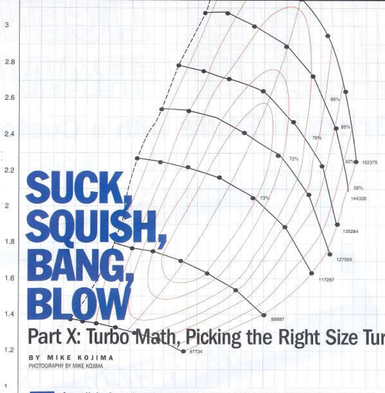

SUCK, SQUISH, BANG, BLOW

Part X: Turbo Math, Picking the Right Size Turbo

BY MIKE KOJIMA
PHOTOGRAPHY BY MIKE KOJIMA

Before all the formulas scare you away, let us remind you how far this series has come. When we started the "Suck, Squish, Bang, Blow" series back in August '99, we were explaining some really basic stuff. What a piston is, for example, and why the crankshaft is there. Now, if you've been paying attention, you have graduated to this month's high-level discussion of turbocharger mathematics. This is PhD-level material; understand this installment and you will be a true guru of horsepower.

Even if it doesn't all sink in, your time isn't wasted. If you can't get access to all the data you need to use these formulas, having a basic understanding of how turbo sizing should be done will still give you a leg up when you need to decide which turbo is the right one.

WHAT YOU'VE LEARNED SO FAR

Part	Issue	Lesson
I	Aug-99	Basics of engines A to Z
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VI	Mar-01	Bottom end, part 1: Reciprocating parts
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HOW TO MATCH A COMPRESSOR TO YOUR ENGINE

Probably the most critical step in selecting the appropriate turbo is deciding which compressor will work the best for your engine. Unfortunately, compressor matching to the engine is also where the most basic mistakes are made. By using the formula we will soon discuss and looking at various compressor maps, you will be able to closely estimate which compressor will work the best for your intended application.

We will be honest with you: The math involved in choosing the correct turbocharger is somewhat complicated and requires that some technical information from the manufacturer be available to make the correct judgment. The most important bit of information is the compressor map. The compressor map is a graph of the compressor's efficiency when the boost expressed on the Y axis of the map and the flow is expressed on the X axis.

Boost is usually expressed as a pressure ratio, where 1:1 would be atmospheric pressure, 2:1 would be 14.7 psi, etc. Flow is usually measured in pounds per minute. The compressor map is two dimensional and the areas of different compressor efficiencies are called islands. The area of compressor surge (the area of operation where the air column inside the compressor hits supersonic speed and the flow starts to oscillate and becomes unstable) is a line bordering the islands on the far left side of the map. Compressor maps are available from Turbonetics, Innovative Turbo Systems and sometimes from calling the manufacturer of the turbos.

To determine if the compressor is a good match for the engine, you must figure out the engine's flow requirements over its operational rpm range and plot them on the compressor map. Ideally, the plot will fall over the map's best efficiency island and stay out of the surge range. The calculations are somewhat involved, but if you remember high school algebra, they are not too bad. The more computer literate may find this a useful tool and can put these equations into an Excel spreadsheet to make it user-friendly. Bust out the calculator and sharpen your pencil.

The first thing you must do is decide the maximum level of boost you plan to run. Most stock import engines with proper fueling and tuning can handle at least 7 to 10 psi on 92-octane pump gas. Some very strong stock engines, like the Nissan SR20DE, can withstand up to 20 psi if enough fuel is provided and detonation is controlled. If you plan on running race gas, figure at least a few more safe psi. If you are building your engine as well, lower the compression to a turbo-friendly 8 to 8.5:1 compression, then figure you can run 14 to 18 psi on pump gas and more than 20 psi on race fuel. This is general information; much depends on how good your tuning is, how big your budget is and how much intestinal fortitude you have.

Let's do a compressor match on an SR20DE.

First, we'll assume we're running 20 psi of boost, the maximum a stock SR20 with race fuel can safely take. We'll also assume pressure drop across the intercooler is 1.5 psi. This is a good generalization, but if you have a Spearco intercooler, you can reference the pressure drop in the company's comprehensive catalog.

From this information, you can calculate absolute pressure out of the compressor (Pco):

Absolute turbo outlet pressure (Pco) = Boost + Atmospheric Pressure + Intercooler Pressure Drop

TURBO TERMS

What the Heck is Trim?

