TECH

THE
BOOST IS LOOSE

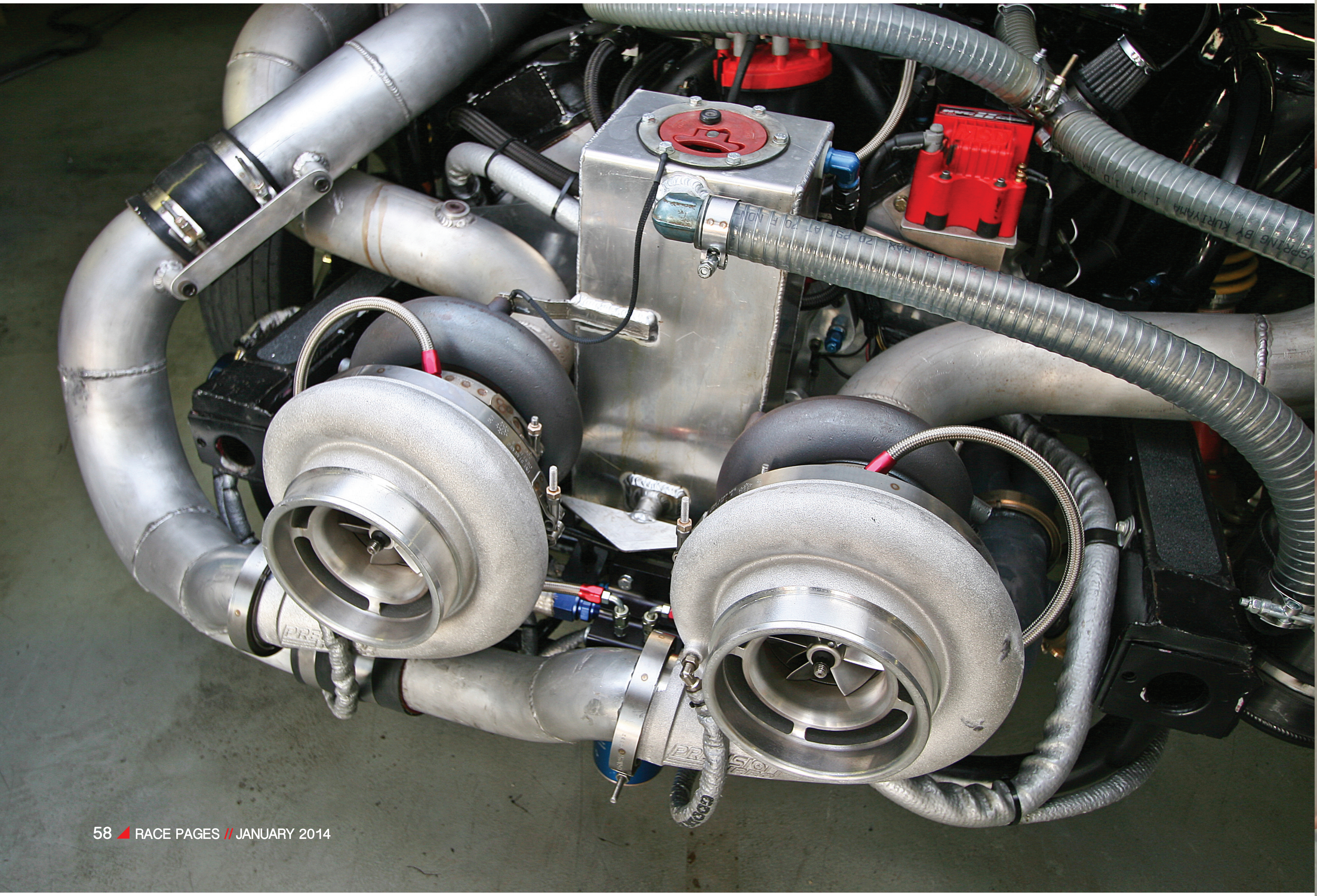
TURBO SPECIAL

Wanna Get in on the Turbo Action?

