
# Exhaust Anatomy

## Part 2: Step on the gas

by Doug Neilson

*(Left)* A nice, pristine 400-CPI E46 M3 OEM catalyst before being abused at the track. *(Right)* A nasty, melted 400-CPI E46 M3 OEM catalyst after being abused at the track.

**To achieve maximum power** output from a free-flowing performance exhaust, it must be engineered as a complete system from manifold to mufflers. As preliminary measurements on the Audi RS4 and BMW E92 M3 in part one showed, each component has its own backpressure and temperature characteristics. These values must be taken into consideration during prototype development, as the new system will change these characteristics. Temperature data, although not as critical, is also utilized to account for material expansion and to minimize pressure changes.

The main goal in prototyping is to reduce backpressure, while at the same time maintaining or increasing exhaust gas velocity. Development begins at the mufflers and works back toward the cylinder head. This results in a performance exhaust that bolts directly to the OEM system, so individual components may be replaced separately in a convenient modular fashion.

Decisions on which pipe diameters and component variables are dictated by: engine type and displacement, cylinder head design, power and torque output, maximum rpm, camshaft timing, and the physical location of the engine. The process for a prototype cat-back system begins with the fabrication of two or three muffler assemblies with varied pipe diameters and a consistent muffler unit for dyno testing. The system follows OEM routing to clear various undercarriage obstructions. Test one usually results in selecting pipes that are slightly bigger than stock by a few millimeters, but sometimes this remains unchanged. Larger pipes will generate more noise. The muffler selection is more critical to backpressure changes than the pipe diameter itself.

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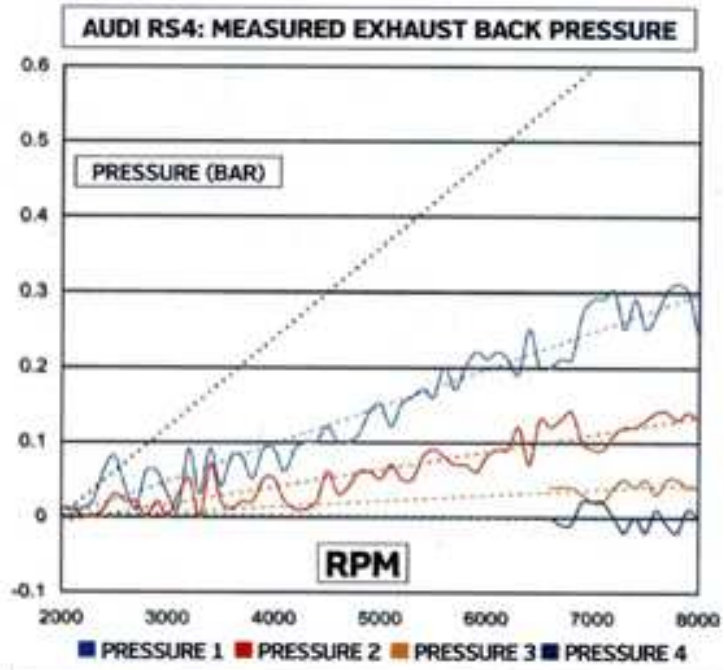
(Above) Inside a catalytic converter. In this case, a BMW E46 M3 Emitec 100-CPI metallic catalyst.

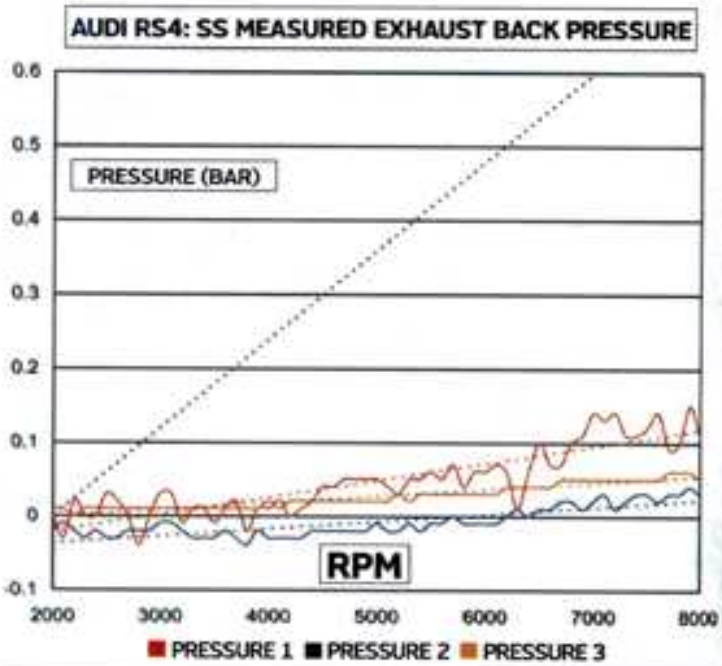
1. Supersprint's metallic catalysts for the BMW E46.

