WELLS Counter Point

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THE ELECTRONIC, DIAGNOSTIC AND DRIVEABILITY RESOURCE.

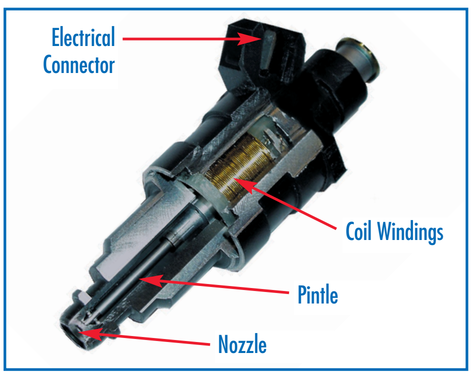
Fuel Injectors...To Begin With

Deliver exactly the right amount of fuel for one cylinder – that's the task for each fuel injector. Here's how it does the job, and how to tell when it doesn't.

For many years, almost every new car and truck in the United States has delivered its fuel through fuel injectors, usually one to a cylinder. The description fuel injector is misleading: Just as shock absorbers don't absorb shocks (the springs do), fuel injectors don't inject fuel (the fuel pump does). Most of the time, injectors simply block the flow of fuel. Only when the computer activates them by completing their electrical circuit, do they open and let fuel spray. Fuel injectors are fast-acting, precise electromechanical nozzles, metering the pressurized fuel into a finely atomized spray for the next power stroke.

SPOOLS AND NOZZLES

In the hundred and fifteen years since the first functional automobile *[Patentwagen 1886, Karl Benz Entwickler, Untertuerkheim – JW]*, there have been many types of fuel injectors, but the majority now work when an electromagnetic coil lifts a ferrous pintle or needle off its seat so fuel can squeeze through the nozzle's aperture and into the intake air channel. Because gasoline has such low viscosity, even minuscule pintle movement is enough to release the amount of fuel the engine needs next. The **P**owertrain **C**ontrol **M**odule (PCM) operates the fuel injectors, varying their delivery volume by the time it actuates their coils, the on-time or pulsewidth is measured in milliseconds. The computer calculates this time based on information from its sensors.



These include the throttle position sensor, the engine coolant temperature sensor, the intake manifold pressure sensor, the cam- or crankshaft position sensor and various other inputs depending on the vehicle's fuel/ignition system.

Most fuel injection systems determine fuel pressure at the injectors by the interworking of the fuel pump and the fuel pressure regulator, a pneumatic/hydraulic modulator is used to release fuel back to the tank. The regulator's return flow corresponds inversely to pressure in the intake manifold. As manifold pressure increases (increased load), the regulator returns less fuel back to the tank. As manifold pressure decreases (reduced load), the regulator returns more. On most cars, the electric fuel pump works at 100 percent capacity the entire time the engine is running, but the engine rarely or never uses all the fuel pumped.

At low coolant temperature, wide-open throttle, high load and high rpm, the engine burns almost all the gasoline the pump delivers. At high coolant temperature, idle and no load, the regulator returns most of the fuel back to the tank. This way the difference between the pressure of the fuel in the rail and the pressure of the air in the intake manifold remains constant. With a constant pressure difference, the only variable determining the quantity of fuel injected is the pulsewidth. This is the time the computer turns the injector on.

As fuel re-enters the tank, it produces substantial vapor. With tighter emissions standards, later injection systems have no pressure regulator or return line and run at a constant fuel pressure. It turned out easier to control fuel mixture at a constant fuel pressure (regardless of manifold vacuum/pressure) rather than to expand and complicate the charcoal canister vapor purge system. Fuel injectors on these 'returnless' fuel injection systems work the same as on the previous systems, but with shorter pulsewidths at low manifold pressure. When there is a greater difference between the fuel and the intake air pressure – at idle and deceleration – injector pulsewidth is extremely brief, or even non-existent.

