DELOREAN FUEL INJECTION SYSTEM

BY MARK HERSHEY

The fuel injection system chosen for the DeLorean was developed by West Germany's Robert Bosch company as a low-cost alternative to their elaborate, computer-controlled L-Jetronic system. First introduced in 1973, the DeLorean's K-Jetronic is an entirely mechanical system which has proven reliable enough to be selected for such premier automobiles as the 1977-79 BMW 320i, various Mercedes-Benz 280, 450, 380 and 500-series models from 1976 through 1985, and 1973-88 911, 911 Carrera and 911 and 924 Turbo models from Porsche. K-Jet is also found on various Volkswagen models, and most Volvo 4 and 6-cylinder models from 1974 through 1986. Curiously, it was not used on Renault and Peugeot models that share the DeLorean's PRV V-6 engine.

Strictly speaking, the system uses no electronics to perform its primary function of creating a proper air/fuel mixture, although two adjunct systems also found on the DeLorean use electronics to maintain a constant idle speed and to compute minor adjustments to the fuel/air ratio to improve emission specifications. These systems are called the Constant Idle System and the Lambda system, respectively.

This article describes operation of the K-Jetronic system and some of the standard tests that any qualified K-Jet repair center will perform on the system should service become necessary. Subsequent articles will cover the Constant Idle and Lambda systems in more detail.

FUEL INJECTION HISTORY

Fuel injection is not a new technology. As early as 1887, fuel injection systems were available on commercial stationary engines produced by the Charter Gas Engine Company of Sterling, Illinois. Considering that the carburetor was not considered mature until about 1905, this was a remarkable achievement that went largely unnoticed at the time. Several other companies produced similar systems for specific applications (generally not automotive), but it was not until about 1936 that engineers with Mercedes-Benz began testing single cylinders "engines" based on the geometry of their Grand Prix racing engines with an eye toward future automotive applications.

By the end of World War II Mercedes-Benz and Bosch realized that they possessed key elements of an exciting new technology, and, along with other independent developers, began the research that led to the creation of mass-produced injection systems. Famous names like Rochester Carburetors, Lucas Electric, Bendix and Bosch developed competitive systems in the early 1950's for Formula One racers, but it was not until 1957 that an American car company introduced fuel injection in a production car — the 1957 Corvette from Chevrolet, and a virtually identical system for the 1957 Pontiac Bonneville. Both Chevrolet and Pontiac dropped fuel injections by 1959, due mostly from field service problems.

About the same time, American Bosch (at the time part of Germany's giant Robert Bosch conglomerate but later to become a part of United Technologies) developed a mechanical high-pressure injection system that appeared in the racing circuits, as did Kugelfischer of Germany (later taken over by Bosch in 1974) and America's Bendix Corporation. Bendix, in the late 60's' modified one of their aircraft engine designs (dubbed the RS-II) which by 1971 appeared on 32 of the 33 cars qualified to start that year at Indianapolis Speedway.

