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The difference between Roots, centrifugal, and screw superchargers, and give you the skinny on maximizing your power with each.

By David Vizard
Photography by the author

A n English major may disagree, but the way to spell "power" is "supercharger." Let's face it, the word just reeks of big horsepower numbers—and not without good reason. The basic definition of "super" is "more than," and in this instance, it implies charging a cylinder with "more air than" a normally aspirated cylinder would.

So much for a fundamental definition of what a supercharger does. Now let's pose a question that has a less-than-obvious answer. Why supercharge, why not just more cubes? The fact of the matter is that a piston/rod/crank system is very effective at taking a source of high-pressure gas and turning it into rotating mechanical energy at the end of the crankshaft. Such a mechanism is not only mechanically far more efficient than is often accredited, but is also relatively effective in terms of size and component weight necessary to do so. Nonetheless, it is far less capable of moving atmospheric air at just less than 15 psi absolute (pressure above a total vacuum) from outside of the engine to inside the cylinder. For this operation, a piston/rod/crank is a heavy, cumbersome mechanism in terms...
Roots-type blowers really respond well to high-flowing heads. Even with a streetable cam, a 582-inch big-block such as this BDS-injected setup can exceed the 1,200-lb-ft and 1,100hp mark, and idle like a watch. Also, note that the intimidation factor is very high.

"... a cam company cannot sell you an appropriate cam for a turbo motor until the pressure differential across the motor is known."

Just for the record, Roots-type blowers such as this Holley/Weiland unit work really well with stroker cranks in smaller cube engines, such as a 302 Ford (out to 331 or 347) and 350 Chevy (out to 383 or 408). The trend for best Roots blower results when building from scratch: more cubes and less boost work better than less cubes and more boost. Eight pounds of boost in this 347 small-block Ford produced results comparable to a 418-inch stroker motor.
assembly strength. Some production blocks, such as Ford's 5.0 blocks, are not as stout as we might wish for. To date, I have already seen two 5.0 blocks (used for about 550-600hp builds) crack right up the middle of the litter valley. If about 900 or so horsepower is all you are looking for, you might want to consider a Bessel Engineering block conversion as a cost-effective alternative. As for four-bolt mains, they are a good idea on almost any block where big numbers are contemplated.

Also, if piston squirter are on the menu, it is a good idea to upgrade the oil pump. If we are trying to keep from ventilating the pistons, a thermal barrier coating is a great idea. I have not lost a coated piston engine to boost or nitrous in the last 20 years.
serves only to make a lot of steam. It does not come close to putting out the fire. In addition to pushing the apparent octane of the intake charge up, the water also cools the peak temperatures to the extent that melting anything down is totally countered. To give you an idea just how effective water injection is, I can say while I was a student we successfully ran a 17:1 compression tractor engine on kerosene (less than 50 octane) and water injection. More in line with what we are doing here: how about a 1,100hp 350 small-block Chevy on 35-psi boost and 87-octane fuel? Water injection flat works, and if you are in the market for a system, check out Snow Performance.

Controlling excess heat can become a major part of any supercharged installation. The water injection just mentioned is a good start, but when very high output is in the cards, this needs to be backed up with a big radiator and piston oil squirts. The big radiator is self-explanatory, but to those who may be new to supercharging’s little nuances, an explanation of squirts is in order. Here, engine oil is squirted through jets onto the underside of the pistons, thereby cooling them. This is a procedure I have used on all my serious nitrous and supercharged engines since the late 1980s. Many of the newer, small four-valve factory turbo engines are now adopting this method of increasing piston life. If you are supercharging a typical V-8 and live in the Los Angeles area, then it may be of some help to know that Performance Techniques in San Bernardino can modify your block to a squirt configuration at a relatively modest cost.

