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Can You Tell Me About Exhaust Systems?

Exhaust Theory

From: www.overboost.com

We've seen too much misinformation regarding exhaust theory. What kind of misinformation? For starters, there are a lot of people in the "Bigger is Better" camp. We're talking about exhaust pipe diameters. Even the big magazine editors are boldly smattering statements like, "For a turbo car, you can't get an exhaust pipe that's too big." Also, terms like "back pressure" and the statement, "An engine needs back pressure to run properly!" really rub us the wrong way.

Let's start from the beginning. What is an exhaust system? Silly question? Not hardly. Exhaust systems carry out several functions. Among them are: (1) Getting hot, noxious exhaust gasses from your engine to a place away from the engine compartment; (2) Significantly attenuating noise output from the engine; and (3) In the case of modern cars, reduce exhaust emissions.

Hardware

In order to give you a really good idea of what makes up an exhaust system, let's start with what exhaust gas travels through to get out of your car, as well as some terms and definitions:

After your air/fuel mixture (or nitrous/fuel mixture) burns, you will obviously have some leftovers consisting of a few unburned hydrocarbons (fuel), carbon monoxide, carbon dioxide, nitrogen oxides, sulfur dioxide, phosphorus, and the occasional molecule of a heavy metal, such as lead or molybdenum. These are all in gaseous form, and will be under a lot of pressure as the piston rushes them out of the cylinder and into the exhaust manifold or header. They will also be hotter 'n Hades. (After all, this was the explosion of an air/fuel mixture, right?) An exhaust manifold is usually made of cast iron, and its' primary purpose is to funnel several exhaust ports into one, so you don't need four exhaust pipes sticking out the back of your Civic.

Exhaust manifolds are usually pretty restrictive to the flow of exhaust gas, and thus waste a lot of power because your pistons have to push on the exhaust gasses pretty hard to get them out. So why does virtually every new automobile sold have exhaust manifolds? Because they are cheap to produce, and easy to install. Real cheap. Real easy. Like me.

"Ok," you ask, "so now what?" Ah, good thing you asked. The performance alternative to the exhaust manifold is a header. What's the difference? Where a manifold usually has several holes converging into a common chamber to route all your gasses, a header has precisely formed tubes that curve gently to join your exhaust ports to your exhaust pipe. How does this help? First of all, as with any fluid, exhaust gasses must be treated gently for maximum horsepower

production. You don't want to just slam-bang exhaust gas from your engine into the exhaust system. No way, Jo-se'! Just as the body of your '94 Eclipse is beautiful, swoopy, and aerodynamic, so must be the inside of your exhaust system.

Secondly, a header can be "tuned" to slightly alter your engines' characteristics. We'll go in-depth into header tuning a little later.

Nextly, exhaust gasses exit from your manifold or header, travel through a bit of pipe, then end up in the catalytic converter, or "cat". The cat's main job is to help clean up some of the harmful chemicals from your exhaust gas so they don't end up in your lungs. In most cars, they also do a great job of quieting things down and giving any exhaust system a deeper, mellow tone. You'll see a lot of Self-Proclaimed Master Technicians (SPMT's) telling people that removing a cat will get you tons of power. There's room for debate on this, but in our experience, removing a catalytic converter from a new car won't gain you much in the horsepower department. It can also get you a \$1500 fine if the EPA finds out! If you drive an OBD-II equipped car, you'll also get that damn annoying CHECK ENGINE light burnin' up your dashboard. (And for all you racers concerned with OBD-II's fabled "limp mode", you can put your fears to rest.)

From the catalytic converter, the exhaust gasses go through a bit more pipe and then into a muffler, or system consisting of several mufflers and/or resonators.

Are you a muff?

Exhaust gases leave the engine under extremely high pressure. If we allowed exhaust gasses escape to the atmosphere directly from the exhaust port, you can well imagine how loud and cop-attracting the noise would be. For the same reason gunshots are loud, engine exhaust is loud. Sure, it might be cool to drive around on the street with that testosterone producing, chest-thumping, 150 decibel roar coming from your car... for about 5.3 seconds. (Not 5.2 or 5.4 seconds... 5.3.) Even the gentleman's gentleman has gotta use a muffler, or system of mufflers, on their exhaust.

Again, you may hear a few SPMT's tell you that "Borla mufflers make horsepower!" Or "An engine needs some backpressure to run properly!" Nonsense. A muffler can no more "make" horsepower than Wile E. Coyote can catch roadrunners. Any technician with any dyno experience will tell you that the best mufflers are no mufflers at all!

Types of Muff

Mufflers can take care of the silencing chores by three major methods: Absorption, Restriction, and Reflection. Mufflers can use one method, or all three, to attenuate sound that is not so pleasing to the ears of the Highway Patrol.

The absorption method is probably the least effective at quelling engine roar, but the benefit is that "absorbers" are also best at letting exhaust gas through. Good examples of absorbers are the mufflers found in GReddy BL-series exhausts, DynoMax UltraFlow, and the good old-fashioned Cherry Bomb glasspack.