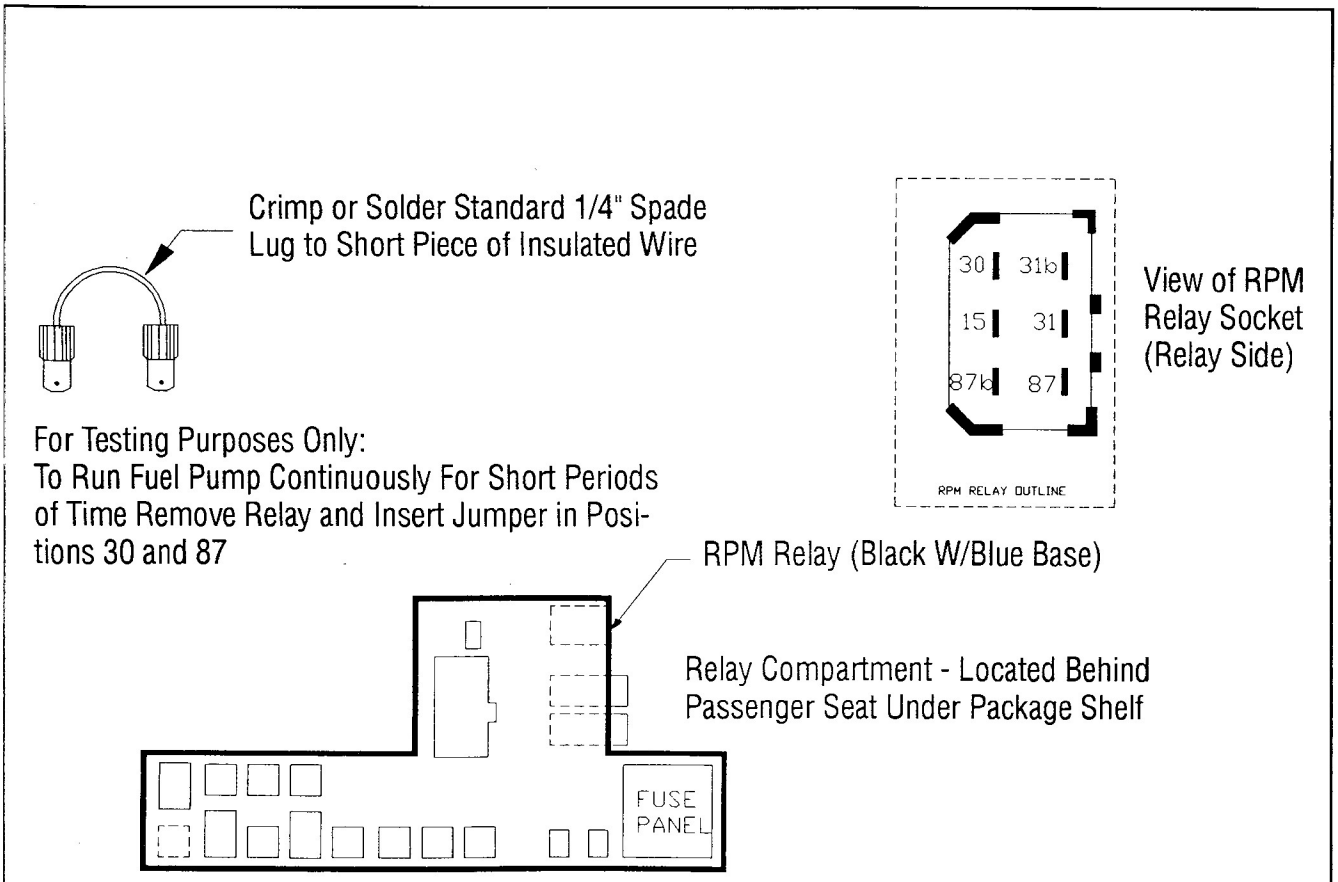
While the Americans were disillusioned with fuel injection systems, Bosch continued development of commercial systems and had some success in placing injection systems in Mercedes-Benz autos as early as the mid-Forties. It was not until 1951 that they developed the injection nozzle that has become the basis for all subsequent high-pressure injection systems. That other gullwing automobile, the Mercedes-Benz 300 SL, had a prototype fuel injection system in two racing models in 1952. Production model 300 SIs had a Bosch-developed system on the 1954-55 models.

Prior to 1957 all fuel injections were mechanical. The first electronic system was announced by the Eclipse Machine division of the Bendix Corporation, a practical version of which was finally patented on April 18, 1961. The prototype was installed in a 1953 Buick V-8 and driven from Lockport, New York to Towson, Maryland with the electronic control unit sitting on the front floor. According to chief engineer Robert Sutton, "Once we got to the Radio Division at Towson, we discussed with their engineers what we had in mind (to create the production electronics for a commercial version). They said there was no way to electronically meter fuel for an automobile engine. We gave them a ride in our car and afterwards they were enthused and agreed that it might be possible."

Although Bendix succeeded in creating a production version (the Bendix Electrojector) they failed to generate much interest in Detroit and eventually killed their fuel injection development projects in 1961 after investing more than one million dollars in research and development. They granted patent rights and signed cross-license agreements with Robert Bosch in 1966 and 1968, and jointly negotiated license agreements with Nippodenso of Japan and Joseph Lucas Industries of Great Britain. These agreements resulted in a sharing of technology from this point forward, which continues to this day.

