fasttech

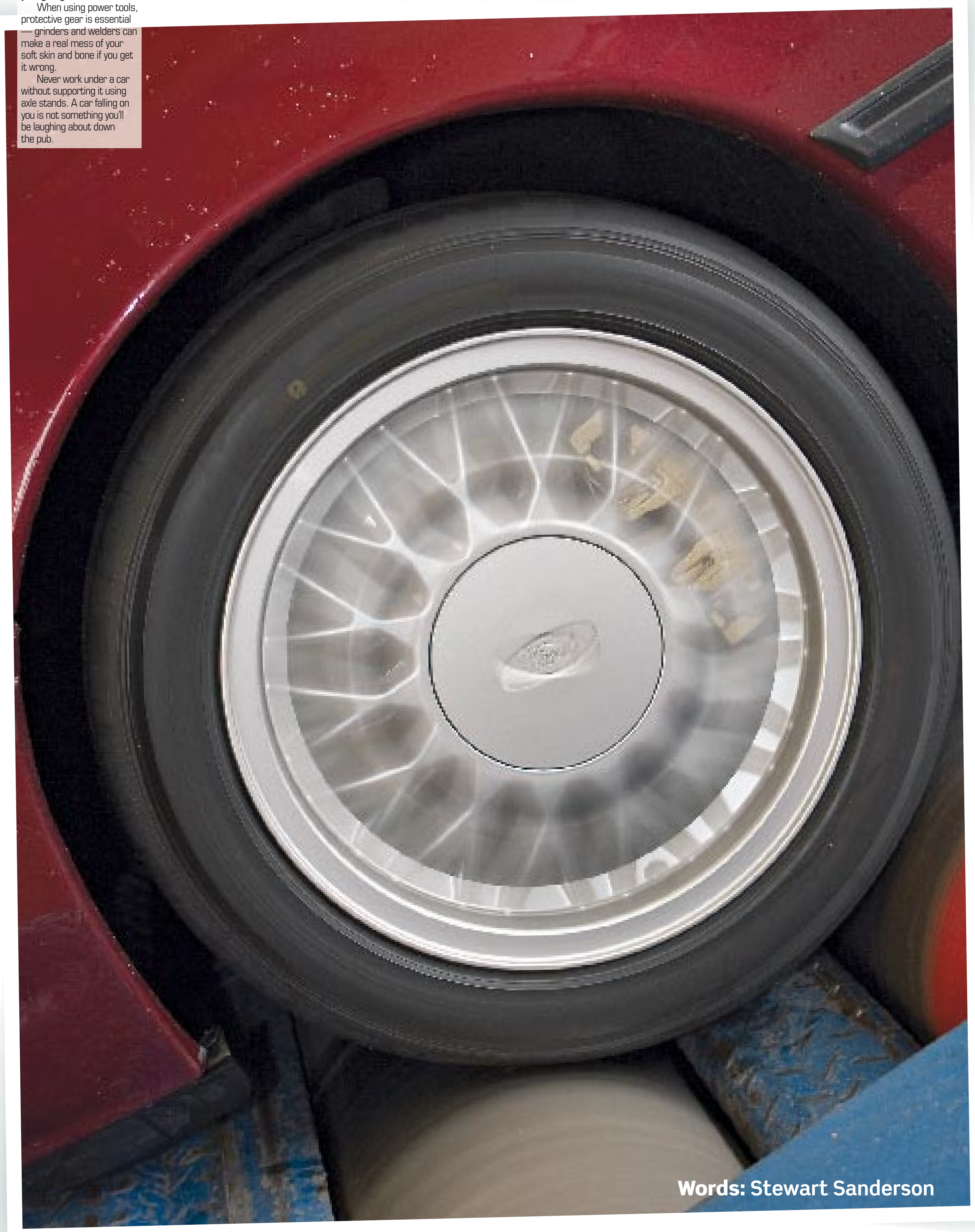
BEFORE STARTING...

The first rule of working on cars and using tools of any kind is don't ever skimp on decent protection. Goggles, gloves, ear defenders, masks and a set of overalls should be in your garage. Use them.

When using power tools, protective gear is essential — grinders and welders can make a real mess of your soft skin and bone if you get it wrong.

Never work under a car without supporting it using axle stands. A car falling on you is not something you'll be laughing about down the pub.

UNDER PRESSURE



Words: Stewart Sanderson

If the dyno operator tells you you're engine's running lean at full boost, don't just turn the fuel pressure up. Here's why.

