TALKING TURBOS

Part II

Last issue, we explored the basics of how turbochargers work and the importance of intercooling, now let's look at some of the intricacies of choosing a turbocharger

Scott Taylor
Karl Dietrich

Turbo nomenclature is a tricky subject, with the turbo type not always telling the full story. This XTR T72 ball-bearing turbo is good for 800hp

We've got a lot to talk about and not much space to say it, so let's get straight into it. Last issue was all about the basics of turbocharging, but is turbocharging really that basic?

No it's not. If it were, everyone would make a gazillion horsepower and have instant throttle response regardless of engine or turbocharger size. Turbocharger sizing is vitally important, and there are many factors to consider when choosing both the general size of the turbo and specific housing sizes for performance and throttle response.

LAGGING BEHIND

You've all heard about turbo lag; it's the time between the point when the driver steps on the gas to the point where the turbo starts making at least half of its maximum boost. The boost curve of a turbo always starts slow. The time for the turbo to reach half the maximum boost is about three times as long as the time it takes to go from half to full boost, an exponential curve.

Turbo lag can be measured in hundredths-to-tenths of seconds on a good set-up, up to even full seconds on a poor set-up; it all depends on the turbo selection. Naturally, if it takes a few full seconds for the engine to get to full boost, your race is over before it has even begun. Any decently sorted turbocharged, supercharged or naturally aspirated car will have scooted away in the meantime, leaving you choking on their exhaust fumes.

What's the best way to select a turbocharger for your engine? Most methods start with the sort of horsepower you want to make – and be realistic here, there's no point picking a turbo to make 1500hp on a V6 because it just isn't going to happen. However, if you want to make around 500hp with a V6, then that is totally doable and there is a bunch of turbos that can do the job.

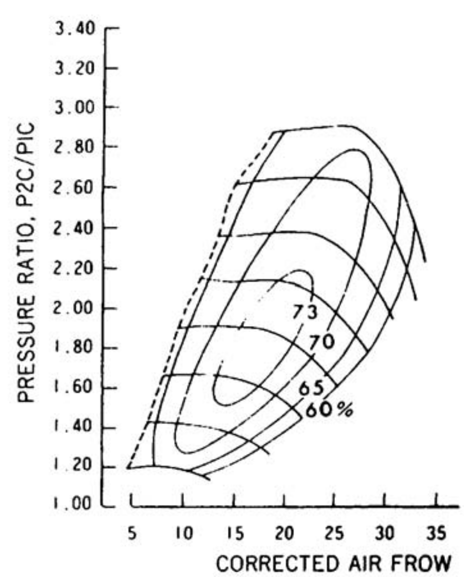
Many people will simply grab a turbo based on its horsepower capabilities, whack it on and leave it at that. They might get lucky and end up with a set-up that makes excellent horsepower and delivers it on demand, or they might get a set-up that chokes on its only exhaust due to housing limitations. Worse still, they'll have no power down low, but come on like a steam train at 4500rpm.

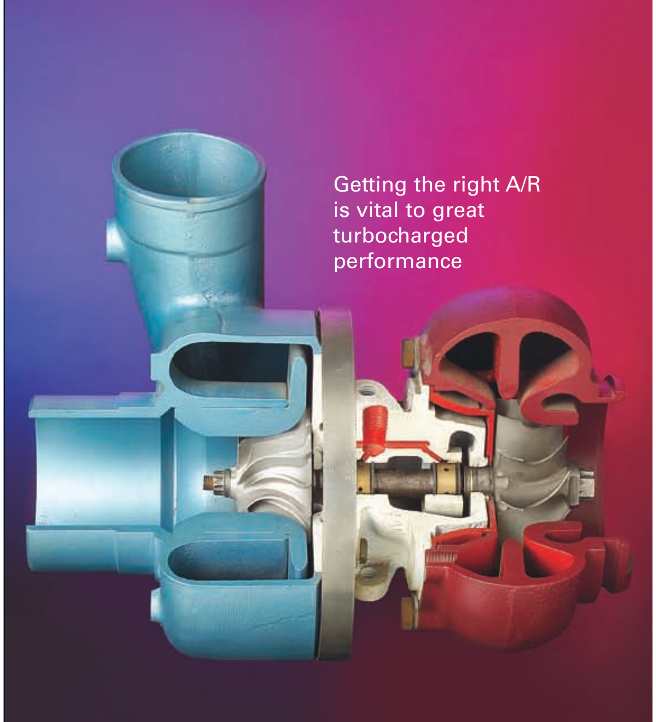
Compressor maps are the best way of choosing the right turbo, but most turbo companies don't want to have their compressor maps freely available, so they are very protective of them. By using compressor maps, we can ascertain the efficiency of a given turbo and compressor housing combination at specific boost pressures and airflow requirements. This makes the compressor map an important item in choosing the right turbo for your engine.

Up the vertical axis of the table is the pressure ratio, which is the ratio of atmospheric pressure versus the desired manifold pressure. While atmospheric pressure is 14.7lbs per square inch generally, it may vary depending on location and elevation, which is why the pressure ratio isn't a simple psi measurement. For our amateurish use, though, we can just convert it into a general psi measurement, which sees a pressure ratio of 2.00 being around 14.7psi; in fact, let's just say it's 15psi for ease of explanation.

