Project 911S

Part 10: Feeding and nurturing the induction and exhaust systems

by Mitchell Sam Rossi
PHOTOS BY THE AUTHOR

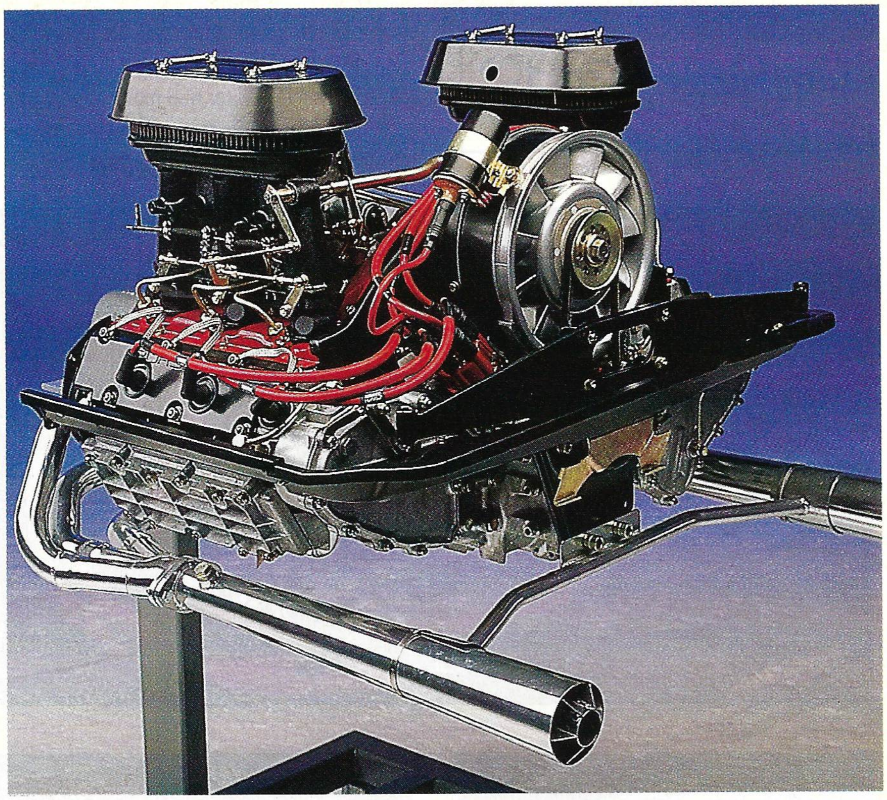
"Think of it like this," suggested Gus Pfister of Pacific Fuel Injection, one of the leading refurbishing shops for Bosch mechanical fuel injection pumps. "Instead of being etched into a computer chip, the fuel map is engraved here." Between fingers roughened by decades of solvents and oils, the veteran of Bosch wizardry held a three-dimensional cam, a thick, odd-shaped ring of dark steel. Pfister pointed to the cam's gnarled surface. "This is the pump's mechanical brain," he grinned, certain I would see the analogy.

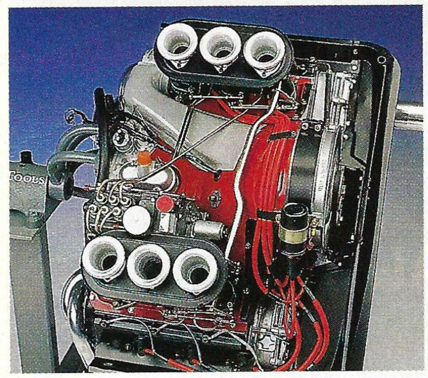
Though completely mystified, I nodded enthusiastically. His brow gathered under a scatter of brownish-gray hair as he withdrew into his labyrinth of workbenches and testing machines, looking for a simpler way to explain his life's work to the dimwit who had stepped through his door.

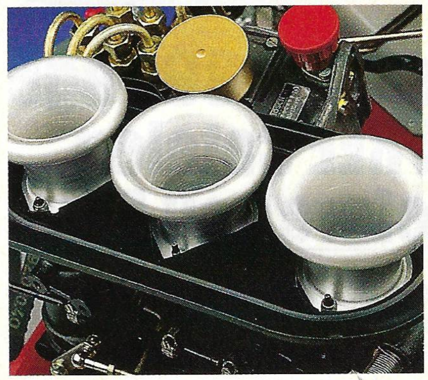
In 1969, after producing its boxer motors with a variety of carburetors, Porsche topped the E and S models with mechanical fuel injection. The Bosch system had proven itself in the 906E race cars, early tests showing an increase in horsepower and fuel economy—both important advantages for long runs to the checkered flag.

