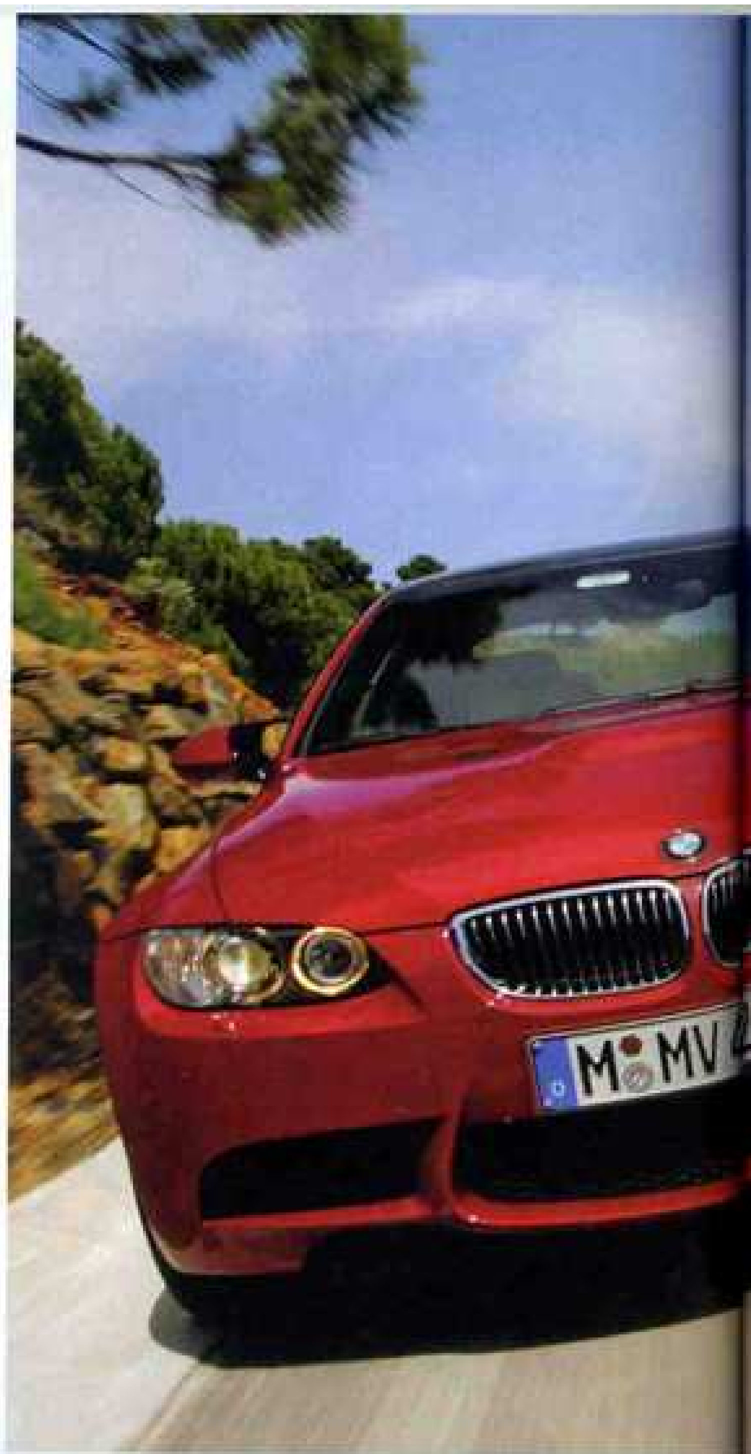

(tech)

Exhaust Anatomy

Part 1: Riffing on the baseline

by Doug Neilson

Supersprint has been designing and manufacturing high-quality performance exhaust systems in Mantova, Italy, since 1955. Its current line of aftermarket applications takes in over 30 manufacturers from Europe, Asia and North America. With this experience, the company has gained a great deal of expertise in full exhaust performance evaluations, ensuring additional power, quality sound and TÜV-approved status for all its street products. Small wonder why Supersprint is also the choice of many high-end European tuners for R&D consulting and the manufacturer of exclusive private label exhaust systems.