2. Step headers for the BMW E46.

3. This cutaway shows how the Powerloop muffler twists and turns.

4. A look inside a flow-through muffler.

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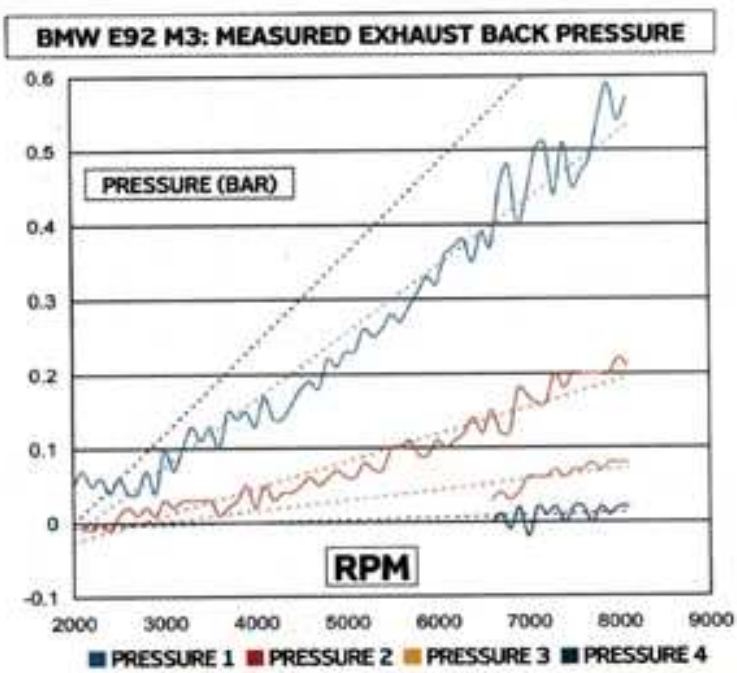
Several different designs with various canister volumes, shapes and inner constructions are tested, and must fit within the original location. Four or five mufflers are tested to determine the ideal configuration for a given application. All those tested use a flow-through resonator to ensure maximum power output—none has chambers or baffles to reduce exhaust velocity by any significant degree.

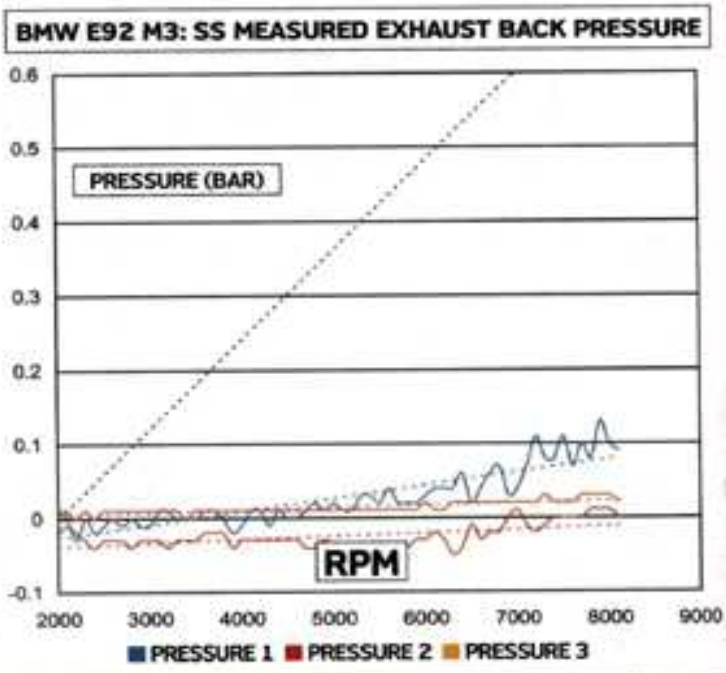
Supersprint currently uses two different types of flow-through resonated mufflers in order to satisfy sound level requirements and conform to the given space of a particular application. The first is the louder 'Sport' single flow-through resonated design, while the second is Supersprint's patented 'Powerloop' double flow-through design. This was developed to conform to the limited space by looping the pipe twice through the muffler housing for additional noise suppression. The longer the exhaust path in a flow-through resonated muffler (whether it be a single or double flow-through design), the quieter the note. Resonators are deleted, unless additional sound cancellation is required to pass the tight European sound emission tests.