On the horizontal axis of the table is the airflow, which can be taken two ways: the airflow of the compressor wheel or the airflow demands of the engine when choosing a turbo. Roughly every 10hp demand requires 1lb/min of airflow, so if your turbo can flow 30–35lbs/min of air, then it can roughly support 300–350hp at the engine. This is a fairly simple explanation of the facts, but you get the point. Let's now look at the map itself.

The map looks like a contour map, much like you would use to navigate your way through the national park, but instead of





Getting the right A/R is vital to great turbocharged performance

With a compressor A/R of 0.60, this XTR GTST-400 is all about throttle response while supporting up to 400hp

being elevation lines, the lines represent differing areas of efficiency. On our demonstration map, you can see that the maximum efficiency of our compressor wheel and housing combination is 73 percent. So you would assume that you plot your requirements based on the centre of the compressor's maximum efficiency, right? Wrong!

You can actually get more performance out of your compressor if you plot your requirements into the area just to the right of the area of maximum efficiency, thereby maximising the amount of flow you efficiently use. It's a bit like revving your engine past the point of maximum power for the best quarter mile time. Most turbochargers only start operating efficiently when they are above the 10psi mark, which gives them a great advantage when comparing turbos to superchargers.

On the left-hand side of the map is a line called the 'surge limit', an area that must be avoided if you want to make decent, reliable power. Compressor surge occurs when the turbo is too large for a given application and the engine struggles to get the turbo up to speed. The exhaust energy spins the turbine wheel, which in turn spins the compressor wheel. However, with the turbine wheel being too large for the engine capacity, the turbine wheel cannot maintain speed, and this creates a surging affect in the compressor side.

An aeroplane has the same effect when there isn't enough airspeed. Without enough airspeed, the plane stalls, a term that has nothing to do with the fact of whether the engine is running or not. A wing without airspeed has no lift, and a turbine without enough flow will not spin consistently, so the turbine stalls intermittently and this is not good for power production.

On the other side of the compressor map (the far right-hand side of the map) is the 'choke' area. Here, there is so much flow that it actually fills the housing to capacity and the compressor wheel can't actually force more air through the housing. This will see reversion in the compressor flow and overspeeding of the turbine shaft, which will severely shorten the life of the bearings and the wheels if a worn bearing allows a wheel to come into contact with the housing.

Clearly, matching the turbo to your engine application is vital for responsive and powerful performance. Too far either way can result in an inefficient system that may work, but will not work anywhere near advertised.

WHAT RATIO?

If dealing with compressor maps wasn't bad enough, what about A/R ratios? Do you even know what it is? Or how different A/Rs affect your turbos, and therefore your engine's performance. Well, read on because we aim to really give you a headache now.

To start off, A/R stands for Area/Radius and is the relationship between the cross-sectional area of any part of the outer scroll housing to the distance between the centre of the housing and the centre of the selected cross-section. Sounds confusing, right? Well, let's look at the compressor housing as an example.

We all know that air is drawn through the front of the housing and fed into the outer scroll section of the housing, before being shot out of the housing and into the intake system of the engine. Take a part of that housing and imagine that you cut a pie-shaped wedge out of it, much like our coloured turbo in the picture. If we look at the top side of the cut, you can see the inside of the scroll is somewhat oval-shaped, and if you were to work out the surface area of the opening, this would give us the 'area' portion

TURBO TERMINOLOGY

Compressor: the intake side of the turbocharger.

Turbine: the exhaust side of the turbocharger.

Wheel: usually the name given to either the compressor or turbine impeller; ie, 'compressor wheel' would be the impeller on the intake side.

Ball-bearing turbos: most older and larger turbos use bronze bushes for bearings, whereas small modern turbochargers use ball bearings for less drag on the shaft.

Wastegate: a device for dumping excess exhaust energy direct to the exhaust system, bypassing the turbine wheel.

Cartridge: the centre section of the turbo, encompassing the area that contains the bearings, oil system and cooling jackets. Sometimes it's the whole assembly including the turbine and compressor wheels, but without the housings.

Housings: the housings guide the intake air or exhaust around the wheels to spool them up as per the requirements of the engine. There are many different housings for each wheel and turbo type, which offer different performance characteristics depending on requirements.

A/R: stands for Area/Radius. It is the relationship between the scroll cross-sectional area of the housing and the radius distance between the centre of the housing and the centre of the cross-sectional area.

The A/R of a given housing determines the speed at which the turbo will spool up, and therefore determines how much lag an engine has. It also determines how much power an engine will make because smaller A/Rs will choke the airflow, while larger ones will allow an engine to make more power.

Spool: a term to describe the acceleration time of the wheels and how long they take to reach their most efficient operating rpm.

Lag: the time it takes for an engine to start making significant boost.

Boost: the amount of addition air pressure being forced into an engine above normal atmospheric pressure.

Compressor map: a chart that shows the performance characteristics of a given turbocharger, which is used to make the right selection given the parameters set out by the engine builder. Using desired power levels and boost requirements, an engine builder can work out if a turbo is suitable for his requirements or not.

