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.

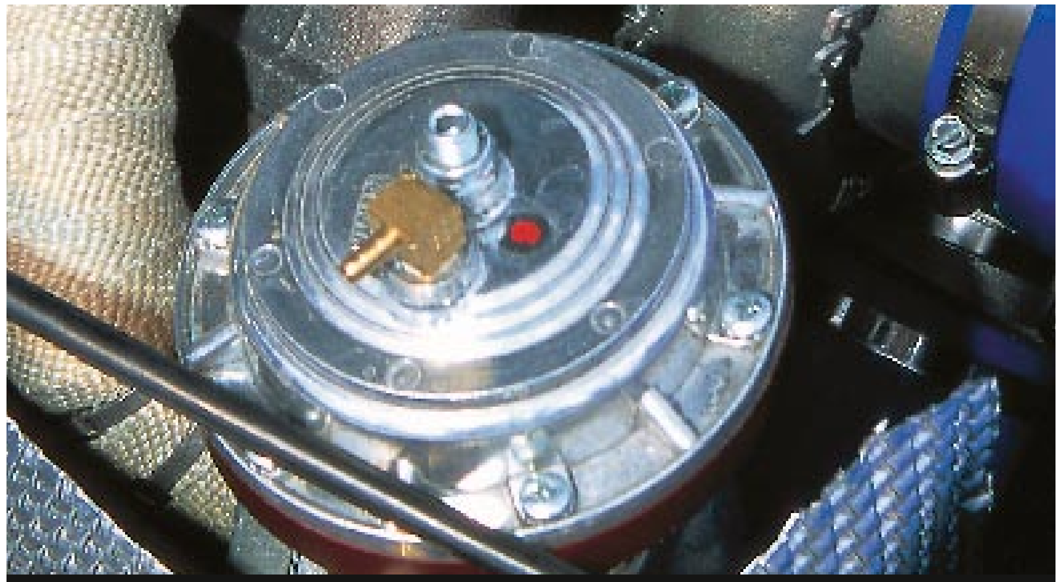
Never work under a car without supporting it using axle stands. A car falling on you is not something you'll be laughing about down the pub.