FUEL RAMPING, CURRENT RAMPING

Fuel volume corresponds closely to the injectors' pulsewidth, but not in a linear correspondence. Understanding the electricity and fuel hydraulics

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Fine Tuning

*Fine Tuning questions are answered by Mark Hicks, Technical Services Manager. Please send your questions to: Mark Hicks c/o **Wells Manufacturing Corp., P.O. Box 70, Fond du Lac, WI 54936-0070** or e-mail him at **technical@wellsmfgcorp.com.** We'll send you a Wells shirt if your question is published. So please include your shirt size with your question.*

Q: "I recently replaced the distributor cap, rotor, and spark plug wires in my 1993 Jeep Grand Cherokee, 6-cylinder, with Wells products. Since that time, my garage door opener will only work about 50% of the time when the vehicle is running. If I turn off the ignition, the opener works 100% of the time. I tried a newer door transmitter from the manufacturer, but it has the same result. Have you ever had this problem before? Do you have any suggestions?"

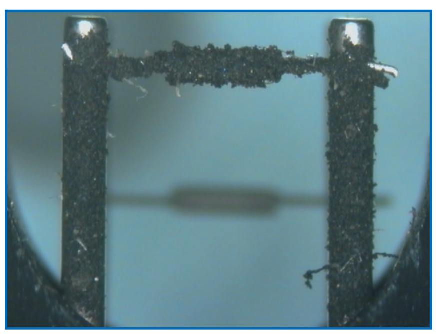
Mark Hull, Wausau, WI

The problem you are experiencing can be a very difficult one to pin down. It is caused by radio frequency interference (RFI). RFI occurs when electricity bridges a gap. Check the spark plug connections, you will feel a "snap" when they are correctly installed. Make sure you are not running the ignition wires completely parallel to each other. The spark plugs need to be the resistor type. Because of the difference in the porcelain from various manufacturers be sure to use the die-electric grease provided with the wire set.
Results: installing the die-electric grease solved the problem.

Q: "I have a 1991 Ford Explorer with 100,000 miles on it. I have owned it since it was new. Recently I have been experiencing a pinging noise when I am driving down the highway at cruising speed. If I accelerate, the ping goes away. I talked to my local garage and the technician there says I should disconnect the Octane clip. Does this sound correct to you or can you give me another idea?"

Wayne Smits, Depere, WI

In the technical services department we have received several calls pertaining to the problem you are experiencing. We have found that the mass airflow (MAF) sensor is usually at fault. On your vehicle the MAF sensor functions by keeping a coiled wire at a constant temperature. The current flow necessary to keep the wire temperature constant determines the amount of mass air entering the air intake. This coiled wire will become contaminated over time. With this contamination on the wire the PCM calculates less air than what is actually entering the intake. In turn the PCM will lean the fuel mixture. With a lean mixture a ping is created. I would suggest a close inspection of the MAF wires. If one is contaminated with grit the MAF needs to be replaced or cleaned.
Results: after the MAF was replaced, the problem was resolved.



Contaminated MAF Sensor

Diagnose The Problem Win A Shirt

I have a '96 Mercury Grand Marquis with a 4.6L engine. The Malfunction Indicator Lamp(MIL) has been coming on. I checked the codes and a P0121 was stored in the PCM. This code means the calculation between the MAF and TPS are not within specs. I have replaced both the TPS and MAF sensors and the light still comes on. What could be wrong?

The first reader to respond with the most accurate answer via e-mail or fax, and the first reader to respond with the most accurate answer via snail-mail, will each receive a Wells golf shirt. The answer, and the winners' names, will appear in the next issue.

Here is the answer to last issue's question regarding the 1997 Ford Taurus 3.0L with the random misfire codes:

At first it may seem like everything imaginable has been checked, reprogrammed or replaced to repair the intermittent miss fire on this 1997 Ford Taurus. The injector's feed wires have been thoroughly tested. However, the ground side is what really controls the function of the injector. If the PCM has an intermittent driver(s) to the injector(s) it would cause this problem. Another reason for this problem would be Electromagnetic pulses (EMP's). For example if the ignition wires are routed too close to the primary wires they could induce random false signals to the PCM.

The first correct answer we received was from Tony Greco from Comack, NY.

Quality Points

Wells Adds State-of-the-Art Component Placement Systems

Wells continues to grow and add new products. In order to meet those growing needs in an effective and efficient manner, we continually invest in new equipment and upgrades. Recently, we upgraded our **S**urface **M**ount **T**echnology (SMT) equipment to allow for additional placement capacity.

