fasttech

Words: Stewart Sanderson

THE TRUTH ABOUT DYNOS

So you want to know what power your Ford makes? This month Stu explains the differences between the various types of dynos and why you shouldn't always believe the figures...

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.

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.

THIS month, instead of discussing cars we are going to look at dynos. There are quite a few different types and it is good to know which is which, how they differ and what benefits one has over another, so let's crack on.

WHAT IS A DYNO?

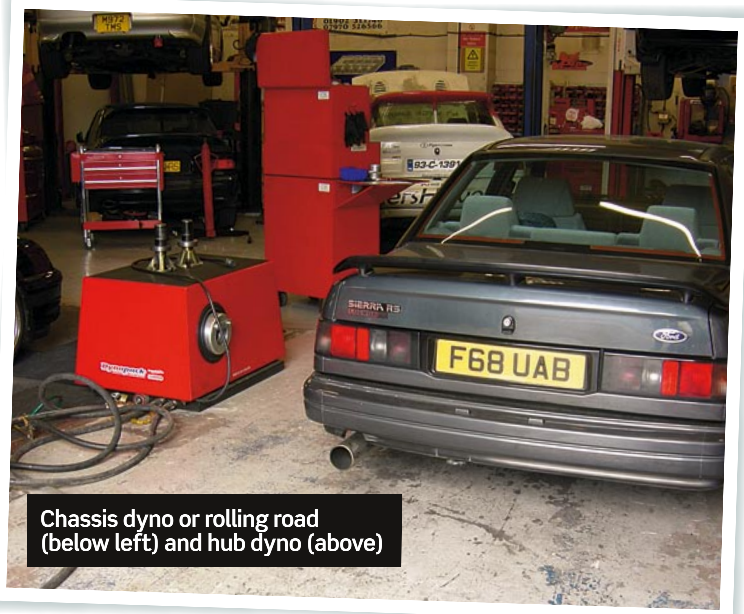
In its simplest form it is a means of measuring the force generated by a rotating item. In an automotive case, we would hope to get accurate flywheel power figures from it, but that's not always possible as you will see when you read on. We also expect that a good dyno will provide us with a printout detailing useful things such as rpm, engine torque, engine horsepower and ideally boost and Air Fuel Ratio (AFR), too.

WHAT DIFFERENT TYPES OF DYNO ARE THERE?

In essence there are three types commonly available:

CHASSIS DYNO

This type of dyno measures power at the road wheels, or more accurately, the tyres. This one is the easiest to use as you just drive the whole car onto the platform, strap it down and drive it almost as you would on the real road. This tends to be commonly referred to as a rolling road.



Chassis dyno or rolling road (below left) and hub dyno (above)

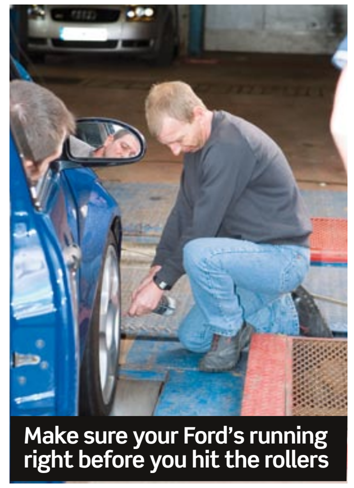
HUB DYNO

This type of dyno measures power at the hubs — this removes any margin for error with wheel slip and

PREPARING YOUR CAR FOR THE DYNO

It's worth a little mention here of a few things you must always do to ensure your car is fully prepared for its dyno run. First of all make sure it's running properly. There is no point taking a faulty car for a power run. No point at all, so don't. Secondly make sure you have enough fuel and that it is of the correct grade.

Make sure your tyres are well inflated, ideally to the fully-loaded high-speed setting in the manufacturer's handbook. And please, get there on time...



Make sure your Ford's running right before you hit the rollers

Engine dynos are the only set-ups that can give accurate flywheel power figures

other issues, such as having more than one tyre contact point. (Real Tarmac roads have one contact point per tyre — many dynos have two). This one is the next easiest to use as all you have to remove are your road wheels to use it.

