K before L, L before M.

The Beginnings of Fuel Injection: Bosch K-Jetronic.

At the center of the K-Jet system is the fuel distributor, an originally all mechanical injection system, modified in later versions (as here) with provision to respond to signals from the oxygen sensor through a control unit.

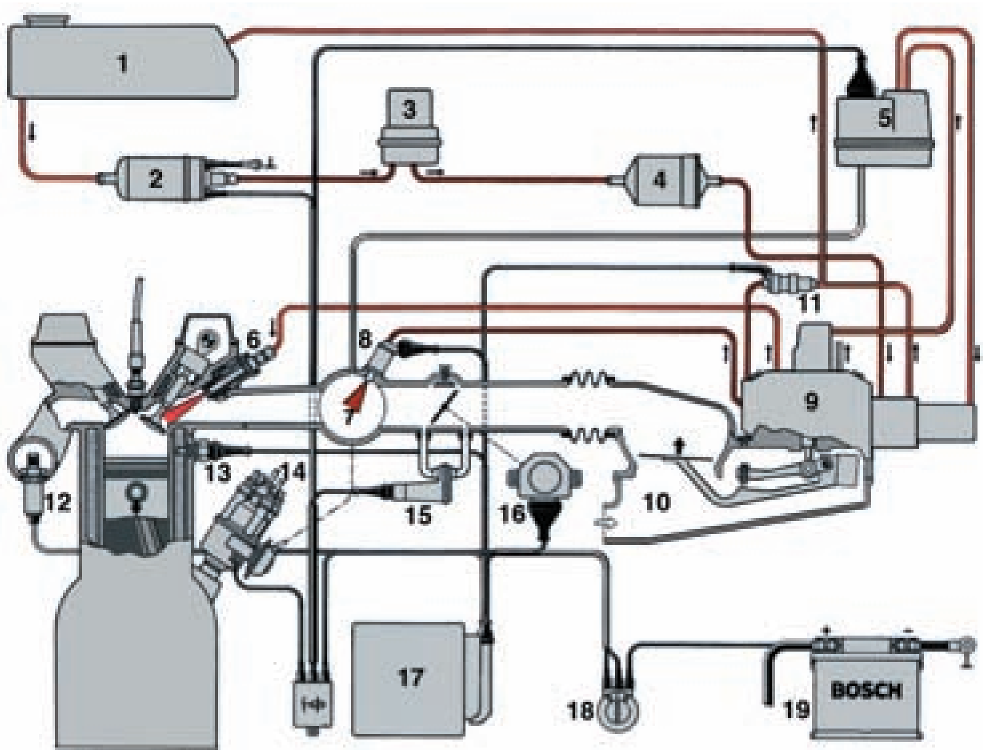
In the history of fuel injection, the alphabet should really start with the letter K. The Bosch K-Jetronic system was not only the first fuel injection system most of us ever saw in any numbers, but a basic design that, for all its Teutonic complexity, lasted while both international emissions regulations and motorists' expectations made exponentially increasing demands: Make the exhaust environmentally cleaner but make the car's performance invisible to the motorist, plain, simple and requiring minimum maintenance. The K-Jet, or in its English acronym, CIS, generally worked very reliably.

Understanding this earliest, most widespread fuel injection system provides a good basis for understanding all the later fuel injection systems to come along because it enables us to see what problems the K-Jet system set out to solve, how it went about them and what problems remained for later fuel systems to overcome.

Bosch has now and had then the engineering depth and experience for the system, having produced several limited-production designs such as the Benz LS's direct (into the combustion chamber!) injection system, as well as Diesel injection systems going back practically to the time Dr. Rudolph Diesel disappeared over a ship's railing in the English Channel. If anyone was going to invent the first fuel injection system successful worldwide, it was the Robert Bosch company and those painstaking Stuttgart engineers.

But even in its earliest form, K-Jet was hardly simple. The injectors themselves were deceptively so: finely atomizing spray nozzles just upstream of the intake valves, opening as soon as fuel pressure flexed their internal spring valves and squirting a cloud of fuel proportionate to the load as long as the engine kept running.

