EXHAUST GAS TEMPERATURE

This month Stu gives you the lowdown on exhaust gas temperature.

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, in the past Stu has worked for a Ford Rallye Sport dealer, a well-known fuel-injection specialist and various tuning companies.

Then seven 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'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. His new forum, **www.fordrsforums.co.uk**, is also up and running.

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 most importantly how they can be improved.

I can't believe it has been a month since I last wrote my last feature. Don't forget, if you have any suggestions for topics you would like to cover in the future, drop us an e-mail.

So, let's get to it. I'm sure that the majority of you have heard the term EGT, and a smaller proportion of you might know what it means too... Rest assured that as from today you will all know more than just what it means. EGT simply stands for exhaust gas temperature and it's a measurement of just that, the exhaust gas as it leaves the cylinder head and enters into the exhaust system.

WHAT DOES EGT INDICATE?

EGT is an indication of how hot the combustion process is in the cylinders. This is directly related to the air/fuel ratio, which is mainly why we use the reading. Knowing the overall EGT is a great indication of the running mixture of the engine at that particular time and makes it easy to see if we are running lean or have issues such as retarded ignition. Measuring EGT on each cylinder separately can even warn us of things in individual cylinders, such as failing injectors.

CAN EGT BE USED TO TUNE AN ENGINE?

EGT is often cited as the best way to tune an engine, but let's get that statement ironed out right now: it is absolute rubbish. It's easy to understand why this theory came about.

If you know from experience what sort of EGT any given engine will run when assembled with a known set of components and parameters, ie you dyno'd it, and found at peak power that it made 800 degrees C EGT with intake temps of 50 degrees C, then you can ensure that all subsequent engines are tuned to run the same EGTs at the same power, and all of them should in theory be correct. However, if you were to change spark advance, compression ratio, cams, turbos, intercoolers or anything else that affects power output then

the figure would become meaningless.

The correct and best way to tune an engine is via AFRs. Aircraft engines have been tuned in flight using EGT for decades but they are using one engine that doesn't change, and they aren't changing engine components in flight. So, whatever EGT they're told to maintain by the engineers is gospel and it's safe to tune that way. Don't try it with a modified engine unless you have dyno or live-mapped data to compare it with.

You'll find that many cars running race fuel or leaded fuel tend to have an EGT gauge (or several) but no AFR gauge. This also fuels the myth that EGT is better than AFR for tuning high-power cars, but the real reason is simple. Your wide-band Lambda sensors are poisoned by lead and have a very short life span in the presence of race fuel. This is where your EGT gauges score as they couldn't care less about such contaminants and will again be monitored utilising existing data collected on a dyno using AFR as a basis for the tune and EGT because of the correct tune.

Excessive exhaust gas temp can cause varying forms of engine damage

WHAT FACTORS INFLUENCE EXHAUST GAS TEMPERATURE?

On a petrol engine, the EGT will normally be hottest around stoichiometry and cooler either side of that. If we add fuel at stoichiometry (this is where the air/fuel mixture is approximately 14.7 times the mass of air to fuel. Any mixture less than 14.7 to 1 is considered to be 'rich', any more than 14.7 to 1 is a 'lean' mixture) then we cool off the EGT due to excess fuel. If we lean off from stoichiometry we cool down the EGT due to excess air.

It's worth noting that on a diesel engine it is much simpler. The more diesel you add to the combustion, the hotter the EGT gets, but bear in mind that a diesel engine's EGT getting hotter may not only mean that you have too much diesel, it may simply mean you haven't enough air, so look at clogged filters etc.

Spark advance also plays a large part in the temperatures seen at the exhaust. When the spark advance is at its optimum position in the cycle, the mixture is fired nice and early on in the piston's power stroke and the heat generated is used to propel the piston down. Much heat is also lost into the cylinder head's water jacket. The later we start this process the less energy is used to produce power and heat the water, which means more of it is sent out into the exhaust. As far as the ignition system is concerned, less advance (more retard) = higher EGT.

It's also worth noting that rotary Wankel engines run higher EGTs than their more conventional crankshaft-driven counterparts due to their inherent thermal inefficiencies.

HOW DO WE MONITOR EGT?

There are really only two types of temperature measuring sensors in common use in the automotive industry, one being what we normally find controlling fans or feeding water and air temperature information to ECUs. This type of device is a very fine wire encased in a sensor body often made of brass for its conductive and anti-corrosion properties.

As the temperature of the unit changes, the electrical resistance of the wire encased within it changes. By passing a small current through this wire and measuring the resistance, the temperature can be determined. This system is extremely reliable and accurate, but has a major drawback for us in an exhaust system... It would normally melt, and the chances of the electrical connections working for any length of time are slim, and that is before we get into its relatively narrow measurement range.