Words: Stewart Sanderson

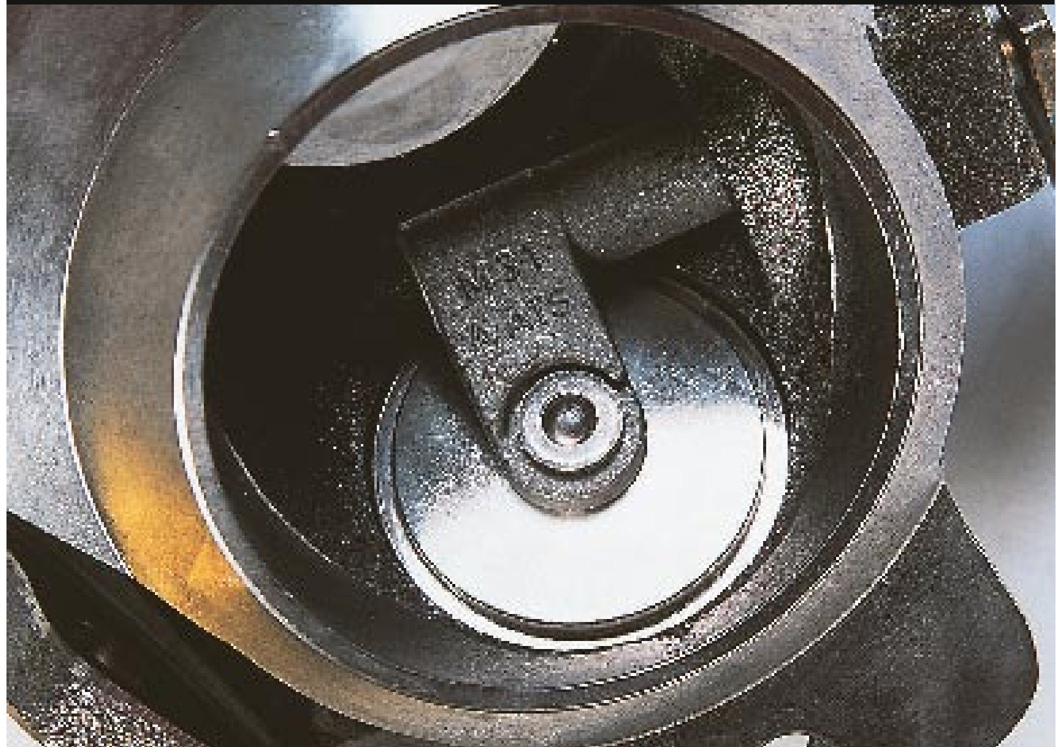
BOOST IT

Ever wondered how boost is controlled on turbocharged cars? Our tech guru, Stu reveals all and explains the different types.

AS an engine tuner, one of the things that I spend a lot of time doing is adjusting the boost pressure on turbocharged engines. Very often I find it needs adjusting as a direct result of someone's ill-informed meddling.So I thought this month it would be interesting to explain the various forms of boost control available to you and how each type of boost controller actually works. But before you can understand the various methods of control, we need to take a look at the standard methods and requirements in some detail.



On monster-power engines where huge amounts of gas are needed to be bypassed, external waste-gates are used. These are located next to the turbo with the outlet welded directly to the downpipe



Most standard turbos feature an internal wastegate which is integral to the turbo assembly and lives inside the turbine housing. It's often referred to as a wastegate penny for obvious reasons...

THE WASTEGATE

All turbochargers have one of these — normally mounted in or before what is known as the turbine housing. This housing is the part of the turbocharger that the exhaust gas flows through — once it leaves the exhaust ports via the exhaust manifold in order for it to reach the turbine itself and spin it up to a speed that will generate our required boost pressure.

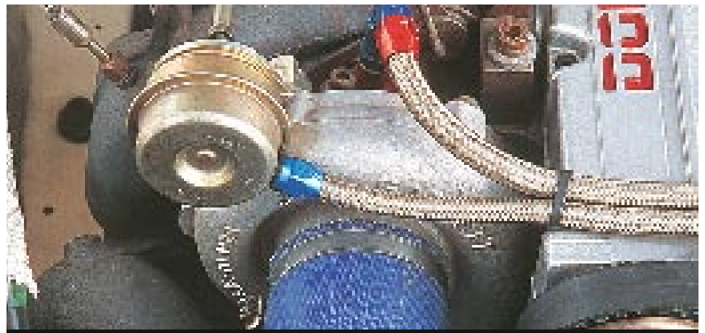
The turbine housing takes the flow of gas from the engine and accelerates it towards the exhaust downpipe by sending it through a narrowing passage. Before the gas reaches the downpipe itself it has to pass through the turbine wheel which reacts by rotating at a speed proportionate to the volume, temperature and velocity of the gas that is passed over its blades. Obviously, we get to a point where we need to limit turbine speed to stabilize our boost pressure at the desired boost pressure limit of our engine design, and this is where the problem of control arises.

The way to limit the turbine speed is to limit the gasflow over its blades thus limiting its rotational speed. This is almost exclusively done by using a wastegate. The gate is installed in or near the turbine housing, always prior to the turbine wheel, and is designed in such a way as to bypass enough gas to limit the turbine to a very low speed if required. The gas bypassed is known commonly as waste gas and thus the gate it passes through to avoid the turbine became known as the wastegate.

There are two types of wastegate commonly in use today. The first type is the internal wastegate, literally designed into the turbine housing itself.

The second is the external type that is added onto a turbocharger installation by the engine designers, commonly piped up with its inlet prior to the turbine housing, and its outlet welded into the downpipe itself. The latter type is normally used when we need to bypass huge amounts of gas on very high power engines as the size of the gate means it would not physically fit into the turbine housing.

This is the wastegate actuator. The sealed canister contains a diaphragm and spring that act on the wastegate control arm on the turbo using the rod to hold the wastegate shut until required to open



The amount the actuator opens the wastegate is controlled by a pressure input (above) direct from (in this case) the Amal valve

THE WASTEGATE ACTUATOR

So, this brings us directly to the wastegate control device itself. This is what's used to control the pressure that the wastegate itself actually opens and tries to stabilize the turbine speed. Its name is the wastegate actuator.

