THE EXPERT STEWART SANDERSON

Having worked as a tuner for over 20 years, Stewart 'Stu' Sanderson is one of the most-respected names in the business.

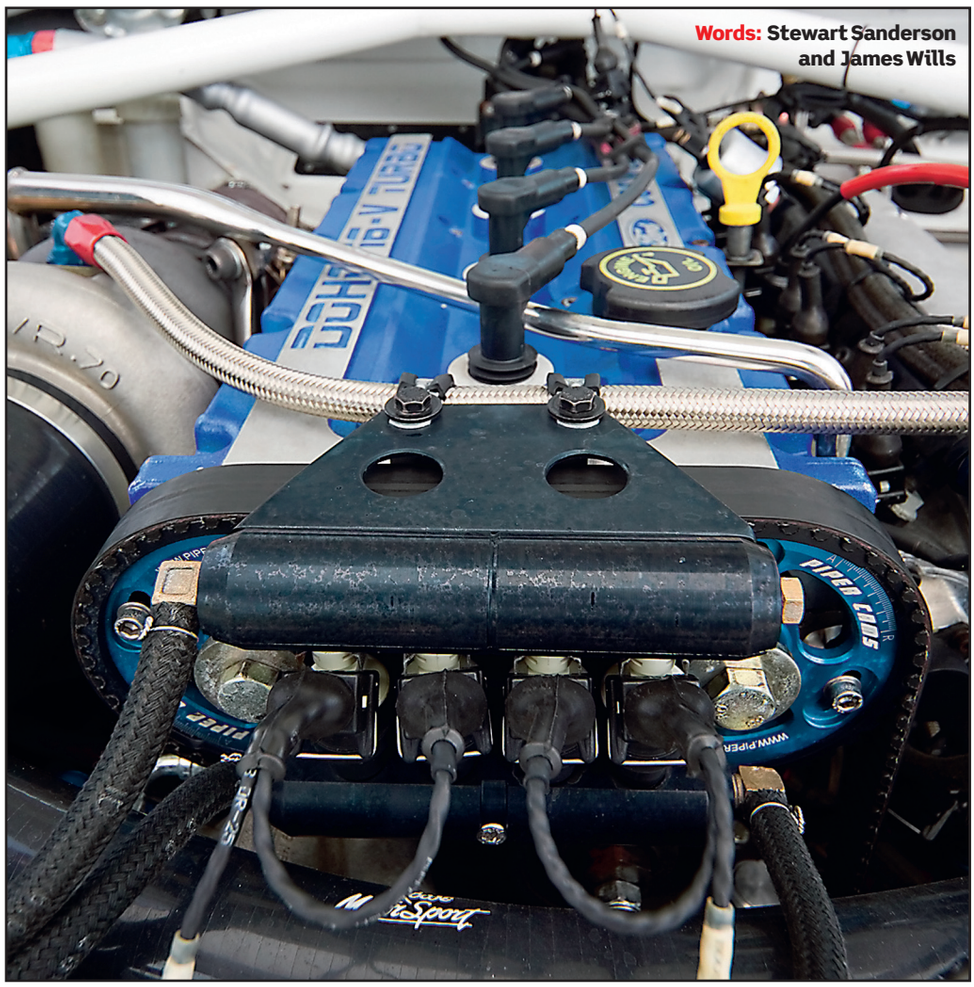
A Level 5-trained fuel-injection technician, Stu has worked for a Ford Rallye Sport dealer, a well-known fuel-injection specialist and various tuning companies.

11 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



AIR INJECTOR SYSTEMS

WE TAKE A LOOK AT AIR INJECTORS – WHAT THEY ARE, WHAT THEY DO AND EVERYTHING ELSE EXPLAINED RIGHT HERE.

Most of you petrolheads out there will probably have heard the term 'air injectors' and often wondered what they are.

Well, this month we will look at them in some detail and explain not only what they are, but also how they work, how they differ from other forms of boost control and when you may need them, along with what to look for when buying.

SO, WHAT ARE AIR INJECTORS? AND HOW DO THEY WORK?

First of all, let us get one thing straight – the air injectors we are looking at this month are a form of boost control. There is an air injector system related to emissions, but us petrolheads aren't overly concerned with that when we could be talking about boost and going faster right?

OK, SO AIR INJECTORS ARE A FORM OF BOOST CONTROL, BUT HOW DO THEY WORK?