Here are Some Helpful Tips for Designing and Building a Turbo System the Right Way

BY **STEPHEN KIM** PHOTOS **THE AUTHOR**

The boost is loose, and a glorious era of massive PSI is upon us. Turbochargers have their eyes set on global domination, and as blow-off valves continue popping off pressurized fury with angst and determination, the world of heads-up drag racing has become a much faster place. Not too long ago, 500 rear-wheel horsepower used to be mark of a fast street car. These days, it's merely the difference between the low-boost tune and the high-boost tune on a fast street car. Despite the seemingly limitless horsepower potential they offer, turbo systems are some complicated little demons to design and build, especially for first-timers. So how exactly do you transform boxes of U-bends, flanges, clamps, silicon couplers, and aluminum tubing into a real turbo system capable of spooling out 1,000-plus horsepower? Fortunately, we have friends in high places willing to bestow their battle-tested knowledge upon us.



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The source of our education is one of the most dominant Outlaw drag racers of all-time, Mike Murillo. In case you haven't heard, his iconic SCT-sponsored '93 Mustang rips 6.35 at 241 mph thanks to a pair of Precision 88mm turbos that kick out 3,000 horsepower. The man has owned NMRA and NMCA competition forever, and much to his competition's dismay, he's turned bagging one championship after the next into a yearly tradition. In a highly decorated racing career that stretches back more than 20 years, he's won 14 championships between NMRA, Fun Ford, Clash of the Titans, and the World Ford Challenge competition. When he's not deflating the ego of the guy in the other lane, he's building some of the world's wildest turbocharged Mustangs at his San Antonio-based shop, Murillo Motorsports (www.murillomotorsports.com). To make the most of the opportunity to chat with one of the premiere authorities on turbo system design, Race Pages threw every newbie turbo question in the book at him. From tubing material to primary sizing to intercooling to A/R ratios to wastegate selection to general turbo system layout, we've got it all covered. So if you want to be like Mike, listen up.

SINGLE OR TWINS?

One of the first decisions an aspiring boost junkie needs to make is whether to build a single- or twin-turbo system. Often times, this will be determined more by rules restrictions and weight breaks (or penalties) enforced by the class you're interested in running in rather than any practical advantage of either layout. In a street application, however, single- and twin-turbo systems each have their own pros and cons. Since the turbine wheel is driven by exhaust energy—and a V-8 features two banks of cylinder—the lack of a crossover pipe in a twin-turbo arrangement offers the potential for improved exhaust header efficiency. The absence of a crossover pipe also means that the hot side design of a twin-turbo system is less complex than a single-turbo layout. Furthermore, from a packaging standpoint, fitting two smaller turbos in the tight confines of a late-model engine compartment can be easier than making room for a big single turbo. On the flip side, twin turbo systems require purchasing two turbos, two wastegates, and two sets of oil lines and fittings. The cold side plumbing is also more complex in a twin-turbo system, as two sets of compressor discharge piping must merge together in front of the throttle-body.

Conversely, single-turbo systems have simpler cold side plumbing, but a more complex hot side, as the headers must merge together using a crossover pipe before reaching the turbo. Consequently, the heat loss through the crossover pipe can increase turbo lag. In the all-important speed department, twin-turbo systems held an advantage in ultimate power potential not too long ago. However, with single-turbo cars now running low-seven-second ETs, much of that advantage has been nullified. The obvious drawback of running one enormous turbo instead of two smaller turbos is the challenge of effectively managing the tremendous exhaust flow into and out of the turbo housing. With a large single-turbo system, the wastegate must work overtime to maintain steady and consistent boost pressure, especially in small-tire racing applications that require bleeding off substantial exhaust volume to slowly ramp in the

In naturally-aspirated engines, installing a merge collector in the exhaust system is an age-old trick used to improve performance, as its hour-glass shape increases exhaust velocity. The same can apply to a turbo header, especially since any increase in velocity will spool the turbo more quickly.