DURING my day-to-day work as a tuner, one of the things I often find myself doing is adjusting people's fuel pressure back to standard.

Now, given the fact that all standard fuel regulators that I can think of are tamper-proof in one way or another to avoid DIY adjustment, why on earth do they always seem to be untamper-proofed when they get to me? Worst of all they are always set too high, very rarely too low.

It seems to me that the answer can only be that people can't help but mess with things they don't fully understand. The term 'A little knowledge is dangerous' can easily be applied to fuel pressure.

All too often I hear the excuse, "I just turned it up for a bit of extra fuel", not to mention the old chestnut, "More fuel pressure gives it more power doesn't it?". Then I end up spending the next half-an-hour explaining why that is absolute garbage, and how you are almost as likely to end up with a melted piston by running too much pressure as you are with too little — not to mention you are more likely to have a meltdown with excess pressure in some systems than if you simply ran the correct pressure (presuming air-fuel ratio (AFR) is correct at standard pressure, of course).

So, why is it possible to melt an engine with excess fuel pressure? Surely, too much fuel is far safer than too little? Well, the additional pressure brings about its own pitfalls, so let's go back to basics and see if I can explain it using some easy to understand terminology.

Electric fuel pumps can fire out fuel at a massive 9 bar...

PLUMBING

How are fuel injection systems plumbed in? The most basic fuel injection systems will have an electric fuel pump, connected via high pressure fuel lines (pipes) to a fuel rail that in turn houses the fuel injectors that deliver the fuel to the engine.

At the end of this fuel rail will normally be a fuel pressure regulator. The regulator, as its name suggests, regulates the pressure seen in the pipe and fuel rail.

The fuel pump fires out fuel at a maximum rate of approx 9 bar into the fuel line and the fuel regulator — depending on its settings — will drop this pressure down to the desired running pressure by simply controlling the amount of fuel allowed to leave the pipe and flow back to the fuel tank via the fuel return lines.

So, for a system such as the Sierra Cosworth, we start at 9 bar and then the regulator opens up as it reaches 3.5 bar and leaks fuel back to the tank in a controlled manner, thus achieving a regulated 3.5 bar of fuel pressure at the injectors. This is the correct setting for this system with most commonly-used fuel injectors. Simple you think? Yes it is simple, at least until the engine actually starts running...

HIGH PRESSURE

Why do we actually need to be under such high pressure? OK, that's a good question, and the answer lies at the all important fuel injectors. The fuel injectors on most EFi systems are simply solenoid valves that are capable of both handling fuel in a harsh unforgiving

Fuel injectors are simply valves controlled by the ECU

environment and operating very quickly and reliably — typically as fast as 0.5 milliseconds.

Operation is simple; the injector takes the fuel in at the top (or sometimes from the side) and then under command from the ECU, opens for as long as it is told to and injects the fuel.

The fuel is required to come out of the nozzle in a particular spray pattern and be atomised to a certain level so as to ensure correct mixture into the air stream. This atomisation level and spray pattern is chosen by the engine designers, and they then choose an injector to suit their requirements. The injector

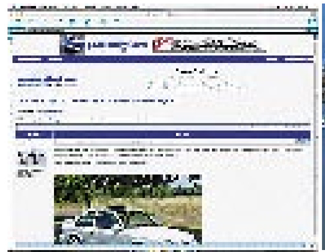
WHO IS STU?

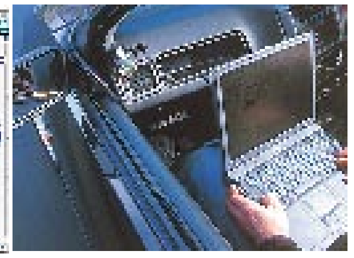
Having worked as a tuner for over 16 years, Stewart 'Stu' Sanderson is one of the most respected names in the business.

A Level 5-trained fuel-injection technician, in the past Ford nut Stu's worked for a Ford RS dealer, a well-known fuel-injection specialist and various tuning companies. Then six years ago, he joined forces with Kenny Walker and opened up Motorsport Developments near Blackpool, 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.

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





Fuel pressure regulator is the pork pie hat-shaped canister halfway up the left-hand side of this pic. The top pipe connects to the plenum chamber and relays a pressure signal back to the spring and diaphragm inside the regulator to determine the fuel pressure supplied

chosen dictates the fuel pressure required and the system is designed from here upwards. Most commonly, these pressures are in the 3-4 bar range.

