TECH

TURBO SPECIAL

ALL ABOUT TURBOCHARGERS

BY ROB KINNAN
PHOTOS COURTESY OF MANUFACTURERS

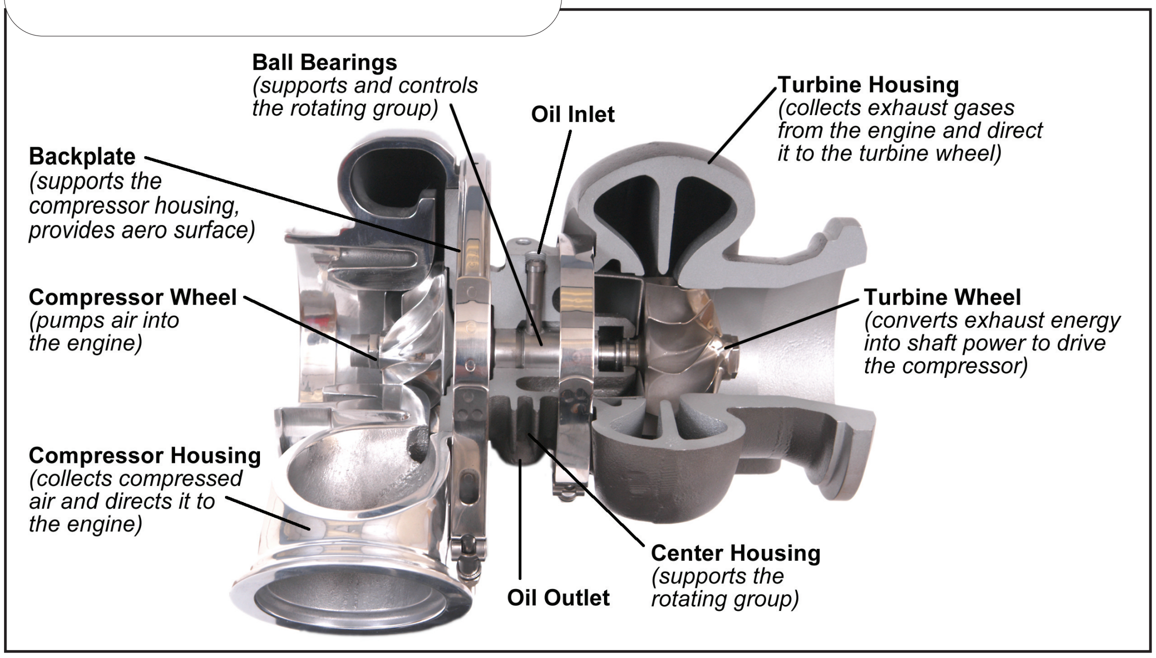
This is a Garrett ball-bearing cartridge, a single-sleeve system that contains a set of angular-contact ball bearings on either end, as opposed to the traditional bearing system that contains a set of journal bearings and a thrust bearing. Garrett claims the loss in friction makes a turbo that spools faster.

Elsewhere in this issue, Stephen Kim has a story on how to build your own turbo system, but without a doubt the most crucial part of any turbo setup and the hardest to choose correctly is the turbocharger itself. So we put together this story describing what a turbo does, how it works, the options available, and a little bit about choosing the right one for your application. The complicated part is that this story cannot possibly tell you exactly which turbo to use. You can have an identical car to your buddy, but you might want something slightly different from it, or want it to perform in a slightly different way than the other car, and that dictates turbo choice. Plus, there are nearly infinite combinations of turbo designs and sizes and each one will make your car perform a little differently. The right way to choose a turbo is to have a conversation with one of the manufacturers about your engine, car, and desired use (a specific rules-regulated racing class, a street car, etc.) and they'll help pick just the right turbo.

