves a potentiometer on the pedal itself, which sends a signal to the ECU giving information on throttle position or angle. The ECU very accurately takes care of the rest!



The main pump simply supplies the fuel at the required pressure, and the ECU distributes it via electronically controlled injectors

Modern diesel fuel injectors are incredibly delicate bits of kit



FUEL INJECTORS:

Fuel injector designs are pretty much changing by the year, but none more so than the diesel fuel injector. The top part of a modern diesel injector is now electronically controlled by the ECU which literally tells them when to open and how long for. Just like petrol injectors always have, a small electrical current is fed from the ECU to the injector which then opens a hydraulic or mechanical valve in the lower part of the injector. Fuel is then injected at the rail pressure into the cylinder, either directly or indirectly depending on the type of system used and the engine configuration.

Because the fuel rail is at a constant pressure, and the injector simply opens and closes to allow fuel to enter the cylinder when required, the injection is crisp and clean and can be quickly repeated. This is very important as some of the modern systems will inject up to five times per stroke. These different firing cycles are commonly named as pre, main and post injection events. The pre injection is done to dramatically reduce engine noise, and the post injection

is to control exhaust gas temperature. As we know from last month's feature on diesel particulate filters, the exhaust gas temperature needs to be intentionally increased to promote the regeneration process of DPFs.

One particular type of injector, named the 'Piezo', uses tiny crystals which instantly expand when the electronic signal is sent to them. These are becoming

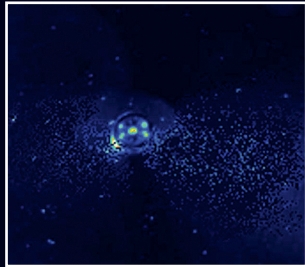


commonly used as the reaction time is up to four times faster than a standard solenoid type injector. Interestingly, the pressures used in a modern diesel system mean the internal components of a diesel fuel injector now contain chambers and items so miniscule that modern production methods can no longer guarantee exact repeatability when creating them! This is because at 26000psi, even an orifice 0.000001mm too big is going to flow a lot of extra fuel, as is a solenoid that opens for 0.0001ms longer than intended. Because of this each injector is tested after manufacture and a performance code assigned to it so that the ECU knows exactly how much fuel will flow from it for any given

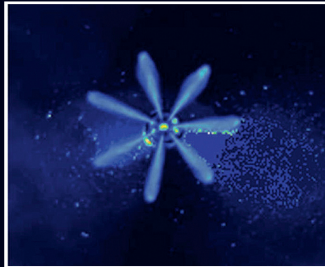
Piezo injectors use tiny crystals to accurately control the amount of fuel delivery



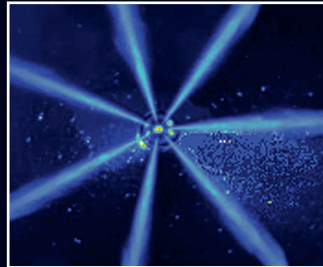
DELPHI DF13 PIEZO DIRECT ACTING DIESEL FUEL INJECTOR



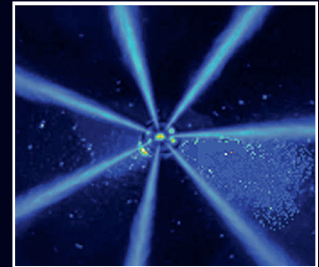
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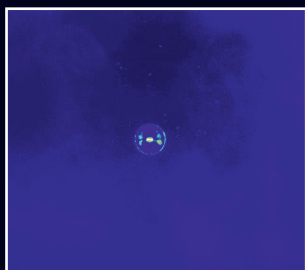


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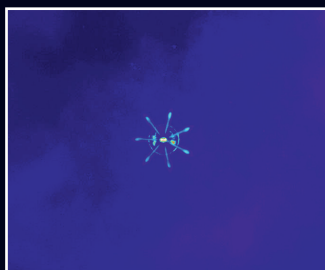


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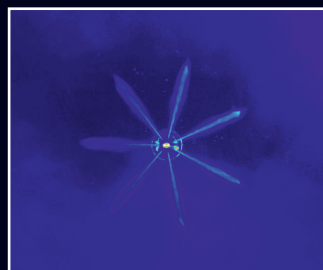
DELPHI SOLENOID SERVO DIESEL FUEL INJECTOR