Well, to understand that we need to go right back to basics and look at why we need boost control... On

In a turbocharged car, the turbocharger is driven by the exhaust gases which rush into the exhaust housing and force the exhaust wheel in the turbocharger to rotate. This exhaust wheel is directly connected to the compressor wheel via a shaft which runs through the centre of the turbocharger core.

The faster the exhaust wheel rotates, the faster the compressor wheel rotates which pumps more air into the engine; the more air pumped into the engine, the more exhaust gases are produced, producing a cycle where the turbocharger can quickly produce lots of boost pressure and lots of exhaust gas.

Now obviously this cycle has to be controlled otherwise things can very easily get out of control. We do this by opening a wastegate, which bypasses the exhaust wheel of the turbocharger, so gases no longer drive the exhaust wheel but in fact take a short cut straight into the exhaust front pipe allowing the turbocharger to slow down and in turn boost pressure made by the compressor will drop.

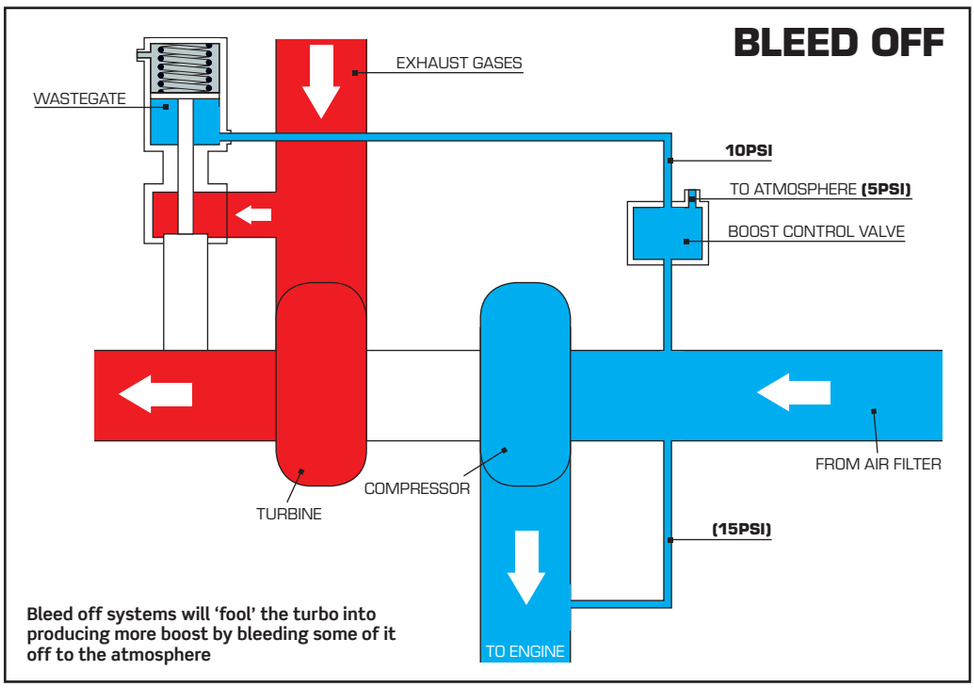
This wastegate can be built into the turbocharger, or externally fitted to the manifold itself, but either way it needs to be controlled and told when to open and close... in brief, it needs to be regulated in much the same way fuel pressure is.

Now... 90 percent of turbochargers have what is called a wastegate actuator which is a sprung canister that will open the wastegate at a predetermined pressure. External wastegates usually have the spring built into the unit, but again will open at a predetermined pressure.