By 1966, electronic fuel injection was heralded as the solution to the world's emerging pollution problems and, despite its added cost over carbureted systems, appeared on a number of production cars of the period. Bosch developed their first electronic system under the Bendix patents in '66 through '68, introducing the D-Jetronic system (as it was later called) on various SAAB models. In 1973, the D-Jet system was phased out in favor of the L-Jetronic system designed by Heinrich Knapp, chief engineer of fuel injection systems at Bosch. All of these systems used intermittent injection techniques — injectors that used electricity to turn on and off the fuel stream in step with the opening of the cylinder intake valves. The amount of fuel delivered for a given volume of air was determined by the on-time of the injector, as determined by a computer that measured, among other inputs, the air flow into the engine.

Despite advances in electronics technology these systems were expensive, primarily



RPM RELAY

due to the costs of the computer and the electrically-operated precision injectors. Heinrich Knapp reasoned that a system which produced a continuous fuel stream from the injector would cost considerably less than a system that required solenoid-operated injectors. The DeLorean's K-Jetronic system is the direct result of this design effort.

K-JET TECHNOLOGY

The K-Jetronic borrows the Jetronic name from its predecessors, but the similarity ends there. Basically the K-Jet system differs from previous models in that electronic control of injector on/off times is not used. Instead, K-Jet mechanically "measures" air flow into the engine (via the amount of deflection of an air plate just downstream of the air cleaner) and continuously injects a proportional amount of fuel into the intake air stream just ahead of each of the engine's intake valves. The air deflection plate is mechanically linked to a fuel distribution unit that determines the correct fuel flow rate to the injectors. Since fuel is continuously injected, the mechanical "computer" must create a fuel spray that represents the average requirements of the engine over a short period of time.

Some injection systems use a single injector located in the center of the intake manifold, letting the manifold distribute the resulting air/fuel mixture in the same manner as a conventional carbureted engine. The DeLorean and other K-Jet systems use individual injectors at the intake valve positions to avoid "wetting" the intake manifold passages and creating an artificially lean condition at the cylinders. By injecting fuel near the intake valves, the satisfactory engine performance is achieved with the leanest mixture possible, resulting in improved fuel economy and reduced emissions.

BASIC COMPONENTS OF THE K-JET SYSTEM USED ON THE DELOREAN:

High-Pressure Fuel Pump - the DeLorean uses an electric roller-cell fuel pump located under the inspection plate in the spare tire well. It is suspended in the fuel tank by a rubber "boot" that also serves as a shock mount and a noise suppressor, and it continuously delivers fuel at high pressure at a rate that exceeds worst-case engine consumption. The pump is equipped with a one-way valve which helps maintain residual fuel pressure in the fuel lines when the pump is shut off. Original DeLorean fuel pumps had a non-

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serviceable check valve that nearly always failed. Redesigned pumps available today have a replaceable valve that rarely fails at all.

RPM Relay - Although not strictly a part of the fuel system, this relay located in the lower rear of the DeLorean's relay compartment, supplies electricity to the fuel pump. It is activated whenever the ignition is ON and the relay senses pulses from the ignition coil. If the engine stalls, the RPM relay senses the lack of keep-alive pulses from the ignition coil and shuts off the pump. Some (but not many) fuel delivery problems are actually ignition problems that prevent the RPM relay from energizing. Service personnel will need to bypass this relay to test the fuel system pressure without running the engine, so be prepared to tell non-DeLorean repair technicians where this relay is located. Figure 2 shows the location of this relay and shows how to bypass it for test purposes.

Fuel Accumulator - Located in a virtually inaccessible position in the DeLorean's center chassis frame, the fuel accumulator dampens any fluctuations in fuel pressure caused by changes in the pump output (i.e., electrical fluctuations or mechanical shocks) and cushions the rest of the injection system from the shocks associated with pump start-up and shutoff. If you have ever heard the water pipes in your house rattle when a faucet is turned off, you will appreciate the need for this type of cushion. The accumulator also contains a stop valve which helps maintain residual fuel pressure in the fuel lines when the pump is shut off.

Fuel Filter - Located under the DeLorean near the rear driver-side wheel, the fuel filter is a special high-pressure aluminum cannister containing a paper filter with a large surface area. According to Chilton's Guide to Fuel Injection and Feedback Carburetors, the filter plays a role in reducing the amount of water entering the fuel distributor, a very expensive and rust-prone component of the fuel system. Frequent replacement of the filter is thought to reduce the risk of rust damage.