This actuator comes in a few different forms, but it is to all intents and purposes always the same concept. We have a sealed pressure canister with a pressure input welded onto it. Inside the canister is a diaphragm and a spring that isolate the pressure canister from the mechanical workings that are attached to the wastegate. Underneath the diaphragm and spring is a rod that exits the canister and connects directly to the wastegate control arm, often via an adjuster mechanism.

The connection to the wastegate is always under some tension so the gate is held tightly shut until it is required to open. This gives the turbine maximum exhaust gas to spool it up to speed. Once the boost pressure in the engine starts to rise, a proportion of this pressure is directed to the actuator via its pressure input, where it acts upon the diaphragm and spring, compressing it, thus extending the rod, opening the wastegate.

Once the wastegate is open, exhaust gas starts to flow through it and bypass the turbine wheel, dropping the boost pressure, which in turn drops the signal pressure that is seen at the actuator spring by a corresponding amount, thus closing the wastegate a little again — this is how the boost is regulated and maintained at a set level.

The boost pressure that the gate actually starts to open at is directly related to the strength of the spring inside the wastegate actuator. Common springs in the Ford tuning world are known as the Garrett -31 and Garrett -34 (approximately 8 and 14 psi lift-off, respectively).

So that's the basic turbocharger boost control method covered — the wastegate and its wastegate actuator. This brings us neatly onto the topic of ECU and user-adjustable methods of making those devices do what we want them to do — the boost controllers.

BLEED VALVES

Undoubtedly the most primitive of all boost control devices is the simple bleed valve.

These devices are incredibly simple yet still commonly misunderstood. The device is very much like a household tap. We have boost flowing through it, from one side to the other and the adjustable screw on the top of it regulates how much we get from the outlet (on the bottom).

When it is fully closed, we send all the boost pressure input directly from one side to the other, in other words it bypasses the outlet all together. When we open the tap on the top, we basically introduce a controlled air leak to the pipe. This air leak puts a pressure drop into the pipe from one side of the valve to the other.

So if, for example, we have a standard engine running 8 psi, and we want the engine to run 16 psi, we need to convince the actuator not to open the wastegate at 8 psi as it normally does. The way we do this with a bleed valve is easy; we open the tap on the valve and allow a full 8 psi to bleed away before it ever reaches the actuator.

This introduces an air leak in the pipe, so even though the turbo sends out 16 psi towards the actuator, the actuator itself never sees it all as some of it leaks away elsewhere, keeping the wastegate closed for longer. This allows a turbo boost pressure of 16 psi because at this pressure the actuator will receive its normal 8 psi as expected and start to open the wastegate, limiting the boost at the engine to 16 psi instead of 8. Make sense? Good!

The simplest, most common form of boost control is the bleed valve. This is a Forge Motorsport item, designed for in-car fitment

The Amal valve was fitted as standard to RS Turbos and Sierra Cosworths, and is a simple electronic bleed valve that works well

It's worth mentioning here that there are two different types of bleed valve, the two-port and three-port type. The three-port one simply has a nozzle on the output so it can be connected back into the car's intake system. This third port is essential for cars with airflow meters (the Escort RS Turbo, for example).

WASTEGATE CONTROL SOLENOID

All turbocharged Ford cars have some form of wastegate control solenoid to give the ECU some control over the boost pressure. Early turbocharged cars such as the Escort RS Turbo and the Sierra Cosworth had a three-port device, commonly known as the Amal valve (a company called Amal made them in Sweden).

This valve is, to all intents and purposes, an electronic bleed valve. We have three pipes going to it: the pressure input pipe is fed air from the compressor housing of the turbo; the outlet pipe is from the wastegate actuator; and the bleed (or leak) is piped to the air box.

It operates exactly like a bleed valve but instead of a screw on the top we have an electrical solenoid that the ECU can operate at will. The amount the port leaks air is controlled by little jets fitted into the outlet pipe so when the solenoid is open, only a set amount of air is allowed to leak out.

A jet is also fitted to the intake pipe to control the speed of entry and to stop a massive surge of pressure damaging the valve. As tuners we often adjust both of these jets to alter the boost curve and make it do what we want it to do.

