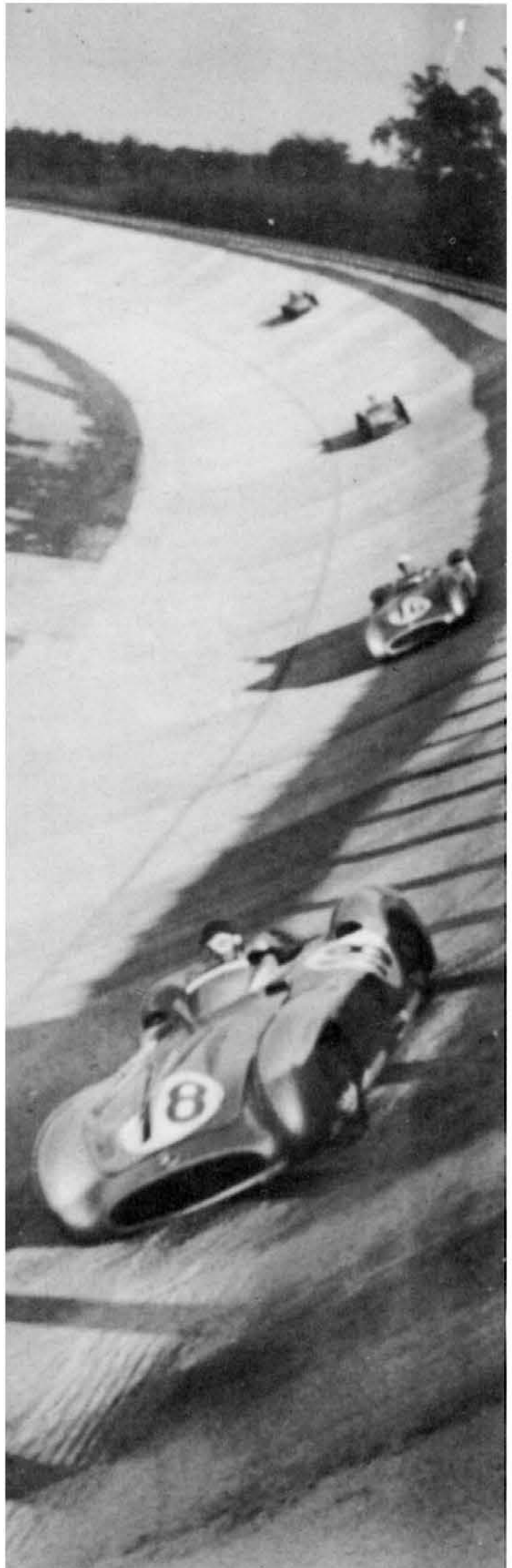
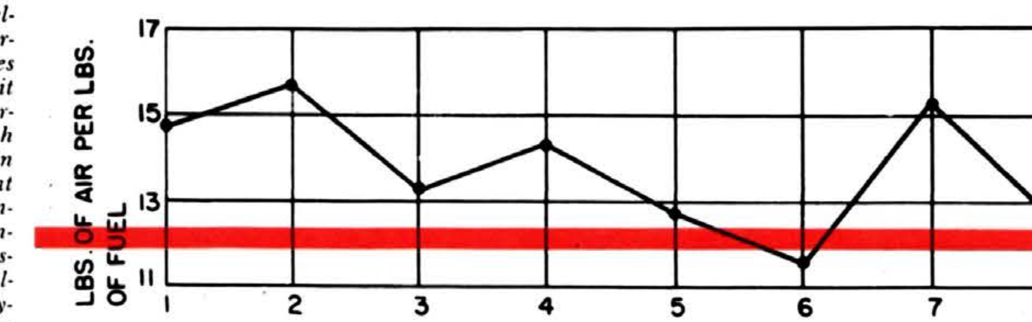


fuel injection for your next car

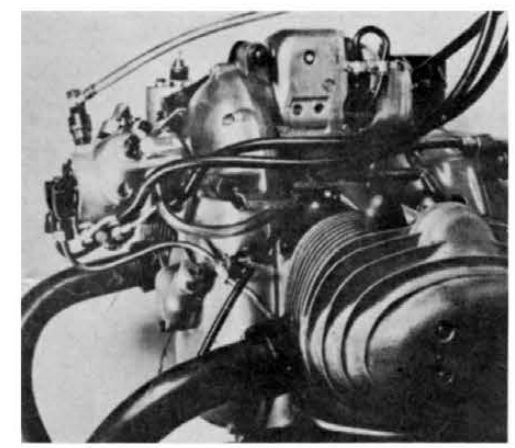
An accomplished fact, FI is coming as sure as the sunrise. Here is what it is and does.