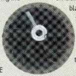
When talking to turbo people, you will frequently hear the term "trim" thrown around. What is trim? Trim is a term to describe the size of a compressor or turbine wheel within the family of turbos. The term trim is thrown around rather loosely in the turbo industry; it could be a commercial marketing term like Turbonetics uses to describe many of its wheels, like O-, P- and Q-trim for their TO4 family of turbines with the O being the smallest trim and Q the largest. Conversely, Turbonetics uses S, V and H to describe the trims of its TO4 compressors. It can also be the actual mathematical definition of the wheel size, like the Garrett TO4E compressor in 46 trim, 50 trim, 57 trim and 60 trim. Garrett also uses 62, 68, 76, 79 and 84 trim etc. for its turbine wheels.

What is the mathematical formula for trim? Figuring out the mathematical number is really quite simple:

$$\text{Trim} = \left(\frac{\text{Minor Wheel Diameter}}{\text{Major Wheel Diameter}}\right)^2 \times 100$$

This is the relationship between the major and minor diameters of the wheel or the total diameter and the inducer diameter (for the compressor) or the exducer diameter (for the turbine). What do these numbers mean? Generally the bigger the trim number, the more flow the wheel will have.

Bigger trim compressor wheels tend to be a few points less efficient than the smaller trim wheels because of the mach differential across the face of the inducer blades, especially with bigger compressor wheels. The face speed of the blade is higher at the outer ends of the inducer than in the inner edge because of the distance traveled by the blade every revolution. This speed differential somewhat screws up the efficiency and is one of the reasons why the blades are swept and contoured like they are in a well-engineered compressor wheel. The other reason is to reduce stagnation losses—but this is getting beyond the scope of this article.



Usually it is a better compromise to use a bigger trim, smaller wheel and give up a couple of points of efficiency, than use a bigger wheel and gain more lag-causing inertia.

In turbines, a bigger trim in the same wheel-size family will flow better and have less backpressure, but recover less energy from the exhaust flow and take longer to spool than a smaller trim wheel.

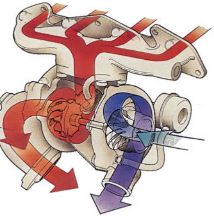
Above: These are two T3 compressor wheels, a 50 trim (top) and a 60 trim (bottom). Note how the inducer of the 60 trim is larger than the 50 trim. This allows the 60 trim to have more flow.

You can assume atmospheric pressure is 1 bar, or 14.7 psi:

$$\text{Pco} = 20\text{ psi} + 14.7\text{ psi} + 1.5\text{ psi} = 36.2\text{ psi}$$

From this, you can calculate the pressure ratio, or Pr:

$$\text{Pr} = \frac{\text{Pco}}{\text{Atmospheric Pressure}}$$



So, in our case:

$$\text{Pr} = \frac{36.2\text{ psi}}{14.7\text{ psi}} = 2.463$$

Next, guess what the post-intercooler temperature might be. We'll use 130 degrees F as a starting point, as we have found this is fairly representative of what we have measured with many turbocharged cars with a fairly good aftermarket intercooler.

We will now calculate the approximate density of the air after the compressor and intercooler, or Di:

$$\text{Intake Air Density (Di)} = \frac{\text{Boost Pressure} + \text{Atmospheric Pressure}}{\text{R} \times 12 \times (460 + \text{intake temp.})}$$

What's all that come from? R is a constant from the ideal gas law. You don't really have to know what it means, just that it is 53.3. The 12 is there to keep the units in inches (trust us on this one), and 460 is to convert degrees Fahrenheit to degrees Rankin, an absolute temperature scale. You don't need to understand this, just always plug these into the equation.

Now, in our case:

$$\text{Di} = \frac{20 + 14.7}{53.3 \times 12 \times (460 + 130)} = 0.0009195\ \text{lb/in}^3$$

From this, we can calculate Mf or the mass flow rate of the engine at the rpm where we want to do the match:

$$\text{Mass Flow Rate (Mf)} = \text{Di} \times \underset{\text{(cubic inches)}}{\text{displacement}} \times \left(\frac{\text{RPM}}{2}\right) \times \text{Volumetric Efficiency}$$

For Volumetric Efficiency, we can assume 90 percent, which is typical for most modern, four-valve DOHC sport compact engines. For an old-school, two-valve engine, you might want to plug in 80 percent.