Each K-Jet injector consists of a finely machined tube with a threaded fitting on the fuel line end, a final fine-mesh conical filter and a valve and seat held closed by a pressure-metering spring. Once pushed open by the fuel flow, the valve needle wobbles and oscillates in the fluid passage, further breaking the liquid fuel into readily evaporated fine droplets.

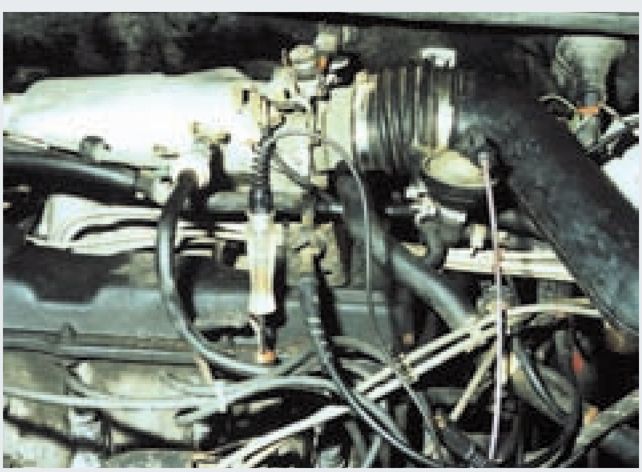


The K-Jetronic system
1) Fuel tank
2) Electric fuel pump
3) Fuel accumulator
4) Fuel filter
5) Warm-up regulator
6) Injection valve
7) Intake manifold
8) Cold-start valve
9) Fuel distributor
10) Air-flow sensor
11) Timing valve
12) Lamda sensor
13) Thermo-time switch
14) Ignition distributor
15) Auxiliary-air control
16) Throttle-valve switch
17) Control unit
18) Ignition and starting switch
19) Battery

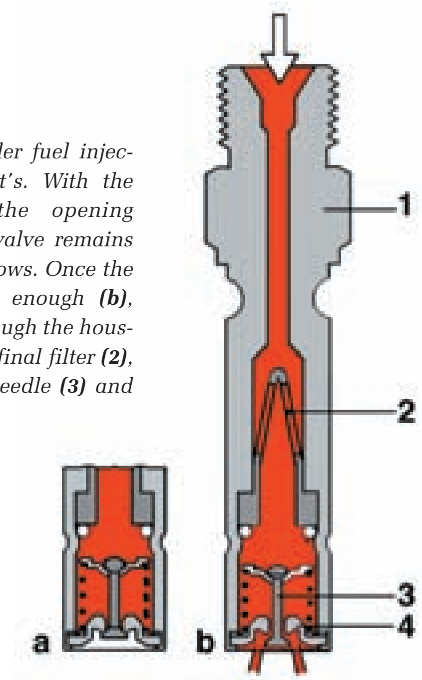
What can go wrong with these injectors? Not much, and almost all of it related to dirt that somehow ran the gantlet of filters between the tank and the injector's needle valve. A few, of course, developed broken springs and leaked; probably more succumbed to ham-fisted overtightening of the fuel line flare nut. More than a few just clogged from debris. But with no electrical connections, no moving parts but the injector valve whizzing the fuel stream into a mist, and in a position insulated from the greatest engine heat (and as immune to heat as only a steel part can be, anyway), failure of a K-Jet sprayer was unusual.

So let's look upstream for any troubles. All the way up the fuel stream is the refinery and bad gas — corrosive, dirty, watery or whatever. That may have been splendidly profitable for the oil companies, but those ill-gotten gains bought them a powerful enemy: the automobile industry.

Pressure tests can check differential pressures within the fuel distributor, as well as the total pressure the pump can deliver. The specified pressures vary by year and model, so check the data for the car in front of you.



If a K-Jet car won't start when the weather suddenly goes cold overnight, this is a good clue the cold-start system is flawed. The cold-start injector sprays fuel into the manifold log. You can unbolt the injector and, observing proper safety precautions against gasoline fires, test it for function and spray pattern, provided the engine coolant is overnight-cool. Check also for power to the cold-start thermo-time switch in the block during cranking.