Okay, so how does a turbo work? It would be cliché to use the tired old phrase of "a turbo is free horsepower!" but it's pretty true. In a simplified explanation, a turbo is like an air compressor that crams air into your engine. The more air and fuel in and out, the more power it makes. A supercharger (and even nitrous oxide) does the same thing, but whereas a supercharger is driven off the crankshaft by a belt, a turbo spins by exhaust gas flowing through it. One side of the turbo is spun by the exhaust and the other side is the "air compressor" that moves the air. The "free horsepower" phrase came up because driving a blower off the crankshaft is not free; it costs power and sometimes a lot of power. A turbo uses spent exhaust gas to drive it, hence using the byproduct of the power that was already made.

Of course, it's not really that simple. Exhaust backpressure, or the force the engine has to use to push the exhaust out of the exhaust ports and through the headers and turbo, takes some effort (power). And with both types of power adder, the more air you try to stuff in the engine, the greater the load (and power loss) on the engine. It doesn't matter if it's load at the crankshaft or on the exhaust stroke, it's still load and a power loss. The difference is that a supercharger will always require a heavy load and while a properly sized turbocharger does restrict exhaust flow potential to some extent, the pumping losses are much less than the parasitic drag from by a conventional supercharger's belt or gears. Roughly 30 out of every 100 hp added by a supercharger is wasted turning the drive pulleys and

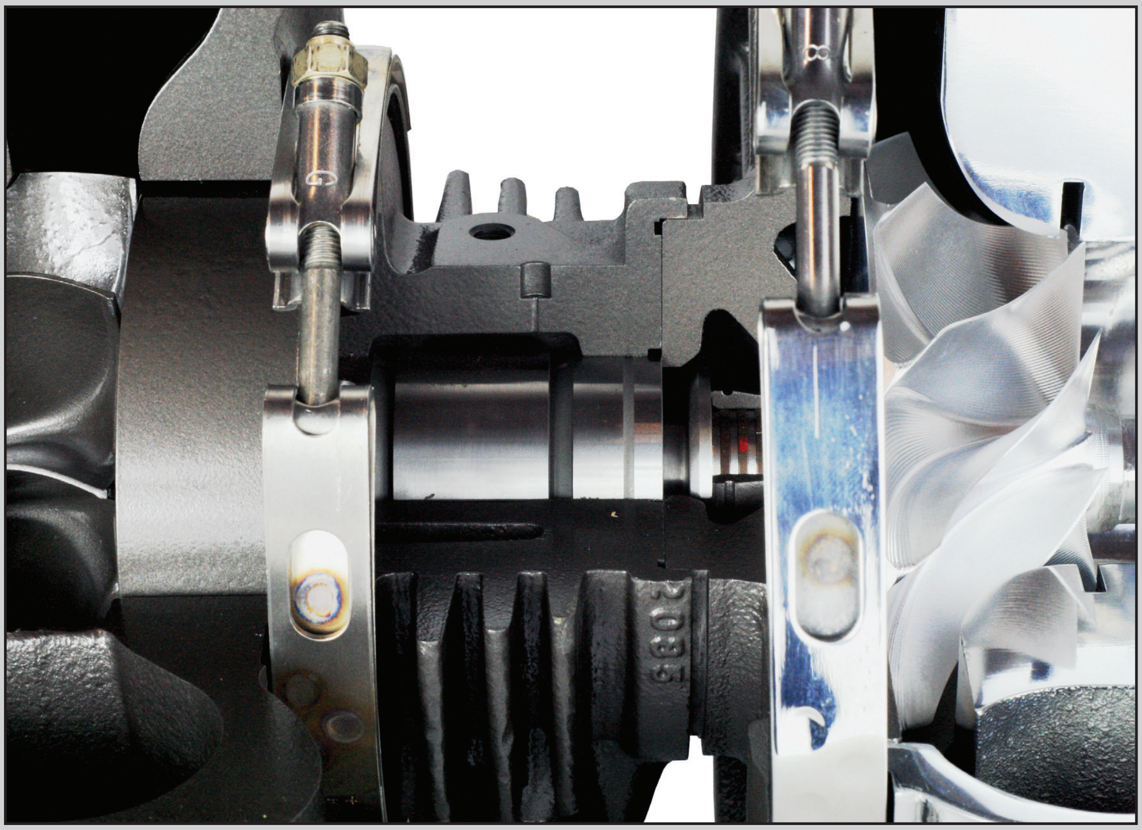
This photo from Garrett shows a turbo cutaway. On the right is the turbine (exhaust) side, on the left is the compressor side, and a shaft that rides on various types of bearings connects them.