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As one of the premiere manufacturers of turbochargers in the world, Precision Turbo & Engine offers a mind-boggling variety of turbos for any imaginable application. By mixing and matching different compressor wheels, turbines and proprietary compressor covers, Precision continually ups the power ante. Just a few years ago, a 67mm turbo could barely muster 750 hp, but now Precision's got 67mm units capable of 1,000 hp. The same goes from 88mm units, which have gone from maxing out at 1,300 hp not too long ago to pushing close to 1,700 hp.

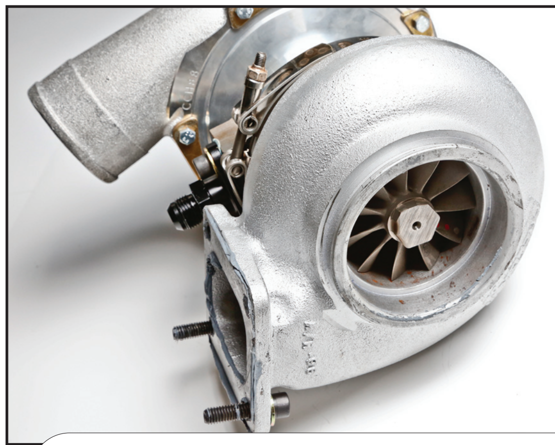
When building a turbo system, there will inevitably be random pieces of tubing and flanges that need to be ordered up even after the bulk of the fabrication is under way. To help you start off on the right track, many companies offer header builder kits that bundle together the most commonly needed components. This Stainless Works kit includes two laser-cut header flanges, 12 J-bends, two collectors, and two filler diamond plates.

boost off the line. As such, it's becoming more common to see dual wategates employed on single-turbo applications, especially with compressor wheels measuring 88mm and larger. Likewise, dumping the exhaust out of one giant downpipe instead of two smaller ones makes a single-turbo system more sensitive to inefficiencies in downpipe design.

MILD OR STAINLESS STEEL

In a naturally aspirated engine, the rust-free benefits of stainless steel headers have helped it earn a reputation of superiority over mild steel. With exhaust gas temperatures that can reach 1,600-plus degrees in a turbo motor, however, stainless steel doesn't always make sense. Although stainless steel offers excellent heat retention properties, it also has a very high coefficient of thermal expansion, which compromises long-term durability. "When we first put the Star Car together, we built the turbo system out of stainless steel. It started cracking after two years of racing, and after we rebuilt the hot side out of mild steel, the headers lasted twice as long," Mike explains. "Stainless steel has a limited number of heat cycles it can handle before it starts cracking. Since street cars see so many more heat cycles than a race car, we highly recommend mild steel. If you're worried about rust, just get the mild steel ceramic coated."

When referencing stainless steel, it's important to distinguish between T-304 and T-321 alloys, which are the most common grades of stainless used in header applications. In a T-304 alloy, the carbon content in the steel combines with chromium molecules at high temperature, which forms chromium carbides. This process is known as carbide precipitation, which reduces the steel's corrosion resistance. Unlike T-304 stainless steel, T-321 stainless is alloyed with titanium to stabilize the metal and enhance heat resistance, particularly at temperatures above 1,600 degrees. This makes T-321 stainless far more resistant to cracking than T-304 stainless, but the enhanced durability comes with a stiff price. While a 2-inch T-304 stainless U-bend costs about $50, a T-321 bend costs twice as much at around $100. In contrast, a mild-steel 2-inch U-bend can be had for $25.