The number of Bosch pumps awaiting Pfister's magical touch not only spoke of his meticulous work but also of the MFI's durability. The last time a street 911 rolled out of Stuttgart equipped with mechanical fuel injection was 28 years ago. In late 1973, the 911T was fitted with Bosch's K-Jetronic Continuous Injection System (CIS), and from then on it has been a continuing evolution toward semi-electronic to fully computer-controlled fuel systems.

In the early years, however, the electronic injection was not up to the task of feeding Porsche's highly-tuned racing motors, and the factory continued to rely on Robert Bosch's hardy units for their competition machines. Following this wisdom, the new 2.7-liter motor inherited the Bosch components from the







Clockwise from above: Form, function and beauty. The high-powered elegance of a Porsche 2.7-liter motor. TWM's velocity stacks top the project car's new powerplant.

original S engine.

The mechanical injection system seems simple. Fuel is initially fed to the Bosch unit by the car's electric fuel pump. The fuel is dispersed to six plungers that are articulated by a small camshaft driven at half the engine speed by a toothed belt running off the left engine camshaft. The plungers pressurize the fuel as it sends it to the cylinder head injectors at the precise moment the pistons enter their suction stroke.

Again, simple—at least until the parameters that determine the air-fuel mixture are taken into account. The main regulating element in the pump is the control rack, a pencil-sized shaft with vertical teeth machined into each side. The plungers, wrapped with corresponding toothed sleeves, are set in two rows with the rack running down the center. The back and forth movement of the rack adjusts the entire fuel flow.

All the devices that influence the fuel mixture—throttle position, engine speed, temperature and atmospheric pressure—activate the control rack. But, where they converge in the pump's rear housing is nothing less than an astonishing maze of levers and springs.

For temperature input, a thermostat uses air coming from the engine's left heat exchanger box. The warmed air manipulates bimetallic washers to affect the control rack. The decision to replace the exchangers with headers on the 2.7-liter made the thermostat useless and, therefore, it was eliminated from the pump.

When driving in the mountains or in severe weather conditions, the pump relies on a barometric cell to adjust the mixture, again via a lever connected to the rack. As this component only benefits the system, it was retained.

On the first 2.0-liter MFI engines, the pump was equipped with two solenoids, one for cold starts and one to switch off the fuel supply when the car was coasting. For the 1970 cars, the cold start solenoid was removed, its duty being transferred to the secondary solenoid atop the fuel filter. An initial turn of the ignition key signals the solenoid to allow a pulse of fuel to be squirted directly into the velocity stacks via brass lines running through the air box.

The shut-off solenoid, activated by a micro-switch on the throttle linkage, moves the control rack to the off position during deceleration. Below 1300 rpm, an rpm-transducer interrupts the solenoid, releases the control rack and allows the engine to idle. This interruption to the fuel source when coming to a stop or coasting not only yielded better fuel economy but also aided Porsche in meeting the ever tightening U.S. emissions standards.

The principal element to the Bosch pump is the three-dimensional cam and its ability to implement the engine's fuel map, the predetermined air-fuel mixture required for the optimal performance at various engine speeds and throttle input.

A bearing-like roller, attached to a lever and ultimately to the control rack, reads the engraved hills and valleys as the cam maneuvers beneath it. Changes in the accelerator pedal rotate the cam left and right, while engine speed shifts it forward and back via a spring-loaded centrifugal governor. The third dimension is attained from the vertical contours inscribed into the cam's surface.

By design, each engine type requires a particular fuel map that is determined by displacement, compression ratio, camshaft profile, the size of its intake and exhaust ports, throttle valves and muffler.

For a factory-built 911 engine, all the variables were known and taken into account by the engineers who manufactured the corresponding 3-D cams. While the Bosch MFI system has some latitude for certain changes in a motor, trouble ensues when one or more of these quantities are taken to the extreme by engine builders and tuners.