ENGINE DYNO

This type of dyno, as its name suggests, bolts directly to the engine. Normally measuring from the flywheel.

This is the hardest to use as you have to remove your whole engine and bolt it onto it in a special room, but it is the only one that can give you accurate flywheel power figures.

WHAT MEASURING SYSTEMS ARE USED?

There are two main types in use with chassis dynos and they are as follows:

BRAKED

A braked-type dynamometer measures power by braking the rotating part and slowing, or even stopping its rotation or acceleration, be that part the flywheel, the hub or the tyre depending on the type of dyno you are using. It then uses a load cell or spring balance (a mechanical device that measures turning force on the rollers) to measure the torque required to hold the engine's rpm steady. Torque x rpm = power, so from this simple calculation we have the power figure at the point of measurement.

INERTIA

An inertia dyno uses a heavy solid steel drum or drums, and no brake! The drum is free to be accelerated by the driving force. A computer logs the rate of acceleration and since the mass of the drum is a known constant, uses simple maths to plot the power and allows us to plot the power against either road speed, or engine rpm.

DIFFERENCES BETWEEN THE TWO SYSTEMS

The main difference is that a braked system allows the operator to vary the load at the rollers, so that the engine can be held at constant speeds so that such things as ignition and fuelling can be adjusted to optimum values under differing throttle openings and engine rpms. The load system is actually akin to a home exercise bike where you can vary the load on the pedals to make your job as a pedalling engine easier or harder… it's the same thing, just on a bigger scale. This is very useful indeed for mapping an engine management system and you can get most of it done quite accurately indeed. This is the main reason that anyone actually tuning cars and mapping as well will need to buy a braked dyno over an inertia one if they require a dyno.

Inertia rollers are really for dynamic testing only. This means that when you open the throttle the drum always accelerates. It is not possible to hold a steady under-load rpm. So, making changes to fuel and ignition maps is much more difficult.

WHAT DAMAGE CAN BE DONE TO THE CAR OR ENGINE?

A dyno cannot itself damage an engine, let's get that straight right now. Over-revving, shock loadings, incorrect fuelling or ignition advance and lack of cooling are all engine damaging things… and dynos don't cause any of those, but the operator could do so, if he wasn't careful.

So if your engine does sustain damage on an adequately-cooled dyno, you can be sure that had you operated it at the same engine rpm and load on the road, it would have happened there too! That said, running a chassis dyno with bald or flat tyres could have disastrous results. Can you imagine what a blowout at 150 mph looks like on a static chassis dyno in a small room? I wouldn't like to be stood near it, would you?

The fact is, all of these things are far more likely to happen while driving on the road than when under controlled and monitored conditions on the dyno during testing. This is providing that the operator knows what he is doing, and that the dyno's cooling fans are large enough. When you are stood next to a car at full power and 100-plus mph it sounds very painful on the ears, but you have to be aware that it is no different to it doing it on the road, it just sounds louder now because the wind isn't carrying the sound away.

CORRECTION FACTORS COMMONLY USED

The very term 'correction factor' instantly makes people think that this is a complicated subject whereas in fact it is actually quite simple. If you look at the dyno printout you will find the number that relates to a correction factor that has been used. The reason we have a correction factor is because whenever we use a dyno we wish it to output the same result on the same engine every time we test it otherwise our figures from one day to the next will be completely incompatible, meaning the figures are rather useless.

The problem we have is this: let's say that we run the car up on a cool Friday evening with 10 degrees C ambient temperatures and achieve 100 bhp. We then lock the unit up and go home for our tea and come back in the morning to find it's a nice sunny Saturday and the ambient temperature is now 30 degrees C. Fabulous… We make ourselves a nice cup of tea and proceed to run the car up once again and get it warm. On our power run we only make 94 bhp… what has happened? We didn't change anything on the engine! Well, the 6 bhp loss is very simple to explain, the 20 degree difference in air temperature has resulted in an air density change that has cost us horsepower.

Because of this, dynos normally have a correction factor that will correct all readings back to a known standard air temperature. Using this correction factor, no matter what the ambient temperature is, we should always receive 100 bhp from this engine on this dyno. But there is another small problem that needs correction, too!