One of the things wrong with carburetors is that the fuel-air ratio mixed in the carburetor throat changes greatly by the time it reaches an engine's far-flung cylinders. The graph shows typical variations in fuel-air ratio "slugs" that actually reach the cylinders of an in-line 8-cylinder engine. A good FI system would give a horizontal-line graph (red line) lying between 11 and 12 on the vertical axis.

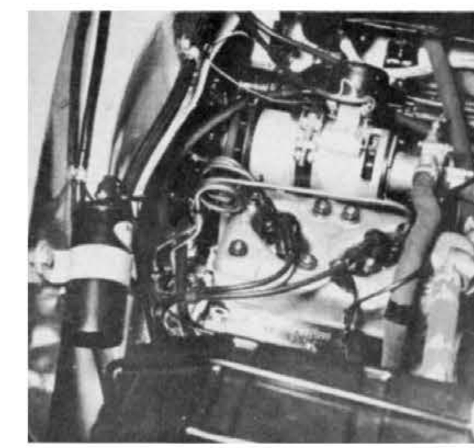


(Graph from Obert's "Internal Combustion Engines," 9th edit.)

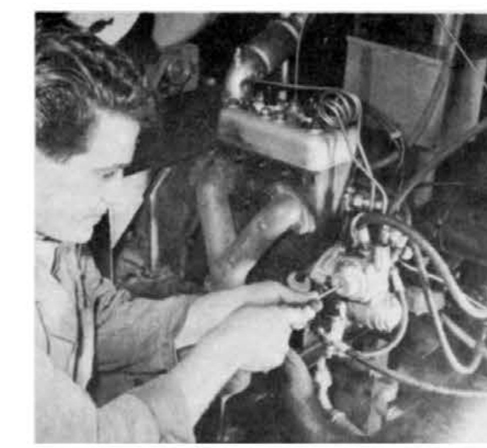
By GRIFF BORGESON



BMW, winner of Grand Prix motorcycle races, is equipped with the Bosch gas injector. Injector pump mounts high at front of engine.



Goliath two-stroke car, made by Carl Borgward, uses Bosch fuel injection. It pays for extra cost in performance and economy.



Here, mechanic adjusts travel of injector pump control rod. While system seems complex, adjustment is simpler than most.

ONE DAY in 1953 the International Sports Commission met in Paris to determine the rules that would govern Grand Prix competition for the next three years. The gentlemen pondered, discussed and finally reached a firm agreement. They'd rig the rules to handicap the one thing they were all afraid of – superchargers, which were making cars far too fast for anyone's good. The formula they decided upon pitted 2500 cc unblown engines against blown ones of just 750 cc (45 cubic inches!), and it was greeted with agonized howls by those manufacturers who had made two-stage supercharging a formidable, near-perfect weapon. But the decision stood. If it hadn't, the carburetor probably would not be on its way out today.