Again, plugging in our numbers:

$$\text{Mf} = 0.00009.19 \times 122 \times \left(\frac{7500}{2}\right) \times .90 = 37.84\ \text{lb/min}$$

Now we need to find the corrected mass flow, or CMf, to get us in the ballpark:

$$\text{Corrected Mass Flow (CMf)} = \text{Mf} \times \frac{\sqrt{\dfrac{\text{Compressor inlet temp}}{545}}}{\dfrac{\text{Atmospheric Pressure}}{\text{Corrected Comp. Inlet Press.}}}$$

Note: 545 Rankin is 85 degrees Fahrenheit (Rankin is absolute temperature, used in many engineering calculations, 0 degrees R is absolute zero), which also happens to be the standard temp Garrett uses in its compressor maps. For matching to Garrett compressors, we use this figure. We will also use it for our ambient temp just to make things easier for us. You can subtract the actual temperature you want to use from 545, but we figured 85 degrees is a good, rough estimate of average underhood intake temp and it makes our math easier. Convert your ambient temp degrees from Fahrenheit to Rankin by adding 460 to the number. As for the ambient air pressure, it is 14.7 psi. Garrett uses 13.95 psi as the corrected compressor inlet pressure, considering the pressure drop across your typical air filter.

To find corrected mass flow for our imaginary engine:

$$CMf = 37.84 \times \frac{\sqrt{\frac{545}{545}}}{\frac{14.7}{13.95}} = 35.9 \text{ lb/min}$$

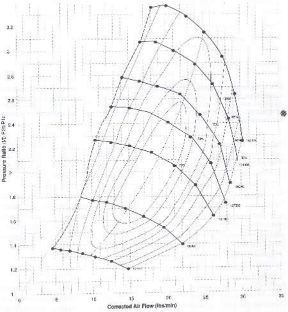
Now you have your pressure ratio of 2.46 and your mass air flow of 35.9 lb/minute. Next, plot these points on the compressor map to compare how well your engine matches up to it.

If you want to plot more points, you can do so by plugging in different rpm values, remembering that no turbo is going to produce 20 psi at idle. We would figure for something between 4500 to 7500 rpm for the SR20DE. For a high-revving VTEC B18C, it might be between 5000 to 8500 rpm. Like we said before, you want to stay away from the surge line and fall across the areas of maximum efficiency. We plotted out data points (large dot on far right) on three compressor maps, one of which is too small, one of which is too large, and a third, which is a good match.

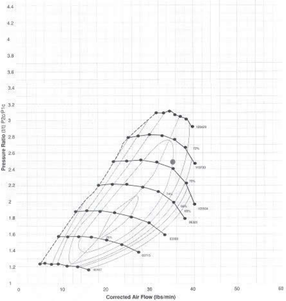
Perhaps the most important thing to be aware of when matching compressors is avoiding surge. Surge is where the air backs up in the compressor and oscillates violently back and forth in the compressor wheel. This happens when the engine's swallowing capacity is exceeded by the compressor's output, causing the air to back up in the intake tract. The mechanics of surge is when the pressure after the compressor exceeds the energy of the radial velocity component of the compressor wheels output, which causes the airflow in the compressor wheel to back up. The airflow backs up, the pressure after the compressor drops and the airflow resumes. In severe surge, this can become a violent oscillation that destroys the thrust bearing of the turbo and even cause mechanical failure of the wheel. Surge can be felt as something as mild as a slight fall in power to a violent jerking while driving. It also makes a faint thrumming noise that can be heard over the engine.

To avoid surge, turbos that are optimized for higher boost pressures have a narrower B-Width on the compressor wheel and a shorter, narrower diffuser in the compressor housing. B-Width is the tip height of the compressor wheel on the exducer or major diameter of the compressor wheel. The narrower B-Width on the compressor wheel increases velocity of the air leaving the wheel and the shorter, narrower diffuser has less drag losses after the wheel while keeping the important velocity up. These design differences give the air enough velocity and energy to avoid the backflow that starts surge. This is somewhat of a compromise as these design features usually reduce peak efficiency by a few points. Higher pressure ratio compressor wheels also tend to have less backsweep on the blades and thicker blades, both of which also reduce efficiency.