Most days there is also a difference in atmospheric pressure, so when the pressure is high your engine will make more power and conversely, when it's low your engine will make less… So we now need another formula that corrects the measured power for atmospheric pressure variations. We now have correction for both temperature and pressure in the dyno cell. Excellent, but remember that the pressure and temperature data has to be measured accurately and entered into the system one way or another before each run is made, if this is not done, the run cannot be accurate.

Just to add a curve ball, there is more than one correction standard, and they all give different results yet technically all are correct. The two most common are SAE-J1349 and DIN 70020. So as usual, nothing is simple. No wonder some people aren't going to be happy unless they can be measured on a TüV-approved dyno!

Power data								Ambient data			
Corrected power 1)	P_{Norm}	412.3	BHP	/	303.2	kW		Ambient temperature	$T_{Ambient}$	17.1	°C
Engine power	P_{Eng}	419.5	BHP	/	308.5	kW		Intake air temperature	$T_{Intake\ air}$	18.5	°C
Wheel power	P_{Wheel}	275.8	BHP	/	202.8	kW		Relative humidity	H_{Air}	50.6	%
Drag power	P_{Drag}	143.7	BHP	/	105.7	kW		Air pressure	p_{Air}	1027.9	hPa
Max. power at		6755	rpm	/	242.6	km/h		Steam pressure	p_{Steam}	9.9	hPa
Torque 1)	M_{Norm}	480.9	Nm					Oil temperature	T_{Oil}	16.0	°C
Max. Torque at		4820	rpm	/	173.2	km/h		Fuel temperature	T_{Fuel}	----.-	°C
Max. attained RPM		6755	rpm	/	242.7	km/h					

1) Correction acc. to DIN 70020
Correction factors: Q_V = 0.00 %

Correction factors in the dyno software should allow consistent figures whatever the conditions

WHY DO SOME READ HIGH AND OTHERS LOW?

There are many reasons why some dynos will read higher and indeed lower than others. Very occasionally the dyno may actually be calibrated incorrectly, either by mistake or maybe on purpose. The latter normally being because the operator knows his customers prefer higher figures and it results in less unhappy customers for him to have to console. You can see the attraction there I am sure… More often a high or low sounding figure is a simple case of people not comparing like with like. For example, the first thing you need to do is ensure that the reading you're looking at is quoting power measured at the same place as the reading you are comparing it to, such as flywheel or wheels. Secondly, are both readings corrected using the same correction standard?

If indeed the readings are taken from the same place and the correction factors are the same then one of the most common reasons for the high or low figure is inadequate dyno cooling. The first clue to cooling being inadequate is that the more runs you do the worse the power gets. This is due to the intake system, transmission, hubs and brakes all getting far hotter than they would do on a motorway doing equivalent speeds and generating equivalent power due to the lack of cooling effect from the high speed airflow.

Secondly, many of the twin-drum roller systems generate significant heat and friction in the vehicle's tyres and as such they are largely dependent on tyre pressures, tyre temperature, tyre speed and even vehicle weight (so all your mates in the boot may actually lower your power figure), and can certainly affect the power reading in most cases.

ACCURACY AND REPEATABILITY

Let's make one thing clear… It is possible to have a dyno with 100 per cent repeatability regardless of whether or not it is accurate. The purpose of a dyno is to give a repeatable power graph, so that when you're tuning and making adjustment you can see for certain whether you have made gains or losses with your adjustments, and where those gains or losses are achieved. As long as your dyno achieves this, then your dyno is fine, no matter what figures it produces. It is after all a tuning tool for making comparisons, and not strictly speaking a tool for accurately measuring power.

As mentioned earlier, an inertia dyno has a head start on repeatability because being a known mass it will never change from one day, month or year to the next, it will always require the same energy to accelerate and rotate it and therefore should, by its very nature be at least accurately repeatable as far as the results go.