Now for point number three: maximizing air mass through the system. There are many misconceptions here, the most notable of which concerns the cylinder heads. Do not fall victim to the misconception that heads don’t need to be good, because the supercharger forces the mixture into the cylinder. Ask yourself where the power to generate the force came from. The reality is, the better the heads, the more the power is for a given boost, because more air is passing through the system. Also, you should note that for higher boost figures, it is better to trade off some intake valve diameter for a larger exhaust diameter. We are currently putting 15 psi (and planning on 20) into a 331 small-block Ford, and are using a 1.94/1.70-inch valve combination, rather than the 2.02/1.60 combo. For what it’s worth, be aware that the lower the compression, the larger the exhaust valve should be in relation to the intake.

GETTING THE CAM RIGHT

The next factor on the agenda is the camshaft spec. Forget turbo installations for the moment. As for all others where the exhaust flow is uninhibited, we can set some ground rules that apply across the board. The most important factor is the lobe centerline angle (LCA). This is very dependant on the boost/cubes combination in relation to the circumference of the intake valve, and the intake-to-exhaust flow ratio. The bottom line is this: Assuming your engine had the optimal LCA for a normally aspirated application, the LCA would need to get progressively

This rear-mounted turbo installation from Squires Turbo Systems is probably the most unusual of the systems we’re reviewing. A similar remote installation was used for the P47 Republic Thunderbolt, a very successful WW2 fighter. When space is limited up front, this makes for a viable option. Another benefit is that underhood temperatures are also reduced.
For a 10-psi boost requirement, these curves show the difference in how the boost comes on between the two fundamentally different types of superchargers. Although there are a lot of reasons for choosing one type over another, the basic difference comes down to the shape of the power curve. Essentially, a positive-displacement supercharger produces more low-speed boost, where a turbine one can develop more high-speed boost.

The Weiand blower on this mildly modified 350 small-block Chevy added about 110 lb-ft and 110 hp over what we would have expected in normally aspirated form. In essence, this 350 produced a power and torque curve similar to a mildly warmed-over 454 big-block, but without the big weight increase.

wider the higher the boost. Also, if the exhaust valve is too small for a supercharged application (as is most often the case), it will need to be opened earlier, thus widening the LCA in its own right. Although not so good for the bottom-end output, the early exhaust opening can appreciably help the top end. What we are trying to avoid is the boosted intake charge passing right through the combustion chamber, and out through the exhaust. Also, another factor to take into account is that for a street setup, you will find that the cam for the job can be shorter, thus boosting the low-speed output from a centrifugal type supercharger. If the heads are good, then the supercharger will take care of the top end.

Now on to the subject of turbo cams. One thing you should appreciate here is that a cam company cannot

"... we can say that for off-idle and low-speed torque, a positive-displacement blower is the ticket."
sell you an appropriate cam for a turbo motor until the pressure differential across the motor is known. Let me explain. When a turbo goes into boost on the intake side, it will have been driven there by pressure built up between the engine and the turbo. Other than in a pulse-driven turbo, it is this pressure that drives the exhaust turbine. A typical turbo kit has an intake-to-exhaust pressure ratio of about 2:1, but that can vary from 1:1 for a really well-designed installation, and right through to a mediocre 3:1. Let's assume that your turbo setup is going to be about 2:1. What this means is that if there is 15 psi of boost in the intake, there will be 30 psi of exhaust pressure in the exhaust manifold. If you install a cam with a typical street overlap, when the intake opens, rather than having the mixture enter the cylinder, the exhaust goes out through the intake and into the intake manifold. This heats the charge considerably, and more often than not, increases the likelihood of detonation. Working with a turbo fanatic friend of mine, we looked at cams with negative overlap in such a situation. We tested a cam that had about minus 25 degrees of overlap. Guess what? It worked great. Big torque right off idle, big power, and a glass-smooth 600-rpm idle.

When I build my own turbo motors, I really work hard to target a 1:1 pressure ratio across the engine. If this is achieved (our road race championship-winning turbo Ford Cosworth Sierra in England was this way), then whatever cam events work best for a normally aspirated engine also work best for the turbo setup.

One more valvetrain factor to take care of concerns the valvesprings. Because boost pressure tries to open the valve, a stronger spring will be required on the intake of a regular supercharged engine, and on both the intake and exhaust of a turbo motor.