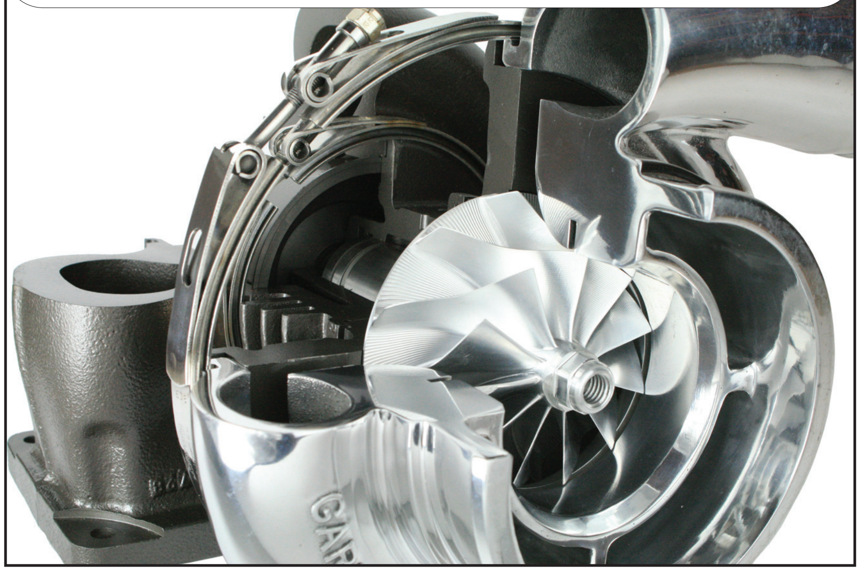
One side of the turbo is spun by the exhaust and the other side is the "air compressor" that moves the air.

IT'S ALL ABOUT BALL BEARINGS

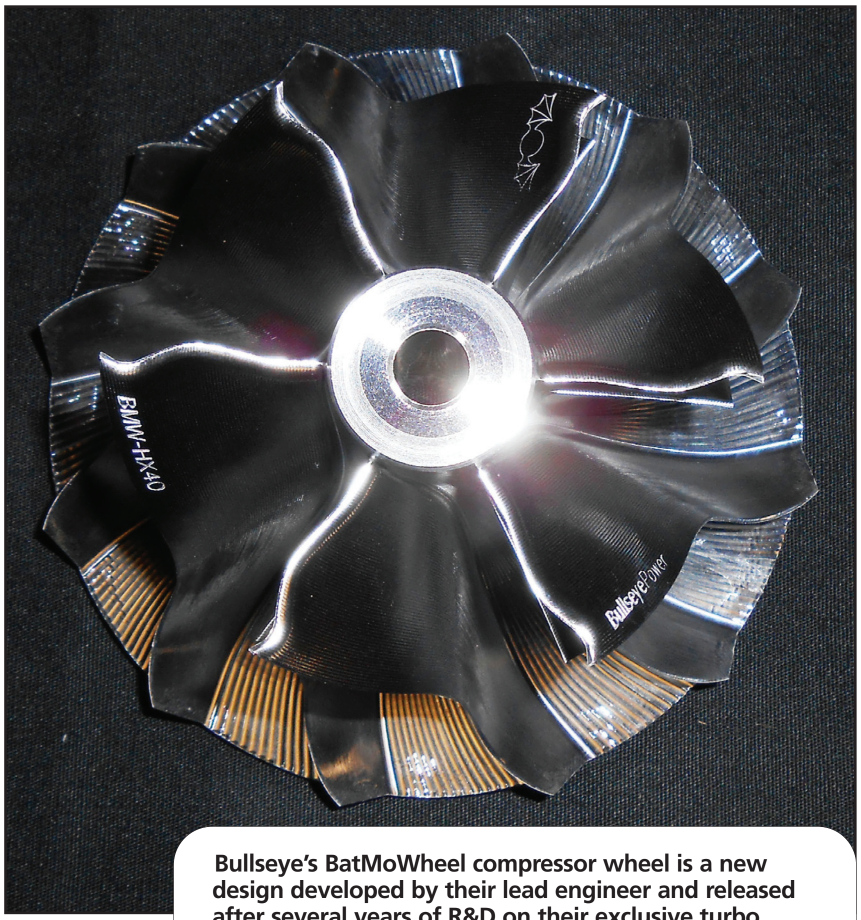
The bearings that the turbine and compressor shaft rides on are subjected to extreme heat and abuse at over 100,000 rpm wheel speeds, and are also important in the design of a turbo. Bullseye Power's Bill Devine said, "We have improved the bearing system in our turbos on several levels. We have designed heavy-duty thrust and journal bearings to provide maximum oiling, cooling, load and shaft speed capabilities. Drag racers are constantly pushing the envelope to the extreme in search of a maximum power and ET. While the OE designs are run well past their limits in drag racing and other venues, we are constantly improving our product to increase the capabilities and performance of the turbo. With this in mind, while I cannot mention specifics, I can say that we are currently in the process of testing a newly designed complex ball bearing system that will stretch the limits of turbocharger capabilities beyond the industry's current platform so that we can take it to the next level. So far our testing has been met with great results." Garrett uses their new silicon nitride ball bearings in their large-frame turbos for reliability and resistance to deformation under heat and friction loading.



