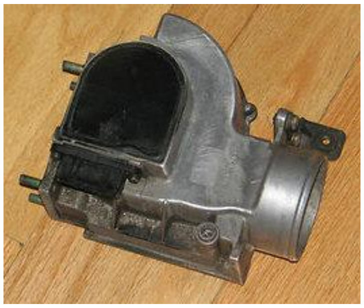
Toyota Fuel Injection

The multiport fuel injection system Toyota has used from the early 1980s to the 1990s on its various engine families is based on the Bosch L-Jetronic system. The system has evolved over the years and has earned a reputation for being relatively trouble-free. Even so, older high mileage cars and trucks can develop problems common to all fuel injection systems: pumps wear out, regulators fail, injectors become dirty or worn, cold start injectors can leak, and intake systems can become restricted due to accumulated carbon and fuel varnish.

HOW TOYOTA FUEL INJECTION MEASURES AIRFLOW

To regulate the air/fuel mixture, the engine computer needs to know how much air is being sucked into the engine. On the older Toyota EFI systems, air flow is measured mechanically with a flap-style airflow meter. A flap inside the meter rotates when incoming air pushes against it. Connected to the flap is a arm that rubs across a resistor grid (potentiometer). This changes the airflow meter's output voltage in proportion to airflow. The greater the air flow, the higher the resistance created by the potentiometer. So the meter's output voltage drops as airflow increases.



Older style Toyota flap-style merchanical airflow meter.

Over time, the potentiometer's contacts inside the airflow meter can wear causing erratic or inconsistent readings. Shorts or opens in the circuitry will also disrupt the voltage signal, depriving the engine computer of this vital bit of information. The result can be poor cold drivability, hesitation or poor performance.

The TCCS (Toyota Computer Control System) should set a code 2, 31 or 32 if the airflow meter signal is missing or out of range, but it may not always detect an intermittent problems. To find this kind of fault, an oscilloscope can help you analyze the airflow meter's output voltage as a waveform. If you don't see a nice linear change in the output voltage as the flap moves from idle to wide open throttle, it means the potentiometer is skipping and the airflow meter needs to be replaced.

Another way to check the operation of the airflow meter as well as the entire feedback circuit through the computer is to use a scope to compare injector dwell (on time) to the airflow signal. If you have a good airflow signal but injector dwell fails to increase as airflow goes up, there is a control problem in the computer.

The flap type air flow meters should also be inspected by pushing the flap with your finger. There should be no binding when the flap is pushed open, and spring pressure should return it to its closed position. A buildup of varnish or dirt may cause binding. Be sure to inspect the air filter if you find any dirt in the unit.

A temperature sensor located in the intake plumbing is used to measure air temperature so the computer can calculate how much air is actually entering the engine. Cold air is denser than warm air, and requires a slightly richer fuel mixture. The air temperature sensor changes resistance, so if the signal goes flat or disappears it too can upset the air/fuel mixture and cause drivability problems. Codes that would indicate a fault in the air temperature sensor circuit include 8, 23 and 24. You can use an ohmmeter to check the sensor's output. If the reading is out of specifications or fails to change as the temperature increases, the sensor is bad and needs to be replaced.

Newer style Toyota mass airflow sensor.

SECOND GENERATION TOYOTA AIRFLOW SENSOR

Starting in the mid-1990s, Toyota introduced a second-generation airflow sensor that combines the functions of the airflow meter and air temperature sensor into one unit. The new mass airflow sensor uses a hot wire to measure air mass rather than volume and has no moving parts. A reference voltage is applied to a thin wire inside the sensor that heats it to about 100 degrees C hotter than ambient air temperature. As air flows through the sensor and past the hot wire, it carries away heat and cools the wire. The electrical control circuit for the wire is designed to maintain a constant temperature differential, so the amount of extra voltage that's required to offset the cooling effect and keep the wire hot tells the control box how much air is entering the engine.

With both the early and late style airflow sensors, vacuum leaks can cause drivability problems by allowing unmetered air to enter the engine. Air leaks around the throttle body, injector O-rings, intake manifold gaskets or vacuum hose connections can cause the air/fuel ratio to go lean. So if you find a code 25 (lean air/fuel ratio), start looking for leaks.

Finding an air leak can be a time-consuming exercise in patience. One method is to use a propane bottle and hose to check out suspicious areas. When propane vapor is siphoned in through a leak, the idle will smooth out and the rpm will change. Another trick is to turn off the engine and lightly pressurize (no more than 5 PSI max) the intake manifold with compressed air. Then use a hand bottle to spray soapy water at possible leak points. Bubbles would indicate a leak. Another technique is to use a device that fills the intake manifold with smoke to reveal leaks.

Another often overlooked cause of air leakage is the EGR valve. If the valve sticks open, it will act much like a vacuum leak causing lean misfire at idle and hesitation problems.