Our last subject is the effective and reliable conversion of the air mass throughput into torque and horsepower. The golden rule above all else is to have the tune-up right. A lean mixture, or too much ignition advance, will kill a supercharged engine far quicker than a normally aspirated engine. I have seen a poorly tuned motor (too much throttle too soon in the tune-up session) eat itself in less than five seconds. I'm just glad it was not my motor. Also, the ignition and plug requirements.

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ATI PERFORMANCE PRODUCTS
Paxton manufactures this centrifugal system for the '03-06 model Dodge Viper (PN 1201840-P, suggested retail $8,995). Estimated power at the flywheel is 700 hp and 633 lb-ft at 8.5 psi of boost. This Novi 2000 kit comes with an air/water charge cooler, high-flow fuel pump/fuel control unit, and timing control computer. Installation is a bolt-on deal, and takes approximately 16 hours.

are more stringent. The safest plan is to use plugs that run really cool, and go into overkill mode on the ignition system as a primary step. But even then, the situation can go down the drain. Once detonation starts, it leads to more detonation. The best safety measure I can recommend here is the J&S Safeguard, which monitors the onset of detonation and backs out timing as necessary.

As for the mechanical parts of the engine, there is some good news for those who are looking at bolt-on blower power, while maintaining stock bottom-end parts. Rods are often a problem, but it is rpm that kills rods much sooner than cylinder pressure. As a result, rods that may be good for around 450 hp in a normally aspirated engine may well be good to 550 in a supercharged situation. Of course, once we start talking of a built-from-the-ground-up deal for as much power as the chassis will take, then we need to address block and rotating

The biggest name in the water-injection business is Snow Performance. The use of this on my Magnuson-blown Sierra pickup allowed me to use 87-octane fuel without detonation or sacrificing any power.

Superchargers and high-flow heads are a match made in heaven. Each complements the other, and the sum total of the two is greater than each one independently.
induced. In essence, any supercharger of merit is, size for size, a far more effective means of moving significantly greater quantities of air than a piston/rod/crank system. If you want absolute proof of what is being said here, just check the size of a turbo compared to the engine it's feeding. A turbo of about one twentieth of the size of an engine can pass as much as four to five times the volume of air. By utilizing a supercharger of any type, we are in effect making the engine act as if it has far more cubes because the magnitude of the induction process is now determined by the supercharger, not the basic displacement of the longblock itself.

SUPERCHARGER TYPES
Basically, there are two fundamental types of superchargers: The positive-displacement type, and all the rest that are not. The best-known positive-displacement supercharger or blower is the Roots type. Originally developed in England by the Roots brothers to pump air into deep mine shafts during the middle of the 1800s, this type of pump started to see use on aircraft engines late in WWI. Although this style was successfully used between the wars on Mercedes and Auto Union F1 cars, and the highly successful British ERA F2 cars, they really came to the forefront when the likes of Don Garlits and a few other Top Fuel racers of the late 1950s and early 1960s figured they could go faster with a blower atop the motor—and they did. Back then, the blower of choice (because there was not a lot else to choose from) was the GMC supercharger used for supercharging GM’s two-cycle diesel. The sizes most commonly used were the 6-71 and the 8-71. These big blowers could puff about 20-25 psi into a Chrysler Hemi and bump the output to what was then an incredible 2,500 or so horsepower, and about 3,200 lb-ft of torque. Today, we see many superchargers that owe their heritage to the GMC range of blowers. A few examples are those from Holley/Weiand, Edelbrock, Magnuson, I-Charger, BDS, Littlefield, and Eaton. When taking a casual look at this type of supercharger, it is easy to assume it draws air into the middle of the rotors and passes it down into the manifold. In reality, this does not happen. The best way to see how it works is to look at a small-block Chevy oil pump, as this is in fact a mini Roots-type pump.

"If the goal is the biggest boost number possible, then be aware that welding the intake valves closed will produce the highest boost, but not much power."