Compressor wheels have progressed from cast to billet and now forged aluminum. Garrett's new billet GTX compressor wheel is a forged billet piece with the right design and blade count to improve power and response over previous designs. Garrett's engineers are constantly working on new, innovative wheel designs.



The A/R ratio is the area (A) of the inlet scroll cross-section divided by the distance from the center of that cross-section to the center of the shaft (R).



Bullseye's BatMoWheel compressor wheel is a new design developed by their lead engineer and released after several years of R&D on their exclusive turbo dyno. Devine said, "This BatMoWheel technology has proven to provide the best spool up and horsepower/ flow of any turbo in its class. The compressor cover was designed specifically to suit the needs of the higher flow BatMoWheel technology."

Ford fans should know the name Bill Devine, more widely known as "Wild Bill" for his early days in Pro 5.0 racing and the NMRA. Devine is now the sales and marketting manager at Bullseye Power and he's on a mission to get their turbos on the market and dominant.

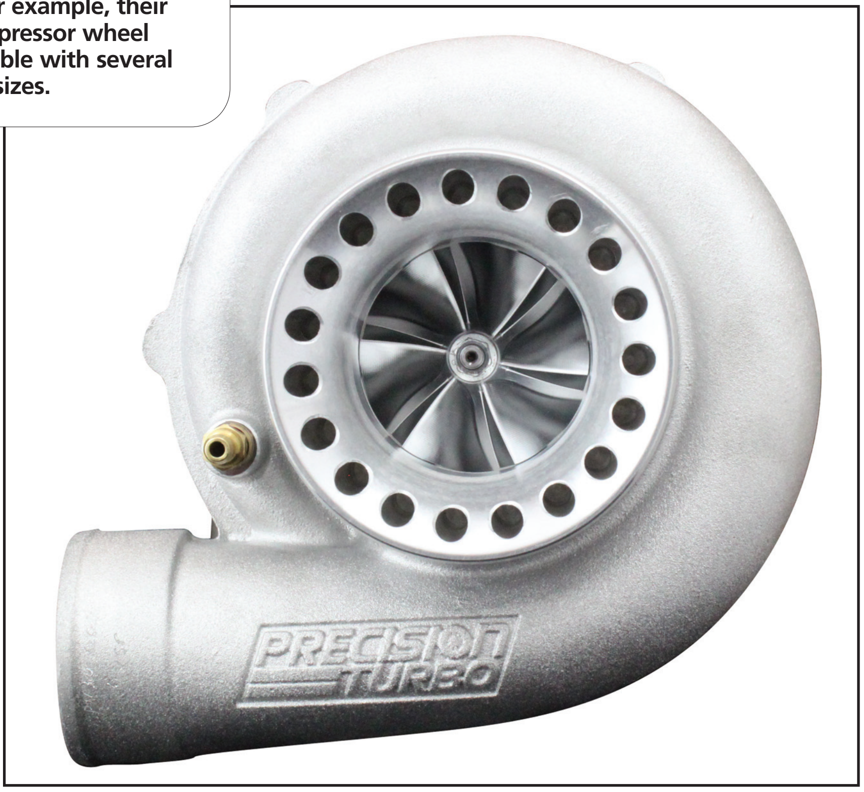
belts; this compares to about 5-10 horsepower per every 100, suffered as pumping losses by a typical well-designed turbo installation.