Absorption mufflers are also the simplest. All of the above named mufflers utilize a simple construction consisting of a perforated tube that goes through a can filled with a packing material, such as fiberglass or steel wool. This is similar to simply punching holes in your exhaust pipe, then wrapping it up with insulation. Neat, huh?

Another trick absorption mufflers use to kill off noise is, well, tricky. For example, the Hooker

Aero Chamber muffler is a straight-through design, with a catch. Instead of a simple, perforated tube, there is a chamber inside the muffler that is much larger than the rest of the exhaust pipe. This design abates sound more efficiently than your standard straight-through because when the exhaust gasses enter this large chamber they slow down dramatically. This gives them more time to dwell in the sound insulation, and thus absorb more noise. The large chamber gently tapers back into the smaller size of your exhaust pipe, and the exhaust gasses are sent on their merry way to the tailpipe.

Restriction

Doesn't that word just make your skin crawl? It's right up there in the same league with words like "maim" and "rape".

Obviously, a restrictive muffler doesn't require much engineering expertise, and is almost always the least expensive to manufacture. Thus, we find restrictive mufflers on almost all OEM exhaust systems. We won't waste much time on the restrictive muffler except to say that if you got 'em, you might not want to flaunt 'em.

Reflection

Probably the most sophisticated type of muffler is the reflector. They often utilize absorption principles in conjunction with reflection to make the ultimate high-performance silencer. Remember any of your junior high school math? Specifically, that like numbers cancel each other when on a criss-cross? That's the same principal used by the reflective muffler. Sound is a wave. And when two like waves collide, they will "cancel" each other and leave nothing to call a corpse but a spot of low-grade heat.

There are numerous engineering tricks used in the reflective muffler. Hedman Hedders makes a muffler that looks a lot like a glasspack. In fact, it is a glasspack with a catch. The outer casing is sized just-so, so that high-pitched engine sound (what we deem "noise") is reflected back into the core of the muffler... where those sound waves meet their maker as they slam right into a torrent of more sound waves of like wavelength coming straight from the engine. And, this muffler is packed with a lot of fiberglass to help absorb any straggling noise that might be lagging behind.

The Exhaust Pulse

To gain a more complete understanding of how mufflers and headers do their job, we must be familiar with the dynamics of the exhaust pulse itself. Exhaust gas does not come out of the engine in one continuous stream. Since exhaust valves open and close, exhaust gas will flow, then stop, and then flow again as the exhaust valve opens. The more cylinders you have, the closer together these pulses run.

Keep in mind that for a "pulse" to move, the leading edge must be of a higher pressure than the surrounding atmosphere. The "body" of a pulse is very close to ambient pressure, and the tail end of the pulse is lower than ambient. It is so low, in fact, that it is almost a complete vacuum! The pressure differential is what keeps a pulse moving. A good Mr. Wizard experiment to illustrate this is a coffee can with the metal ends cut out and replaced with the plastic lids. Cut a hole in one of the lids, point it toward a lit candle and thump on the other plastic lid. What happens? The candle flame jumps, then blows out! The "jump" is caused by the high-pressure bow of the pulse we just created, and the candle goes out because the trailing portion of the pulse doesn't have enough oxygen-containing air to support combustion. Neat, huh?

Ok, now that we know that exhaust gas is actually a series of pulses, we can use this knowledge to propagate the forward-motion to the tailpipe. How? Ah, more of the engineering tricks we are so fond of come in to play here.

Just as Paula Abdul will tell you that opposites attract, the low pressure tail end of an exhaust pulse will most definitely attract the high-pressure bow of the following pulse, effectively "sucking" it along. This is what's so cool about a header. The runners on a header are specifically tuned to allow our exhaust pulses to "line up" and "suck" each other along! Whoa, bet you didn't know that! This brings up a few more issues, since engines rev at various speeds, the exhaust pulses don't always exactly line up. Thus, the reason for the Try-Y header, a 4-into-1 header, etc. Most Honda headers are tuned to make the most horsepower in high RPM ranges; usually 4,500 to 6,500 RPM. A good 4-into-1 header, such as the ones sold by Gude, are optimal for that high winding horsepower you've always dreamed of. What are exhaust manifolds and stock exhaust systems good for? Besides a really cheap boat anchor? If you think about it, you'll realize that since stock exhausts are so good at restricting that they'll actually ram the exhaust pulses together and actually make pretty darn good low-end torque! Something to keep in mind, though, is that even though an OEM exhaust may make gobs of low-end torque, they are not the most efficient setup overall, since your engine has to work so hard to expel those exhaust gasses. Also, a header does a pretty good job of additionally "sucking" more exhaust from your combustion chamber, so on the next intake stroke there's lots more fresh air to burn. Think of it this way: At 8,000 RPM, your Integra GS-R is making 280 pulses per second. There's a lot more to be gained by minimizing pumping losses as this busy time than optimizing torque production during the slow season.