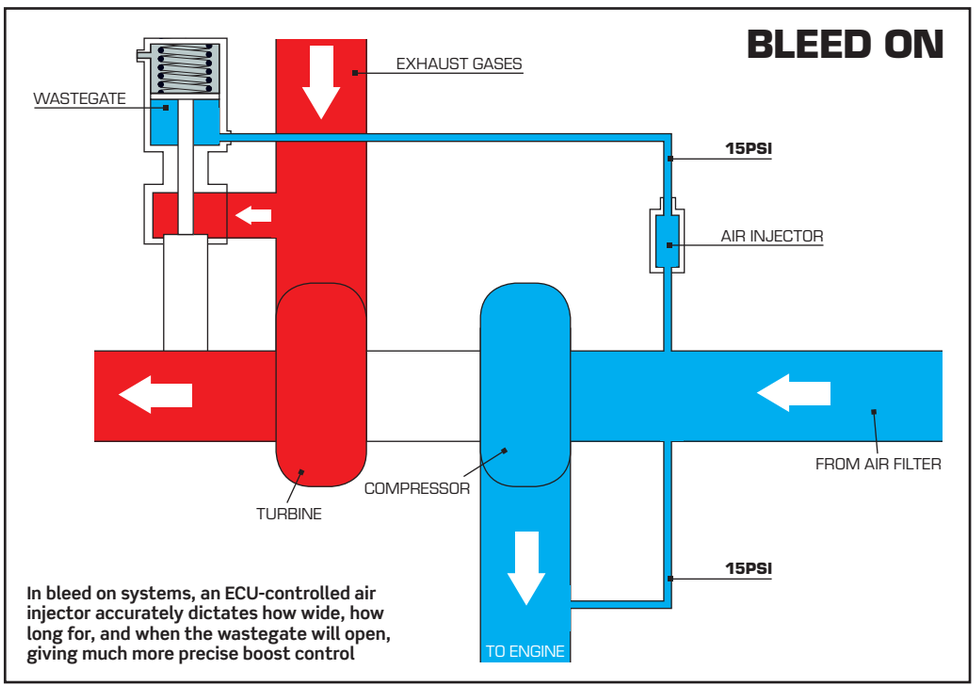
The boost pressure is fed to them and, once that pressure is reached, usually between 8 and 14psi, the valve opens and stops exhaust gas from flowing through the turbocharger, limiting our boost pressure. The pressure signal that is fed to these units to open them is where our boost control system and, of course, the air injectors are plumbed in.

Air injectors are a method of boost control which allow us to very precisely regulate exactly when the wastegate will be opened, how wide it will open and how long it will open for. They look similar to fuel injectors, but internally are very different.

Fuel Injectors are designed to be kept cool and lubricated by the fuel flowing through them. Since we are using air and not fuel this is not possible, so the air injector units are therefore designed to be cooled by air and they are also self-lubricating to ensure reliability.



Bleed off systems will 'fool' the turbo into producing more boost by bleeding some of it off to the atmosphere



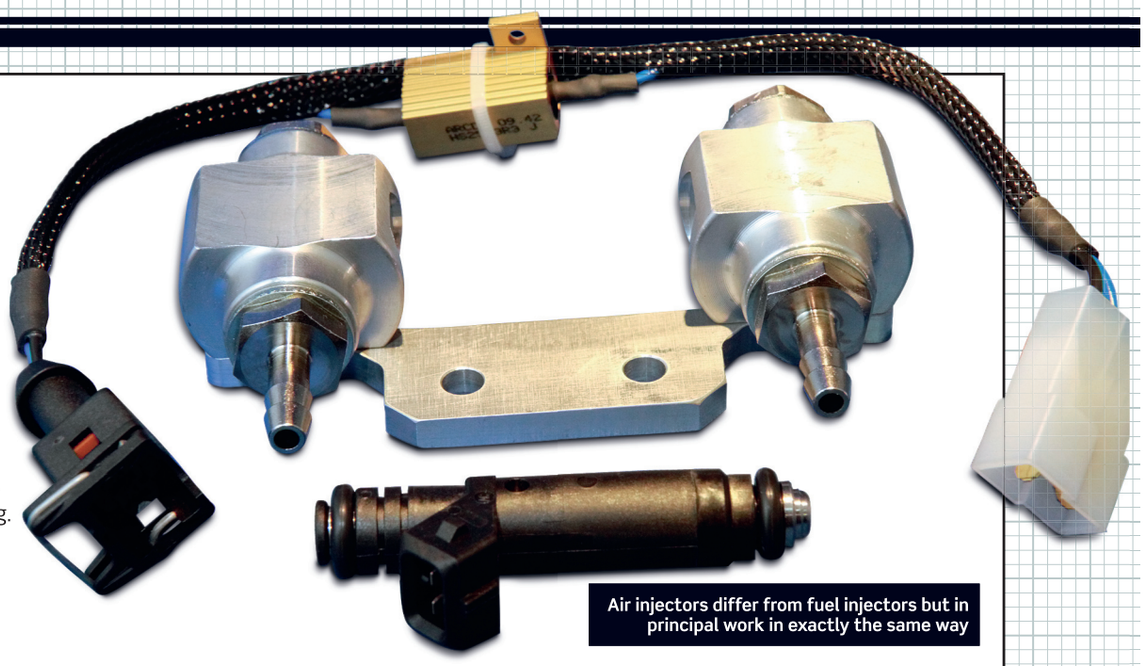
In bleed on systems, an ECU-controlled air injector accurately dictates how wide, how long for, and when the wastegate will open, giving much more precise boost control

SO, HOW ABOUT OTHER FORMS OF BOOST CONTROL? AND HOW DO AIR INJECTORS DIFFER?