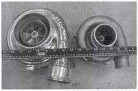
It is also possible for the surge to occur in the diffuser of the compressor housing due to the dynamics of the system. In this case, a ported shroud compressor housing is used. You might have seen these on really big turbos. A ported shroud looks like a really big inlet bib with the inducer bore of the housing inside it. Looking closer, you can see an annular groove around the inducer of the compressor in the housing. What this does is allow air to recirculate around the compressor wheel at



Here is the SR20 match for this small trim T3 size compressor. Note we are totally off the map. Although this compressor will work and is a decent match at lower boost pressures, it is going to blow hot in this engine at higher boost pressures.



Here is the match for a mid-size T04 compressor wheel. Note there is plenty of room to the surge line and since the match point is at redline, the engine will operate right across a pretty efficient operational area of the map. Note that at lower boost levels and slightly higher boost levels, the compressor will still be operating in reasonable areas of the map. This is a very flexible compressor selection for this engine and, I would say, a good selection.



The massively large turbo on the AEBS Focus is good for 750 hp. Note the ruler scale. The huge inlet for the compressor inducer is what is called a ported shroud compressor housing. A ported shroud housing is designed to prevent compressor surge. The turbo on the right is what is normally considered large for most people, a 60 trim T04E.

higher boost pressures, "fooling" the compressor into thinking it is actually flowing more and helping prevent surge. This also costs you some peak efficiency, but preventing surge is much more important. Ported shroud housings are useful in preventing surge at higher pressure ratios as well.

You want to select a compressor with maximum efficiency for two reasons. The more efficient the compressor, the cooler the intake charge. Even more importantly, a more efficient compressor requires less turbine power to create the same amount of boost. This allows the turbo to have less backpressure since the turbine does not have to strain against the exhaust flow to recover the energy to spin the compressor. Less backpressure means better volumetric efficiency. This also reduces turbo lag. A good intercooler makes having a super-efficient compressor less critical, but lower intake charge temp is always good.

With these numbers, you can plot your match point on your typical compressor map to see where in the efficiency range your engine falls in respect to the compressor you are considering. Typically, this amount of mathematical gyrations will get you to easily within 10 percent of your actual flow. You can get closer with a few more rounds of math, but for a street car, this is probably close enough for you to be able figure out if the turbo salesman is full of B.S. or not.

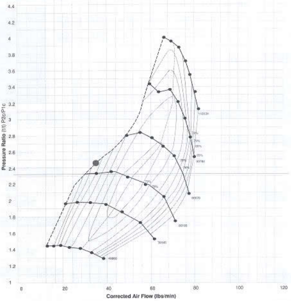
HOW TO MATCH A TURBINE TO YOUR ENGINE

Once you have figured out what compressor will work well with your engine and intended use, the next step is figuring out which turbine will match that compressor. Sizing turbines is pretty difficult, as I have yet to see any engineering data for turbines available to the general public in aftermarket catalogs or in turbocharger books. The formulas involved, however, are published public domain and involve calculating the power balance between the compressor and turbine to determine the turbine expansion ratio. Unfortunately, I have yet to see a turbine map use this data. For some strange reason, it seems as if the turbo manufacturers want to keep turbine maps a closely held secret. The math involved in turbine matching is also more involved.

Fortunately, turbochargers are not as sensitive to turbine sizing as they are to compressor sizing. Because of this, we have a few rules of thumb to consider when figuring what sort of turbine to use.

1. Keep the major diameter of the compressor and turbine wheels within 15 percent of each other. One of the fads in the aftermarket is to do what is called a hybrid turbo. A successful example of this is a medium size Garrett T3 turbine with a larger family T04 compressor. Some of the T3 family has good flowing turbines and they have been successfully teamed with higher-flowing T04 compressors. This turbo combo has powered more than a few powerful Honda turbo kits and many 10-second Quick Class racers. This combo takes advantage of the lower inertial mass of the smaller T3 compressor wheel. Most of these combos work pretty well. The compressor in this case is 13 percent bigger than the turbine, which is still in line with the 15 percent rule. In fact, the T3/T04 hybrid is one of the best-working turbo combinations for a sport compact four cylinder. That being said, stay away from the extremes of size mismatches between compressor and turbine wheels.