REGULATE

So does the regulator just regulate to a set pressure and that's it? No. And this is where people start to fall over and make silly and often costly mistakes.

You will notice that most fuel pressure regulators have a small pipe on the top that is connected to the plenum (or somewhere similar) where it can sense manifold absolute pressure (MAP). This pipe has the incredibly important job of carrying a vacuum or pressure signal to the spring and diaphragm assembly that is assembled within the regulator.

READ THE SIGNAL

Why does the regulator need this signal? What does it do with it? This is where the regulator becomes more complex. It is deemed necessary to run a different pressure depending on the depression or pressure within the inlet tract itself. The reason for this is to keep fuel flow linear regardless of vacuum or boost pressure. Please allow me to elaborate in the most simple of layman's terms...

Let's imagine that your lungs are the fuel pump, the water in your mouth is the fuel, and a straw in your mouth is the fuel line and injector. A glass on the table can be our engine's cylinder. You have a mouth full of water, and you wish to empty that water, into the glass, using the straw in your mouth.

Now let's imagine we have measured your lung capacity and know it to be exactly 2 psi, so you blow the water out into the glass and it takes you 10 seconds to do so. With no resistance at the end of the straw you blew the water out very easily, as you would expect. Now try and imagine that exercise mimicked a fuel injector that was injecting fuel into the cylinder of an engine that was turned off. No real

Inside the Cosworth YB plenum (top pic) you'll find these four inlets. It's the air pressure going into these that the fuel regulator needs to monitor before it can distribute fuel at high pressure into those four holes on the inlet manifold via the injectors difference between a cylinder and your glass in that scenario (other than the injector being at a higher pressure).

Now, what would happen if you tried the same exercise again, but this time someone was sucking at the end of your straw very hard? You would be right in thinking you would empty your mouth full of water faster than 10 seconds. Why? Because your 2 psi pressure now has something at the other end helping it to travel through the pipe, effectively increasing the transfer rate of the fluid through the straw (injector).

Let's imagine then, that scenario was the fuel injector firing fuel into an engine that is idling. (We presumably all know that petrol engines with a closed or low throttle generate a partial vacuum in the plenum don't we? That's how the air is sucked in to be mixed with the fuel.)

Now for an interesting scenario. Let's imagine the same job is to be done, with your straw and mouthful of water, but this time we are going to put an *equal pressure* at the other end of your straw. So you are blowing water down the straw with 2 psi of lung pressure, but you now have 2 psi at the other end of your straw pushing back at you, so what happens now? Well, nothing at all, it's a stalemate. The differential pressure is nil so we have no flow. What you have just learnt is the effects of a pressure differential on fluid flow, and that's where the little pipe comes in...

THE LITTLE PIPE?

What effectively happens when the engine is running is this:

The fuel pressure is set in this example, to 3.5 bar at atmosphere. That's with the signal pipe disconnected. When we connect the pipe, it acts on a diaphragm and spring and affects the fuel pressure with a ratio of 1:1.

This means that for every 1 psi of difference the plenum has to atmosphere, the fuel pressure will be adjusted accordingly by 1 psi. For example, if we have 1 bar of pressure at the pipe (1 bar of turbo boost), we will run our 3.5 bar plus 1 bar of additional pressure.

This has the effect of ensuring the fuel pressure at the nozzle is always exactly 3.5 bar above whatever pressure is measured within the inlet tract, so the fuel flow is always constant and of a known entity, unlike the flow we had through the straw once we equalised the pressure. Just think what would have happened if we had applied 8 psi to the other end of your straw... oops.

So, in a nutshell, we need to keep the fuel pressure a set amount above whatever pressure is seen in the plenum at the injector pintle. If we have 1-2 bar of vacuum in the plenum, our regulator works the other way and drops the pressure a bar, too.

WHY IS MORE PRESSURE BAD?

Let's look at what pressure we are likely to run on a Sierra Cosworth running Bosch 403 injectors (greys). We have 3.5 bar line pressure as standard and then we run a held 2 bar of boost. This equates to a real world fuel pressure of 5.5 bar (3.5 + 2) so our fuel pump is being asked to supply the fuel required at 5.5 bar now — this incidentally is over double your tyre pressures. Quite some pressure to have fuel at under your car, I'm sure you will agree?

So, why do people adjust this and turn it even higher? Well, it is quite a common occurrence that a person will discover his car is running lean somewhere and thus increase the fuel pressure to account for this leanness and this, sadly, is a really bad thing to do because it is a big compromise and has almost always compromised the rest of the system.