THE WHIPPLE BLOWER
A casual look at the Whipple supercharger might lead you to the conclusion that it is a Roots blower with a very high helix angle. Not so; it actually belongs to a class of compressor known as a screw compressor. To see how it works, take a look at the second illustration.

First, imagine these two rotors housed in a case with an opening at the upper back, and a discharge at the lower front. Starting from the left, imagine that the groove on the right-hand rotor is full of air. As the lobe of the left-hand rotor rotates into this groove (middle), it can be seen to close off any exit toward the back where the intake is. This traps air in the groove, and as further rotation takes place the air trapped in the groove gets pushed forward as per the right pair of rotors. This squeezing action to compress the air takes place very efficiently with figures rivaling that of a turbo.

In its original form and right up through the late 1980s, the big drawback with the Roots blower was its relatively inefficient (about 55 percent) pumping characteristics. Here, substantial credit can be given to ace blower designer Jerry Magnuson; his efforts to improve the Roots-style positive-displacement blower have brought its efficiency throughout the typical operating range and duty cycle to a level closely comparable to a turbo-style supercharger. To put that into perspective, he has in the last 20 years done what engineers in the previous 120 years largely failed to do. Today, 98 percent or more of the superchargers sold have Magnuson technology in them. In other words, your modern Roots-style supercharger is not the one your father knew.

The Roots-type supercharger, though, is not the only positive-displacement style available. Among the many others in this category are the Zoller vane-type supercharger, the novel (and supposedly very efficient) VW G-Lader, and the Whipple-style screw compressor. Of these, only the Whipple unit, also a high-efficiency unit, is in any kind of aftermarket volume production.

TURBOS AND CENTRIFUGAL SUPERCHARGERS
Unlike positive-displacement superchargers (which, barring leakage, move a certain amount of air per revolution), centrifugal superchargers develop boost by imparting motion into the air. When the air reaches a sufficient speed, the pressure rises significantly. Typical centrifugal superchargers are of the radial blower type, in which the air enters the blower at the centerline of the casing and exits at the periphery. This type of blower has high volumetric efficiency, but lower efficiency at high speed ratios (source: Wikipedia).
the slowing of the air turns the kinetic energy into pressure energy. For that reason, the boost and airflow throughput of a turbine supercharger are very much interdependent on the characteristics of the engine it is feeding. About this moment, it’s worth making a very pertinent point concerning boost. Most people think that a supercharger’s whole existence is to develop boost, and as obvious as that may seem to be, it’s not quite true. If the goal is the biggest boost number possible, then be aware that welding the intake valves closed will produce the highest boost, but not much power. The real job of a supercharger is to move the greatest mass of air through an engine, which then must subsequently use it effectively. A turbine supercharger can move a great deal of air very effectively. Also, since a centrifugal supercharger’s mode of operation does not involve so much beating of the air, it can, when optimally designed, do so with high efficiency. But there is a downside: its speed sensitivity. As the turbine spins, the boost goes up with the square of the rpm. This means at low speed minimal boost, and at high speed possibly too much boost. Fortunately, a lot of work over the years by a bunch of smart engineers has brought about a number of moves that minimize this characteristic.

To see how the “too much upstairs and not enough low down” situation has been addressed, let us first look at a turbocharger installation. What we have here is an intake turbine driven by a shaft powered by a turbine fed via the engine’s exhaust. In simple terms, the exhaust energy is driving the intake compressor turbine. The general principle is to size the intake turbine such that it is a little too big for the job at high speed. This means it starts to boost the engine sooner, but if left to its own devices, would provide too much boost at high speed. To prevent this, the exhaust side has an exhaust wastegate. When the boost reaches a certain predetermined level, the wastegate opens and bypasses any excess exhaust beyond what is needed. Along with impeller design, this characteristic and the inlet sizing helps spread a turbo’s boost range down into the lower rpm band.

For a mechanically driven turbine supercharger (ProCharger, Vortech, Paxton) of the type originally pioneered by Paxton 60 years ago, we find the situation a little different. Because the drive ratio between the supercharger and the engine is fixed (Paxton did actually develop a variable drive unit used on Ford Thunderbirds back in the late 1950s), limiting top end boost while trying to enhance low-speed boost comes down mostly to impeller design and overall unit sizing. In that area, significant strides have been made just in the last 15 years.