From the back of his shop, Pfister brought out several large sheets of paper rolled into a tight tube. He hustled the rubber band off and spread the pages across a workbench. Yellowed with age and printed in German, they are

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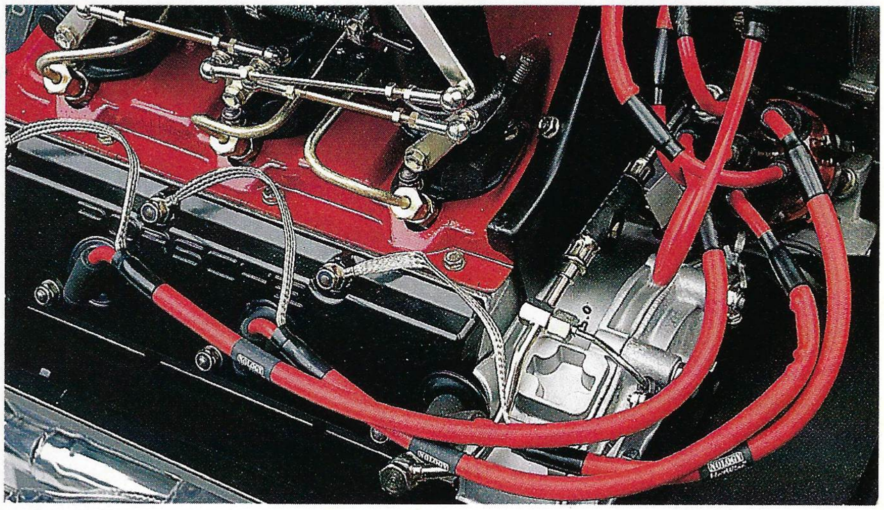
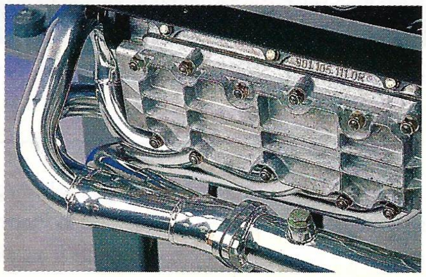
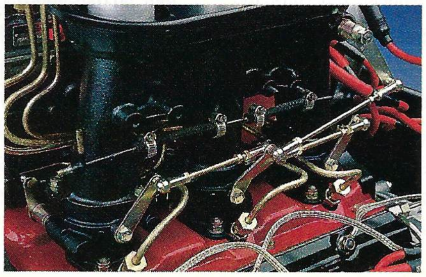
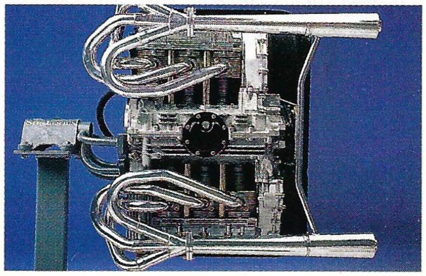
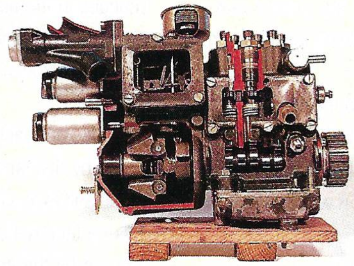
Porsche's fuel charts, the schematic representation of horsepower vs. air-fuel mixture. The top page is for the 2.8-liter RSR motor. "Every time you make a change to your engine," Pfister stressed, "the fuel map should be changed."

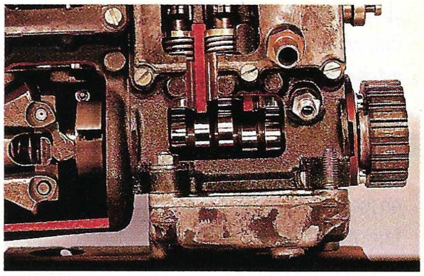












Left to right, descending: 1. Spark-enhancing HotWiresJ from Performance Products weave about the engine cowling. **2 &3.** Gilded with Jet-Hot Coating's ceramic finish, the headers frame the engine's Carrera valve covers. **4.** Eurometrix's pristine throttle body linkage. **5**. A rare view of the 2.7. European Racing Headers by George with Jet-Hot Coating's premiere finish. **6 & 7.** Bosch mechanical fuel pump cutaway.

"I can estimate what the engine requires from experience, but it is never going to be as accurate as this," he said, stabbing a finger at the chart. "That's why I strictly recommend to everybody who builds an engine to stay as close as possible to the original factory specs."

In 1972, the size of the 3-D cam was increased to further improve fuel metering. Thus, the pump taken from the 2.2-liter engine could not be converted to the RS specifications necessary for the project car's motor. Instead, a 1973 T pump was built to meet the fuel systems requirements.

