CHAPTER 16

FUEL INJECTION

I approached the subject of fuel injection with some trepidation, as would many shade-tree mechanics my age. We all grew up with carburetors, so this newfangled fuel injection stuff was pretty foreign. But once I pierced the mystery about these systems and started working with them, I found that they were, in general, much easier to convert to alcohol than carburetors, and that it was possible to conserve a lot more fuel.

HISTORY

Historically, carburetors' crudeness at responding to the needs of the engine at different points in the engine cycle meant a general overuse of fuel and a correspondingly high level of emissions. Over a ten-year period, carburetor manufacturers tried to make adjustments—and the price soared. So, driving fuel-injected cars became more attractive to consumers.

Fuel injection did not magically appear in the 1970s. Diesel vehicles began using high-pressure mechanical direct fuel injection in the late 1920s. In the early 1930s, some European two-stroke gasoline engine manufacturers were using timed mechanical fuel injection on cars in an attempt to reduce the loss of around one-fourth of the fuel—the intake and exhaust valves were both open at the same time, and the raw air/fuel mixture was going out the exhaust without ever being burned.

The first well-known four-stroke fuel-injected engines were the 1952 Mercedes M196 Formula One racer and the 1954 300SL gull-wing sports car,[1] both developed by Bosch. These early systems, although better than carburetion, shared many of its limitations. They were also solely air/fuel systems, and had nothing to do with other parts of engine control, like spark advance. The early systems operated best at wide-open throttle (WOT) or at idle, but had many idiosyncrasies at the partial throttle settings and during acceleration.

FUEL INJECTION SYSTEMS ARE GENERALLY ALL CARBON STEEL WITH GENERALLY ALCOHOL-PROOF MATERIALS. THEY REQUIRE AT LEAST 185+-PROOF FUEL, AND, IF POSSIBLE, 192+-PROOF. LOW-PROOF, ACID-CONTAMINATED ALCOHOL COULD DAMAGE FUEL INJECTION SYSTEMS BY PULLING LEAD OR TIN FROM SOLDER, OR BY CAUSING RUST. IF YOU ARE USING HOMEMADE ALCOHOL OF SUSPICIOUS ORIGIN, USE A CORROSION INHIBITOR—ONE-HALF OF ONE PERCENT OF A SYNTHETIC, ALCOHOL-SOLUBLE, TWO-STROKE OIL; OR ABOUT THE SAME PERCENTAGE OF BIODIESEL—TO LENGTHEN PUMP AND INJECTOR LIFE.

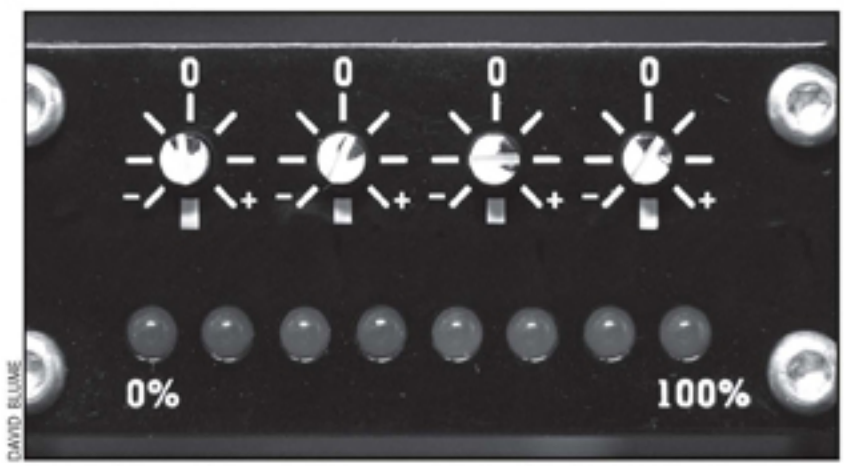

Fig. 16-1 Mass air tuner. *The four screwdriver-adjustable knobs adjust the varied conditions an engine encounters, from idle to wide-open throttle. The knob on the left is for idle, the next one's for initial acceleration, the third for high-end acceleration, and the last on the right for WOT. This unit can also be plugged into a laptop for more precise adjustment.*

Innovators quickly figured out that direct injection and timed, high-pressure delivery of fuel weren't required in gasoline engines! After all, carburetors delivered fuel full-time outside the cylinder into the engine manifold without exotic high-pressure injector timing. Early racers came close to matching fuel injection's even fueling of each cylinder by having manifolds that sported a carburetor for each cylinder.