SMT component placement systems are rapidly evolving with particular focus on two distinct system features. The first relates to the capability of handling the next generation of surface mount components and second is to handle increased volumes or placement rates. Wells upgraded their current DIS assembly line with the latest technology available in pick and place equipment. It has the flexibility to pick components not only from magazine feeders but also from multi-stick feeders as well. The placement heads alternately pick up components from the stationary component feeder and place components on the substrate, which is motionless. This allows for extremely accurate placement.

With current demands and increasing additions of new sensor assemblies, Wells also upgraded the current sensor assembly line surface mount equipment with a high-speed flexible machine rated at 18,000 components per hour. Eight placement heads simultaneously pick components from any mix of feeders and scan on the fly across a vision camera ensuring accurate placement of all components.

At Wells, our investment in new technology is driven by our commitment to you. We want to ensure that no matter what product we supply you; it is manufactured to the highest quality standards and delivered on a timely basis.

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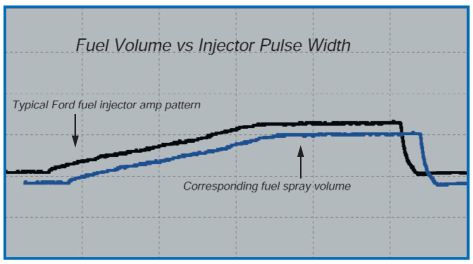
Fuel Injectors...To Begin With

involved accounts for how an injector can deliver a wide range of volume over a relatively small range of injector on-time. If you watch fuel spray from an injector, it seems to blast on instantly at full force and then to snap off. This is a trick of the eye. We cannot see different events separated by less than approximately a twentieth of a second from one another. The fuel flow actually 'ramps' gradually up and gradually down, though over a very short, millisecond of time. The flow rate at any instant is the product of the exact position of the pintle. We'll see shortly how this allows the wide range of delivery volume and, even more important, what this means when there are mechanical or electrical problems with an injector.



Fuel volume will intensify as the injector's Current flow increases.

It's not only fuel flow that 'ramps' up and down at the beginning and end of an injector pulse. The electric current through the injector's coil behaves similarly because of the coil's reluctance. Reluctance is a form of electrical resistance unique to coils. As electric current flows through the coil's windings, it builds a magnetic field pulling the pintle off its seat and releasing the fuel. But as that field grows, its lines of magnetic force pass through the same windings, causing a reversed-polarity voltage resisting the applied current. Finally, the reluctance disappears just as the coil reaches full magnetic saturation, the lines of magnetic force become stationary and the applied current reaches its maximum potential. When the PCM cuts the injector coil circuit, the magnetic field collapses. But as it collapses those same magnetic lines of force pass through the coil windings in the opposite direction, thus extending the duration of the magnetic field and the opening of the nozzle.

This answers a puzzle. You know the vehicle's system voltage, and you can measure the coil's room-temperature resistance. Using Ohm's Law, it ought to be possible to calculate the current through an injector coil. Of course, the injector is not constantly activated, so you'd multiply your calculated product by the duty-cycle (the percentage of time-on to time-off). But you get an amp number substantially higher than you'll measure with an ammeter. Why? Because of the reluctance, the current flowing through the coil functions as an electromagnetic brake on itself until the coil is saturated. If you monitor this current with an oscilloscope, the shape and slope of this current ramp reveal a great deal about the condition of the injector, as we'll discuss in subsequent articles. For present purposes, though, the current is what matters: Electromagnetism, the force that moves the pintle, is directly proportional to current. This verifies the pintle movement is also gradual.

Since the PCM controls the injector's on- and off-time, it can achieve very small but very precise pintle movement and correspondingly small but precise doses of fuel with a very short injector pulsewidth, hardly lifting the pintle off the seat. When conditions call for it, the PCM can achieve a large-volume delivery by extending the injector's pulsewidth, maximizing the time the injector flows as much fuel as it can. The difference in fuel per power stroke an engine requires varies by more than 100 to 1 from cold maximum power to warm idle, but the available pulsewidth of the injectors varies by much less. High volume injection is simple to achieve with maximum pump capacity and enough injector flow-through. It's at low volume that injector problems become most apparent. Only by using the fuel flow delay resulting from coil inductance, pintle and fuel inertia can the PCM deliver the smallest fuel quantities required with the accuracy to meet emissions standards.