At the cylinder head, the 2.7-liter received a new set of injectors from Performance Products, the aftermarket parts distributer in Van Nuys, California. Often overlooked, the injectors must atomize the fuel completely and evenly across the combustion chamber. Failing to do so results in an uneven burn and loss of potential horsepower.

Beyond reliability, another benefit of the MFI over the later CIS is the induction system. The 1970 911S used six 38mm-wide throttle plates, creating an air inlet totaling 228mm in diameter. In comparison, the 1978 911SC CIS injected 3.0-liter motor was topped with a single throttle body measuring a mere 63mm.

While engine building seems to be nearing the sophistication of rocket science, one basic rule remains: More air volume drawn into the cylinder allows for more fuel, which directly translates into more horsepower.

In a further quest for air flow, Performance Developments, a high-performance and race preparation shop in Costa Mesa, California, widened the upper opening of the stock aluminum induction stacks from 42mm to 48mm.

The original steel velocity stacks were replaced with high-quality spun aluminum units from TWM Induction. Specializing in competition inductions systems, TWM's most recent victories include the Le Mans-winning Chrysler Vipers.

The smooth surface and tulip shape of TWM's velocity stacks lower the air-flow resistance increasing air intake from 22 to 24 percent. Tested on Performance Developments' flow bench, the larger diameter of the induction stacks, along with the new air horns, increased the air flow from 284.0 cu ft per minute to 293.0 cfm.

To remove any possible choke point, the original air box was replaced with K&N air filters purchased from Performance Products. Although the K&N mounting plates can be bolted directly to the top of the induction stacks, in order to keep the air flow as clean as possible, Jeff Erickson, the engine's builder and the owner of Randall Aase Motors, suggested moving the cover plates away from the crown of the velocity stacks. This was

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done by cutting the lower portion of a stock air box in half and welding the K&N plate directly to it. The K&N plate was modified so the air horns would bolt to the induction stacks.

When making this modification, clearance under the rear deck has to be considered. As the S was going to wear a ducktail spoiler, we were limited to increasing the height of the air filter shields to just over an inch.

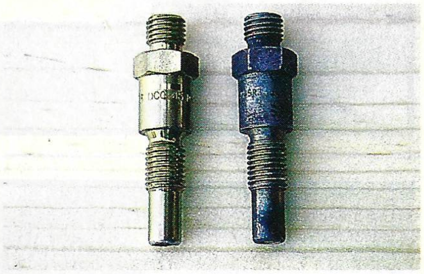
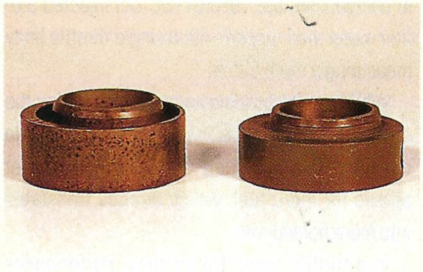
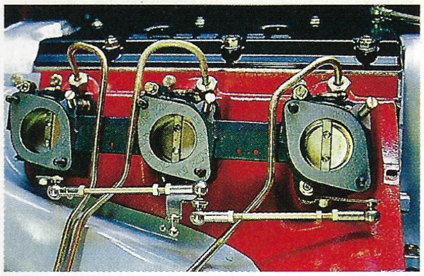
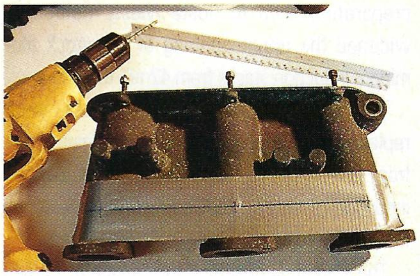
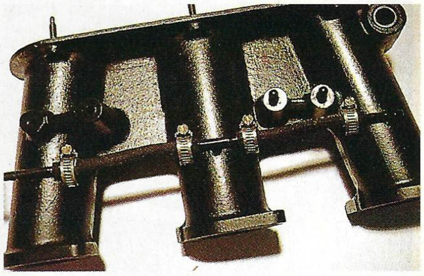
The major hurdle with replacing the stock air box is relocating the cold-start system. On the original 2.2-liter motor, the cold-start solenoid sent fuel to a pair of brass rods running above the velocity stacks inside the air box. Beginning in 1972, the 911 induction stacks were made of plastic with cold-start fuel squirters molded into the side of each tunnel.