**BOLT-ON POWER: MAKING A CHOICE**

The heyday for blowers of any type starts now, and goes into the near foreseeable future. As for those of you concerned that the push for fuel economy will dampen the enthusiasm for forced induction, it’s time to get used to the “new way” of doing things.
The economy may spell the end of big power, fear not. There are plenty of ways to employ a supercharger to both enhance performance and improve mileage—and that means they are not going away anytime soon. If you are in the market for additional power in the form of a bolt-on, then your only problem is making a decision as to which system you should use.

**WHEN LOW-SPEED TORQUE SETS THE RULES**

If you have a truck (like me) that you want performance from, but it really has to function as a truck and do useful work, then a positive-displacement unit is almost certainly the way to go. My 2000 4.8 GMC Sierra has to haul a payload as much as 10,000 pounds without making the race car to the track. To do this effectively, it needed real low-speed grunt, along with the capability to deliver good mileage. Up to this point, I had experience with the Holley/Weiland kits, Magnuson, Edelbrock, and Whipple, but mostly with the Holley/Weiland and Magnuson stuff. A few years ago, on a mild-cammed 350 with pocket-ported aluminum heads, I saw some 541 hp and 545 lb-ft using a Holley/Weiland blower. That’s a pretty good showing for what is essentially one of the lower-cost installations on the market. But since the truck was to be used for long-haul towing, mileage was very much on my mind, and I had not, up to this point, tested a Magnuson setup with the bypass valve. This valve, also used on the Edelbrock blowers, reduces parasitic losses to nowhere, so what it takes to spin a couple of sets of roller bearings. With mileage in mind, I selected a bypass-valve-equipped positive-displacement kit, in this instance from Magnuson. Because the Magnuson kit was charge cooled via a water-to-air intercooler between the blower and block, it could manage 8 psi on a 9:1 engine without being detonation-prone or octane-sensitive. To make the most of the blower, the stock 4.8 heads were ported, and a Gale Banks exhaust system installed. Dyno tuning was done at Custom Performance, and PCM for us. Results were very satisfying.

Quarter-mile performance showed up just short, by a truck’s length, when run against a stock ’04 Mustang GT. Freeway mileage just missed the 21-mpg mark by a hair’s breadth, while a consistent 17 mpg was seen about town. That was virtually unchanged from stock.

When towing, mileage was surprisingly good. I saw low 14s. Maybe the trick for performance and mileage is a smaller engine with an efficient blower. Since I tested this unit from Magnuson, they have made yet another significant step forward in rotor design. In fact, as we go to press, rotor design seems to be a hot topic and some new developments from Edelbrock are in the works. Some insider info indicates we should stay tuned on this one.

At this point, we can say that for off-idle and low-speed torque, a positive-displacement blower is the ticket. But what if you are happy with the output of your engine up to about the 2,000-2,500-rpm mark? If that’s the case, then a whole slew of supercharger types become a viable bolt-on option, and that’s what we’ll look at now.

**CENTRIFUGAL SUPERCHARGER**

For the most part, the easiest installation is a belt-driven centrifugal blower, rather than a turbo. Although they may lack the low-speed capability of a positive-displacement blower, they can usually deliver a cooler boosted charge, thus allowing more power to be developed before an intercooler or water injection becomes necessary. That said, most installations still take advantage of boost cooling by an intercooler. As a result, a 10-psi ProCharger unit feeding an otherwise stock 4.6-liter, Three-Valve ’07 Mustang shows some impressive bolt-on gains. A ProCharger kit, as per the Mustang shown on p. 64, was able to boost rear-wheel horsepower from typically 260 to just over 460.