A turbo's A/R ratio refers to the area of the turbine housing cross-section divided by the distance from the center of the turbine shaft to the center of that cross-section. Although the turbine housing reduces in diameter as you move toward the turbine shaft, the A/R ratio remains constant for any given spot along the turbine scroll. As the A/R gets bigger, a turbo will make more power but won't produce boost until higher rpm. Bigger engines typically require larger A/R ratios, while smaller engines need smaller A/R ratios. Since finding the ideal A/R ratio is dependent upon a multitude of variables, when in doubt it's best to consult with a turbo manufacturer.

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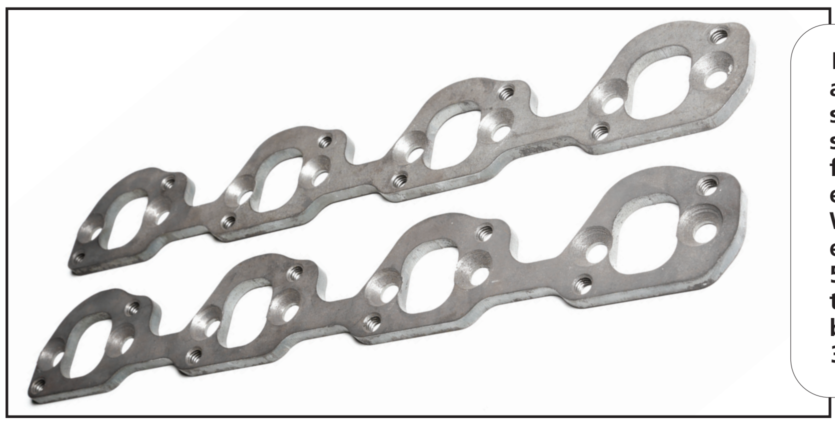


Due to the extreme heat and pressure that a turbo system's hot side is subjected to, thick header flanges are mandatory to ensure leak-free operation. While naturally aspirated engines can get away with 5/16-inch header flanges, turbo motors are much better off with thicker 3/8- or 1/2-inch flanges.

For ease of fabrication and serviceability, both the hot- and cold-side of a turbo system are built in multiple sections. The best way to secure these sections of piping to each other is with a V-band clamp. After welding the V-band flanges onto each end of tubing, the outer rings of the flanges fit snugly into a grooved clamp. Cold-side V-band flanges also feature a rubber O-ring to further improve sealing.

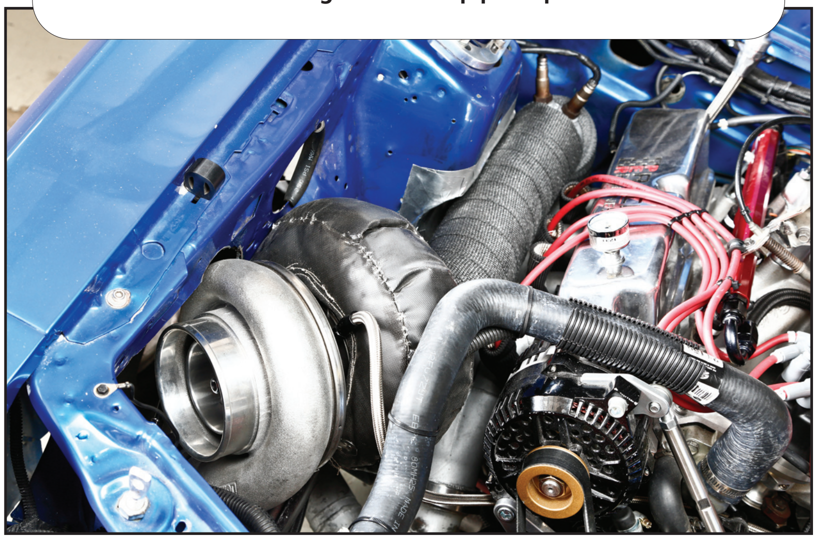
On drag cars that only run for six-seconds at a time, it's not always necessary to run a flex coupler on the hot side of a turbo system. However, since street cars experience constant swings in exhaust temperature, running a flex coupler is a must. It allows for some flexibility and movement in the exhaust side of the system, reducing the potential for cracked pipes. On this single-turbo Mod-motor Mustang, the flex coupler is installed on the crossover pipe.