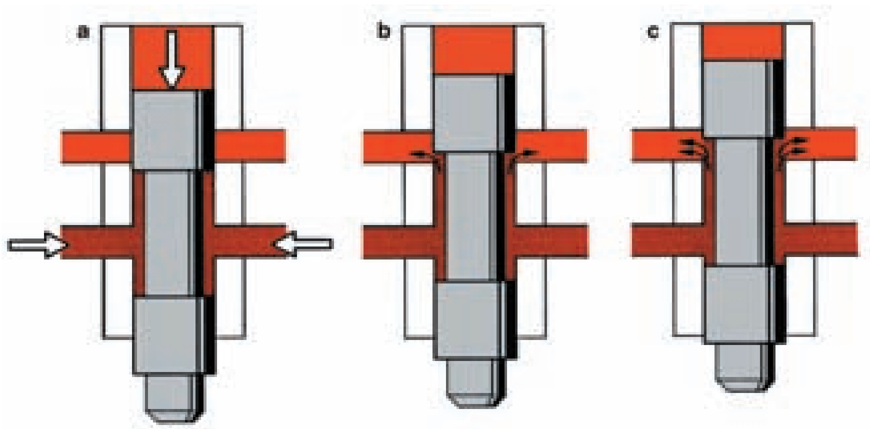


*There are no simpler fuel injectors than the K-Jet's. With the pressure below the opening threshold **(a)**, the valve remains shut, and no fuel flows. Once the pressure increases enough **(b)**, gasoline sprays through the housing **(1)**, the conical final filter **(2)**, around the valve needle **(3)** and out the nozzle **(4)**.*

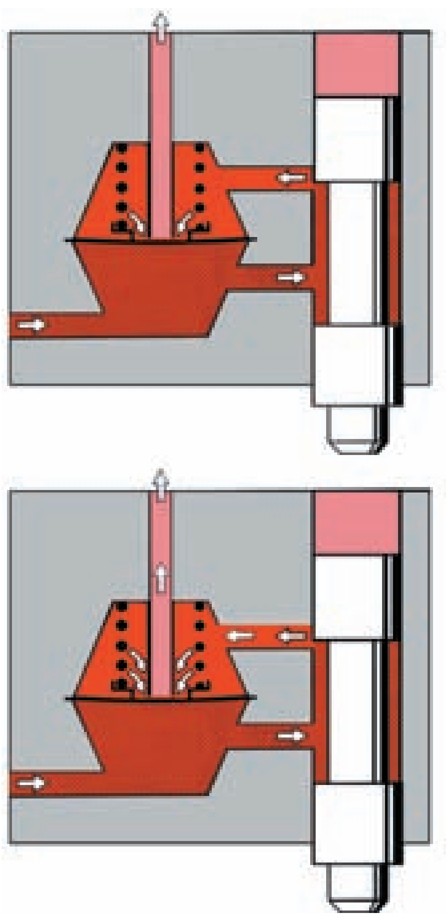
Finally, in the late 1980's a senior vice-president of General Motors sent a letter to virtually every gas company in the country saying in quite clear if politely veiled terms that if gas quality didn't improve there could be another set of letters from GM, this time to its customers, listing fuels by brand name, fuels whose use would void their car's warranty. Even Big Oil didn't want that kind of fight with the largest corporation in the world, a corporation that could have left them with storage tanks full of millions of gallons of unsalable fuel practically overnight. So gas quality improved, again practically overnight. Amazing what results you can get when your eloquence is also so persuasive!

After the Pump

Whatever the quality of the gas, as long as it was liquid, the roller pump forced the gasoline into the fuel rail at a pressure slightly higher than the system would ever need, regardless of load. Mounted shortly after the pump, a fuel accumulator filled in about a minute. Its two functions were to reduce the sound of the pump by absorbing the pressure pulses and to keep the system under pressure when the engine was turned off. Check valves in the pump and, as we've seen, in the injectors themselves, held the fuel in. Keeping the system pressurized, of course, kept the fuel liquid and avoided vapor-lock problems during hot restarts.