Mixture Control Unit with Air Flow Meter and Control Pressure Regulator -

This is the brains of the injection system. Located under the DeLorean's air cleaner, the air flow meter is a circular plate that deflects downward in proportion to the volume of air entering the engine. Downward deflection is mechanically transmitted to the Mixture Controller located on the same aluminum casting as the air flow meter, directly behind the air cleaner. The mixture control unit meters fuel flow to the injectors in proportion to the physical position of the air meter's deflection plate. To maintain a constant fuel delivery pressure from the pump, the pressure regulator balances incoming fuel pressure against a calibrated spring inside the flow metering assembly.

If the pressure from the pump is higher than the "pressure" exerted by the spring, the spring is compressed slightly which opens up a passage to the fuel that returns excess fuel to the fuel tank. The resulting constant pressure at the regulator is about 54 PSI, adjustable (but rarely necessary) by adding special shims between the spring and the fuel return passage.

Warm-Up Regulator - The warm-up regulator adjusts (enriches) the fuel mixture whenever the engine is cold, to prevent combustion miss whenever while the engine warms up. The unit is mounted directly on the engine's left valve cover to pick up and react to engine heat. Additionally, it is electrically heated by an internal resistive element that is energized whenever the ignition is on. Either engine heat or heat from the electric element return the enrichment and return the air/fuel mixture to normal when the engine reaches operating temperature.

This unit on the DeLorean also includes a full-load enrichment circuit that monitors engine manifold vacuum. When the vacuum is suddenly decreased (such as when the accelerator is abruptly floored), manifold vacuum is reduced and the regulator enriches the mixture for better acceleration. Some regulators, including the model used on the DeLorean, also have a high-altitude compensation circuit that adjusts the air/fuel mix in higher altitudes. The short rubber hose that connects to a port on the top of the regulator (and is free on the other end) is part of this option, and care should be taken to avoid blockage or loss of this tube.

Fuel Injectors - The six injectors used on the DeLorean are located in the left and right cylinder banks near the spark plugs. All injectors inject fuel all the time that the engine is running,, and, when mixed with air in the intake manifold, the resultant mixture is sucked into whichever cylinder's intake valve is open at the time. The injector nozzle is designed to shut off fuel flow below a minimum pressure, or produce a fuel "fog" of tiny droplets whenever fuel is delivered at a pressure of at least 48-50 PSI. Each injector has an internal nylon mesh filter with holes of about fifteen micromillimeters width, so clogging is possible.

The injectors are mounted in plastic carriers that help insulate the injector from engine heat and provide an adequate seal to prevent air leakage around the injector. A three-pronged spring-steel clip holds the injector in place. Replace the seal and the clip whenever the injector is replaced. These injectors are about $33 each at best (considerably more at full list price) so change the DeLorean's fuel filter regularly or you will be buying and cleaning them before long. Since these are high-pressure nozzles, extreme care must be taken when testing these devices, or when any portion of the DeLorean's fuel system is tested or serviced.

Cold-Start Valve - The DeLorean uses a cold start valve to provide fuel enrichment to the cylinders whenever the engine is first cranked with a coolant temperature below 68 degrees F. The need for enrichment is due to the condensation of some fuel vapor on cold cylinder walls, which effectively leans out the mixture and makes starting difficult. The valve is controlled by an electric device called a thermo-time switch, located in a completely inaccessible place on a coolant pipe under the intake manifold.

The cold-start valve is similar to an electric fuel injector, activated by the thermo-time switch for only a few seconds, and only on a cold engine. The switch is equipped with an internal electric heater element that heats up a set of electrical contacts inside the switch. When the DeLorean's ignition is turned on, electricity is applied simultaneously to the cold start valve through the thermo-time switch. Fuel is injected for about 3-10 seconds, depending on engine temperature, after which the heater opens the contacts and the injector is shut off. If coolant temperature is above 68 degrees F., the contacts inside the thermo-time switch are always open, so the cold start valve is not activated at all.

The valve is located on a flanged pipe extending upward from the left side of the air cleaner. The pipe connects to the approximate center of the intake manifold, such that fuel sprayed into the pipe by the cold start valve is evenly distributed to all six cylinders.