TOYOTA FUEL INJECTION CIRCUIT

Fuel flows from a tank-mounted pump through the fuel line to an inline filter usually located in the engine compartment. It then goes to a common fuel rail (which Toyota calls the "fuel delivery pipe") on the engine to supply the injectors. The fuel injectors plug into the rail and are removed as an assembly with the rail. On V6 applications, there's a separate rail for each cylinder bank. Unfortunately, Toyota doesn't include a test valve on the fuel rail for checking fuel pressure. To perform a pressure check, you have to disconnect the cold start injector fuel fitting and attach a pressure gauge.

The pressure regulator is mounted on the end of the fuel rail, and maintains pressure at a constant level as engine load and intake vacuum change. A vacuum hose connected the regulator to the intake manifold so the diaphragm inside can react to changes in intake vacuum. A bypass valve inside the regulator routes excess fuel through a return line back to the fuel tank.

Toyota uses many different fuel pressure regulators so make sure you get the correct replacement.

System operating pressure varies depending on the application, but is typically from 30 to 37 PSI with the vacuum hose connected to the regulator, and 38 to 44 PSI with the hose disconnected and plugged.

NOTE: If you're replacing a regulator on a turbocharged engine, make sure you get the correct replacement because the regulator on these applications is calibrated differently from those on nonturbo motors.

Also, do not confuse the pressure regulator with a little round plastic gizmo that may be mounted on the end of the fuel rail. This is a pulse damper that helps dampen noise and resonance caused by the pulsing of the injectors.

Starting in 1996, some Toyota EFI systems switchd to a returnless EFI system. The regulator on the returnless EFI systems is located in the fuel tank with the pump.

TOYOTA FUEL INJECTION PRESSURE PROBLEMS

If fuel pressure reads low, or the engine seems to starve for fuel under load, don't overlook the fuel pickup filter inside the fuel tank as a possible cause. In many instances, the system may flow enough fuel at idle to develop normal pressure, but run out of fuel at higher speeds or loads. Rust, dirt and scum inside the tank may be blocking the flow of fuel into the pump. Likewise, accumulated dirt and debris may be clogging the inline filter.

Toyota says the best method for confirming a suspected fuel starvation problem is to road test the vehicle with a fuel pressure gauge safely installed on the engine. If the pressure reading drops when the engine is under load, it means the system isn't maintaining normal pressure. But is it the pump, filter or what?

You can rule out the pressure regulator if the system maintains normal pressure at idle, and the pressure rises when you disconnect the regulator's vacuum hose. No change in pressure would indicate a defective regulator or plugged vacuum line.

A good way to check out the pump, pickup filter and inline filter is to measure fuel delivery volume. Relieve system pressure, then disconnect the fuel supply line at the fuel filter or fuel rail, or disconnect the return hose from the rail. Place the open end of the fuel hose in a measuring cup or graduated cylinder. If you're disconnecting the return hose, you'll have to attach another piece of hose to the fuel rail and use that to route fuel into the container. With the engine off, use jumpers to bypass the pump relay. Energize the pump for 30 seconds and measure the volume of fuel delivered.

As a rule, a good pump should deliver about one quart of fuel in 30 seconds.

If a pump's output volume and/or pressure is low, the pump motor might be running slow due to internal wear. A typical fuel pump runs at 5,000 to 6,000 rpm and pulls about 3 to 6 amps. But as the armature brushes become worn and the brush springs weaken, increased resistance will reduce the pump's current draw and cause the motor to run slower causing it to deliver less fuel.

The pump motor can be checked using an ohmmeter to measure the motor's internal resistance. As a rule, most pumps should read 2 to 50 ohms if good. If the pump is open (reads infinity) or shows zero resistance (shorted), the motor is bad and the pump needs to be replaced.

Even if the pump motor is okay, fuel delivery problems can be caused by the pump's voltage supply. Low battery voltage, low system operating voltage, a poor ground connection or excessive resistance in the pump's wiring connectors or the relay can all have an adverse effect on the operating speed of the pump. The pump must have normal voltage to run at full speed, so always check the pump's wiring connectors and voltage supply when you encounter a pump with low pressure or volume output.

The pump's supply voltage should be within half a volt of normal battery voltage. If low, check the wiring connectors, relay and ground. A good connection should have less than a tenth of a volt drop (ideally no voltage drop) across it. A voltage drop of more than 0.4 volts can create enough resistance to cause a problem.

RESIDUAL FUEL PRESSURE

If an engine is hard to start when hot, fuel may be boiling in the rail because the system isn't holding residual pressure when the ignition is shut off. To prevent vapor lock and reduce the cranking time when restarting the engine, a check valve inside the fuel pump holds the pressure in the line. Toyota says pressure should remain above 21 psi for five minutes after the engine is turned off. If the system fails to hold pressure, either the check valve or pressure regulator is leaking, or an injector is leaking. Regulator leaks can be ruled out by pinching off the return line. Injector leaks can be checked by removing the fuel injector and rail assembly from the manifold, and pressurizing the rail. No fuel drips? Then it's the pump check valve.