TUBING DIAMETER

Once you've decided on sticking with mild steel or taking the plunge for stainless, the next step is determining the correct tubing header primary and collector diameter for your application. With the infinite combinations of various engine displacements, cylinder heads, camshafts, compression ratios and turbo sizing, it's impossible to come up with an end-all-be-all rule for selecting tubing diameter. Nevertheless, a good starting point is opting for a similar primary diameter as a naturally aspirated engine combination of similar displacement. For instance, 1.5- to 1.625 inch primaries are a good place to start for 281- to 347ci small-block Fords, while 1.75- to 1.875-inch primaries are well suited for 351- to 434ci Windsor motors. Likewise, 460-plus cubic-inch big-blocks can get away with larger 1.875- to 2-inch primaries. "When in doubt, it's better to go smaller rather than larger. Since exhaust gas velocity is what drives the turbo, the turbo will have a hard time spooling up if you go too big with the primaries," says Mike.

As someone on the forefront of turbo technology that has built countless systems to date, Mike has learned through hardcore track testing that primary sizing isn't nearly as important as collector sizing. "You can go pretty big on the header primary diameter, but you have to be very selective with the collector and crossover diameter, because they greatly impact exhaust velocity. The trend lately is going with larger primaries and more restrictive collectors," he reports. "We recently had Kooks Custom Headers build a brand new set of headers for the Outlaw car, and while I didn't think they would make that much of a difference in performance, boy was I wrong. We increased the header primary diameter from 1.875 to 2.125 inches, and reduced the collector diameter from 3.00 to 2.75 inches. Instead of taking the turbos 10-12 seconds to spool while staging the car, they now spool in half the time. With the old headers, if I wanted to leave the line at 8 psi of boost, the turbos would only spool to 6.5 psi, and the boost wouldn't flat line until later in the run. With the new headers, I can leave the line at 8 psi. The car has picked up 200-300 horsepower just from changing the headers. I totally wasn't expecting that. Remember that this is on a 548ci engine. The smaller the motor, the more important primary and collector sizing becomes because they have a harder time getting the converter to stall."

Downpipe diameter is often determined by packaging constraints, especially in a street car, but bigger is usually better. "If you have the space, go with the biggest downpipe you can get," Murillo advised. "Although you can make the exhaust too big on a naturally aspirated motor, that's not the case with a turbo. Since there's already so much restriction between the cylinder heads and the turbo, you want to flow as much exhaust through the downpipe as possible."



While using V-band clamps throughout most of the cold-side piping prevent leaks, Murillo recommends having at least one silicon connection per turbo to allow for expansion. "The piping in a turbo system moves around a lot from the expansion and contraction of the metal. If everything is solid with V-bands clamps, then you won't have any play in the system," he says. "The piping has to be able to move a little bit, and if it can't, it will find weakest link. Often times the weakest link is he compressor housing, which means it will flex until it touches down on the compressor wheel. That's why you need to have a silicon connection somewhere close to turbo."

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BRACE YOURSELF

Considering that an 88mm turbo weighs over 40 pounds, it's always a good idea to build custom brackets to support big, heavy turbos to the chassis. Race Part Solutions offers turbo flanges that have integral support tabs, which made it easy to weld steel rods to the frame and radiator support in this '93 Mustang. As Mike Murillo explained, "Medium- and larger-frame turbos have to be braced to the car. As turbo piping gets red hot, it gets soft. When you attach a heavy turbo to a header without any bracing, it's like hanging it off of a wet noodle. I recommend bracing the turbo whenever you can."

The trend lately is going with larger primaries and more restrictive collectors.