Auxiliary Air Regulator - Many K-Jet-equipped systems use an Auxiliary Air Valve to increase engine idle speed when the engine is cold. The DeLorean uses an electronically-controlled Constant Idle System (C.I.S.) for this function, which is fully described in the DeLorean service manual. It is mentioned here since most commercial K-Jet service manuals (including those listed here) seem to expect you to find this device, which you will be unable to do on a DeLorean.

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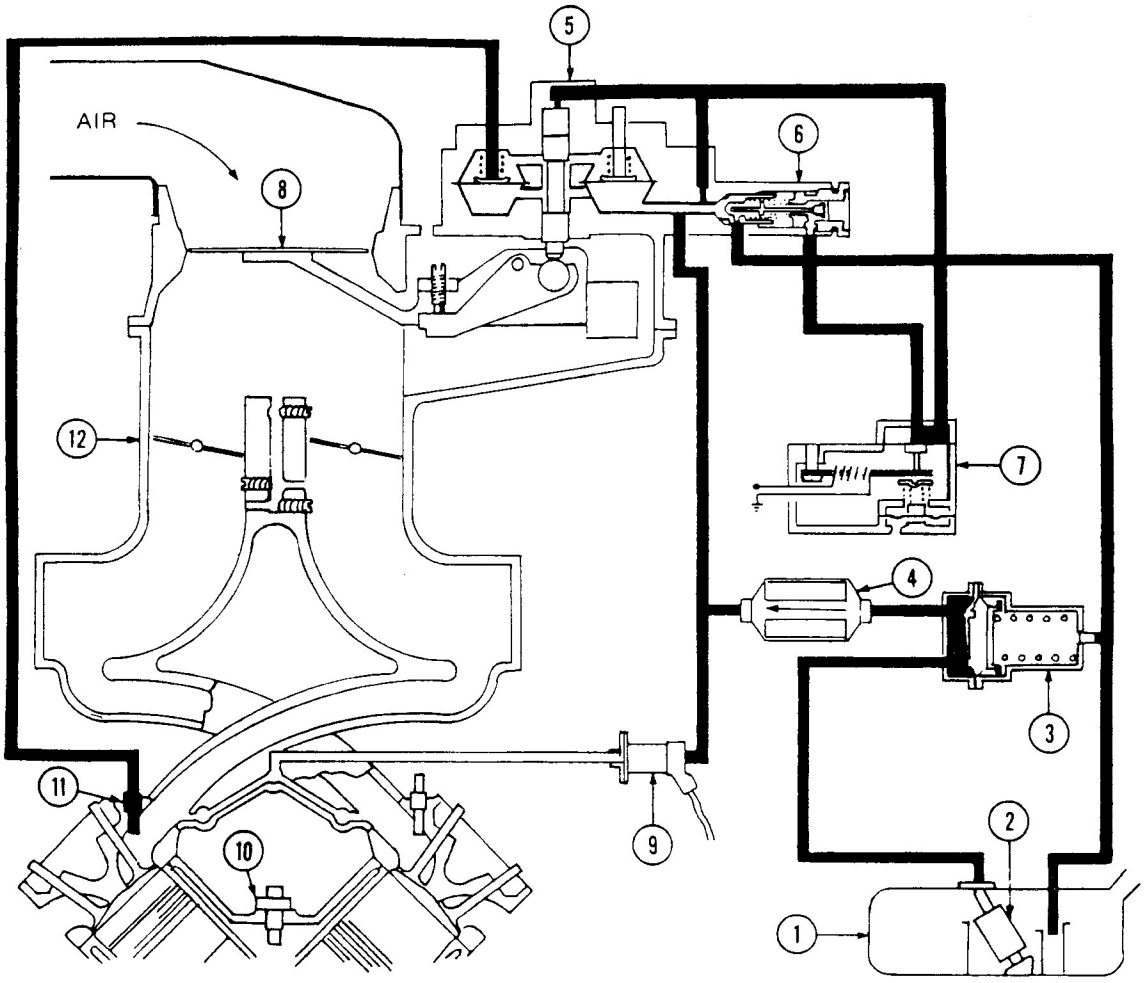