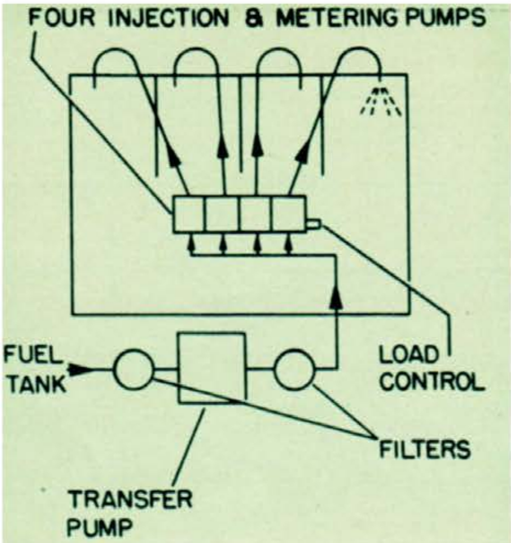
One of the manufacturers least enthusiastic about the new formula was Mercedes-Benz, which built its fantastic pre-war reputation on blown cars. But even if superchargers were out, Mercedes was not about to scuttle its racing plans. Its engineers, who had been certain until now that the unblown engine had reached the limits of its development, began casting about for something that would prove them wrong. They found it in a device that had been familiar in diesels since the Twenties, in aircraft since World War II, and in some alcohol-burning race cars since 1949: fuel injection. Working in secret with the Robert Bosch company, they worked out new FI systems for both alcohol and gasoline and used them in their 300 SL, production sports car, their 300 SLR competition sports car, and their Grand Prix machine. FI was a costly area for experimentation but well worth the investment. In '55, aided by Fangio, Moss and others, FI helped Mercedes walk away with the G.P. world's championship, the sports car world's championship and the European touring car championship.

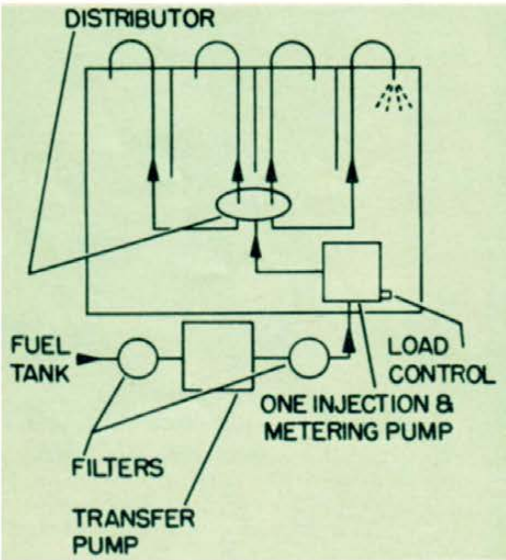
Repercussions from the original Mercedes experiment with FI began immediately. German economy cars, Gutbrod and Goliath, made FI optionally available. Then FI penetrated world's championship motorcycle competition, via B.M.W. and Moto Guzzi. Borgward's record-setting sports cars used it and so did the Grand Prix Alta and Connaught. As we go to press, rumor is that Ferrari's '56 Indianapolis contender will use FI. It will just about have to if it's going to compete with the Offys, most of which have been running without carburetors for seven years.

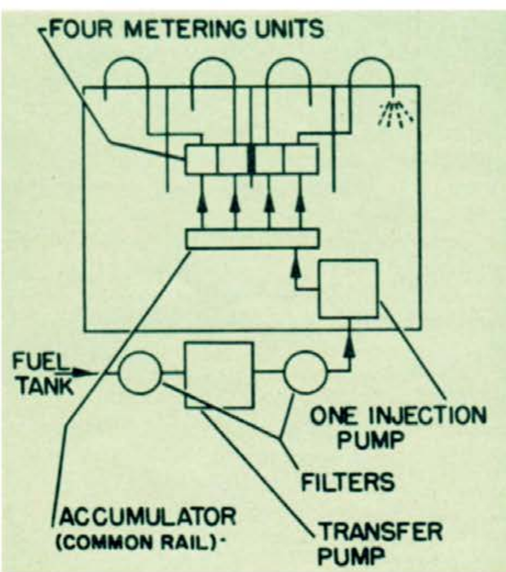
FI is no dream-scheme of the future; it is an accomplished fact. It entered the sports car field through the back door and it will invade the family-car field in the same way. This time the cause will not primarily be performance but looks. FI permits the chucking of space-consuming carbs, air cleaners and manifolds, and thus permits hood lines at least four inches lower than those that sell today. The low, slinky FI profile will be a gimmick that Detroit can market to the motoring masses on the grounds of novelty and beauty. Add the "gravy" of performance and fuel economy and it's an unbeatable combination. And it's coming as surely as the sunrise.

This is not just a personal opinion. I've discussed FI with at least a dozen product-planners and engineers in Detroit and they all agree that it's just a matter of a year or two until FI shows up as optional equipment on some cars and standard on some of the higher-priced lines. Cars that will probably get it first are the Thunderbird, the Corvette, and the high-performance models offered by Chrysler and Studebaker. Four years from now FI should be about as commonplace as automatic transmission on cars in all price brackets.