Supersprint gave us full access to technical personnel and 'top secret' areas. We'll begin with the preliminary testing sequence done for each OEM exhaust system evaluation. An Audi RS4 FSI V8 was in the R&D facility at the time of our visit and a new BMW E92 M3 arrived a couple of weeks later, so we will use these two machines as our real data examples.

In order to comply with TÜV noise restrictions for street-legal vehicles, Supersprint begins by gathering baseline data on the stock vehicle using standard TÜV methods. There are two parts: the first is the sound level of a stationary vehicle with the revs held constant at 75 percent of the maximum rpm; the second test is measured with the vehicle in motion: starting at 30 mph (second gear for a five-speed, third gear for a six-speed, or D for an auto), the vehicle is accelerated at full throttle for 65 feet. For each section, the microphone is set 25 feet from the center of the road and the motion tests are run in both directions. When the exhaust development prototype is complete, these tests are repeated to ensure the new exhaust is no more than 1dB louder than the OEM item, as per the TÜV standard for aftermarket exhausts (see the table at the bottom of the opposite page).

For a full evaluation of the OEM system's baseline performance characteristics, Supersprint

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selects three or four locations for exhaust pressure and temperature measurements. If the given system is a true dual exhaust, then only one side is used for testing. For the Audi RS4 and E92 M3, Supersprint selected four locations: primary cats, secondary cats, resonator and rear muffler. Two threaded fittings were welded in place at each location to attach Supersprint's proprietary pressure and temperature measuring equipment during dyno testing, and to cap the fittings during the later prototype road testing.

The subject vehicle is then

Stock baseline TÜV sound test results for Audi RS4 and BMW E92 M3

Audi RS4	BMW E92 M3
Stationary test @ 5850 rpm Left: 92.3dB Right: 93.5dB	Stationary test @ 6200 rpm Left: 92.0dB Right: 93.3dB
Motion test, third gear Median value: 73.6dB	**Motion test, third gear** Median value: 73.5dB

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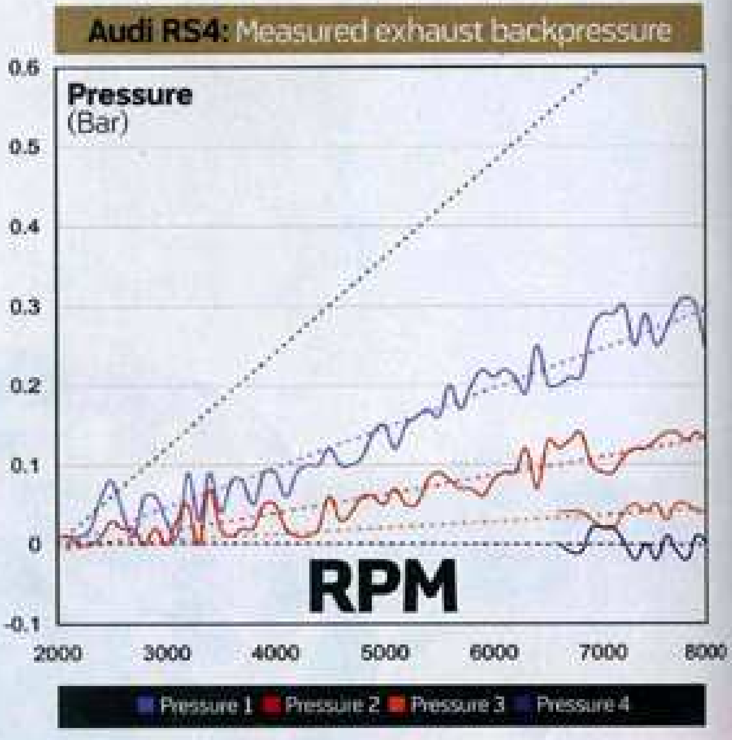
moved to Supersprint's in-house Maha LPS3000 four-wheel chassis dynamometer. The high-tech, German-made Maha is renowned for scrupulously honest methods of power calculation. Baseline pressure and temperature figures are collected along with power and torque data during two types of dyno tests: a fixed-load test where the vehicle is slowly brought up to its top gear and cruised at 60 mph for about 90 seconds per run, and a full-load test (the regular dyno pull we all know and love) where the vehicle is run full throttle from about 2000 rpm to redline in its closest gear to direct drive (1:1, gear ratio to final drive ratio). Both tests are run three or four times for statistical consistency. At the same time, Supersprint also logs various other data through the OBD-II port, such as the air/fuel ratio (Lambda), ignition timing, intake temperature, throttle opening, etc.