COMPONENTS AND DESCRIPTION

1. **Fuel Tank**
   A molded plastic fuel tank is located in the front wishbone of the frame. Access to the tank components is gained by removing the inspection panel inside the trunk.
2. **Fuel Pump**
   An electric rotary pump is used to provide fuel for the system. The pump is mounted inside the fuel tank.
3. **Fuel Accumulator**
   The accumulator keeps the system under pressure when the pump is not running. The accumulator is mounted inside the rear section of the frame backbone.
4. **Fuel Filter**
   A special filter is used to remove foreign particles from the fuel. The filter is mounted on the left rear frame rail.
5. **Fuel Distributor**
   The fuel distributor determines the necessary volume of fuel to be delivered to each injector.
6. **Primary Pressure Regulator**
   The primary pressure regulator controls the primary or main line fuel pressure in the system. The regulator is located inside the fuel distributor.
7. **Control Pressure Regulator**
   The control pressure regulator provides fuel enrichment during warm up and cold acceleration. The regulator is mounted on the left valve cover.
8. **Air Flow Sensor**
   The air flow sensor measures the amount of air entering the engine.
9. **Cold Start Valve**
   An electrically operated cold start valve is used to supply extra fuel to the engine during cold start conditions. The valve is mounted on the left side of the engine.
10. **Thermo-Time Switch**
    The thermo-time switch regulates injection time of the cold start valve. The switch is mounted in the thermostat housing.
11. **Injectors**
    The injectors are always open when the engine is running. Their main function is to atomize the fuel as it enters the intake chambers. The injectors are mounted in the cylinder heads.
12. **Throttle Valves**
    The throttle valves control the amount of air entering the engine. The throttle valves are located between the mixture control unit and the intake manifold.

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COMMON FUEL INJECTION PROBLEMS

The most common problem blamed on the DeLorean fuel injection system isn't with the injection system at all. As our vehicles age, various rubber components deteriorate and create vacuum leaks in critical locations in the intake system. Any air that enters the intake system without going past the metering plate changes the air/fuel mixture beyond the point where the mixture control unit can compensate, resulting in an incorrect mixture.

Most vacuum leaks occur on rubber hoses that port vacuum over to various accessories. The power brake system uses vacuum to assist braking action, and the under-dash air control doors are vacuum actuated as well. Check the hose connections to these devices for cracks and loose fit.

Vacuum lines also connect to the vacuum advance unit and control solenoid on the distributor, and to the warm-up regulator.

There is a rubber bellows that joins the air/fuel mixture casting to the aluminum casting that houses the throttle plates. Some of these have become brittle, and a leak here will have a drastic effect on air/fuel ratio. If you have ever removed the manifold section above the water pump (to expose the throttle plates or to replace the water hose underneath), air can leak into the joint if you failed to replace the O-ring and paper gaskets, or if the mounting bolts are not properly tightened.

Another occasional air leak is a loose injector or damaged plastic injector mounting bushing. The injectors are normally somewhat loose in their mounts, but they seal well when manifold vacuum is present, so leaks here are difficult to confirm. Usually real leaks are severe enough to cause obvious engine misfire.

Don't forget to inspect the hose connections on the fuel evaporative cannister. Remove the plate on the inside of the left pontoon where vacuum and fuel lines pass through to the cannister located inside the pontoon. Check for hose deterioration or looseness.

If the entire intake manifold has been removed, the six O-ring gaskets that seal the manifold to the engine block must be replaced, and the manifold mounting bolts tightened to torque specifications.

Professionals often use a propane torch to find these and other vacuum leaks. The torch is fitted with a small 1/16th-inch brass tube that serves as a probe. The engine is started, and propane is allowed to escape from the end of the tube (don't light it!). The end of the tube is passed over possible air leaks and the technician listens for changes in engine RPM. When the propane is brought near the leak, it is sucked into the air/fuel stream in place of surrounding air, which enriches the air/fuel mix, changing the engine's operation and usually increasing RPM slightly.

A less dangerous technique is to pressurize the manifold slightly by applying low air pressure to one of the manifold vacuum ports (toward the manifold) after first blocking off vacuum-operated accessory ports. With the engine switched off, a soap and water solution is sprayed lightly over the area. Air leaks will often show up as soap bubbles.