The two-port valves as seen on the Fiesta RS Turbo and the small-turbo Escort Cosworth work slightly differently in as much as the T out of the signal pipe is made by a conventional plastic T-piece and the two-port valve simply controls the flow into the airbox. The rest of the theory of operation is the same.

The methods above are all known as *bleed off* — so called because when activated they bleed air away from the wastegate actuator in order to increase the boost pressure.

AIR INJECTORS

These are the form of boost control with the largest amount of mystery and old wives' tales surrounding them. They are, as their name suggests, a pair of injectors (or more recently, a single one) mounted in a body with an input and an output that are used to control boost. They look very much like fuel injectors but in fact are not, so whatever you do don't be tempted to throw some old injectors into a housing and use it to control your boost — it will more than likely end in an engine failure in the very near future.

The difference here is these injectors are designed from the outset to flow a gas, not a liquid, and as such do not require the liquid cooling of the core that a fuel injector does. Sadly, a fuel injector will soon burn out when used to inject a gas, as many poor unfortunates have found out to their peril over the years.

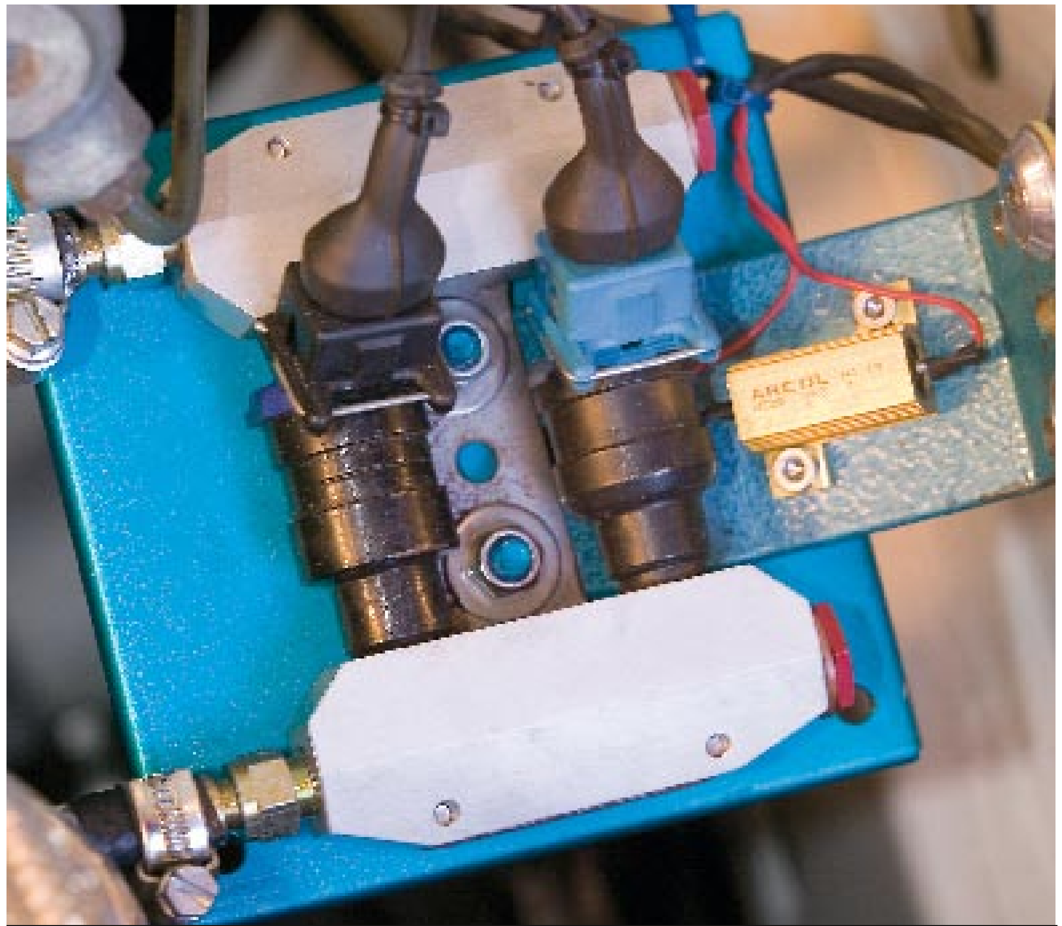
This type of boost control is piped into the line between the actuator and turbo directly, with no bleed off port at all. This is where the benefits can be found. This type is known as a *bleed on* system and is so called because we actually control, via the ECU, how much air is allowed to reach the wastegate capsule. In other words, we bleed the air onto the wastegate. This can be varied almost infinitely between no pressure and the whole pressure from the turbo.