On their best runs, the RS4 produced 372 hp and 312 lb-ft, while the E92 M3 put down 416 hp and 301 lb-ft. In part three, we will show the complete before-and-after development curves.

A performance exhaust system should consist of a specific diameter of pipe tubing that optimizes back pressure and exhaust gas velocity for maximum horsepower and torque. This diameter is related to an engine's displacement, performance output and operating range. But there's no magic formula to calculate what should be used. Also, the tubing need not necessarily be constant from the downpipe to the tailpipe (primary header tubes being the exception), due to pressure and temperature changes through the system. Also, bends and curves must be as gentle



Ride the Wave

Muffler design for noise attenuation

Sound is nothing more than energy traveling in a waveform. As with most forms of energy, it's possible to either redirect it or change it into another form. Sound waves from a car's exhaust are no different. A sound wave is generated every time an exhaust valve opens, releasing high-pressure gas into the exhaust port. Then the sound propagates down the exhaust pipe. If you've ever heard an engine with short open pipes, you know how loud an engine is with no sound control apparatus.

There are essentially two ways to decrease (or attenuate) exhaust noise. The first is a dissipative method. Mufflers are filled with mechanical packing; usually steel, glass or synthetic fiber. The theory is that sound travels through the fibers and transforms from wave energy to heat through friction between those fibers. It's an effective method, but sometimes requires more space than is available to achieve the desired level of attenuation.

Because of their design, dissipative mufflers generally give the highest flow rates with the least backpressure. Exhaust gases move through a perforated tube (that's first wrapped in a screen to keep the packing in place). The muffler's internal volume and the size of the perforations determine frequency attenuation. Both factors are employed to tune the muffler to a specific frequency range. These mufflers are often referred to as 'turbo' or 'straight-through' and are common in aftermarket applications.

The second method is reactive. This form of attenuation reflects sound back toward the source instead of allowing it to escape from the tailpipe. There are a couple of reactive muffler forms. The first is a Helmholtz resonator, a cavity of a tuned size used to catch and reverse a specific frequency. This concept is similar to making sound by blowing over the top of a bottle. Energy is absorbed into the chamber in the first half of the cycle and then sent back during the second. Returning sound waves cancel out some new ones, decreasing total energy. It's highly effective, but only within a chosen range.

Another form of reactive noise attenuation is through a low-pass filter, often referred to as an expansion chamber. Whenever there's a change of area in an exhaust system's cross-section, some wave energy is reflected back toward its origin. A low-pass filter is not as efficient as a Helmholtz resonator, but it absorbs a greater range of frequencies. Also, a low-pass filter will still let some sound through, even from the frequency range it is designed to work in.

Many muffler manufacturers employ a combination of both methods. Helmholtz resonators and low-pass filters can be filled with packing material to give a decent amount of dissipative attenuation. OEM exhausts are designed using mostly reactive attenuation, since the mufflers are only being designed for one particular application. Aftermarket manufacturers, however, quite often have universal mufflers for use on several applications, so a design cannot be so highly specialized.

Tip choice can also affect exhaust tone and volume, via changes of the cross-sectional area at the junction with the tip and also where flow goes into the atmosphere. Enthusiasts looking for small changes in sound can do some actual tuning through this method.

When choosing an aftermarket exhaust, enthusiasts can select from several different designs and prices. The muffler type chosen by a manufacturer will give an idea of intended performance. Many of the more expensive systems will offer a higher level of engineering and a more refined sound at closer-to-factory volume levels. More economical systems and those more focused on weight reduction will likely use dissipative mufflers that will be louder and may drone at certain rev levels. If you are concerned about noise and still expect maximum performance gains, it will be well worth the extra investment in a higher-end system.