Another area of concern for DeLorean owners is rust contamination - not from the fuel tank, but from water inside the fuel distributor! The K-Jet system is designed to trap any water in the fuel in a small area in the center of the fuel distributor, which will eventually rust out the unit, or at least create enough rust particles to interfere with proper operation. If the engine is started frequently and allowed to reach full operating temperature this is not usually a problem, since engine heat will help vaporize any water in this area. If run infrequently, water tends to accumulate here and cause damage to this expensive component.

Other fuel injection problems can usually be pinpointed through a series of standardized tests that check fuel pressure at various points, and under various conditions. The test require a special K-Jet Fuel Injection Test Gauge, since ordinary fuel pressure gauges lack the proper pressure range, and usually lack the correct threaded fittings for K-Jet systems. A low cost gauge set suitable for the do-it-yourselfer is available for about $50 from J.C. Whitney and Co., part number 12-3617U. Anyone qualified to run a do-it-yourself operation on a high-pressure injection system knows who J.C. Whitney Company is, so no need to explain further. The gauge comes with all necessary fittings and a less-than-elegant set of instructions.

A description of all test procedures is beyond the scope of this article (or the space available in the magazine), but several excellent manuals are available on K-Jet systems (see listing at the end of this article) that go into great detail on proper service procedures. However, tests are described below in general terms and any noteworthy differences between standard K-Jet procedures in the referenced service manuals and equivalent tests on the DeLorean are detailed. Please do not attempt to service your injection system without consulting at least one of these manuals for specific techniques and safety precautions not presented here.

TESTING K-JET SYSTEMS

First a few words of caution before we get into test procedures. Since the K-Jet system employs potentially dangerous high-pressure fuel delivery techniques (up to 70 PSI), service should be performed only by individuals knowledgeable in this type of environment. The tests require "tapping" a high-pressure fuel line with a pressure gauge, and the potential for fuel leakage onto hot engine components, or spray into the eyes, can create serious fire and safety hazards. The procedure is safe if proper care is exercised, but if you do not feel comfortable with these procedures, take your DeLorean to a qualified repair center and use your knowledge of the system to validate what your mechanic tells you and help avoid unnecessary repair charges.

The DeLorean service manual has a good description of K-Jet operation, including some service instructions. You will need the specification data from this manual to complete the tests, since specs vary between DeLorean and other K-Jet systems, and (predictably), the commercial manuals don't go into specific detail on DeLoreans.

GAUGE CONNECTION

The referenced gauge connects between the fuel distributor and the warm-up regulator at the point shown in the DeLorean service manual. The gauge set includes a shutoff valve to stop fuel flow through the gauge hose to the warm-up regulator during certain tests, while allowing the gauge to continue to monitor pressure at the fuel distributor. The free end of the hose that does NOT connect directly to the valve should go to the fuel distributor. If you connect it backwards, shutting off the valve will shut off the gauge reading. The gauge comes with a set of fittings; use the fittings that the included instructions suggest for Volvo models.

BASIC TESTS

Basic tests for the DeLorean fuel system that are made without the gauge are:

Fuel Volume Test - Tests the volume of fuel delivered by the pump by measuring the amount of fuel delivered in 30 seconds of

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pump operation - about 1 quart. Nothing special here, except that you will need to run the fuel pump without running the engine. Figure 1 shows how to activate the fuel pump without starting the engine. Otherwise, instructions in referenced manuals apply as written.

Fuel Injector Test - Tests the volume of fuel delivered by each injector and the spray pattern. Ideally volume and pattern will be nearly the same, since you want each cylinder to get the same fuel/air charge. The test involves removing all injectors at once and placing their spray ends in jars (baby food jars work fine). Run the pump as shown in Figure 1 to about half-fill the jars, following standard procedures shown in the manuals. The procedures may ask you to raise the air sensor plate to start fuel delivery; in the DeLorean you depress the plate instead, since the DeLorean uses a downdraft venturi and the manuals consistently depict the updraft models.

Tests to determine if the fuel system is properly functioning require the gauge set and are performed in the following sequence:

Cold control pressure - tests a pressure used to control the amount of fuel delivered to the injectors while the engine is cold (not run for several hours)

Hot control pressure - same as above after engine has reached temperature of at least 68 degrees F. (20 degrees C.)