A braked dyno has the cards stacked against it from the start for repeatability due to the electronics and load

Extra bodies in the boot to aid traction could actually lose you power…

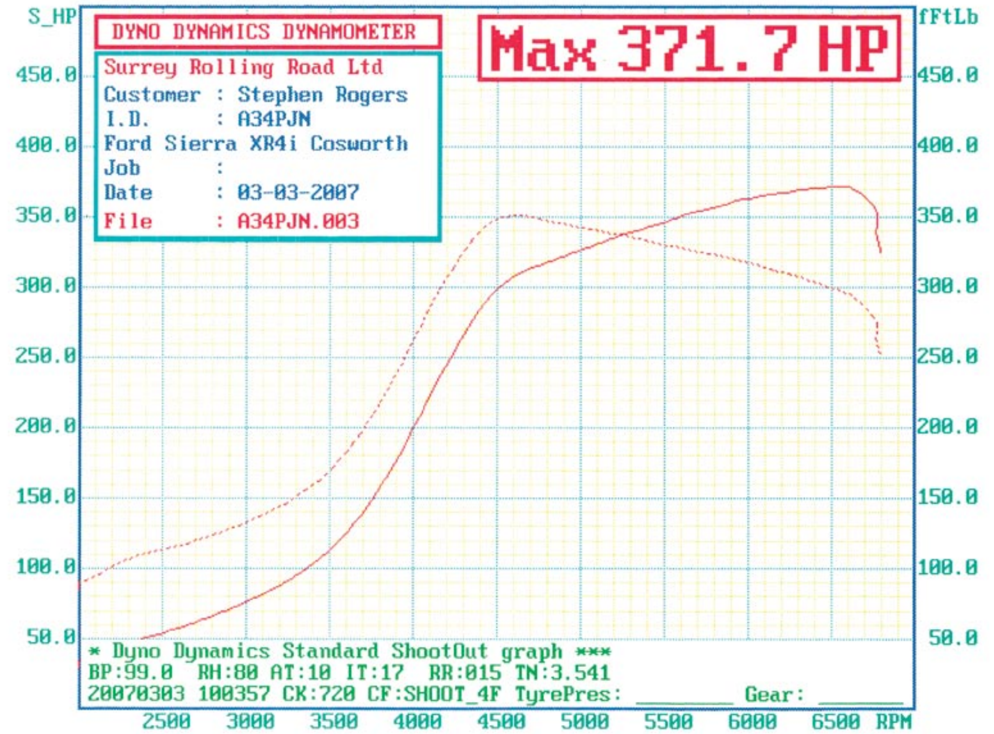
HOW TO READ A DYNO GRAPH

No dyno feature would be complete without a section that explained how to read the graph, so let's have a crack at this before we get in depth about dynos.

Most graphs will have an X and a Y axis. The vertical axis is normally the power and the horizontal is normally engine speed. You will then have a squiggly line running from one end to the other representing your power and another one representing torque. These lines are simply the power and torque numbers for each engine rpm speed point on the horizontal chart connected together so you can see the power curve.

If you look at the graph on this page, you'll see that the solid line representing power shows a peak reading of virtually 372 bhp at 6500 rpm. The dotted line shows the car made 350 lbf. ft of torque at 4500 rpm. You can see how much power or torque was made at any point in the rev range by simply reading it off at the correct graph intersection.

There may also be other information plotted on the graph as mentioned above, but we are just concentrating on the actual power part of the graph. Incidentally, it is worth noting that the lines representing power and torque on your graph will always cross at 5252 rpm as shown in our example — as long as the graph uses the same scale for power and torque, and uses bhp (brake horsepower) and lbf. ft (a 1 foot lever with a pound of weight attached) as measurements. There is no getting round this fact, so if they don't cross there, the graph is inaccurate and totally useless to you. We will go into exactly why that is in the next issue…



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A decent dyno cooling set-up is vital to prevent component failure

generators involved, but accurate and repeatable braked dynos certainly do exist, although I am not going to start naming names as that's not why we are here.

THE IMPORTANCE OF COOLING

Cooling is something that does not seem to get taken seriously enough by dyno operators. I have seen lots of dyno set-ups in all different kinds of installation and I can honestly say that in my opinion over 90 per cent of the dynos out there have totally inadequate cooling systems. A small 2-foot wide fan that you can talk over is OK for maybe one power run and it will hopefully stop the engine overheating, but of course that isn't all that it is there for.

The engine bay in a modern car is designed to be force-fed with air at high speed. The airbox needs to see pressurised air and the intercooler, radiator and transmission components are all designed to be cooled by high-speed air. This is why they pretty much all have finned casings.