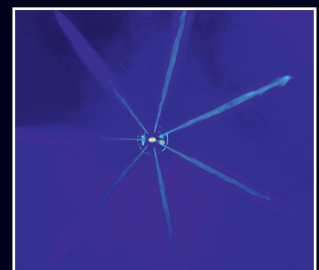
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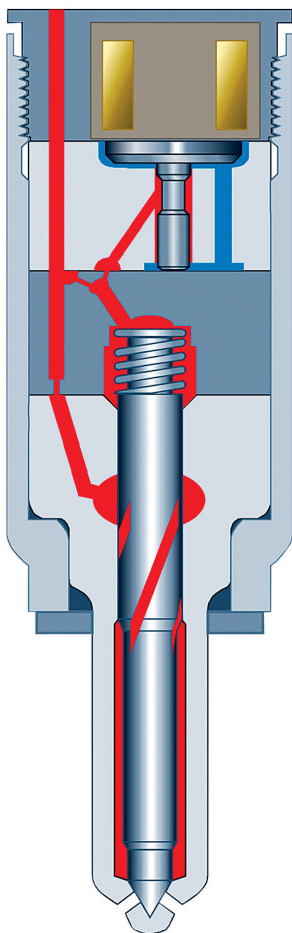
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The tolerances inside modern injectors are so fine any dirt particles entering them can cause total destruction

“MODERN PIEZO INJECTORS REACT UP TO FOUR TIMES AS FAST AS A REGULAR SOLENOID FUEL INJECTOR.”

opening time.

The ECU is programmed with the exact characteristics for each injector individually, so it can be as accurate and efficient as possible across all the cylinders. It is not uncommon for worn or tired injectors to actually get ‘re-coded’ when the ECU is programmed with new data relating to the condition of the injector, but the effects of this are usually short lived and unfortunately for the owner simply delays the fact that new injectors are required.

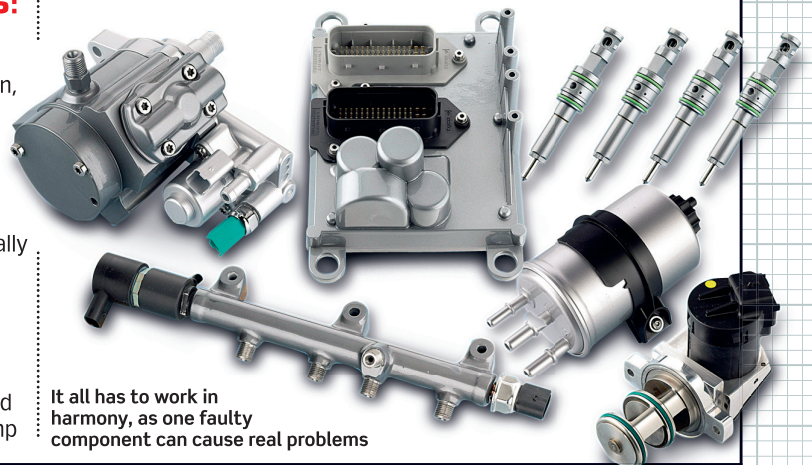
OTHER COMPONENTS:

Due to the extremely high pressure that the diesel fuel is compressed to prior to injection, it dramatically raises the fuel temperature so manufacturers will usually fit a fuel cooler into the system to bring these temperatures back down and under control. Coolers are usually fitted in the fuel line under the car where air will pass through them, therefore cooling the fuel. If these coolers were not fitted the excess fuel which is returned back to the tank would re-circulate back up to the pump

and get hotter and hotter each time it circulated the system. A pressure sensor is usually fitted in the high pressure side of the pump which measures the pressure in the fuel rail. This in turn controls the pressure relief valve or regulator, which will open and close on command from the ECU meaning the fuel pressure can be increased or decreased as required to maintain the correct level.

The filters used in these newer systems have to be very, very fine as many of the internal components on these pumps

and injectors are so tiny due to the extremely high pressures involved that any dirt particles can and would create havoc if they entered the system. The same goes for water or other fuel contaminants. Because of the fine tolerances involved, any water or fuel of other types can cause big issues for the injection system and the actual engine itself too. Imagine injecting petrol into a diesel engine at over 1000bar! The consequences of this are usually catastrophic. For this reason water traps



It all has to work in harmony, as one faulty component can cause real problems

and better tank breather systems are fitted as well as the all important fuel neck that helps to prevent us humans filling diesel cars with petrol!