A turbocharger is made up of two sides, the exhaust (turbine) and intake (compressor) sides. When the engine is running, hot exhaust gases blow out of the engine's exhaust ports, into the exhaust manifold/header, and into the turbo's turbine housing. The expanding gas hits the blades on the turbine wheel and makes it spin. The turbine and compressor wheels are connected by a shaft, so when the turbine wheel spins so does the compressor wheel. As the compressor wheel rotates, it sucks air into the compressor housing. Centrifugal force throws the air outward, causing it to flow out of the turbo into the intake manifold under pressure, which is called boost. As engine speed and boost increase, the turbo basically feeds itself: The more air the compressor packs into the engine, the more exhaust gas is generated, which causes the turbine wheel to spin faster, in turn spinning the compressor faster and packing more air into the engine.

The shape and design of both wheels and their housings is the subject of constant evolution from the OE and aftermarket (racing) sides, and because each side has an effect on performance the number of combinations available is staggering. Just like there is no one perfect camshaft for your engine, there's no one perfect turbo for it either, hence the need for professional consultation.

How fast and when the turbo starts making boost is mostly dictated by the turbine—a smaller turbine and housing will respond quicker and make more boost down low than a larger one, but the smaller it is the more restriction (load) there is and the lower the ultimate boost level. The turbine wheel's overall diameter and the turbine housing outlet size determine the turbine's ability to generate the power needed to spin the compressor side, but size isn't the only thing that matters. The turbine has an A/R (area/radius) ratio that dictates when the turbo starts working by determining the velocity of the exhaust gas as it passes through the turbine wheel. A turbine/compressor housing looks like a snail shell, meaning that the exhaust gas entry and exit sides are different to build velocity. The A/R ratio is the area (A) of the inlet scroll cross-section divided by the distance from the center of that cross-section to the center of the shaft (R). For any given housing, A and R vary in the same proportions, so all A's divided by their corresponding R's yield the same dividend—which is the A/R ratio. Get it? If not,

Turbochargers have undergone constant improvements over the years.



Precision Turbo & Engine generally designates its turbos by compressor wheel inducer size and turbine wheel exducer size. For example, their popular 6266 CEA turbo features a 62mm inducer compressor wheel and a 66mm exducer turbine wheel. The 6266 is available with several turbine housing options, including T3, T4 and V-band sizes.

Garrett has a great description and illustration on their website at http://www.turbobygarrett.com/turbobygarrett/turbine_housing_AR_and_housing_sizing