*In the fuel distributor, control pressure from above pushes the plunger down against the air plate lever, shutting off fuel flow **(a)**. Once the engine is drawing intake through the air meter, the lever pushes the plunger up and begins to uncover the slots delivering fuel pressure to the upper chamber of the fuel distributor **(b)**. At higher or wide-open throttle settings, the plunger uncovers more of its slots **(c)**, delivering maximum fuel flow to the injectors.*



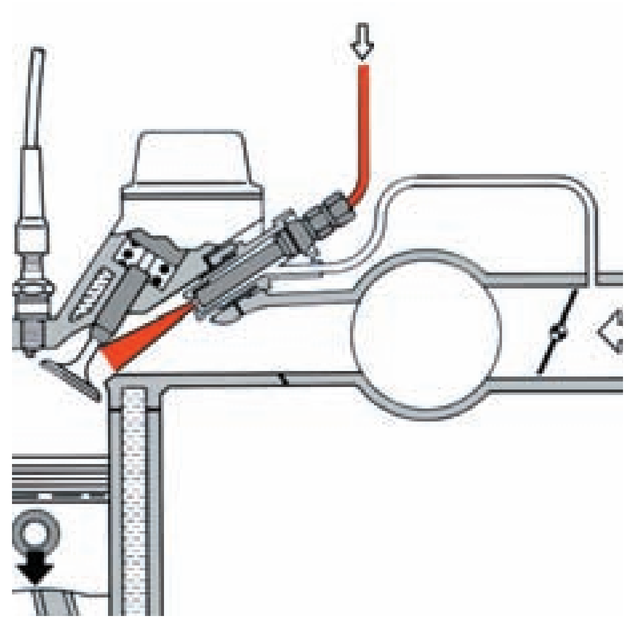
As the difference in pressure between the lower and upper chambers of the fuel distributor is greater, the spring-steel diaphragm bends down, uncovering the lines to the fuel injectors and allowing greater flow.

The K stands for the German word for *continuous*, because K-Jet fuel injectors spray fuel anytime the engine is running. They don't pulse; there's no duty-cycle; there's no injector coil; there's no electrical connector or wiring of any kind. They just maintain a constant fuel spray; they're on if the engine is or off if it's not. They spray more when the engine works harder or faster and less when it coasts or loafs. In its original form, K-Jet was an entirely mechanical fuel metering system except for an electric motor driving a roller pump for fuel pressure. A round air flap in a calibrated funnel moves in direct response to air passing between the two. The air flap pivots a lever that moves a fuel-metering pin in the fuel distributor, which doles out a corresponding ration of fuel to each injector simultaneously. Each injector opens by fuel pressure only (about 3.5 bar/52 psi. for the early systems, but the system pressure increased with the later versions and the need for finer fuel droplets. How do you get smaller drops but the same volume? Blow the gas through more and smaller holes, but blow it harder), and the oscillating needle valve in the tip finishes atomization of the passing fuel.

The first problem the K-Jet system sets out to solve, then, is the equal distribution of fuel to each cylinder. If you ever pulled the cylinder head from a carbureted inline six-cylinder engine with a log-type manifold, you saw the problem vividly: Cylinders one and six were carboned more than the other four. This happens unavoidably, regardless of how complicated the carburetor and runners are because the inertia of the heavier fuel droplets made them want to continue in a straight line down the manifold log until they got to one end or the other. Come what may, the leanest cylinders had to get a rich enough mixture to fire, so the other cylinders had to run overrich.