This arrangement was recreated with brass tubing carefully cut and soldered into six T-shaped squirters. One end was filled with solder, then opened with a .050-in. drill bit to create the squirter. Holes angled downward were drilled into the induction stacks, and the tubing was cemented into place. The tubing was linked together with fuel line hoses and clamps.

While all these steps enhanced the initial air flow into the induction system, the improvements were restrained by the car's competition class, which prohibited any modifications to the MFI's throttle bodies.

"That's going to be your limiting factor," said Matt Blast of Eurometrix, a premiere renovator of Porsche carburetors and Bosch MFI throttle bodies. Blast noted that the bottom diameter of the 1969 911S induction stack was similar to the project car's but were 45mm at the top, leading us to believe that our modifications to the stacks would ultimately prove beneficial.

Like the induction stacks, the throttle bodies


Left to right, descending: 1. Fuel injectors, new vs. old (l to r). **2.** 2.7RS three-dimensional cam (right) vs. 2.2S three dimensional cam (left). **3.** Refurbished 1970 911S throttle bodies. **4.** Drilling 911S induction stacks for cold-start squirters. **5.** 911S induction stacks with cold start squirters and fuel lines. **6.** Rich Creedon works the flow bench at Performance Developments.

were mooched from the 2.2-liter motor. Over the 22 years I had owned the S, the bodies had never been rebuilt and were in dire need of a complete overhaul.

"The pre-'72 throttle bodies had steel bushings, so it didn't take much in terms of mileage to wear them out," Blast said. "That gives you excessive slop in the throttle shafts. Instead of drawing a precise quantity of air into the system, you have a sporadic amount." This leakage, Blast pointed out, often prevents the engine from holding a proper idle, causes popping and can keep the car from being correctly tuned. "Newly rebuilt throttle bodies with calibrated linkage rods will give you the exact air-fuel mixture."

Once the fuel pump, induction stacks and throttle bodies were set to generate optimal horsepower, the next component to consider was the exhaust system. Removing the heat exchangers not only promised better performance but also eliminated nearly 25 lb from the rear of the car.

George Narbel, of European Racing Headers by George, offered the recipe for the proper header design. "You try to keep the tubing length as equal as possible," he said. "Of course, that's not always easy due to clearance situations." Located in Henderson, Nevada, Narbel's shop builds exhaust systems exclusively for 911, 914-4 and 914-6 engines.

"It is the exhaust flow that is important," Narbel said, noting that not only does he match the lengths of each tube but also the diameter of the megaphones. For a stock motor with three 35mm exhaust ports emptying into one header, the end of the megaphone should have a maximum opening three times that diameter.

"The moment the exhaust valves open, the exhaust gases must leave under a certain amount of pressure that should remain constant all the way to the end of the system." Of course, like the induction system, this formula varies with compression ratios, cam profiles and the like, but unless a customer has specific needs, Narbel tunes his headers for a strong mid-range response.

Cooled only by air and oil, excessive temperature is always a major concern with 911 engines. As the exhaust system weaves beneath the cylinder heads, what heat is not dispersed by the air flow passing across the headers is transmitted back to the engine, reducing longevity and robbing horsepower. This re-emitted heat can also affect the adjacent components, such as the transmission, brake and fuel lines and, most importantly, the rear shock absorbers.

To combat this, the header/megaphone system was sent to Jet-Hot Coatings to be dressed with its premium ceramic finish. At first glance, the chrome-like shine looks merely cosmetic, but the coating, applied both inside and out, carries a high value in thermal reduction. "It actually puts up a wall that prevents a portion of the heat from reaching the metal," said Jim Wieszczyk, Jet-Hot's director of special programs. "That means a lot less radiant heat on the outside of the headers." In many cases, Wieszczyk said, the heat absorption is reduced by as much as 30 percent.

The anti-corrosion quality of the coating also lends itself to be used on other components. Builders of street rods use Jet-Hot on the suspension, hardware pieces and throughout their well-tended show cars. Yet, while the cosmetics of the coating is secondary for the project car, the treated headers and megaphones add an unexpected gleam.

Throughout its 37-year history, much has been written about the 911 engine. Most have revered its breathtaking power and its ability to transport car and passengers from comfortable to thrilled within seconds. Countless essays have herald its long, raspy voice as a near-angelic tone sung *a cappella*.

Yet, one pleasure that is easily missed is the engine's beauty, perhaps because it is tucked so tightly beneath the rear deck or that it is unusual to be inspired by a piece of modern machinery. But, in both function and form, the power source of the 911 is simply a masterpiece, the ultimate expression of kinetic art.

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