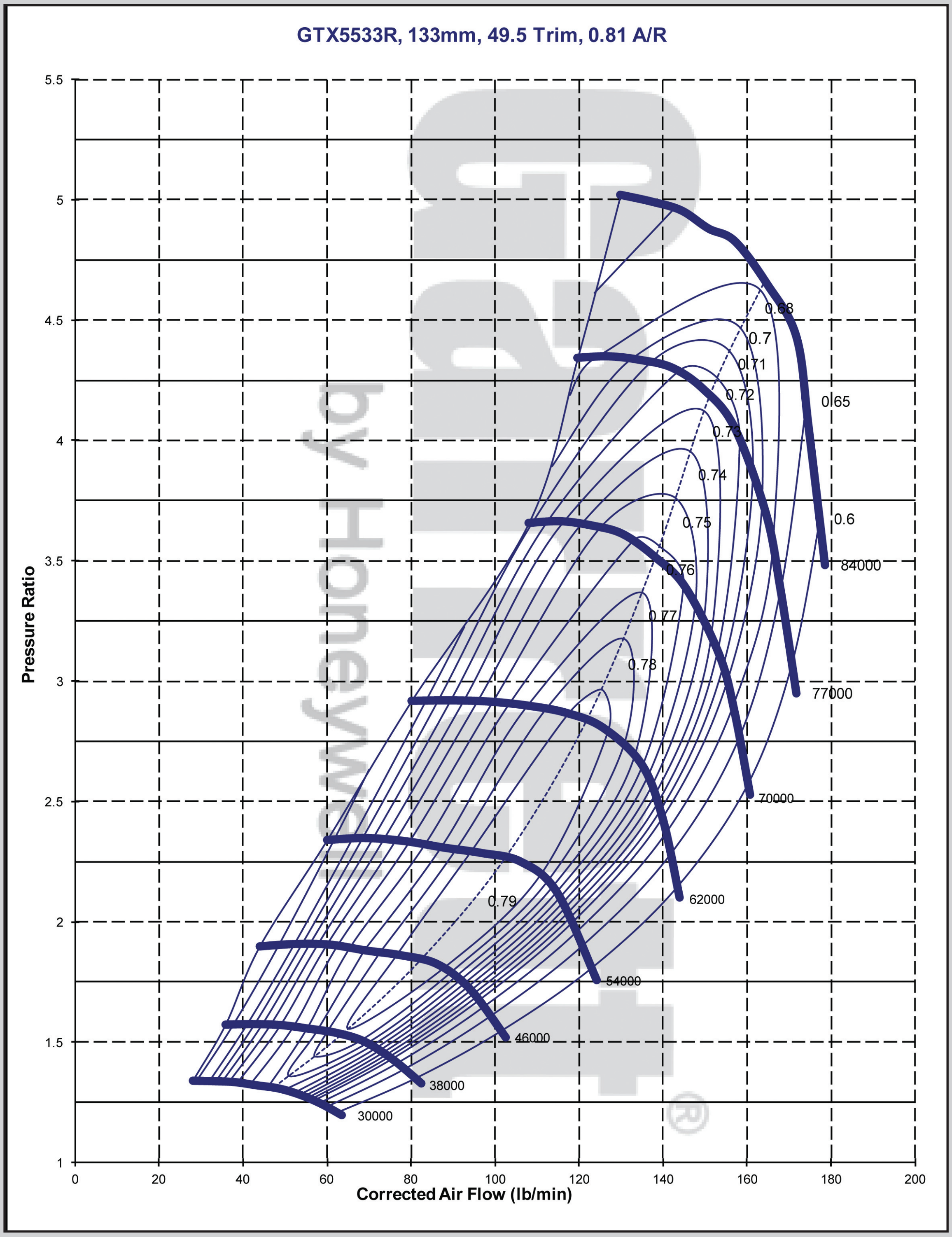
The compressor side generally dictates how much air goes into the engine and therefore how much power is made. The bigger the compressor, the more air it flows and therefore the more power potential it has. In a racing class the maximum size of the compressor wheel, also known as the impeller, is often mandated so that's an easy choice to make—when you see a rule about an 88mm turbo, that size is referring to the inducer diameter, the point where the air enters the wheel. For street use, how much airflow and power you can get away with is a factor of the engine's compression ratio, engine controls, and fuel type (pump or race gas). Generally speaking, 10 pounds of boost is all you can usually get away with on pump gas, or 15-20lbs when using an intercooler.

The good news is that a turbo is modular, so you can change the turbine and compressor sides individually, or you can change just the housings so long as they match the wheel being used—swapping turbine housings is a good way to improve the A/R ratio to adjust the power band higher or lower. As Bullseye's Bill Devine said, "With respect to our line of turbochargers, we have the ability to pour several turbine options in-house and offer multiple A/R ratios to the customer. If the needs of the customer are greater than the largest housing available then the next step is to increase the turbine wheel size. We offer several options for each size turbo to meet the needs of even the most extreme application."