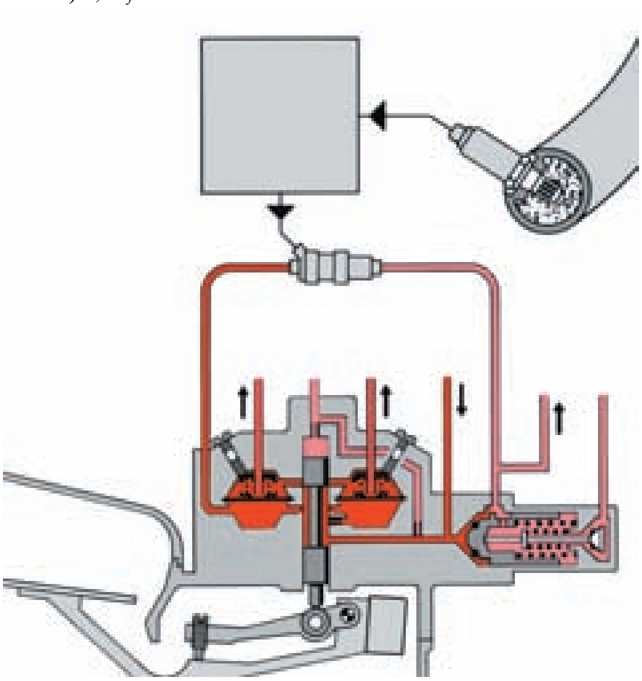
With an injector just upstream of each intake valve, K-Jet avoided this problem almost entirely. At least inasmuch as the combination of fuel injectors and fuel distributor managed to spray equal amounts of fuel from each, each cylinder got an equal mixture. In fact, the K-Jet system wasn't all that accurate by today's standards — injectors could vary delivery volume by over 10 percent, and the beautifully machined fuel distributor was still far from perfect, itself. But even that 10 percent variation was a dramatic improvement over what a carburetor delivered. Also, this fuel equalization had beneficial effects for both performance and emissions.

The second problem solved was what happened when you closed the throttle while the engine was running, particularly during deceleration. Primary and secondary barrels closed (in the absence of decel dashpots), but that left the idle circuits exposed to the full deceleration vacuum. The combination of high vacuum, sudden loss of pressure and thus plummeting temperature, resulted in a virtual fuel cloudburst in the intake manifold. While some carburetors propped the throttle open under deceleration to vent the vacuum, a fuel injection system has a simpler and entirely satisfactory solution: It shuts off all the fuel.



One of the modifications of the KE-Jet system was the inclusion of "air-shrouded" injectors. What this means is that the air passed around the throttle for idle speed emerges in a collar around the fuel injector, helping prevent fuel puddling by the air's turbulence.

As K-Jet moved into oxygen sensor feedback systems, various additional components were added to the basic mechanical system to vary the ratio between the airflow and the fuel delivered. The earlier of these fine-tuned the differential pressure between upper and lower chambers in the fuel distributor; other versions modified the control pressure bearing on the top of the fuel plunger. Each such system essentially consists of something like a fuel injector functioning as a pressure-bleed to affect the fuel pressure differential on either side of the metal diaphragm. The expanded feedback systems is the KE-Jet, E for electronic.