Imagine we have a perfectly good AFR on a dyno test, but as we approach top rpm and boost you are told that it leans out ever so slightly on full boost after 6000 rpm. What do you do? The correct solution is to look at why you don't have quite enough fuel delivery up there. Is it too much boost, is the chip wrong for the spec, do we have restricted fuel lines or filters? Maybe the alternator is getting too hot at high rpm and starving the injectors and fuel pump of valuable voltage? All are very common and simple to fix culprits.

However, the common bodge is to simply wind up the fuel pressure — let's say for sake of discussion they add another 1 bar of fuel pressure. This instantly has two negative effects.

Firstly, our pump and fuel lines are now being asked to supply 6.5 bar instead of 5.5, as well as the physical strain on the fuel pumps and lines we must be aware of the simple fact that when fuel pressure goes up, the pump's delivery ability goes down while its current consumption goes up and places further strain on the wiring system.

Secondly, our perfectly good AFR everywhere up to 6000 rpm is now rich. OK, so we managed to obtain the extra fuel from 6000 rpm at full boost that we required to fix the slight leanness, but everything else that was previously OK is now far too rich. Terrible fuel consumption and greater engine wear are the only real results from this exercise.

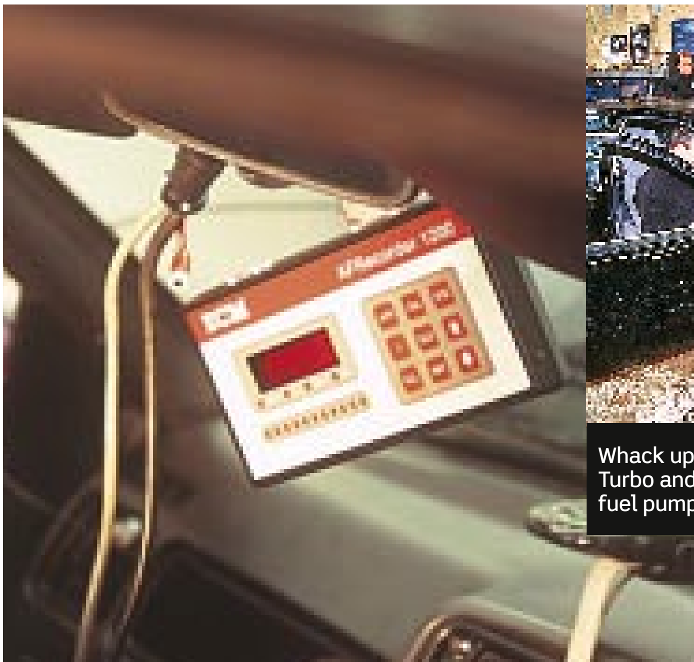
The only way additional pressure can be run without this compromise in overall fuelling is if the engine management software was written with this specific fuel pressure in mind from the outset — although that doesn't in any way alleviate the additional physical and electrical strains this extra pressure creates on the fuel and electrical system.

IN-TANK PUMPS

The final issue is to do with in-tank pumps, and this is worth a mention as many of you run Fords with an in-tank pump, and the most notable one with problems is the Fiesta Turbo.

It is not at all unknown for a Fiesta RS Turbo engine to meltdown due to incorrect and excessive fuel pressure at Stage 1 and above when using the standard fuel pump. Why is this? Well, the standard in-tank fuel pump has a little rubber sealing section on it that connects the high pressure outlet to the fuel line in the tank — and this ruptures at around 5 bar.

The scenario is this: standard fuel pressure is 3.5 bar; boost at Stage 1 is 1 bar. This gives a fuel pump-regulated pressure of 4.5 bar — that's just below where they usually rupture and it is normally fine there. But then one of two things happens: either Joe decides he can run another 0.5 bar of boost; or Joe and his pal down the pub decide a little extra fuel won't do it any harm, and then proceed to wind up the fuel pressure regulator. Hey presto, an engine that was perfectly safe with 1 bar of boost is now a time bomb just waiting for the fuel pump seal to rupture and lean off the engine to the point of destruction. Well done Joe, great safety modification that was...



If the air-fuel ratio starts to lean out a high rpm on a power run, it could be down to a number of elements (too much boost, restricted fuel lines etc) — not just insufficient fuel pressure

Whack up the fuel pressure on a Fiesta Turbo and you risk rupturing the in-tank fuel pump seal, then it's bye bye CVH...

NEXT MONTH

Boost controllers: from the Amal valve to the Japanese controller — the various options and how they work