General Rules of Thumb with Headers

You will undoubtedly see a variety of headers at your local speed shop. While you won't be able to determine the optimal power range of the headers by eyeballing them, you'll find that in general, the best high-revving horsepower can be had with headers utilizing larger diameter, shorter primary tubes. Headers with smaller, longer primaries will get you slightly better fuel economy and better street driveability. With four cylinder engines, these are also usually of the Tri-Y design, such as the DC Sports and Lightspeed headers.

Do Mufflers "Make" Horsepower?

The answer, simply, is no. The most efficient mufflers can only employ the same scavenging effect as a header, to help slightly overcome the loss of efficiency introduced into the system as back pressure. But I have yet to see an engine that made more power with a muffler than an open header exhaust. "So," you ask, "what the hell is the best flowing muffler I can buy?"

According to the flowbench, two of the best flowing units you can buy are the Walker Dyno Max and the Cyclone Sonic. They even slightly out flow the straight through designs from HKS and GReddy BL series. Amongst the worst, are the Thrush Turbo and Flow Master mufflers. We'll flow some of the newer mufflers as they become available at our local Chief auto.

Resonators

On your typical cat-back exhaust system, you'll see a couple of bulges in the piping that are apparently mini-mufflers out to help the big muffler that hangs out back. These are called Helmholtz Resonators and are very similar to glasspacks. The main difference is that firstly, there is no sound-absorbing fiberglass or steel wool in a Resonator. And secondly, their main method of silencing is the reflective principle, not absorption. An easy way to tell the difference between a glasspack and a true Helmholtz Resonator is to "ping" one with your finger. A

glasspack will make a dull thud, and a true Resonator will make a clear "ping!" sound.

Turbos

Another object that might be sitting in your exhaust flow is a turbine from a turbocharger. If that is the case, we envy you.

Not only that, but turbos introduce a bit of backpressure to your exhaust system, thus making it a bit quieter. All of the typical scavenging rules still apply, but with a twist. Mufflers work really well now! Remember, one of the silencing methods is restriction, and a turbine is just that, a restriction.

This is actually where the term "turbo muffler" is coined. Since a turbine does a pretty good job of silencing, OEM turbo mufflers can do a lot less restricting to quiet things down. Of course, aftermarket manufacturers took advantage of this performance image and branded a lot of their products with the "turbo" name in order to drum up more business from the high performance crowd. We're sad to say that the term "turbo" has been bastardized in this respect, and would like that to serve as a warning. A "turbo" muffler is not necessarily a high-performance muffler.

Pipe Sizing

We've seen quiet a few "experienced" racers tell people that a bigger exhaust is a better exhaust. Hahaha... NOT.

As discussed earlier, exhaust gas is hot. And we'd like to keep it hot throughout the exhaust system. Why? The answer is simple. Cold air is dense air, and dense air is heavy air. We don't want our engine to be pushing a heavy mass of exhaust gas out of the tailpipe. An extremely large exhaust pipe will cause a slow exhaust flow, which will in turn give the gas plenty of time to cool off en route. Overlarge piping will also allow our exhaust pulses to achieve a higher level of entropy, which will take all of our header tuning and throw it out the window, as pulses will not have the same tendency to line up as they would in a smaller pipe. Coating the entire exhaust system with an insulative material, such as header wrap or a ceramic thermal barrier coating reduces this effect somewhat, but unless you have lots of cash burning a hole in your pocket, is probably not worth the expense on a street driven car.

Unfortunately, we know of no accurate way to calculate optimal exhaust pipe diameter. This is mainly due to the random nature of an exhaust system -- things like bends or kinks in the piping, temperature fluctuations, differences in muffler design, and the lot, make selecting a pipe diameter little more than a guessing game. For engines making 250 to 350 horsepower, the generally accepted pipe diameter is 3 to 3 1/2 inches. Over that amount, you'd be best off going to 4 inches. If you have an engine making over 400 to 500 horsepower, you'd better be happy capping off the fun with a 4 inch exhaust. Ah, the drawbacks of horsepower. The best alternative here would probably be to just run open exhaust!

Other Rules

A lot of the time, you'll hear someone talking about how much hotter the exhaust system on a turbo car gets than a naturally aspirated car. Well, if you are catching my drift so far, you'll know that this is a bunch of BS. The temperature of exhaust gas is controlled by air/fuel mixture, spark, and cam timing. Not the turbo hanging off the exhaust manifold.

When designing an exhaust system, turbocharged engines follow the same rules as naturally

aspirated engines. About the only difference is that the turbo engine will require quite a bit less silencing.

Another thing to keep in mind is that, even though it would be really super cool to get a 4 inch, mandrel bent exhaust system installed under your car, keep in mind that all of that beautiful art work won't do you a bit of good if the piping is so big that it gets punctured as you drag it over a speed bump! A good example of this is the 3 inch, cat back system sold by Thermal Research and Development for the Talon/Laser/Eclipse cars. The piping is too big to follow the stock routing exactly, and instead of going up over the rear suspension control arms, it hangs down below the mechanicals, right there in reach of large rocks! So when designing your Ultimate Exhaust System, do be careful!



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