FI progress overseas will follow about the same pattern. European budgets for research and development may be relatively small, but there as in the U.S. most of the initial







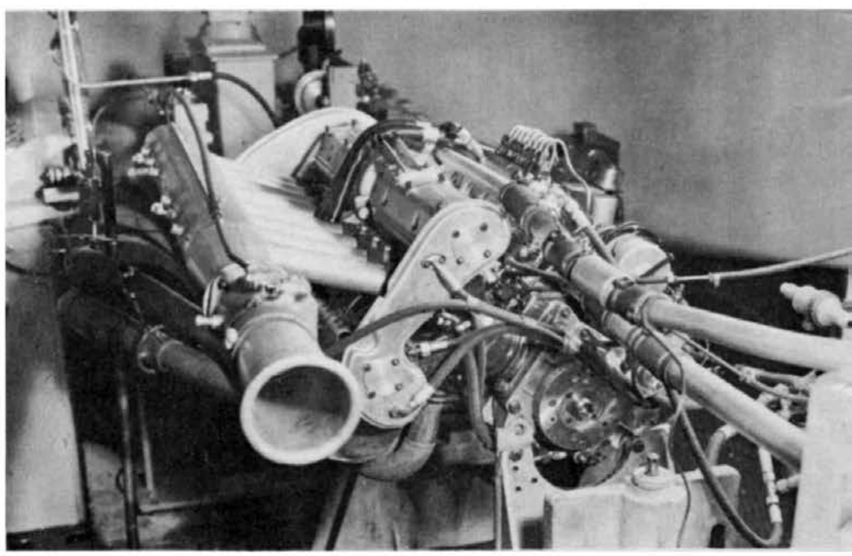
Illustrated above are three typical FI systems now in use. There are, of course, many other methods now in experimental use.

costs were absorbed years ago by manufacturers of FI equipment for diesel and aircraft engines. In Germany FI is already recognized as the only rational way to charge the cylinders of four-stroke and two-stroke gasoline engines. Italy, England and France are approaching the same realization. Even so, it's near certainty that wide mass use of FI will occur first in the U.S., because of the big-volume production on which the U.S. industry is based.

