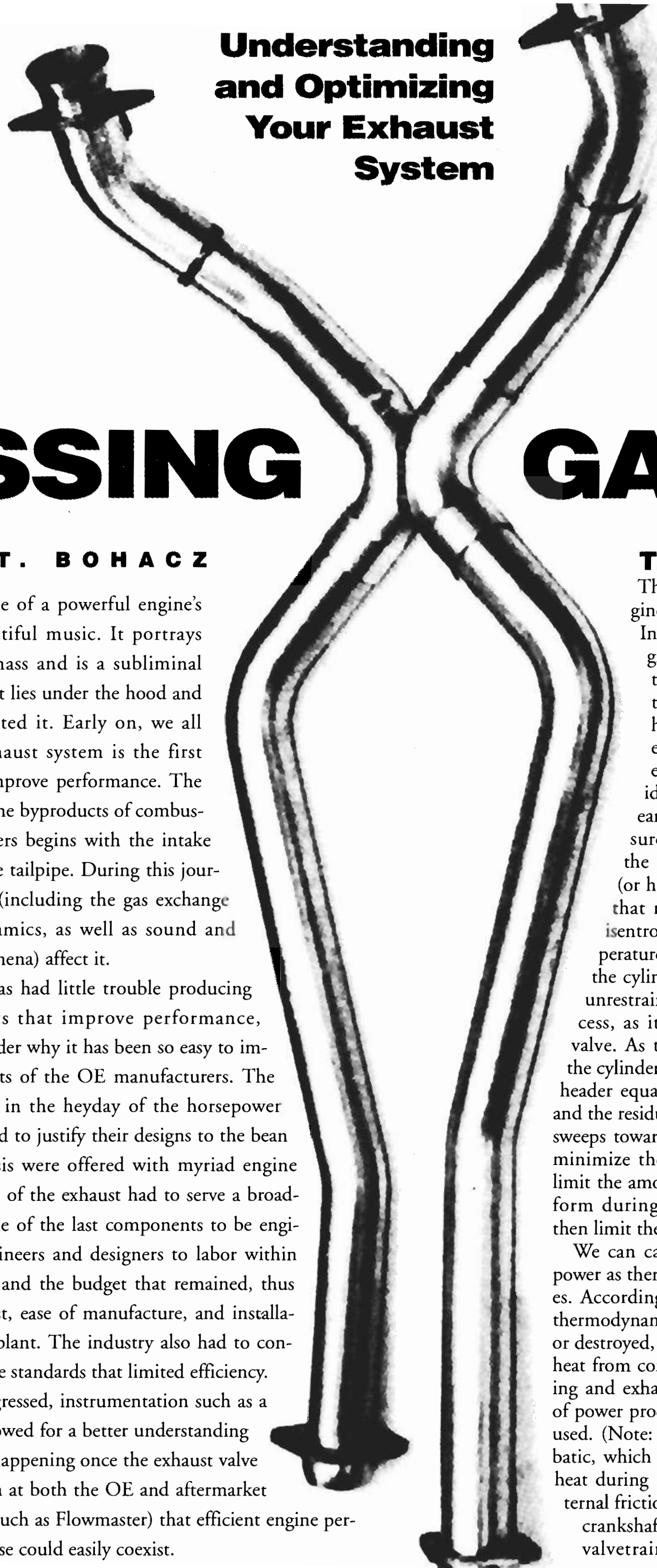
Understanding and Optimizing Your Exhaust System



PASSING GAS

BY RAY T. BOHACZ

The deep baritone of a powerful engine's exhaust is beautiful music. It portrays both strength and mass and is a subliminal representation of what lies under the hood and the nation that created it. Early on, we all learned that the exhaust system is the first place one turns to improve performance. The process of removing the byproducts of combustion from the cylinders begins with the intake stroke and ends at the tailpipe. During this journey, laws of physics (including the gas exchange process, thermodynamics, as well as sound and pressure-wave phenomena) affect it.

The aftermarket has had little trouble producing exhaust components that improve performance, prompting us to wonder why it has been so easy to improve upon the efforts of the OE manufacturers. The sad fact is that even in the heyday of the horsepower wars, engineers needed to justify their designs to the bean counters. Most chassis were offered with myriad engine choices, so the design of the exhaust had to serve a broad-based demand. As one of the last components to be engineered, it forced engineers and designers to labor within the space constraints and the budget that remained, thus function followed cost, ease of manufacture, and installation at the assembly plant. The industry also had to contend with federal noise standards that limited efficiency.

As technology progressed, instrumentation such as a spectrum analyzer allowed for a better understanding of what was actually happening once the exhaust valve opened. It was proven at both the OE and aftermarket levels (by companies such as Flowmaster) that efficient engine performance and low noise could easily coexist.

The Exhaust Stroke

The final phase of a four-stroke engine is identified as the exhaust cycle. In this phase, the exhaust valve begins to open while the piston is stationary at BDC; this ensures that the most complete use of energy has occurred during the power (or expansion) stroke. The instant the exhaust valve begins to open is identified as blowdown, and in the early stages of this process, the pressure in the cylinder is greater than the pressure in the exhaust manifold (or header). During blowdown, the gas that remains in the cylinder expands isentropically (without a change in temperature). The gas that does escape from the cylinder undergoes an irreversible and unrestrained expansion, or throttling process, as it is accelerated past the exhaust valve. As the pressure differential between the cylinder bore and the exhaust manifold or header equalizes, the flow of gas diminishes, and the residuals are then expelled as the piston sweeps toward TDC. The ideal situation is to minimize the amount of residual end-gas to limit the amount of work the piston must perform during the pumping loop, which will then limit the power loss.

We can categorize the areas that consume power as thermal, frictional, and pumping losses. According to the first and second laws of thermodynamics, energy can not be consumed or destroyed, only its state can be changed. The heat from combustion is displaced in the cooling and exhaust systems, limiting the amount of power produced from the fuel that has been used. (Note: The ideal engine would be adiabatic, which means there is no gain or loss of heat during the combustion process.) The internal friction generated by the rotation of the crankshaft and camshaft, piston side-load, valvetrain, and oil and water pumps all