To understand how various boost controls differ, you need to know how most boost control devices usually work and indeed why they even exist, so let's look at that next.

In its most crude form, we would simply run a pipe from our turbocharger's compressor, directly to the wastegate actuator to control the boost. As the turbo made pressure, the actuator would see it directly and the gate would open based on the actuator's spring rating only. Tidy and efficient, so why complicate it? Well, basically, we usually have a fundamental need to actually lower the boost pressure, for reasons such as:

- The engine itself is cold.
- Intake air temperature is very cold.



Air injectors differ from fuel injectors but in principal work in exactly the same way

■ Engine intake air is very hot.
■ Detonation is detected.
■ Exhaust gas temperature is too high.

Most turbocharged vehicles' engine management systems will lower the boost pressure in some or all of the above conditions, and often have different boost pressures for different gears. So, in order to be able to control boost pressure what they do is fit a wastegate spring that is softer than the boost required and then adjust how much pressure ever actually reaches that spring.

Most forms of boost control systems do this in what is known as a 'bleed off' manner, this means that they will bleed air off to atmosphere from the control hose routed between the compressor housing and the wastegate actuator.

A simple example here is this: if your actuator is set to open at 10psi, but you intend to run 15psi of boost pressure at the engine, you will need to bleed 5psi away from the actuator's control pipe via a solenoid (our boost control valve) so that it doesn't 'know' you are developing 15psi of boost. What we do is simply bleed this 5psi off to atmosphere meaning even though the actuator is seeing 10psi and opening as designed, we actually have 15psi of boost pressure at the plenum as desired. Essentially we are fooling the actuator by not allowing it to see the full pressure that the turbocharger is producing.

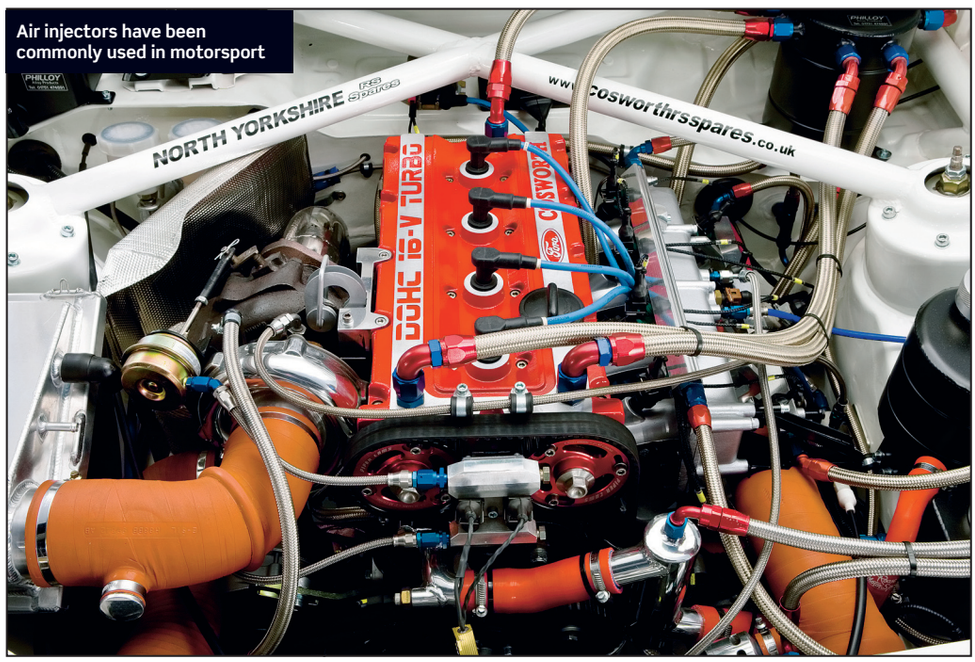
"THESE SIMPLE SYSTEMS ARE FITTED TO MOST OF THE WORLD'S TURBO'D PETROL VEHICLES"

Now, if we ever need to drop the engine's boost from 15psi down to 10psi, all we have to do is turn off the boost control solenoid, removing the air bleed and directing all pressure to our wastegate actuator which of course suddenly sees the full 15psi and instantly opens the wastegate, lowering the boost back to a regulated 10psi.