The reason? To keep the wheel tip speeds similar. One famous tuner with a very good reputation sells what is basically a large Garrett



Here is the SR20 match for a huge diesel truck compressor to show that you can go too big. Note that the matching point borders the surge line, even at redline! This is way too big. With this particular compressor, the engine operates in the surge zone during most of the engine's operation. This will surely damage the turbo. The engine cannot swallow what this compressor can flow unless the VE gets impossibly way more than 100 percent.

T04E compressor wheel hybridized with one of Garrett's latest designs, a small GT25 turbine wheel. The state-of-the-art small GT25 wheel used the flows as much as a fairly large trim T3, thanks to its newer design. Conventional wisdom says the GT25, with its low inertia, should spool very quickly. However, with the large-size differential between the compressor and turbine, the large slip losses make this turbo a laggy, unresponsive dog, despite the low inertia, high flow and the ball bearing center section this particular turbo has.

2. Although we have no math to prove it (yet), we feel that exducer diameter (the exducer is the hole that the compressed air comes out) can be a pretty good way to estimate what turbine is appropriate for the expected power output within turbine families. Although a turbine's power-supporting capability depends on a number of other factors such as turbine trim, B-Width, blade number and blade shape, and housing A/R, exducer diameter is the easiest thing to fathom when "sizing up" a turbine. To explain some of these terms, turbine trim is the same mathematical ratio as compressor trim, B-Width is the blade tip height on the turbine wheel inducer. Typically the taller the B-Width, the more flow a turbine has. The blade sweep and blade shape has a big effect on performance, which is not possible to just size up by eyeball; the blades are swept to reduce what us engineers call stagnation losses (an entirely different subject in itself). The more blades a wheel has and the thicker the blade, the less a wheel will flow. Blade thickness can affect turbine efficiency as well, thicker blades being less efficient. Housing A/R is explained in detail in the next sidebar. Since there is no empirical data on turbines available to the public from the aftermarket, this exducer size method of turbine sizing is an educated guess based on lots of screwing around with turbos. While we don't claim this is the best method, it is better than making a wild guess! Noted turbo guru Corky Bell, in his book "Maximum Boost," also gives exducer diameter as a rough starting point for estimating a turbine's power-supporting capabilities. Real turbo engineers are going to gnash their teeth at this hack, but I challenge them to try this on an actual car; they will find that it works.

3. Smaller trims of the same wheel family will spool faster, but flow less well. The larger variance inducer to exducer gives the exhaust gas more oomph on the wheel. It also gives the gas a less direct path out of the turbine, giving more backpressure.

Here are some of my estimates based on what many people are running on four-cylinder engines in both turbos and power with some popular, easy-to-get Garrett applications. These are some examples available from Turbonetics and Innovative Turbo Systems.

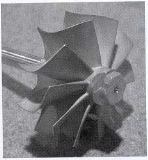
Garrett Turbine Wheels

Turbocharger Family	Exducer Bore Diameter in Inches	Trim	Estimated Supportable Power Level with Appropriate Housing A/R
T25/T250/T28	1.642	62	140-170 hp
	1.855	79	200-320 hp
	1.918	84	250-350 hp
T3/T31/T350	2.122	69	200-300 hp
	2.229	76	300-400 hp
	2.439	76	400-500 hp
T04 (1)	2.544	76	500-650 hp
T04*	2.693	75	550-750 hp

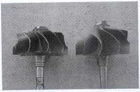
(1) Not too streetable, some leading Quick Class racers run this wheel
* Probably too big for any current four-cylinder

HOW TO PICK THE RIGHT EXHAUST HOUSING

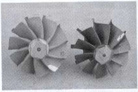
The term A/R has been used in some context or another in this article; you may have picked up on it when talking to turbo people about turbos. A/R is one of the most critical aspects in turbo tuning. Selecting the proper A/R for the turbine housing is one of the major ways a tuner can control the turbo responds to throttle



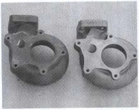
Innovative Turbo Systems' radical R-trim turbine has a trim of 100. Note how the inducer and exducer are the same diameter. This is for maximum flow. Don't even think of using this on your small compact car.



The B-Width on the turbine wheel on the left is much smaller than the turbine on the right. Bigger B-Width usually means bigger flow, all other things being equal.



Here the differences between a 76 trim and an 84 trim turbine wheel are shown. Note the exducer, diameter in relationship to the inducer on the two wheels.