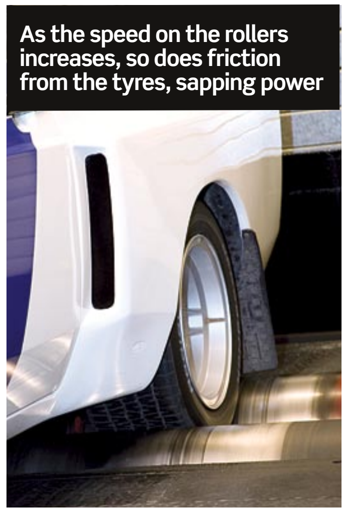
As a final test to convince yourself just what sort of a fan is required to replicate real-life motorway acceleration, try sticking your head out of the sunroof next time you are a passenger at 100 mph. It is very windy indeed. That's the kind of airflow your engine and transmission was designed to generate full power in. There is quite a lot of heat to get rid of, and get rid of it you must if you are not to risk component damage. It is also worth noting that unless the cooling is excellent, your charge temperatures will increase significantly (force-inducted especially), and this means you will lose power at the wheels and you won't get it back in the graph as the inlet manifold temperature is not compensated for in the dyno compensation scheme, only the ambient temperature.

TRANSMISSION LOSSES AND POWER AT THE FLYWHEEL MEASUREMENT

A chassis dyno measures the power produced either at the wheels or the hubs. Now, given the fact that there will always be more power produced at the flywheel, how do we determine how much power was lost between the flywheel and the point of measurement? Well, this is where it all starts to get quite complex and some very educated people seem to argue needlessly because to me is quite simple: gearboxes, differentials and wheel bearings will all consume a certain amount of power as they go about their work. However, the way that some dyno operators calculate the losses is ridiculous.

One thing to remember — and this is quite important, so pay attention — is that the calculated loss can never be 100 per cent accurate unless it was by pure luck. There will always be a little guesstimation in there.

How much so varies between systems. Here are the main two


As the speed on the rollers increases, so does friction from the tyres, sapping power

methods used to calculate power lost through the transmission...

COAST DOWN

Most systems use the coast down method. This system has the operator depress the clutch and allow the transmission to come to a halt on its own while the system measures its resistance to rotation. The system measures this resistance and creates what you might call a negative bhp graph. This resistance is then simply added on to the power we measured at the wheels/hubs and given to us as flywheel power. As an example, if we make 200 bhp on the power run, and our rollers measured that the transmission consumed 30 bhp when slowing down, it would give you a power reading of 230 bhp at the flywheel. Simple...

The problem with the system is that it only accurately measures the resistance in your transmission when it is not under load. You'll find that any mechanical system would generate more friction in things such as gears and thrust bearings when it is under load, yet these systems regularly measure completely unrealistic transmission losses, thus giving you completely useless flywheel power graphs. Some systems just leave it there and others add a percentage loss as well... That brings us neatly to...

PERCENTAGE LOSS CALCULATION

Some dyno operators just add on a percentage to the wheel figure they measured, and that method of calculating losses is so wrong that it is almost criminal!

You probably wonder if I am willing to back this up when so many UK tuners say it daily? Yes I am... As far as I am concerned, there is no way a powertrain can ever be regarded as consuming a percentage of power from anything in a linear fashion. For example, with an average transmission system comprising of a gearbox, differential, wheel bearings and a set of tyres, you are looking at roughly the following variables:

TYRE/ROLLER INTERFACE

For any tyre and measuring drum the resistance value will be quite high when accelerating from rest to movement, and as the tyre (road) speed increases the friction from the tyres will increase too, thus sapping more power. Please note that engine rpm is irrelevant to this as the main point of relevance is road and thus tyre speed, meaning the higher the gear, the more power will be lost through the tyres. How can that be expressed as a definite percentage at the end of the run? Surely, it would lose proportionally significantly less power at peak torque (say 40 mph in fourth gear) than it does at peak power (perhaps 110 mph in fourth gear) so your graph loses out on torque because the operator wanted to say you lost X percent everywhere... Not ideal.