These simple systems are fitted to most of the world's turbocharged petrol vehicles and include the Ford Cosworth's SEM valve (or 'Amal valve' as it is known), the Fiesta Turbo and Escort Cosworth's two-port valves and the Focus RS and ST's more modern solenoids.

They all vary from two to three port designs, but all in essence simply reduce or divert gas away from a softly sprung wastegate in order for us to be able to suddenly fire that gate open in case of emergency. Some are simple on/off switches, so full boost or low boost, some actually regulate the valve and have some degree of control allowing a slightly varying degree of boost to suit various scenarios.

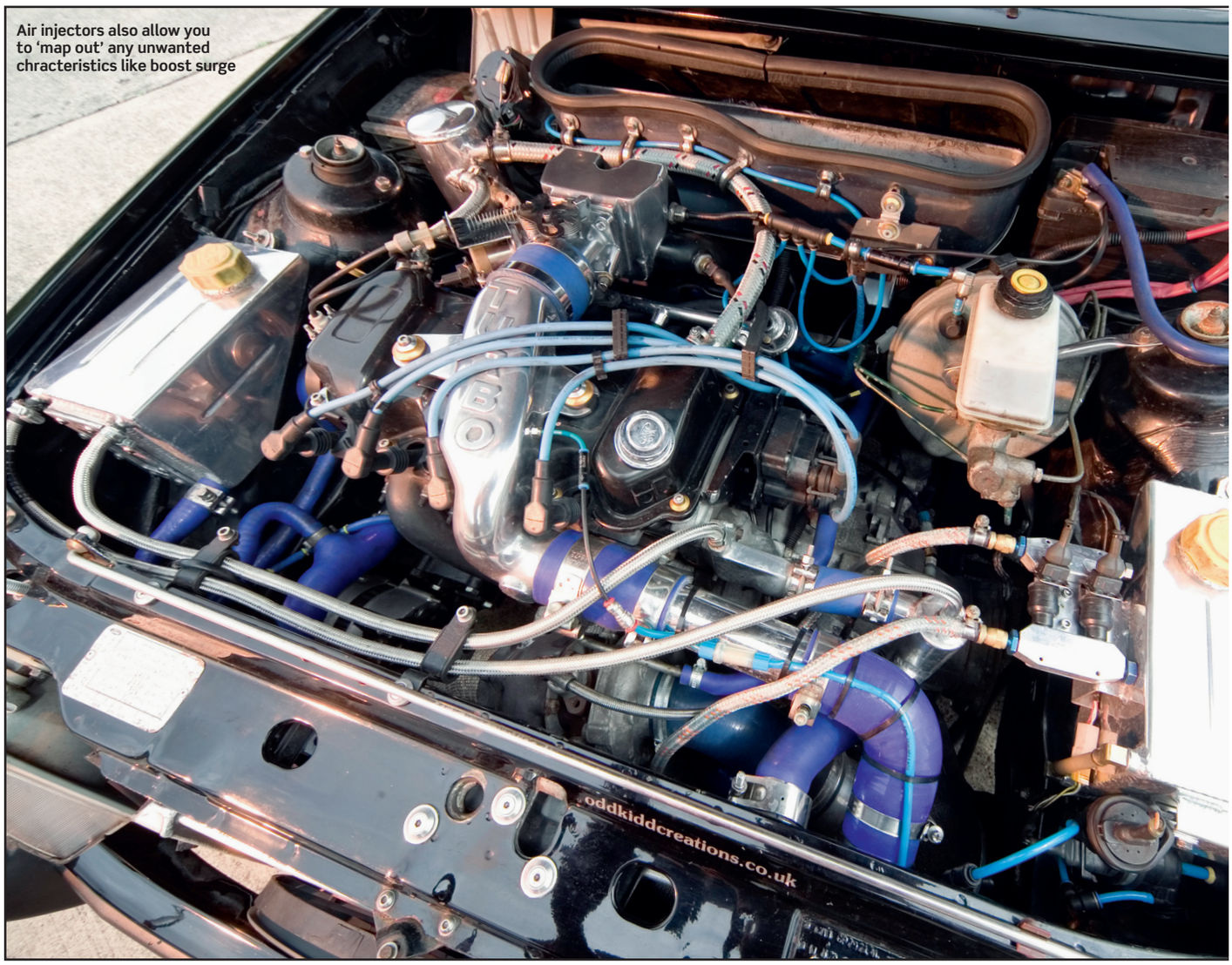
OK, so now you know how 'bleed off' boost control systems work and can hopefully see that they have a pretty crude working brief and are, to all intents and purposes, either working (15psi in our example) or not working (10psi in our example) and while many do indeed regulate, they are far from efficient at being anything other than on or off as they are just solenoids. They do a job, and they do it reliably and well.