The real beauty here is the amount of control we have compared to the earlier methods of boost control — we can alter the pulse width of the injector depending on both rpm and boost pressure seen at the engine, and means we can now tailor our boost curves to our needs.

As an example, we may want 35 psi of boost up until 5500 rpm and then drop to 28 from there to the rev limiter. With air injectors that is not a problem, in fact it's simple (providing your turbo is up to making the boost).

Alternatively, we may want to remove some of the low-down boost due to turbo surge, again, that isn't a problem with this system and we can simply increase the injector pulse width in the rpm and load area and send more boost pressure to the actuator, thus lowering the boost pressure as desired.

The eagle eyed amongst you will notice that the air injector bodies have a very small hole in one side of them; this is the side that should be piped up to the wastegate



Air injectors first appeared in competition cars and eventually found their way into road cars. Controlled by the ECU, they allow you to tailor the boost curve to your needs., but they're not foolproof...

actuator. The reason for this hole is actually quite simple: it allows the wastegate to close again once it is open — as if the system were airtight we would end up with pressure locked in there and the wastegate would never close once it had been opened.

A couple of final things worthy of note are that there is more than one type of air injector doing the rounds. The original type designed years ago by Ford utilized two injectors. The newer types have only one injector that flows twice as much on its own as the old ones did in pairs (1200cc). Depending on the configuration of the injector you may need a wiring alteration to enable you to run the injectors safely on your ECU without burning out the drive circuit.

Finally, some systems will require an additional air injector driver circuit to enable the use of air injectors with your ECU software as the signal is in fact inverse to the normal wastegate control solenoids, due to the aforementioned difference in the bleed method used (bleed on instead of off).

The only real downside is if the injector solenoid fails in the closed position (normal for an injector), the boost will go dangerously high due to the signal to the wastegate actuator being almost totally blocked (other than a small air bleed hole that allows air out when the actuator is closing). Always consult your tuner before fitment as incorrect application and operation can lead to severe engine damage.

ELECTRONIC BOOST CONTROLLERS

The final type of boost controller is the electronic version — commonly seen in Japanese turbocharged cars. These work largely like air injectors in as much as they normally operate using the bleed on configuration and run one or two high-speed solenoids instead of injectors to control the bleed off.

The big advantage some of these electronic devices have is that they are active and in some cases quite intelligent, allowing them to watch the boost pressure input via their own built-in MAP sensor. This then allows the device to actively adjust the boost curve and make amends to the wastegate if the boost goes too high or too low, virtually eliminating poor boost curves on most engines they are fitted to.

A high peak pressure tailing off to very low pressure as the revs rise is a thing of the past with a device like this fitted.

The other bonuses with these modern systems come in the form of multi-colour, high-resolution screens, warning sounds, digital boost read-outs featuring peak recorded boost levels, different boost levels at the press of a button, safety over-boost limits higher than 2 bar (most ECUs cannot do this), over-boost functions to allow more boost in the mid-range, gear selectable boost levels (ideal for programming less boost in first gear to remove traction problems the car may have) and road speed-programmable boost levels (similar to gear selectable but based on road speed) and many more features. As usual, the functions you end up with all depends on how much you want to spend. The only real downside to this form of boost controller is cost.

These devices are not particularly cheap and require specialist fitting and set-up time. Cost aside, these controllers are the future and you will see more and more of them fitted to fast turbocharged Fords as time goes by.

NEXT MONTH

Spark advance: just what the hell is it, and why do we need it? Stu explains all in the next issue

Electronic boost controllers (below) use one or two solenoids rather than injectors to control bleed off of boost pressure

Dig the new breed: electronic boost controllers from Japan are finding their way into more and more big-power Fords. Tricky and expensive to fit, maybe, but they're the future for accurate boost control