DIFFERENTIAL LOSSES

The loss in an average differential is not only road speed-related, but also torque-related as well. All your gear, bearing and internal windage losses will increase as road speed rises. Once again these particular losses are not related in any way to engine rpm or even necessarily bhp...

However, some differential losses are indeed load-related as well, such as the losses experienced in helical-cut gears and thrust bearings due to the sideloadings they experience, so road speed as well as power play a huge part in the losses at this particular component level. Remember, in fifth gear you will present far less torque the differential, but lots more rotational speed and in first gear we would present masses of torque, but very little rotational speed. (A gearbox is merely a torque multiplier remember.)

How do you work out a blanket percentage for that? Express a different percentage for each gear? You can't. Most power runs are done in fourth due to the 1:1 gearbox ratio so that it has no multiplying effect on the flywheel torque, but I know of at least four chassis dyno operators in the UK that use third and a few that use fifth, so again, these dynos cannot be cross-compared with each other as far as figures go.

GEARBOXES

The losses experienced in gearboxes are similar to the losses experienced with differentials... We are generally dealing with gear sideloadings and oil drag losses. These losses are related mainly to rpm but are influenced by load to a certain extent. Also don't forget that the losses in a gearbox will differ depending on what gear is selected, especially those with a 1:1 fourth gear that transfers drive straight through the box with no gears involved at all.

I hope the above examples allow you to understand my line of thinking when I say that no flywheel output figures can be totally accurate and some are indeed wildly inaccurate due to them taking an overly simplistic approach to a difficult task.

Go by what the rollers measured at the point of measurement, as these figures are going to be far more accurate due to not being subjected to wild guesstimations. So, power at the hubs or wheels is king as far as accuracy is concerned when using that type of dyno.

SUSPICIOUS POWER LOSS AND FUDGED FIGURES

Nobody likes to think dyno figures can be anything other than perfectly accurate, but I'm afraid the system is open to abuse, although some more than others. For example, the coast-down system is easy to fudge figures with, all you need do is brake gently and the transmission power loss will be increased significantly, thus increasing the predicted flywheel power output too. Alternatively, adjusted tyre pressures will result in different flywheel figures for pretty much the same reasons.

If you want a reason to be suspicious of percentage claims, as well as coast-down claims, consider this...

A 4wd car generating a genuine flywheel power of 400 bhp was, in my presence, recently quoted as losing 35 per cent of the flywheel power through its transmission. Now while to the uneducated this may seem a realistic figure due to its host of extra components over its 2wd brethren, let's look at that figure a little more closely:

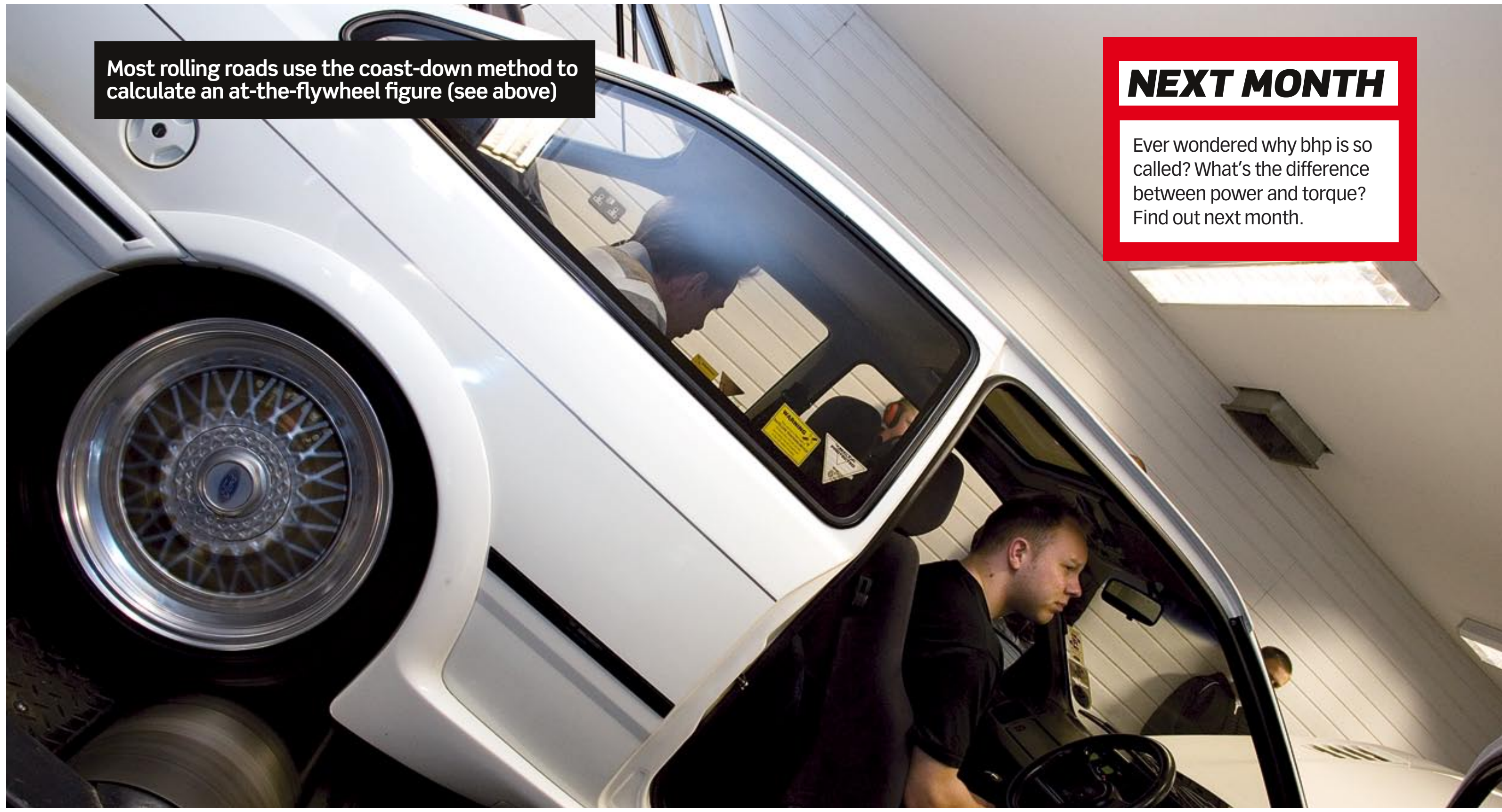
35 per cent of 400 bhp is 140 bhp... To convert bhp to Watts we simply multiply it by 745.7 to give us 104,398 Watts. So, you are being told that over 104,000 Watts (KW) was lost as heat in your transmission? Your lubricant would have boiled and your alloy casings would likely have been near to melting had you lost that sort of heat into them! Just think what these 1000 bhp engines would do to a poor gearbox when they had to cope with 261-plus KW of heat every time you used the power. 261,000 Watts of energy lost in your transmission? Unlikely! To give you some comparison, a large industrial gas space heater generally has an output of between 10-20 KW of heat, so its suggested our transmission is akin to five space heaters, all burning away under the car.

Now, I am sure that the real power loss can be expressed as an average percentage, but the point I want you all to understand is there is no way on Earth the transmission loss will ever be accurately measured by a rolling road, and nor can it be expressed as a linear power loss percentage across the rev range, due to the torque loading having more effect on the mechanicals. The higher that load is and the road speed having more effect on the tyres, the higher that road speed is.

I personally think you would struggle to lose much over 20 per cent no matter how complex the transmission system and bhp of the engine, especially given the proven fact that the more power you have, the less you will lose percentage wise through the transmission due to the fact some of the losses calculated are pretty much fixed and are not affected by power, such as tyre drag and various bearing frictional losses.

CAN TRUE TRANSMISSION LOSS EVER BE MEASURED?

Yes, and it's actually very easy. Whip the engine out and measure its power on an accurate engine dyno, install it back in the car and run it again on your chosen accurate chassis dyno. Use the power at the wheels figure only and subtract one from the other. Hey presto, pretty accurate transmission losses.


Most rolling roads use the coast-down method to calculate an at-the-flywheel figure (see above)

NEXT MONTH

Ever wondered why bhp is so called? What's the difference between power and torque? Find out next month.