Air injectors have been commonly used in motorsport

SO HOW DO AIR INJECTORS DIFFER?

Air Injectors are known as a 'bleed on' system meaning that the whole air supply is controlled and air is bled into the actuator though the injector assembly. You can literally control the amount of air that flows to the actuator in any position from fully closed to fully open. On a typical '80s or '90s Ford ECU this is in up to 255 positions, on a more modern ECU this can be over 65,000 permutations showing just how controllable these systems can be! The system usually works with your existing ECU boost control map so instead



Air injectors also allow you to 'map out' any unwanted chracteristics like boost surge

of just saying 'on' or 'off' we can now adjust how much air is flowing, so if we want 40psi from 3000-4000rpm then 30psi to the limiter from there, we can program it in.

The crudest air injector map is usually boost versus rpm so any sites can be accurately adjusted as the boost increases with revs; better systems allow us to adjust that based on throttle position too. It's the adjustability that makes it so useful to us so when the ultimate boost control is required we tend to fit air injectors.

SO HOW DO I KNOW WHEN I WOULD BENEFIT FROM AIR INJECTORS?

There are various scenarios that tend to warrant such control. Let's look at some of them.

SCENARIO 1

An engine is presented for mapping with an extremely large turbocharger fitted to a completely standard engine. This engine cannot consume all the air this turbo produces at lower rpm and therefore suffers badly from turbocharger surge, making it quite undriveable.

Using air injectors this problem can be overcome. We can map the air injectors to flow a lot of air pressure to the wastegate during these periods of potential surge, thus opening the wastegate a little to keep the boost below the surge line. Effectively we can actually map out this surge at low revs, and then as the engine's efficiency increases at higher revs we can run less duration on the air injectors, which closes the wastegate and increases the boost pressure again.

With normal boost control, like an Amal valve, the turbo boost would have had to stay low everywhere.

"WHEN THE ULTIMATE BOOST CONTROL IS REQUIRED WE TEND TO FIT AIR INJECTORS"

SCENARIO 2

A front-wheel-drive car is having trouble with traction, ideally it needs less torque but can easily use all the bhp at higher revs to ensure it is still very fast.

In this scenario we can again slow the turbocharger down, but this time not because we have surge but because we want less boost for a few revs. We can now use our air injectors to slow the turbocharger down right from the off, aiding the driver with traction by reducing the low down torque the engine will produce. At higher rpm when traction is not an issue the boost pressure can be allowed to increase, and ultimately a hefty power figure can still be achieved with less midrange torque. This is best done while live mapping so traction can actually be assed and boost mapped to suit the car's capability.

SCENARIO 3

A car is presented for mapping

with a modern ECU, the car suffers from traction issues in low gears but feels gutless in the higher gears. In this scenario using air injectors we can do some clever gear-dependent mapping, meaning the boost can be limited and mapped to suit traction just as scenario two, but this time we have different maps for each gear, so first gear can be limited heavily to allow for traction and to safeguard the drive train, but as the car gets into the higher gears we can allow it to run much more boost from low revs as traction is no longer an issue.

This really is the ultimate set-up and infinitely adjustable for absolute control.

SCENARIO 4

An engine has been built to deliver very high midrange torque and as such has a small turbo to help deliver it. The builder wants 45psi in the midrange but knows his turbo can only maintain 15psi at the top-end so needs some way to get the required high boost for a couple of thousand rpm then more sensible boost further on in the rev range.