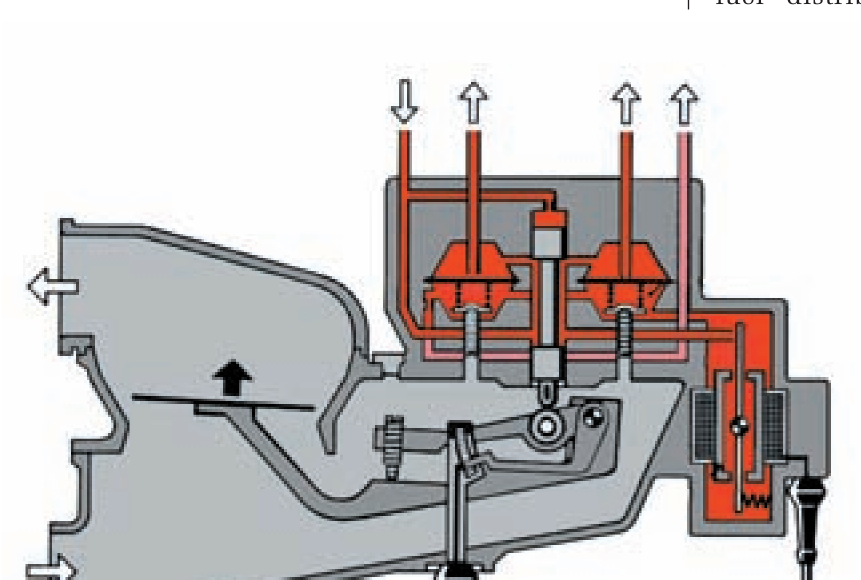


Problem solved. No fuel waste, cleaner exhaust, no backfire, no intake manifold fuel condensation, no oil dilution. The original purely mechanical K-Jets didn't shut off fuel entirely on all cars, but decel fuel cutout was one of the first modifications.

But there were problems, nonetheless. Fuel was said to be "stored" in the intake runner when the intake valve was closed. "Puddled" might have been a more accurate description for certain vehicles, particularly high performance cars belonging (oddly enough) to short-tripping drivers who didn't warm the engine enough to vaporize all the fuel. Low-volatility fuel residue caked on the back of the intake valves and valve stems and built up, leading to hesitation and eventually power loss. This problem was solved fairly early, however when Bosch introduced air-shrouded injectors, installed directly in bypass air channels for the idle air. This system kept the air moving around the injector tip and the fuel vaporized.

Along came the need to adjust the engine's intake mixture to meet emissions laws. On the K-Jet, since the only factor determining how much fuel is sprayed is fuel pressure, the only way to adjust the mixture is to fine-tune that pressure. The only place to do that, given purely mechanical injectors and a fuel pump set to deliver maximum fuel flow and pressure all the time, is at the fuel distributor.

Minimum flow, as we've already seen, is determined by the spring pressure of the injector valves themselves. But actual flow, at any running condition, comes from the difference in pressure on the top and bottom sides of the steel diaphragm in the fuel distributor. The major adjustment is in response to the movement of the air plate in the airflow funnel. But fine-tuning is available with one of several fuel bleeds between upper and lower chambers. Different K-Jet systems used either duty-cycle pulsed pressure bleed devices or variable current electromagnetically moving a resistor plate over a fixed orifice.



Cold Start

Carburetors used a choke to make it easier to start a cold engine. The choke, of course, reduced the amount of air relative to the amount of fuel. Those who worked on classic British cars may remember the SU and other sidedraft carburetors. Instead of a choke, they used a main jet you could lower away from the tapered metering needle, thus richening the mixture for the same fuel-to-air proportioning effect.

The K-Jet works more like the sidedrafts, at least in principle. A separate cold-start injector sprays extra fuel into the intake manifold during cranking. This extra fuel ensures there will be enough vaporized gasoline mixed with the intake air to fire the cylinders.

Characteristically, there were only two problems with the cold-start injector, one electrical, the other calendrical. The injector or its thermo-time sensor/switch were subject to the usual electrical maladies, principally shorts and opens, diagnosed the usual ways. The calendrical problem occurred in early fall: The cold-start injector, doing nothing all summer but riding around in the car, often collected a drop or two of water right at the tip. That water had the time and the means to rust the injector's pintle into place, which you'd notice as progressively harder starting as the days grew shorter. The test was simple: Fire extinguisher at hand and ignition secondary grounded, unbolt the injector and watch its pattern. It should look like the one in our photo.

So Why Are K-Jets Gone?

But they don't put K-Jets on cars anymore. While they were a tremendous improvement over the carburetors that preceded them, there were remaining problems that couldn't be solved without going to a different system. Regardless of how precisely they laser-machined the fuel distributor, differences in flow remained, differences too large to overcome within fuel usage and emissions standards adopted since. The constant spray, simple and elegant as it seems, had the continuing problem that the airflow just upstream of the intake valve is not itself constant. To capitalize on the highest velocity of the intake air, fuel injection has to be sequenced, and that means individual, electrically pulsed injectors. Finally the need to interconnect the fuel management with the ignition system and other functions performed by a current PCM spelled the end of the K-Jet. ■

— By Joe Woods