PLUGS AND SHORTS

Injector problems fall into two groups: mechanical and electrical. Bad fuel and water in the fuel have damaged many injector nozzles and/or pintle tips. You can identify mechanical problems by a visual inspection of the fuel spray pattern. Listening for an injector's click (or its absence) can point to the first injector to observe. If grit or contaminated fuel get past the main filter, they'll quickly plug the small mesh filter in the top of the injector. Deposits formed from fuel droplets that evaporate after an engine shuts off can form gums and tars that clog an injector or skew its spray pattern, preventing the fuel from vaporizing completely. Sometimes such deposits prevent the pintle from seating completely, so the injector dribbles fuel. While fuel cushions the injector pintle's closing against the seat, it's still a mechanical part and will eventually show wear and begin to leak. Even the slowest unmetered leak can often transmit more fuel than we want at unloaded warm idle, as we saw above.

Most failed electrical circuits first become a short circuit and then quickly burn open, but with fuel injectors, you often notice driveability problems before the injector shorts completely. An injector that loses electrical resistance can have an interesting and puzzling effect. The usual way a coil changes resistance is by melting the thin insulation between adjacent windings of the wire. The failure does not occur all of a sudden. If the coil has 100 loops of wire, a short across the insulation between two loops can reduce the coil's resistance by no more than one percent, even if all the current went through the partial short circuit. Such a short may not noticeably affect the injector. It could be very hard to detect with even the best ohmmeter since new injector's resistance vary more than that and temperature changes account for even more. As the resistance goes down, the current goes up, as current goes up so does the heat. The heat increase will melt the next most vulnerable insulation barrier until it also forms a short.

Before long, that partially shorted injector pulls noticeably more current than the others. It is rare for an injector to burn all the way shorted or open. On most vehicles the PCM will shut the injector off to protect the driver transistors when the current exceeds or falls below a certain threshold. Some cars shut off all the injectors if any are shorted or open.

But before that happens, you may find the following: Often two injectors or even entire banks of cylinders fire together, particularly on earlier fuel injection systems and on engines with waste-spark ignition. The injector with lower resistance draws more current because electricity always follows the path of least resistance. Increased current to the partially shorted injector may 'starve' the paired injector of current so it can't lift its pintle and its cylinder gets little or no fuel. We then have the odd circumstance that the good injector does not spray enough for combustion but the defective one keeps working – not for long, but long enough to leave a diagnostician puzzled.

Usually fuel injectors operate and spray once for each complete engine cycle. Some vehicles use additional squirts for cold starting, acceleration enrichment or for other special conditions. Some vehicles have more than one set of injectors (and more than one set of intake runners) for each cylinder, employing the second set only under conditions of very high power demand and high engine speed. But the way individual injectors work in these systems is the same as in everyday vehicles.

In the next Counterpoint, we'll look at particular types of injectors and their characteristic problems and the tests for those problems.

WELLS

WELLS MANUFACTURING CORP.
P.O. Box 70
Fond du Lac, WI 54936-0070

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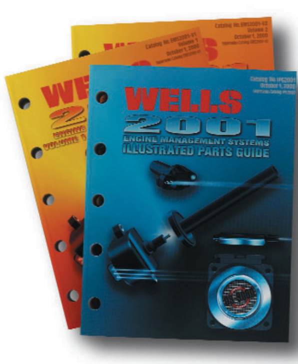
INSIDE: Fuel Injectors

Hot off the Wire

Wells 2001 Catalog & Parts Guide Now Available

Wells Manufacturing Corp. has published its extensive 2001 Engine Management Systems Catalog and 2001 Illustrated Parts Guide, which incorporate more than 3,000 new part numbers covering through model year 2001 vehicle applications.



The 2,291-page catalog has been divided into two volumes for easier storage and use. Volume 1 covers Acura through Ford passenger cars, while Volume 2 covers Ford trucks through Yugo. Both volumes also feature Professional Gold Program listings.

The fully-illustrated parts guide contains 1,014 pages of detailed information and several new categories, including:

- Four Wheel Drive Indicator Switches
- Four Wheel Drive Selector Switches
- Power Seat Heater Switches
- Rear Window Release Switches

In addition to these features, an alpha locator program has been implemented. The locator program indicates the size of each product box with an alpha code. This allows for improved utilization of shelf space, which maximizes return on investment through better inventory management. The program enables all like-size boxes to be plan-o-grammed together.

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