Externally there is not much difference between a large 0.82 A/R (left) and a smaller 0.63 A/R T-3 exhaust housing (right) even though they perform very differently.

The view inside the housings is much different; the 0.82 A/R housing (left) has a much bigger internal volume, so it flows better. This produces less backpressure and more power. The 0.63 A/R housing (right) has a smaller volume, which acts as if you put a nozzle on a water hose, speeding spool up at the expense of backpressure and top-end power.

input. The turbine housing is the iron casting that contains the turbine wheel. Adjusting the housing A/R can control much of the turbo's operating characteristics.

A/R stands for area ratio and is a mathematical description of the cross sectional area of the turbine hosing inlet divided by the radius described by the center of the turbine wheel to the center of the turbine hosing inlet. This ratio stays constant throughout the volute (that's the snail-looking part) of the housing as it tapers from the tight part of the snail shell to the turbine-housing inlet.

A large A/R housing has good flow, less backpressure and creates more top-end power at the same boost pressure by improving the volumetric efficiency. It will also spool more slowly. Conversely, a small A/R housing has less flow and more backpressure but has quicker turbo spool-up characteristics.

If you are wondering why this is so, consider this: Imagine spraying water at a pinwheel with a garden hose. When you spray the water on the pinwheel, the water flow from the hose is good, but the pinwheel takes longer to spin up to speed. Now, put a garden nozzle on your hose. The thin, high-velocity stream of water spins the pinwheel rapidly. There is more backpressure in the hose and the overall water flow from the hose is much less, but the pinwheel quickly gets to speed. This is a simplified example, but is exactly how A/R works inside the turbo.

Here are some commonly available A/R turbine housings for various Garrett turbo families. These are different sizes stocked by Turbonetics and Innovative Turbo Systems.

There are two types of turbine housing configurations, tangential and on-center. Tangential housings have the turbine inlet coming into the housing at a tangent to the turbine wheel. On-center housings have the turbine inlet entering directly into the center of the turbine wheel's axis. A tangential turbine housing is vastly more efficient, as the gas path feeding the turbine has a straighter shot into the housing and a better impingement angle on the wheel. The gas entering an on-center housing must go around a kink in the housing, which causes turbine efficiency to suffer by up to 10 percent. There are studies that show that a 2 percent gain in turbine efficiency can offset gains of up to 25 percent of the turbine's inertia, so a 10 percent loss in efficiency is quite significant. The on-center mounting grants a bit of mounting flexibility to solve a difficult fit problem, but because of the efficiency losses, it is better to try to find almost any other solution to a packaging problem.

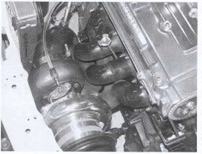
Another variable of turbine housing design is divided and undivided housings. A divided housing is exactly that; the scroll of the turbine housing is split in two. A savvy tuner can use a divided housing to his advantage on an engine with few numbers of

Garrett Turbine Housings

Turbo Family	Exhaust Housing A/R
T25/T250/T28	0.48 (1)
	0.63
	0.64
	0.86
T3/T31/T350	0.36 (1)
	0.48
	0.63
	0.82
T04	0.50
	0.58
	0.70
	0.81*
	0.84*
	0.96*
	1.00*
	1.15*

(1) Probably too small for most applications
* Probably way too big for most four-cylinder applications

cylinders. A divided housing works best on a four-cylinder engine with some advantages on a six cylinder with a properly designed manifold. When a divided housing is used, usually cylinders 1 and 4 are fed into one side of the scroll and cylinders 2 and 3 are fed into the other side. The cylinders fed into each side of the scroll are as far apart in the firing order as possible. This allows the turbine to be hit with four distinct pulses as the engine goes through its firing order. This improves turbine efficiency, sometimes to the point where up to one size larger A/R housing with its attendant lower backpressure can be used—or you can choose less turbo lag with the same size A/R housing. The divided housing can also improve volumetric efficiency by making reversion from adjacent cylinders much more difficult. This is because there is a great deal of separation in degrees of crankshaft rotation between the valve opening events of the adjacent cylinders. In order for a reversion pulse to contaminate an adjacent firing cylinder, it has to travel back through the spinning turbine blades and up the other side of the divided turbine-housing scroll to get to the adjacent cylinder. This is pretty difficult and the pulse will tend to take the path of least resistance, past the turbine to the area of lower pressure.