Placement, type and size of catalytic converters (cats) in a modern engine's exhaust system are critical to performance. Like many current cars, both the RS4 and E92 M3 have two pairs of OEM cats. Most OEM cats are made with a ceramic (glass) structure or substrate casting which are prone to damage in the extreme heat conditions of a modified engine, or by running at the race track for extended periods. They also restrict flow due to their thick walls and small cells, typically 400 or 600 CPSI (cells per square inch), depending on the vehicle. In a performance application, more expensive race metallic cats should be used. A metallic cat uses a thin metal foil core. The wall thickness of each cell is greatly reduced, resulting in less frontal area of the core surface, and allowing the cells to be larger (100 or 200 CPSI) and less restrictive. The heat resistance of a metal-core cat is much greater than a ceramic equivalent. And metallic cats allow for improved adhesion of the metal catalysts to the core walls, critical for durability.

Supersprint uses high-quality metallic cats and typically replaces the two pairs of restrictive OEM ceramic cats with one pair of low-restriction metallic cats when prototyping. These are manufactured by a German supplier (Emitec/HJS), come in five diameters (93, 108, 120, 130 and 150mm) and in two cell counts (100 and 200 CPSI). The varied diameters and cell counts allow for many volume combinations that alter the backpressure profile throughout the system. On most modern vehicles, the additional performance potential of the cat-back portion is rather limited, as demonstrated by the initial measured exhaust pressures at points three and four of the RS4 and E92 M3 in figures one and two respectively. These pressure measurements, especially on the RS4, are already quite low and there's little room for improved

(*Left*) Everything stops for lunch. Even work at Supersprint's exhaust system digitizing table. (*Right*) A first-pass prototype muffler in the process of being built.

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power output. Fortunately, there's enough potential in the header/manifold and catalytic converter sections to make the prototyping process worthwhile.

Dyno testing two or three diameters with a selected cell count is usually sufficient to determine the optimum configuration for improved power and correct emission compliance. If an emission error code or a 'check engine' light is activated, it is necessary to use the higher cell count 200 CPSI cats (more catalyst surface area), as individual engine types have differing fuel burn efficiencies and engine management systems which must be satisfied.

Header design is one of Supersprint's specialties. The E92 M3 is a good candidate for header prototyping—pressure values before the primary cats were in the 0.3- to 0.4-bar range at 6000 rpm, while the RS4 measures a more sporting 0.2 bar. With the ultimate goal of increases in both torque and horsepower, the prototype headers are designed to use the available space, minimize curves, eliminate any crimps in the piping, match tube lengths (if possible), and match exhaust port diameters.

Two different pipe diameters for the prototype header are dyno-tested to determine the optimum performance output to match the engine displacement and powerband characteristics. In some cases, a step header design is also tested. This patented design uses a smaller-diameter primary tube that starts at the exhaust port and increases to a greater diameter at a specific distance from the cylinder head in one or more steps. The results of step header dyno tests show maximum power gains at high revs, while at the same time maximizing low-end torque. It's also important to test the header merge volume and shape to optimize exhaust gas scavenging, balance, and velocity.

Prototyping is an iterative process. Sometimes it's necessary to further refine and re-test cat-back mufflers after building the headers. This allows for a final fine-tuning of the entire system. Figures three and four show the new pressure profiles for the RS4 and E92 M3 respectively, from the primary cats back (the headers, while designed for the E92 M3, will only be available as part of a full engine performance package exclusively from Hamann, to be released soon). Comparing these pressure profiles with the stock results in figures one and two highlights a significant reduction in backpressure (sometimes negative values) at test points one, two and three. The negative values gathered at test point two are due to the increased flow of the larger pipe diameters, EGT changes during the dyno runs and the low-restriction metallic cats in the newly developed Supersprint systems. In the final installment, we'll describe the materials and processes involved in manufacturing a performance exhaust system and show the power improvements on the RS4 and E92 M3.

**(*Left*) A prototype muffler showing off its muffling. (*Right*) Finishing the exhaust manifold port.**