We can help here with air injectors by mapping the boost curve, we can even close the injectors and see what the turbo will do with no wastegate at all and yet we have full control to bring the boost back down as and when we want it to.

AIR INJECTOR TYPES

There are a few different types and styles of air injector available, it is vitally important the correct size and type is fitted to match your map.

Single type injectors are usually around 1200cc in size, most twin type injectors are two 600cc injectors meaning a total again of around 1200cc. But things are not quite as simple as they may seem, some companies will supply twin injector kits, with two 1200cc injectors fitted, but a careful examination of the wiring may show that only one is actually connected. What a waste of money. Some will run one 1200 and one old, dead injector just so you have the old 'touring car look' but are only really running a single, but in a double housing. However, some will run both 1200cc injectors connected but of course that will flow more air than your air injector boost map (if you have one) was calibrated for so will need a remap.

So from this you can see why it is vital to know what they are, and make sure your map is suited to the injectors you are purchasing or are prepared for some mapping to be done.

CAN THEY JUST BE BOUGHT AND FITTED?

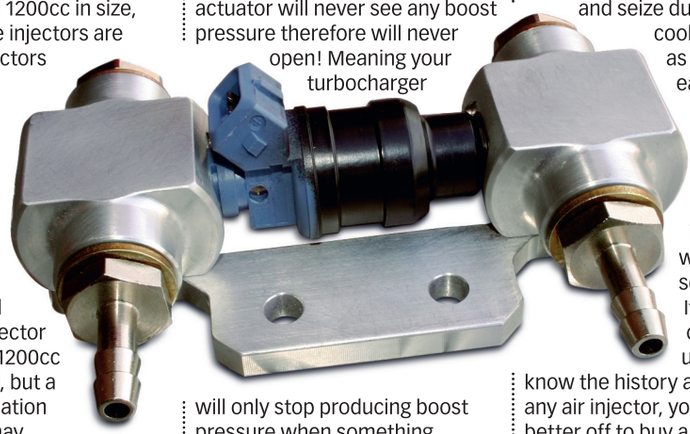
No, they need to be fitted with a suitable ECU calibration as they work inverse to a normal system so if you just fitted them you would end up with less boost and, as mentioned, they ideally need to be mapped in properly.

WHY DON'T THE OE COMPANIES RUN SUCH SYSTEMS TO START WITH?

Well, there is only really one downside to air injectors and that is the way they fail.

All forms of bleed off boost control will fail safe, meaning if the solenoid or valve stops working for any reason at all the boost pressure will drop, as no air will be allowed to bleed off the control line so the actuator will see the full pressure from the turbocharger, in turn opening the wastegate earlier than before, dropping boost pressure.

Now in the case of a bleed on air injector system, should the injector fail in the closed position for any reason the wastegate actuator will never see any boost pressure therefore will never open! Meaning your turbocharger will only stop producing boost pressure when something breaks, melts, or if you are lucky when the exhaust gas pressure forces the wastegate open by overcoming the spring pressure in the actuator, but this can easily be well over 50psi. If you're running big boost, chances are your boost limiter in the ECU will have been removed, so you really are in danger.



These failures are very rare, but it is always worth using a secondary safety device when using these air injector systems. These can be as simple as an adjustable pressure switch fitted to the inlet manifold which will either earth the coil or show a warning light when a set pressure is reached. But it has to be said the driver should instantly know if the car starts to produce much more boost than usual! Alternatively, blow off valves can be fitted which blow open at a set pressure, meaning excess boost pressure will simply be dumped to atmosphere preventing any damage to the engine, but not preventing a turbocharger over speed.

ROGUE TRADERS!

As we have already mentioned these air injectors differ heavily from fuel injectors, but we still all too commonly see fuel injectors being used to control boost, some of the kits we see for sale on the internet are nothing more than old, freshly painted fuel injectors! Yes, that's right – they paint the injector body so the colour will refer to an air or gas injector! So be careful out there as these things will last maybe a few hundred miles before they overheat and seize due to no cooling fuel flow as mentioned earlier.

Since the failure of air injectors can be very serious, is it really ever worth buying second hand? It is my firm opinion unless you know the history and use of any air injector, you are much better off to buy a new kit, and not risk your engine.

So that's it, a brief but fairly detailed look at air injectors and how they work and are controlled.

NEXT MONTH

WHAT IS A WASTEGATE, AND WHAT DOES IT DO?