Properly sizing a wastegate has less to do with power output, and more to do with how much exhaust needs to be diverted. For instance, a car set for 20-plus psi all the time, regardless of max power output, can get away with a small wastegate since very little exhaust needs to be diverted from the turbo. Conversely, a car running just 5-6 psi needs a larger wastegate since large volumes of exhaust must be diverted from the turbo to keep the boost low. Since Murillo's Outlaw car sees 30 psi max, but just 8 psi of boost off the line, it needs one large 50mm Turbosmart wastegate for each of its 88mm turbos.

Whenever two sections of cold-side piping are joined with a silicon connector, the ends of each pipe must be bead rolled to give the clamp a solid surface to dig in to. Taking things one step further, Murillo highly recommends using a boost brace as well. "If you're making 30 psi of boost, when you lift off the gas, the boost will spike up to 60 psi for a fraction of a second until the blow-off valves open up. It is during this brief moment that silicon couplers can pop off and intercoolers can blow up," he says.

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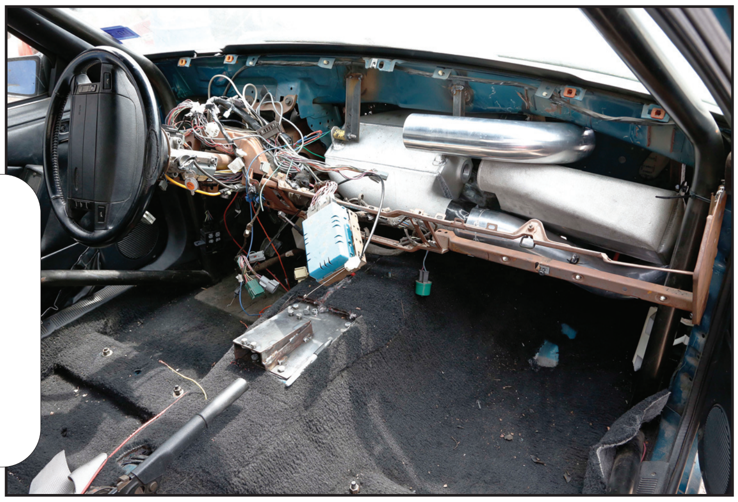
FAB PARTS

To build a turbo system from scratch, you're going to need a whole bunch of raw material, and fortunately, we're here to point you in the right direction. Race Part Solutions (www.racepartsolutions.com) and Vibrant Performance (www.vibrantperformance.com) are great sources for tubing, flanges, silicon couplers, and clamps. For a variety of mandrel bends in addition to a wide selection of collectors, transition tubing, and specialty clamps check out Stainless Works (www.stainlessworks.net), SPD (www.spdexhaust.com), and Burns Stainless (www.burnsstainless.com). Regardless of where you get your tubing from, it's always a good idea to wrap that exhaust to keep underhood temps in check. DEI (www.designengineering.com) has you covered with a catalog full of turbo blankets and exhaust wrap.

The first order of business is determining a horsepower target.

In theory, blow-off valves can be positioned anywhere between the compressor and the throttle-body. Sizing a blow-off valve is very simple, and the pros recommend choosing the biggest one you can get. For twin-turbo setups, that means running one blow-off valve for each compressor. In extremely high boost applications, it's common for racers to fit an additional blow-off valve right before the intercooler inlet to protect it from pressure spikes.



Air-to-water intercoolers can be mounted just about anywhere, so many racers install them in the passenger seat area. For something more sleeper, running two PT1001 intercoolers will still support 2,000 hp, but they are small enough to hide behind the dash of a Fox Mustang.

TURBO SELECTION

As with the single- vs. twin-turbo debate, turbo sizing will often be determined by class rules restrictions, because no one in their right mind is going to run a smaller turbo than the rules allow. In a street/strip application, however, the dizzying array of options can definitely complicate matters. The first order of business is determining a horsepower target. Chances are you'll find multiple turbo units of various sizes that will get the job done, but as long as you have the space for a slightly larger turbo, having some additional airflow capacity in reserve is always a good idea. For example, let's say you want to hit an even 1,000 horsepower. While it's possible to reach that figure with a 72mm turbo, stepping up to an 88mm unit means that you don't have to push the larger turbo nearly as hard as the smaller turbo to make the same amount of power.