Primary pressure - Pressure delivered by the fuel pump, as regulated by the Pressure Regulator in the Fuel Distributor.

Rest Pressure - Residual pressure remaining in the system about 20 minutes after the engine is shut off.

All of these functional tests are conducted with the gauge connected as described above, and with the gauge valve open, except the Primary Pressure test, which is made with the valve closed. Follow standard instructions in the referenced manuals, substituting specifications from the DeLorean manual as appropriate. You will recognize the proper substitution, since the tables and graphs described in the commercial manuals are printed in virtually identical form in the DeLorean service manual.

This is not a complete description of all tests and adjustments that can be performed, but the remainder of the tests described in the referenced manuals apply equally to all K-Jet systems and need not be detailed here. Read up on K-Jet from at least one of the referenced books before starting, get your DeLorean service manual handy, and see if you can track down that elusive fuel system problem.

REFERENCE MANUALS OF INTEREST:

Mitchell's Electronic Fuel Injection Troubleshooting Guide for Import Vehicles - published by Fisher Books, P.O. Box 38040, Tucson, AZ 85740-8040., ISBN 1-55561-031-5. Available from J.C. Whitney and Co. as part number 16-6253A, about $17.95. An excellent manual on K-Jet systems; the best troubleshooting guide of this lot. Some good bookstores carry this manual.

Chilton's Guide to Fuel Injection and Feed-Back Carburetors - published by Chilton Book Company, Chilton Way, Radnor, PA 19089. No ISBN number. Available at almost any automotive shop, including Pep Boys and Chief Auto parts chains. Good section on K-Jet, but contains some errors that are mostly obvious. Good illustrations and tips/techniques. Cover much the same material as the Mitchell's guide, but enough different that both are worthwhile to own.

Automotive Fuel Injection Systems - A Technical Guide, by Jan P. Norbye - published by Motorbooks International, Osceola, Wisconsin 54020. Uncommon manual; I found mine at a Bookstop outlet. Tells all about Bosch, K-Jet, and every other conceivable fuel injection system ever introduced in the free world, except how to fix them. Outstanding history lesson, and details about K-Jet go right down to the designers' names and the formulas for determining the size of the air deflection plate. Interesting, but buy one of the others if interested in service procedures.

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ABOUT THE AUTHOR

Mark Hershey is a former electronics engineer now working in the telecommunications industry as Director of Customer Service for VMX, Inc., a manufacturer of voice message equipment. He is a 1975 graduate of Oklahoma State University, where he developed interests in computers, amateur radio, antique telephones, and anything non-automotive. Mark's inexperience with automotive technology did little to suppress a strong desire to own a DeLorean, which he finally realized with the purchase of a weathered specimen two years ago. Mark has agreed to share what he learned as an owner about servicing and restoring a DeLorean, starting this month with a story on the DeLorean's fuel injection system.

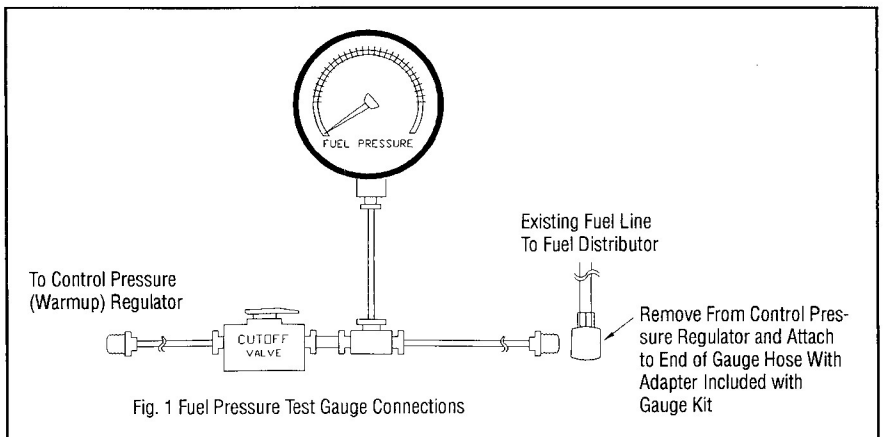

Fig. 1 Fuel Pressure Test Gauge Connections

FUEL PRESSURE TEST GAUGE CONNECTIONS