Lisa Kubo's manifold is built to make use of a divided turbine housing to spool a big T51 compressor. It must work well; she is currently the pilot of the world's quickest unibody Honda.

On engines with more than six cylinders, the divided housing is probably not worth the effort, except perhaps in the rare case of a twin-turbo V8 engine with a 180-degree crank. In this case, the V8 can be treated as two four-cylinder engines.

Lisa Kubo, Steff Papadakis, Myles Bautista and Ben Ma's can have examples of manifolds designed to take advantage of a divided exhaust hosing. Check them out in the pits at the next race.

A divided exhaust turbine housing is used on the AEBS Focus to help spool its monstrous T61 compressor.

It is probably best to avoid extremes of A/R selection, as turbine efficiency dramatically falls when selecting a very small or very large A/R turbine housing. If you feel the need to go to a very small or very large A/R, then perhaps you picked too big or too small a turbo combination for what you really wanted to do. Remember to be realistic when picking a turbo size. A 600-hp racing monster turbo is not going to be a quick-spooling lively street turbo, no matter what A/R housing you put on it.

Note too, that it is often better to put a small trim turbine wheel in a bigger A/R housing to solve a spool-up time problem than to put an extremely small A/R housing on a large trim turbine. The larger A/R housing can offer more expansion across the turbine, allowing more energy recovery by the turbine to spool the turbo more quickly. A good way is to try a smaller turbine trim in the same housing, not to go to extremes. Turbines usually work the most efficiently in housings around the mid-range offerings in A/R sizing. Generally, the turbine/housing combo was designed around this mid-size and the blade angles, etc. are optimized for this. This is another reason to avoid extremes in A/R when configuring your turbo.

Interestingly enough, compressor housings are also available in different A/R combinations, but compressor performance is not linked as closely with housing A/R as it is on the turbine. Smaller A/R compressor housings tend to be slightly more efficient at higher-pressure ratios than bigger A/Rs. Bigger A/Rs are slightly better at lower pressure ratios. Bigger A/R housings also tend to come on later in the power curve—and more violently.

In short, when sizing a recommended turbo combination for your ride, pick your compressor size by the included calculations and the compressor map, then choose the applicable turbine for your power requirements. Fine tune the powerband of your configuration by the A/R of your turbine housing. Be realistic; don't pick a drag racer-sized turbo if you seldom hit the track.

CALCULATING THE POWER POTENTIAL OF A TURBO

Once you have figured your engine's airflow at the boost you plan on running, you can estimate your horsepower output pretty easily. To estimate your potential power output, use this formula:

$$\text{Horsepower} = \frac{\text{Airflow} \times 60}{\text{Air/Fuel Ratio} \times \text{BSFC}}$$

Airflow is in pounds per minute, 60 is to convert minutes units to hours, air/fuel ratio is self-explanatory and BSFC is Brake Specific Fuel Consumption as measured in pounds of fuel per horsepower per hour.

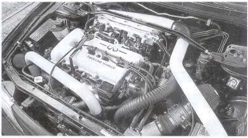
For guidelines, a highly boosted turbo engine running on street 92 octane unleaded pump gas might run an air/fuel ratio of 10.5:1 to avoid detonation. Conversely, a highly massaged drag engine running a specialized high specific gravity turbo fuel might run an air/fuel ratio as lean as 13:1. For estimates on BSFC, a rich tuned pump gas engine might run a BSFC of 0.60. A massaged, tuned-to-the-edge drag race engine on specialized gas might run at 0.45.

Let's try the formula using a hypothetical Nissan SR20DET that is in a crisp state of tune (conservative on race gas). Let's pick a conservative (for race gas) air fuel ratio of 12:1

and a reasonable BSFC of 0.50. These are safe margins where you won't be close to burning down any engines.

$$\text{Horsepower} = \frac{35 \times 60}{12 \times 0.5} = 395 \text{ hp}$$

Our hypothetical SR20DET will put out around 360 hp at 20 psi of boost. If you take the time to play around with the equations, the things the tuner has the most control of are VE (through different size turbines, turbine housings, exhaust systems, headwork, cam combos, etc.) and the tuning factors, which include air/fuel ratio and BSFC. The intake manifold temperature can be changed with different intercoolers or better yet, measure your car's post-intercooler intake temp. Play with these numbers and see how they can affect your power and what you can do to extract more power. ■



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