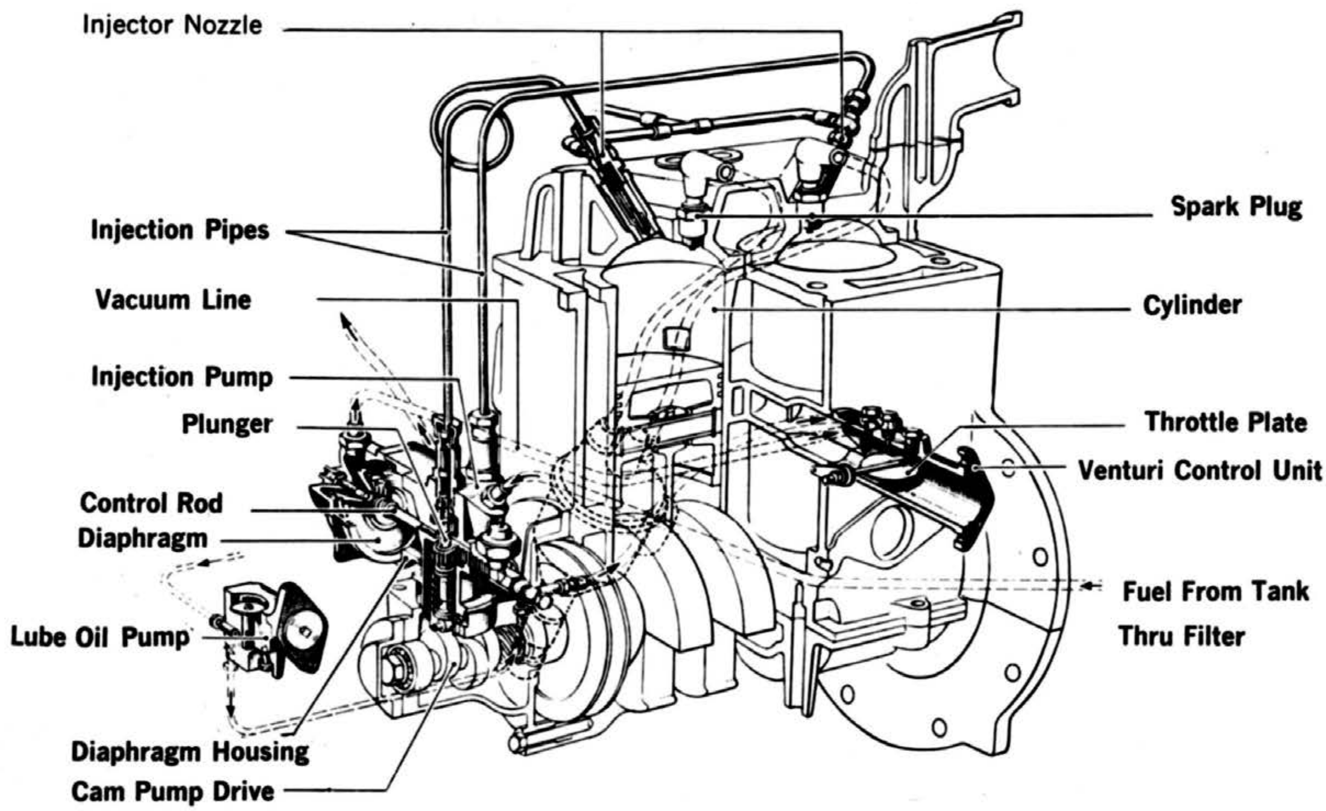
Nearly every article or technical paper on FI that has appeared to date has led the reader through the exotic intricacies of one or more of the FI systems most likely to be adopted by the U.S. industry. We will avoid this here, because a really accurate and complete description of even one system would hardly leave space for a general picture of what FI is and does. And this would be only a starter. The FI systems of GMC, International Harvester, Caterpillar, Cooper-Bessemer, Cummins, German Bosch, American Bosch, Stromberg-Bendix, Lucas, S.U.-Simmonds, Guzzi, Fuelcharger and Roosa-Master are all fairly likely contenders, and a comprehensive description of each of them would fill a big, thick and fairly dull book. Instead, we'll define the basic principles of *all* FI systems, leaving the details of specific makes for progress reports in the future.

All FI systems contain:

1. A fuel tank.
2. A transfer pump much like a conventional fuel pump, which carries fuel from the tank to
3. An injection pump, which delivers the fuel under high pressure to
4. The injection spray nozzles, one for each cylinder of the engine.
5. Fuel filters for protection of injector pump and nozzles.
6. A "throttle" and fuel feed mechanism, which usually responds automatically to engine load, rpm, and inlet vacuum.



View of the W196 engine. The throttle body, foreground, which controls the air-intake also regulates the amount of fuel injected. It operates on a vacuum much the same as a distributor vacuum advance.