–Michael Febbo

A. Cutaway of a straight-through (or turbo) muffler designed for maximum flow and using solely dissipative sound deadening. B. A double flow-through muffler that employs perforated pipe and reactive sound deadening. Supersprint avoids baffles, which hinder exhaust flow and can add unnecessary backpressure.

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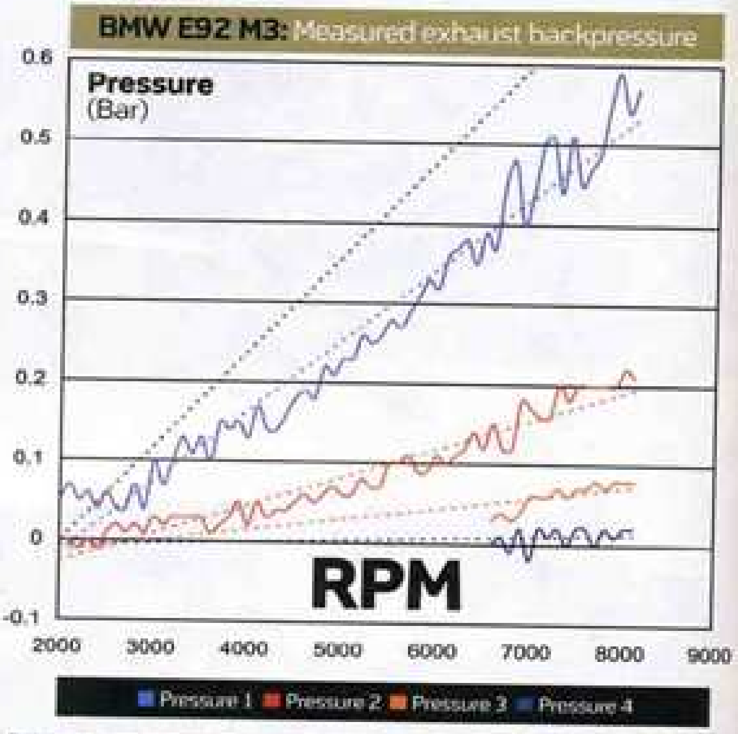
as possible, so as not to create turbulence or restriction. However, available space on a modern vehicle is often limited.

By analyzing the baseline pressure and temperature data throughout the stock exhaust system, Supersprint engineers determine what pipe diameter to use and where maximum performance gains can be made. At each measurement location (or exhaust component) there is a unique back pressure characteristic. The graphs on page 82 and this page show pressure characteristics at the four locations in the OEM system of the RS4 and E92 M3 respectively.

Exhaust pressures increase with revs at each point, decreasing as the exhaust moves through the system. Note that an average vehicle with a 6000-rpm redline will have a 'Pressure 1' value in the 7.3 psi range (dotted black line on each plot), while more sporting models will measure in the 3.0 to 5.5 psi range at 6000 rpm and continue to increase toward their higher redlines. The RS4 and M3 fall into this sporting/performance range and therefore have systems that are well optimized from the factory. However, the new M3 has higher Pressure 1 values, indicating a good candidate for an aftermarket header application. Incidentally, Supersprint is developing a step header for the new M3.

In the next installment of this three-part series, we'll describe the testing and fabricating of a prototype performance exhaust system, and build on our understanding of exhaust flow characteristics and exhaust system design. Then will it become clear how Supersprint engineers can extract more power over a free-flowing factory exhaust system.



-The Audi RS4 (*left*), puts down its power on Supersprint's four-wheel Maha dyno, with full pressure and temperature monitoring of its exhaust system. Pressure and temperature threaded fittings (*top right*) welded in place in the OEM pre-secondary and pre-primary cat position. Fittings are currently sealed (or closed) to allow development to begin at the rear. A good look (*bottom right*) at the Supersprint exhaust tips.