The alternative is known as a thermocouple. There are several different types of thermocouples, which utilise different materials for different temp ranges, but they all operate on the same principal.

A thermocouple consists of two completely different metals welded or fused together. For the temperature range we are most interested in with a car's exhaust gas temperature the K-type thermocouple is the most suitable. This tends to have a maximum temperature of around 1100 degrees C (approx 2000 degrees Fahrenheit).

In the K-type thermocouple, two of the most commonly used metals are chromel and alumel.

This is what an exhaust manifold looks like at around 850 degrees C

An EGT gauge (left) is the ideal way to monitor your engine's temps

A small piece of each of these metals is fused together and then the whole assembly is encased in an electrically insulated sleeving, while the other end of the sensor is connected to an accurate voltmeter. Amazingly, once heated this completely unpowered unit generates its own electrical current, which while only a few millivolts (millivolt = thousandths of a volt), is accurate enough to be related to temperature!

These thermocouples are remarkably robust when installed and used properly as they have no delicate parts to abuse or break. Virtually every domestic central heating boiler in our homes uses one to tell the controller that the pilot light is still lit, thus proving their mainstream reliability.

WHERE DO WE MONITOR EGT?

The thermocouple probe is carefully fitted into the exhaust system relatively close to the engine's exhaust valves. For maximum accuracy you want the tip of the thermocouple to be centred in the exhaust gas stream as it comes out of the engine.

It doesn't matter a great deal where the probe is fitted as long as it's not too far away from the engine, although it is worth bearing in mind that on a turbocharged car you will get different readings if you fit the thermocouple before the turbo as opposed to after it. This is due to, amongst other things, the amount of heat energy that is harnessed to actually drive the turbine itself. It's also worth remembering that it is not ideal to have the sensor under the car in direct ambient airflow as the airstream can have a significant effect on cooling of the components and thus lead to inaccurate readings.

If you decide to monitor each cylinder individually instead of collectively, make sure each thermocouple is the same distance from the exhaust valves to ensure balanced readings.

WHAT TEMPERATURES ARE WE LOOKING FOR?

This will vary from one engine to the next as it depends on many factors. As a rule of thumb I like to see the exhaust gas temperature maintained at no higher than 850 degrees Celsius when a petrol engine is held flat out, and a max of 700 degrees Celsius on its diesel counterpart due to the somewhat weaker turbine materials generally used. Less is better if your AFR etc doesn't have to be too rich to achieve it, just don't forget that the turbine response will suffer if you go too low on a turbocharged engine.

WHAT HAPPENS IF THE EGT GOES TOO HIGH?

Excessive EGT can cause varying forms of engine damage and to be more specific we would have to talk about individual engines. However, you can expect that the turbocharger will be one of the first items to fail on a turbocharged motor, as the turbine blade edges will start to break away as

Ceramic coating your manifold is a good way to keep the heat in and make the turbo more efficient

Be it digital or analogue, there are a few different EGT gauges on the market

they are thinnest and weakest parts.

Excessive EGT will also often crack the turbine housing and wastegate area. If the turbo doesn't fail first, then excessive sustained EGT can damage the engine internals too. Damage can include exhaust valves, cylinder heads and even piston deformation. Melting, burning, holes and cracking of pistons are all common symptoms of excessive EGT.

It's worth noting that the damage is almost always cumulative, so if you slightly burn a piston top the engine may continue to run without problems but the next time you run excessive EGT more damage may be done, and so on, until failure occurs. Piston failure is usually catastrophic and extremely expensive to rectify.

WAYS TO CONTROL EGT

In the main, EGT can only be controlled by adding more fuel or spark advance, although changes to the EGT can be made by altering engine components, maybe to cut down on exhaust restriction by fitting a bigger turbine housing for instance. These are dramatic engine characteristic altering changes, and really only fuel and spark advance revisions will make the difference you need if your engine is running too hot.

Remember, going too cool on a turbocharged engine will affect engine response and performance as your turbocharger is powered by heat, so response can be badly affected by too much cooling of the EGT. It's all about balance...

THERMAL MANAGEMENT

It may interest you to know that modern vehicles, most notably German ones, now have K-type thermocouples as standard feeding the ECU with EGT information, allowing it to tune the AFR and spark lead to suit the running conditions. This means we no longer have to map modern cars rich at top end to ensure safe EGTs as the modern ECU has the capability to richen it up when required all on its own.

So that's exhaust gas temps in a nutshell. I hope you found it interesting and will join me next month when I look at the differences between high and low compression, and which one you should choose for your engine.

NEXT MONTH

Differences between high and low compression