This charge temperature factor is a strong point of any centrifugal-style supercharger with an efficient impeller. The bottom line is that when they...
This 540-inch street-cammed big-block Chevy is essentially a simple build. As-cast Dart 325 heads, an 8.7:1 compression ratio, and a Barry Grant blow-through 850 Demon carb make up the essentials. When this was used with a basic non-intercooled F-1R ProCharger and 12 psi of boost, the dyno peak readings were 1,000 lb-ft and 1,080 hp.

get going, they move more air with less heating.
That is the underlying reason why, when it comes to big mid- and top-end numbers, a centrifugal supercharger is the way to go, but should you opt for a mechanical drive (belt-driven), or an exhaust-driven turbo setup?
Like the decision between positive displacement and centrifugal, there are pros and cons for each type of drive. A mechanically driven setup definitely has no turbo lag (which is totally fixable, and is hardly an issue these days), and unlike turbos with their hot exhaust housings, suffer less underhood heat loading. That said, ultimately a turbo setup, which recovers some of the lost exhaust energy, ends up the top contender for total output. Another advantage of the turbo is that it can be sized to come on sooner with the top end boost limited by the wastegate. At the end of the day, both types will produce dazzling performance from most otherwise stock engines—sufficiently so that the problem becomes one of getting all the power to the ground. If the engine is built for supercharging from scratch, the power potential becomes near insane. A couple of projects I have personally been involved with will put that into perspective. A Mustang with a ProCharger-equipped 351 Windsor turned up the dyno rollers to 850 hp, and at that point, just smoked the tires. I estimate it was still more than 1,000 rpm from peak power. A turbocharged small-block Chevy with a Performance Techniques installation, same deal. Both of these vehicles were most certainly over 1,000 rear-wheel horsepower. Even on the grippiest road tires available, neither of these cars would hook up under 120 mph. That’s on a dry road. On a wet road, you had better have a good share of Michael Schumacher’s driving skills just to survive. At the end of the day, here you need to look at cost and ease of installation, as well as personal preferences when making a decision as to which type of system you should go for. If that sounds way out in left field, Underground Racing’s (Charlotte, North Carolina) street turbo Viper conversion is producing over 1,800 hp at the wheels. But let’s get our feet back on the ground here. A more “bolt-on” turbo kit for an otherwise stock engine such as an LS series GM, or Ford’s Three-Valve, unit will respond to the tune of a 200-300 hp increase, with a boost of 8-10 psi. A good example here is the kit offered by Turbonetics for ’05-08 Mustangs. This boosts rear-wheel horsepower from the stock 250-260 to about 500, and all done with less than 10-psi boost.

**SUPERCHARGERS AND BUILT MOTORS**

So far, we have mainly looked at supercharging as a bolt-on for an otherwise near-stock powerplant. In such a situation, the kit manufacturer pretty much takes care of issues that may arise by limiting the power increase, limiting boost, and including an intercooler.
Now let’s move on and consider what issues you may need to address if you are looking for those monster numbers to annihilate the opposition at the track. Basically, we have to address four primary issues: detonation avoidance, control of excess heat, air mass through the system, and finally, the effective and reliable conversion of the air mass throughput into torque and horsepower.

Let’s start with detonation avoidance. The bottom line is that if the engine is strong enough to withstand all normal forces and stresses, then detonation ultimately limits the power that can be extracted from the engine. First, the higher the boost goes, the lower the compression ratio needs to be to avoid detonation. There is a balance to be struck. If part-throttle fuel economy is an issue, then the balance needs to be struck in favor of compression. If ultimate power is the goal, the balance is strongly toward boost. Just how much compression can be used is determined by the engine’s combustion chamber/exhaust-valve temperature, and the fuel’s octane rating. Charge cooling by means of an intercooler and higher fuel octane are the two routes to success.

At this juncture, it is worth pointing out that water injection can effectively solve two critical problems simultaneously. Firstly, the octane rating of water is virtually infinite. (Think about it; just how high would the compression have to be to get water to detonate?) Don’t想象 for one moment that a fine spray of water is going to put out the fire. Spraying even a huge amount of water as a fine mist into a gasoline fire

“Water injection flat works, and if you are in the market for a system, check out Snow Performance.”