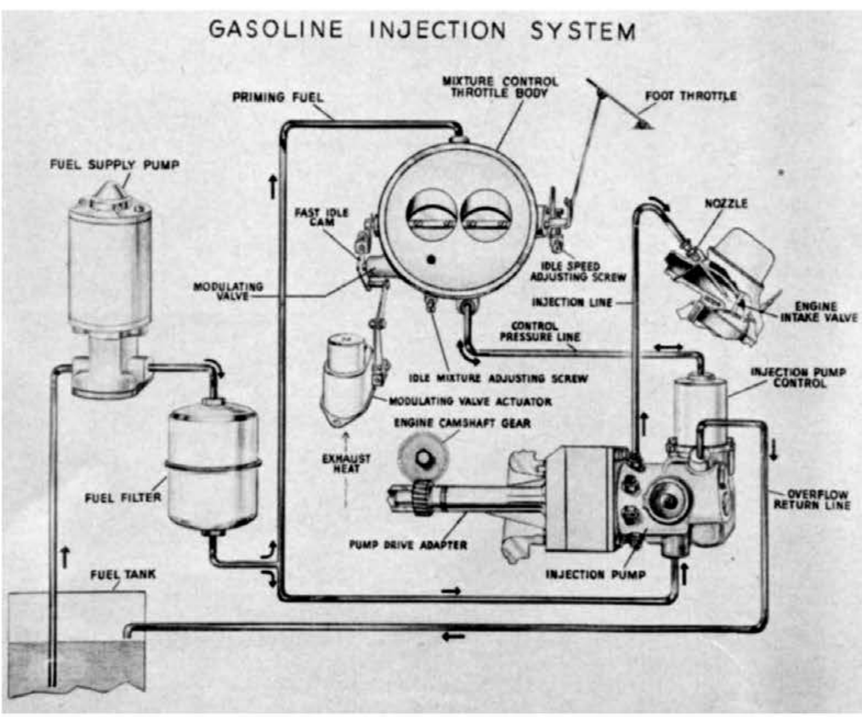


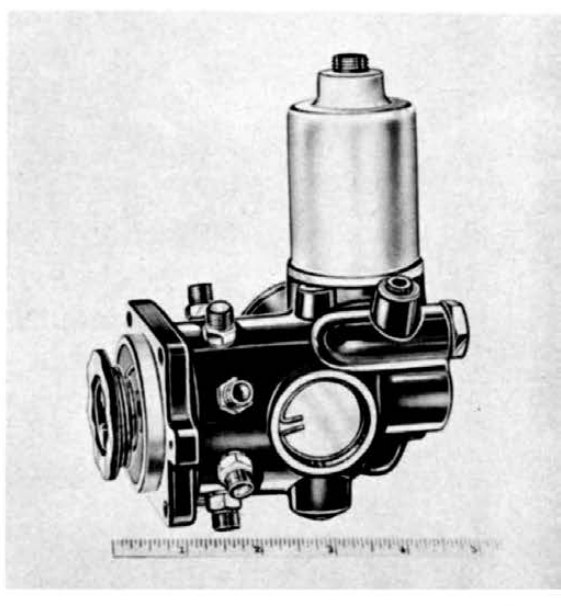
Simple cutaway drawing of the Goliath two-stroke engine shows layout of the entire Bosch injector system.

Some FI systems have "direct" injection into the cylinders, with nozzles in the combustion chamber or the cylinder wall. "Indirect" systems inject into the intake ports, using either a carburetor manifold or a manifold specifically designed for FI. Some systems use a separate injector pump for each cylinder; others use a single injection pump for all the cylinders, feeding them by means of a distributor and metering device. With some there is intermittent injection of fuel, timed to take place mainly during the suction or intake stroke; with others the injection is continuous during all four strokes of the engine's cycle.

A great number of variations has been played on these themes. Some have proved to be especially applicable to touring cars, others to racing cars or aircraft. Each of them has shown that the right FI system is a vast improvement over conventional carburetion.

(Continued on page 63)





This is the American Bosch PDA pump, one of the first to be set-up for mass production. Operation is similar to distributor ignition systems.

Fuel Injection

(Continued from page 15)

To see why, you have only to take a good look at the device that's been feeding our engines for the last sixty years. Engines breathe and burn a mixture of gasoline and air. They suck the mixture in, compress it, burn it, and spew it out, One and sometimes more carburetors sit in the path of an engine's insucked air stream and are designed so that the flow of incoming air past one or more jets drags a mist of fuel along with it.

Unless there's a separate carburetor bolted against each cylinder's intake port, the fuel-air mixture has some distance to travel before it reaches the various combustion chambers. It also has some corners to turn. When this happens, the heavy fuel particles tend to keep going straight ahead; raw fuel accumulates on the manifold walls and the charge that finally reaches the combustion chamber will be of irregular density and have irregular burning characteristics. One way to keep the fuel particles from falling out of the air stream is to be sure that the charge is thoroughly vaporized. So hotspots or water-jacket preheaters are provided on the manifold to heat the incoming mixture.These are fine from the point of view of regular density, but they have their disadvantages too. The heat causes the fuel-air charge to expand, and when it reaches the combustion chamber it is thinner, contains fewer calories to be transformed into power.