TOYOTA FUEL INJECTORS

Four different types of injectors may be used in Toyota engines: pintle style, hole type (cone valve and ball valve), high resistance and low resistance. Bosch pintle style injectors are used on the older TCCS applications, while Nippondenso hole type injectors are used on newer engines. The hole type injectors spray fuel through holes drilled in a director plate at the injector tip. There are currently three different types including side-feed injectors used on the 3S-GTE and 2TZ-FE engines.

One of several different types of fuel injectors Toyota has used.
This one fits 1997 to 2000 Camry & Celica.

The valve design of the older pintle style injectors makes them more susceptible to deposit buildup than the hole type injectors. So if you're diagnosing a lean fuel condition on a Toyota with pintle style injectors, the injector may need to be cleaned.

Low resistance injectors are found on older Toyota up to about 1990, and measure 2 to 3 ohms at room temperature. The are used with an external resistor in a voltage-controlled driver circuit, or without an external resistor in a current-controlled driver circuit. High resistance injectors (13.8 ohms) are used on the newer applications, and do not require an external resistor.

When the ignition is turned on, voltage is supplied to the fuel injectors directly through the ignition circuit or through the EFI main relay depending on the application. The driver circuits in the computer then provides a ground to complete the connection and energize the injectors.

Toyota says never to apply battery voltage directly to a low resistance injector to test it because doing so can overheat and damage the windings in the solenoid. Use a resistor wire to protect the injector.

If an engine is misfiring and has a dead cylinder, and you've already ruled out ignition misfire or loss of compression as possible causes, use a stethoscope to listen to the injector. A steady buzz would tell you the injector is working and that the driver circuit is okay. No buzzing means a wiring or control problem. Check for voltage at the injector terminal when the key is on. No voltage? Check the EFI relay, fuse and wiring circuit. If there is voltage, use a logic probe or oscilloscope to see if the computer driver circuit is grounding the injector. No on-off signal would indicate a wiring problem or bad computer.

Injector resistance can be measured directly with an ohmmeter. An open, short or out-of-specification reading would tell you the injector has failed and needs to be replaced.

If the injector is buzzing but the cylinder is running lean or misfiring, the problem is likely a buildup of fuel varnish in the injector orifice or valve. Cleaning is the solution here, either on or off the vehicle. On-car cleaning saves time and can often restore the injectors to like-new performance. Off-car cleaning means you have to pull the injectors, but it gives you the opportunity to examine their spray pattern. There should be no solid streamers of liquid fuel, only a cone-shaped mist. If cleaning fails to restore the pattern, it's time for a new injector.

Something else that should be done if you're using off-car injection cleaning equipment is to compare the volume of fuel delivered by each injector. A difference of more than 10 percent can cause noticeable drivability and emission problems.

If injectors need to be replaced, always install new O-rings lightly lubricated with clean gasoline. Fuel rail banjo connections should also have new copper gaskets installed to prevent fuel leaks.

On 1991-94 1456cc Tercel engines, cylinders #1 and #3 use a different injector than #2 and #4, so be sure you install the correct injectors in each cylinder.

COLD START INJECTOR

Older Toyota applications use a cold start injector to squirt extra fuel into the manifold when a cold engine is first started. The "on time" of the injector is controlled by a start injector time switch and the computer. The number of seconds the cold start injector is energized (typically 2 to 8 seconds) is limited by a heater circuit inside the timer that has two coils. A bimetallic switch inside the timer is normally closed, so when the engine is started current flows through the cold start injector solenoid and both heater coils inside the timer. Within a few seconds, the heater coils trip the bimetallic switch causing it to open and turn off the cold start injector.

Toyota cold start fuel injector.

If the timer fails, the cold start injector will never come on and the engine may be hard to start when cold. The circuit can be checked by using a voltmeter to test for voltage at the cold start injector when the ignition is turned on. You should also check the resistance across the injector's terminals to check for an open or shorted solenoid. A good cold injector should read 2 to 4 ohms.

On most TCCS engines, an alternate ground may be supplied to the cold start injector by the computer at the STJ terminal. Using inputs from the engine's coolant temperature sensor, the computer can operate the cold start injector for up to three seconds regardless of the status of the timer switch. The maximum coolant temperature at which the computer will cycle on the cold start injector is 113 degrees F. Above that temperature the injector will not be energized by either the timer switch or computer.

Sometimes a cold start injector will hang open and leak fuel. The dribble may not seem like much but it may be enough to upset the air/fuel ratio and cause an increase in idle roughness and emissions. The cold start injector can be checked for leaks by removing it and pressurizing the fuel system.