TUNING AND REMAPPING:

The incredible accuracy of these new injection systems opens many new doors for tuning and remapping. The diesel injection systems of the past were very hard to tune, and the effects of doing so usually ended up with lots and lots of black smoke as the extra fuel added could not be

or even decrease in fuel pressure to give more power and torque where needed. Boost pressure is generally not increased unless a specific model needs more air to clear up some fuel smoke. Torque limiters will be moved and adjusted to suit the new increases in power and give a linear power curve. Pump timing may also be adjusted on some models, as may some governors. When performed correctly more power, more torque and a hefty fuel saving is achievable with a good quality remap. In fact, it is becoming very popular due to the fact that a 200-300bhp turbo

“CORRECTLY REMAPPING MODERN DIESELS INVOLVES ACCURATELY ADJUSTING THE FUEL MAPS”

cleanly combusted.

There are still similar methods used in tuning the new systems, which generally increase fuel pressure across the whole map, or fool the ECU into thinking the engine is colder than it actually is therefore adding more fuel to compensate. It may well work and give more power at some points, but it is very crude and still cannot overcome ECU torque limits and such like.

Correctly remapping these injection systems involves accurately adjusting the fuel map, giving the correct increase

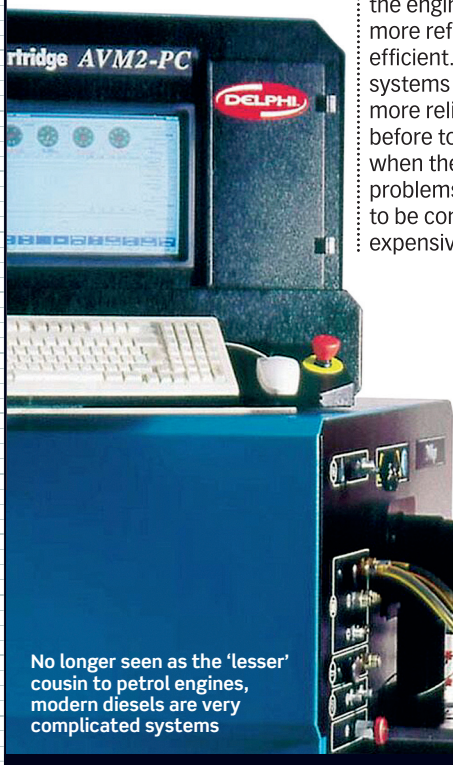
diesel will often still a return over 50mpg and, believe it or not, in some cases even more!

THE FUTURE

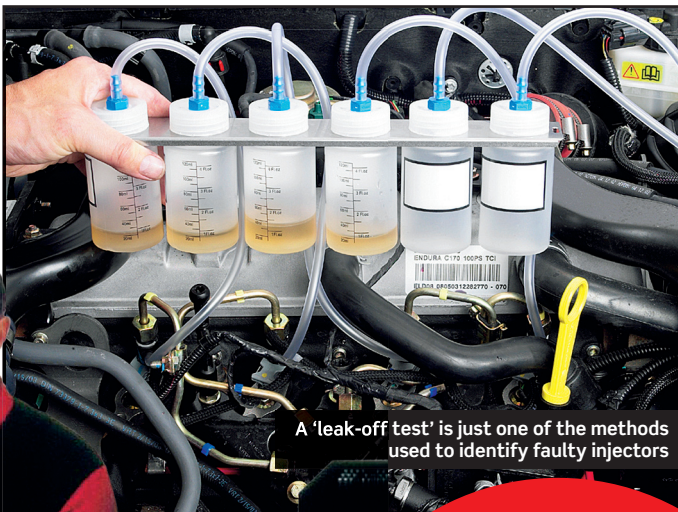
The future for diesels is looking very bright indeed and we are seeing more call for diesel tuning than ever. As fuel prices continue to rise, more and more people are opting for oil burners over petrol engines as they combine great fuel economy with performance. Diesel injection systems are still constantly evolving, allowing more power and torque to be produced while the engines are getting quieter, more refined, and more fuel efficient. What's more, these systems are becoming more reliable than ever before too, although when they do have problems they tend to be complex and expensive.



Modern diesel systems need accurate diagnosis carried out by specialists to pinpoint faults



No longer seen as the 'lesser' cousin to petrol engines, modern diesels are very complicated systems



A 'leak-off test' is just one of the methods used to identify faulty injectors

NEXT MONTH
EGR SYSTEMS
AND DIESEL
SENSORS