Since compressor efficiency drops off as compressor wheel rpm increases and a turbo reaches its maximum capacity, a larger 88mm turbo can operate in the sweet spot of its compressor map—at 70-to 80-percent efficiency—whereas the efficiency of a the smaller 72mm turbo will drop below 60-percent. The resulting decrease in adiabatic efficiency of the smaller turbo adds more heat to the intake charge, which increases the potential for detonation and places more load on the intercooler system. Simply put, a smaller turbo pushed to the max will make less hp per psi than a larger turbo operating in its sweet spot. "When building a turbo combo, there are so many variables that there are no hard rules for turbo selection. Often times, it's best to call a reputable manufacturer like Precision Turbo for advice," suggested Mike. "Just let them know what your goals are, and they can recommend the right turbo for your application. That's the difference between buying from a company like Precision instead of another company with no tech support. You have to rely on companies with experience to guide you, and Precision has recommended thousands of different turbos for thousands of different applications."

INTERCOOLERS

Although it's possible to get away with not running an intercooler by keeping the boost pressure low, where's the fun in that? The process of compressing air adds

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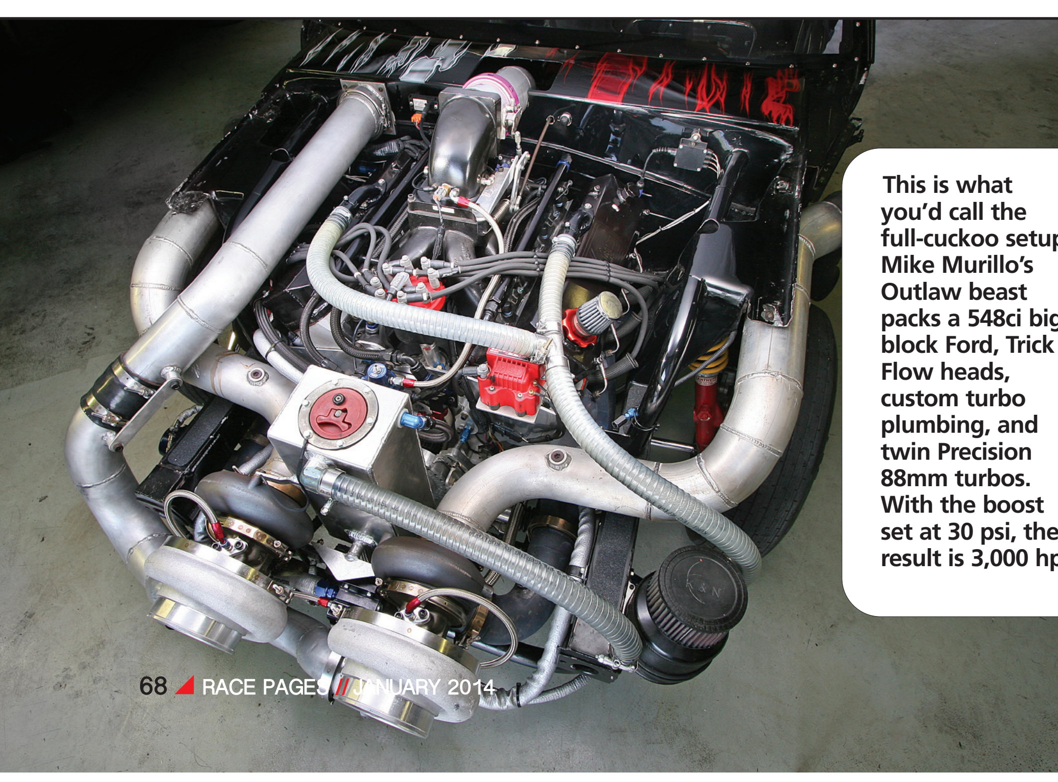
If an off-the-shelf turbo header will suffice for your needs, companies like Stainless Works offers headers for both small- and big-block Fords. This small-block Ford single-turbo header system for Fox Mustangs includes the headers, crossover pipe, a turbo support bracket, and a motor plate.