As we said earlier, turbochargers have undergone constant improvements over the years, concentrating on both sides of the turbo as well as the bearings and cooling methods. The bulk of the attention has been paid to the compressor side, as Devine explained: "Compressor wheel technology has come a long way in the last decade. Materials have progressed from cast to billet and now forged aluminum. The new billet technology has allowed us to create the BatMoWheel using a high-speed 5-axis

Bullseye also has a stainless steel turbine housing for better spool and throttle response because the housing holds more heat around the turbine wheel. The benefits of stainless steel over a cast-iron housing is that it won't rust, won't crack under heat, and will contain parts when a catastrophic failure occurs, like from a dropped exhaust valve or seat. It also much lighter and can also be polished, which is nice.

Purpose-built for improved strength, durability and longevity, Precision's center housing and compressor back plate assembly is an innovative one-piece design, manufactured from an aluminum forging. Additionally, these units come equipped with stainless steel turbine housings complete with an extended turbine discharge with cross-bolt provisions for added safety. The cross-bolt design was originally used in the competition diesel truck and tractor-pulling world, where the engines see ungodly levels of boost on the order of 100-plus PSI.



TURBO SPECIAL

machine to create the exclusive shape of the BatMoWheel blades that would not be possible as a casting. This BatMoWheel technology has proven to provide the best spool up and horsepower/flow of any turbo in its class. The compressor cover was designed specifically to suit the needs of the higher flow BatMoWheel technology."

As Garrett's Yukio Taira explained, "At Garrett by Honeywell, we're always using new technology that is learned through OEM development into our performance aftermarket that allows us to make efficient and reliable power. We have learned that our popular GT Series of turbocharger with cast compressor wheels could use some updating, thus we created the GTX series. The forged billet GTX compressor wheel with the right design and blade count has been able to make a huge difference in power and response and almost all of our sponsored teams have used it to make significant power allowing them to break records and win races. We are also developing other types of turbine housings and future aerodynamic updates that will be released in the near future. Our engineers are constantly working on new, innovative projects."

You may have heard a turbo referred to as a T3, T4, or T6. This is an industry standard term given to the exhaust housing inlet flange's bolt pattern size (though some turbos mount with a V-band. A T4 is bigger than a T3. A larger turbo gives up bottom-end response for high-end power while a smaller turbo does the opposite. A good turbo will offer bottom-end and high power, thus the T3/T4 turbo, a hybrid that has a T3 turbine section with a T4 compressor section. This combination offers the low inertia and fast boost response of the lightweight T3 turbine and the high airflow characteristics of the T4 compressor.

SUMMARY

Nothing in life is free (even if you voted for Obama) and life is about compromise. This is particularly true with engines; in any combination, if you want more low-end torque you have to give up some top-end power, and vice versa. Things like camshafts and turbochargers will dictate how much and when the horsepower is made, and everyone wants something a little different, hence the difficulty in choosing either part. That's why you can't go to the junkyard and pull a turbo from a car or truck and expect it to work like you want it to. Consult with fellow racers and most importantly the manufacturers to get the right turbo (or turbos) for you, and you'll properly enter the wonderful world of turbocharged performance.

MAPPING PERFORMANCE

All turbochargers (and superchargers too) have a compressor map that shows its flow characteristics. It's complicated to learn how to read one but we've found the best explanation, with examples, is on Garrett's website at http://www.turbobygarrett.com/turbobygarrett/compressor_maps. Spend some time there and learn how to read a map before you buy a turbo, although Precision's Ainsley Jacobs said, "While compressor maps are great for understanding theoretical performance and how a turbo should perform, they can't show actual real-world performance and account for all of the different variables that make up actual on-vehicle testing and environmental conditions. It's safe to say that it is not necessary for racers to know how to read a compressor map—but it is a good idea for racers to know how to understand and interpret the performance information recorded by their data loggers in order to get the best performance from their turbo."

SOURCES

Bullseye Power LLC
BullseyePower.com
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Precision Turbo & Engine
PrecisionTurbo.net

Garrett by Honeywell
TurboByGarrett.com