Blow through: This refers to the act of blowing boosted air through the throttle body or carby.

Draw through: While uncommon in EFI applications, the draw-through set-up is mainly used with turbo/carby applications. The carby is mounted in front of the compressor housing and air is drawn past the throttle plates by the turbocharger, requiring few modifications to the carby.

of our equation. The radius portion is simply the distance between the centre of the compressor housing intake and the centre of the cross-sectional area, which will give us the equation A/R or 'area' divided by 'radius'.

Now if you work out the figures for the other side of the pie slice, they will be the same, which means the relationship between the centre of the housing and the size of the scroll opening remains constant. A numerically small A/R will have a lower outright flow capability than a numerically higher A/R, but this allows you to tailor your turbo to your engine.

If your engine feels laggy with a large A/R housing, say, something like 1.34, then it will benefit from a switch to a smaller housing, maybe something in the realm of a 0.70 A/R. Yes, the outright flow of the 0.70 will be less, but the improved throttle response will more than make up for any power deficiencies.

Choosing the right A/R housings for your turbo is a compromise between throttle response and outright power, and if you get it right you're on your way to turbo nirvana. Get it wrong and you'll be driving a real pig that could either make nowhere near its real power potential, or have such poor throttle response that you'll have no decent power below 4500rpm.

Turbocharger housings almost always have an A/R designation cast into the hous-

A monster turbo like this Borg Warner truck turbo might be capable of making huge horsepower, but how is it going to go on your RB30?

TURBO SIZES

When discussing turbo sizes, the terminology varies greatly and can certainly lead to some confusion. The most common terminology is the traditional Garrett turbos, which tend to be T2, T3, T4 et cetera. Garrett T2s are the small boys and are too small for any Commodore applications. T3s were standard VL Turbo fitment and tend to be internally wastegated (not always though), and the T4s are the big boys that are externally wastegated.

There are also the Garrett GT-series turbos, which are the performance ball-bearing turbochargers, and these suffer minimal lag while providing excellent performance.

Many performance turbos are designated by the size of the compressor wheels, which is where you get your T62s, T76s and T100s, but this isn't necessarily a given. Trust has a well-known turbo called the T88, which is a kick-arse sucker that can make in excess of 1000hp at the flywheel in many applications, but they don't have an 88mm compressor wheel, it's actually smaller.

While we're talking Japanese turbos, what about those HKS jobbies? What the hell is a HKS 25/35? These turbos refer to the exhaust housing first, so they use a GT25 turbine, but a GT35 compressor housing for extra airflow. These aren't your standard Garrett housings because Garrett is contracted to HKS to provide certain housings exclusively. Similar deals exist between Trust and Mitsubishi, along with Blitz and KKK, and these turbos will always make more power than their off-the-shelf brothers.

In Australia, we have only one strictly performance turbo manufacturer, XTR, a division of GCG turbochargers. XTR uses a mix and match of wheels, housings and cartridges to makes turbos, which can serve any performance application.

Although a turbocharger is a device with few moving parts, the complexities of turbo selection are mind-boggling

ing for easy identification, although sometimes it's been ground off to protect the innocent, or maybe the manufacturer doesn't want you to know. Some turbo manufacturers don't want you to know so they grind them off, as do some performance shops that don't want their competitors to know what housings are being used on the turbocharger kits.

SINGLES OR TWINS?

This seems to be question that has plagued many since turbos have been around. If one is good, then two must be better.

Well, they are and they aren't. While some engines, especially V-configuration engines, lend themselves to twins, it comes down to capacity. That is, the capacity of the engine, and the horsepower capacity of the turbochargers.

For larger V8s it's easy to find turbos that will work quite well while hanging off the side of a engine that displaces 5L or more, but what about smaller engines like the V6 Commodore? Remember, by employing two turbochargers you are dividing the available thermodynamic exhaust energy that is available to each turbo.

In the case of a V6, you have basically got two 1.9L turbocharged three-cylinders, so if you have two small turbos, something around 250–300hp capacity, it will work quite well. What if you're using two larger turbos, though, maybe with a flow capacity of 380–440hp? It might sound cool to your mates when you rattle the figures off, but they'll be disappointed when nothing seems to happen until 4800rpm.

In such a case, a single turbo with 550–600hp capacity would run rings around the twin-turbo set-up no matter how cool it sounds telling your mates you have twin turbos.

Using a small single isn't the answer either because you will be dumping your exhaust out the wastegate quicker than you can say 'full boost'. Getting full boost at 2200rpm might feel good for the seat of the pants push, but over-speeding the turbo will not only kill the turbo quickly, when the wastegate has reached its maximum flow the rest of the exhaust will be looking for somewhere to go. Here you'll suffer boost creep, as the turbo spins faster than you anticipated and you end up with more boost than you planned and kill your engine through detonation.

As you can see, sizing the turbos is critical, and knowing how to tell one size from another will help you immensely when the time comes to choosing the turbo, or turbos, for your engine.

One thing is for sure: when you try turbocharged performance and get it right, anything else will seem lacking. SC