According to turbo guru Corky Bell, as a cooling medium, water has a heat transfer coefficient that's 14-times greater than air in an aluminum intercooler.

One of the benefits of owning a late-model Mustang is that there are many turnkey aftermarket turbo systems available. Hellion's twin-turbo Boss 302 system features stainless headers, three-inch downpipes, a pair of Precision 62mm turbos, and a Turbosmart blow-off valve for $8,500. It lays down 850 rear-wheel hp on this particular Boss, but is capable of 1,200 hp when boosted to the max.

heat, and intercoolers help remove that heat from the intake charge. This reduction in inlet air temperature increases air density, thereby bumping up horsepower, but determining what type of intercooler works best is dependent on intended power level and packaging considerations. Generally, air-to-air intercoolers are maintenance free and are easier to integrate into the cold side of a turbo system, whereas air-to-water intercoolers require a separate heat exchanger and water pump for the water supply. That said, drag cars don't need a separate heat exchanger, as packing the intercooler tank full of ice water is enough to keep the water from heat soaking during a short pass down the dragstrip.

Granted that air-to-air intercoolers require less hardware to rig up, but the best units on the market are limited to a 1,500- to 1,600 horsepower capacity. According to turbo guru Corky Bell, as a cooling medium, water has a heat transfer coefficient that's 14-times greater than air in an aluminum intercooler. Consequently, for any given hp capacity, an air-to-air intercooler core must be substantially larger than an air-to-water core. For example, a ProCharger air-to-air intercooler rated at 1,550 hp measures 27.5x12x6 inches, whereas a ProCharger air-to-water intercooler rated at 1,800 hp measures 13x9x9 inches. That can make fitting a large air-to-air intercooler into the front of late-model Mustang extremely difficult, and these factors explain why air-to-air intercoolers are very common in street cars, while air-to-water intercoolers dominate the dragstrip. "With a large air-to-water intercooler in our race car, we leave the line with an inlet air temperature of 60-degrees, and at the finish line it's up to 90-degrees. We can make the IAT even cooler, but fuel does not atomize properly when the IAT drops below 90 degrees," Mike explained. "With an air-to-air intercooler, you will typically leave the line with 125-degree IAT, and finish a pass with 200- to 225-degree IAT, which requires reducing the ignition timing. Corky Bell once explained to me that for every 10-degree reduction in IAT, you will see a one-percent improvement in horsepower."



This is what you'd call the full-cuckoo setup. Mike Murillo's Outlaw beast packs a 548ci big-block Ford, Trick Flow heads, custom turbo plumbing, and twin Precision 88mm turbos. With the boost set at 30 psi, the result is 3,000 hp!

SOURCES

Burns Stainless BurnsStainless.com 949 | 631 | 5120	**Precision Turbo & Engine** PrecisionTurbo.net 219 | 996 | 7832	**Turbo Smart** TurboSmartUSA.com 909 | 476 | 2570
DEI DesignEngineering.com 440 | 930 | 7940	**Race Part Solutions** RacePartSolutions.com 561 | 375 | 6277	**Vibrant Performance** VibrantPerformance.com 905 | 564 | 2808
Hellion HellionPowerSystems.com 505 | 873 | 4670	**SPD Exhaust** SPDexhaust.com 888 | 778 | 3312	
Murillo Motorsports MurilloMotorsports.com 210 | 946 | 1199	**Stainless Works** StainlessWorks.net 800 | 878 | 3635	