The intake manifold has other built-in bugs. For the engine to run smoothly, all the cylinders ought to receive the same amount of mixture and the same proportion of fuel to air. But the manifold delivers a bigger, richer charge to the cylinders closest to the carb, a leaner, smaller charge to those farthest from it — and in an in-line engine some of the cylinders are very far away indeed. Another self-defeating fact of manifolding is that the current of fuel-air mixture is constantly changing direction and this interferes generally with efficient breathing. Still another is the fact that in order to keep the current moving at a high velocity—essential for keeping the fuel particles from falling out of the airstream — the manifold has to have a small cross-section. But this constriction reduces the engine's efficiency as a pump, cuts down its breathing ability.

One of the most irritating of the carburetor's defects is its inherent inability to give you quick throttle response when you want it the most. When you want to accelerate quickly, you stand on the throttle. The larger opening permits atmospheric pressure to force more air into the engine instantly. But gasoline is much heavier than air; it has more inertia to be overcome. The air rushes past the fuel jet at higher speed, but it takes an appreciable moment — and often an inconvenient one for the driver — for the fuel to start flowing at the new rate. Similarly, when you decelerate the air shuts off instantly but the dynamic inertia of the heavier fuel keeps it flowing longer.

The automobile industry and its carburetor suppliers have coped valiantly with these and many other problems of the traditional induction system. They've developed ingenious intake manifolds, acceleration pumps, additional carburetor jets for various speed ranges, and the two-throat, four-throat and dual-four-throat setups. These have helped, but they've also increased manufacturing and operating costs. For this reason, FI is now not only preferable to carbs but also economically competitive. Five years ago FI was farther from mass production than the gas turbine. Now, thanks to the carburetion complexities spawned by the horsepower race, it's just as cheap to tool for FI and cash in on its impressive list of advantages.

With FI you can toss away that plumber's nightmare, the intake manifold. Even though today's manifolds will probably be used for economy's sake during the first few years of mass-produced FI, they will only carry air. Fuel particle "fall-out," hot spots, puddling, tiny cross-sections and their asthmatic effects — all these will be eliminated. Opposite each intake port in the air-manifold will be a threaded boss into which injector nozzles will be screwed. The nozzles will discharge directly against the intake valve. Eventually, as the cost of tooling is amortized and newly-designed top ends become feasible, still more FI benefits will become available. The future descendant of the intake manifold will be designed to harness the pulsations of the air column and probably get *more* than 100 percent filling of the cylinder! This technique has already been perfected, while its opposite is already in use in exhaust tuning.

Another, more immediate advantage of FI will be higher compression ratios. Engine designers, whose goal is the highest useful compression ratio because this is the one that gives the most power and fuel economy, have been hideously frustrated for decades by carburetor engines, where different fuel-air mixtures are delivered to each cylinder and the compression ratio is dictated by the worst-fed one. The only way to keep the starved cylinder from knocking is to feed it a mixture that is sufficiently rich. The other cylinders, which could get along nicely on a leaner diet, have to run wastefully over-rich. FI, on the other hand, gives each cylinder exactly the same fuel-air mixture. This permits the use of a higher compression ratio and also makes the engine less fussy about octane ratings.

FI helps engine breathing in many ways. For example, it does not require heat for "gasification" of the fuel and therefore delivers a denser charge. It also keeps the engine much cooler than carburetors can. When the velocity of the airstream is no longer important; the manifold and valve ports can be big enough to provide plenty of cool air. Neither air nor fuel vapor need to be heated. They enter the combustion chamber cool, and help to cool the parts of the engine that are inevitably the hottest—the combustion chambers and the exhaust valves. This is still another factor in lowering octane requirement.

With FI there is no fuel inertia as we have known it and consequently no throttle lag when you accelerate. Fuel goes to the engine in instant response to load requirement rather than in response to the flow of air past a carburetor jet. When you hit the throttle air rushes into the cylinders and the injectors force finely-atomized fuel into them in just the right, uniform amounts to give a consistent ratio of fuel to air and in a consistent distribution pattern throughout all the engine-speed ranges, economical metering of fuel, far greater elasticity of engine response to the controls. The Mercedes 300 SL, for example, can accelerate with perfect smoothness from 15 to 160 mph in top gear. Carbureted engines, with their meandering manifolds and the varying turbulence and velocity that changing positions of the throttle plate cause, can't begin to match this kind of performance. #