So, for gasoline, indirect low-pressure systems were created that either delivered fuel on top of the manifold where the carburetor normally would be, or sprayed it directly on the outside of the valves where the head and intake manifold meet. Although many of these early systems did pulse the fuel on and off, it became unclear whether pulsing fuel was necessary. Fuel delivered outside the cylinder would be sucked into the engine each time the intake valve opened, dozens of times per second. Some companies even dispensed with pulsing altogether and instead continuously injected fuel.

But acceleration required increasing the amount of fuel periodically. The increase in fuel for different levels of acceleration came from systems that would either increase the pressure in the fuel line feeding the injectors, or increase the rate of flow to a fuel distributor that had individual lines running to an injector pointing at each set of intake valves.

Fuel injection, even in these early systems, successfully cured many problems that occurred in carbureted engines. First, delivering fuel to the top of each cylinder, instead of sending it down a long manifold, all but eliminated puddling. The fuel atomized better, and there was no unequal feeding of cylinders, which could create a very lean condition in some of them. These lean mixtures would tend to ping, so engines had to be designed with low compression ratios, since high compression would work great for the cylinders with enough fuel, but cause even more destructive pinging in lean cylinders.

Other benefits of fuel injection became apparent. Since you didn't have to contend with manifold puddling, then you didn't have to use exhaust heat to raise the temperature of the manifold. The engine could "breathe" better, using cooler, denser air. And, as with carburetors, there tended to be extra fuel delivered in many partial acceleration throttle situations to ensure smooth running.

The one drawback was that some unburned mixture would still be lost when both exhaust and intake valves were open. More precise systems were still to come.

The next big advance, which formed the basis of modern fuel injection, happened in the early 1950s. The "Electrojector" was developed by the Bendix Aviation Corporation. Instead of continuous injection with mechanical controls to increase fuel delivery, an electric valve known as a solenoid was installed on each injector. This valve pulsed open each time electricity coursed through the valve and closed when electricity was withdrawn. The amount of fuel delivered depended on how long the valve was kept open during each pulse (pulse width). So the valve would open a fixed number of times per minute, but the time it was open would vary. During idle, the solenoid valve would open very briefly during each pulse. Under sustained acceleration, the time open would greatly increase until it was almost half or more of each pulse cycle.

The pulse width was controlled by the first electronic "brain box," forerunner of the modern electronic control unit (ECU). Long before computer chips, the earliest version calculated the needs of the engine using vacuum tubes.[2] Sensors measured manifold pressure, engine speed, atmospheric pressure, and air and coolant temperatures; this information was routed to the brain box for calculation of fuel pulses. This was the first truly electronic fuel injection (EFI).

Although the Electrojector was tried on a few models of cars, it wasn't ready for full production until 1965, at which point the manufacture was turned over to Bosch. It then appeared for the first time in the transistorized (no vacuum tubes) 1967 Volkswagen 1600.

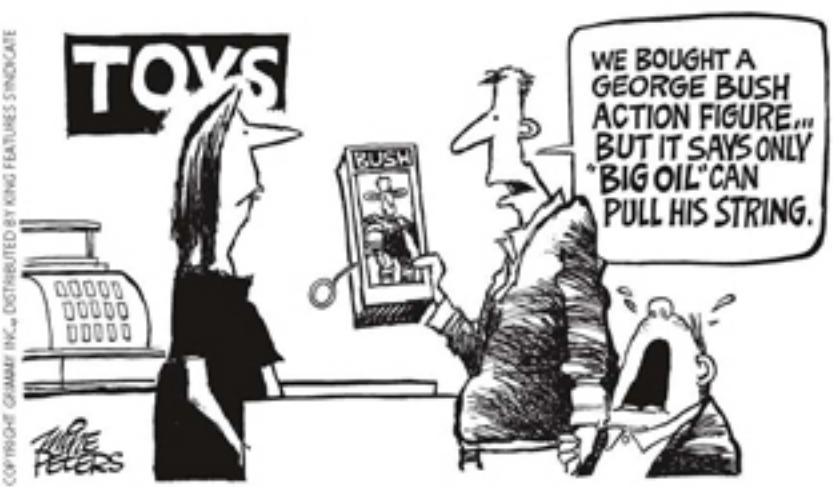

Fig. 16-2