Fuel Injector Testing

Edward F. Sowell

1976 Jaguar XJ-S

Background

Fuel injectors last a long time but, like everything else, are eventually subject to failure. The can fail in various ways, some of which can be fixed and others not. Just to give you and idea of the kind of tests and service injectors normally get by a professional, here is a list of things that were reported when I sent mine out for cleaning and testing in 1999, for $20 each (a unit of measure or the qualitative assessment indicators used is given in parentheses):

- **Flow** for an equivalent of 15 seconds continuous operation (CC), before and after cleaning. Rate of flow is critical because the ECU depends upon the specified flow during an energizing pulse of particular duration. Since injectors are designed for pulsed rather than continuous operation they are tested by pulsing, but the results are expressed in terms of "equivalent continuous operation." Dirty injectors have lower flow rates. In my case flow rate went up by about 10% or more due to cleaning.

- **Leaks** (OK or Leaks), before and after cleaning. Leakage can be either through the tip or internal. Tip leakage is caused by the valve not closing completely, perhaps due to dirt particles at the seat, which can't be seen without removing the injector from the car. Sometimes cleaning will resolve tip leaks. Internal leaks are when the casing breaks or something so that fuel goes where it shouldn't be. Sometimes this results in visible leakage from the plastic part of the injector body, so they can be seen without removing the injector. However, the testers rejected two of my injectors for internal leakage and I don't remember seeing any external signs, so I don't fully understand this failure mode. At any rate, cleaning won't fix this.

- **Spray pattern** (OK, stringy, or plugged), before and after cleaning. Even if the flow rate is OK and there are no leaks an injector can develop a poor spray pattern, possible affecting combustion. I have heard of shops servicing the racers that give actual spray patterns recorded on a blotter for each injector. The service I used only say OK, Stringy, or Plugged. Four of my 12 went from Stringy to OK after cleaning.

- **Coil resistance** (Ohms), cool and hot. The resistance of the solenoid coil is one measure of electrical soundness of an injector. I don't know everything that can happen in this category, but coil burn out is possible I suppose, in which case the resistance would be infinite. Perhaps internal leakage could result in corrosion, leading to higher than normal resistance.

In this writeup I address primarily testing for tip leakage. However, I describe how the test rig I built could be used for spray pattern testing, and what extensions would be necessary to do flow and resistance testing.

I assume the injectors have already been taken off the engine.

Air Pressure Test Rig

The easy way to test an injector for leakage is with air. In Figure 1 I show a simple test rig you can build with readily available parts. It looks more complicated than it really is. In its most basic form it is just a matter of hooking a bicycle pump and pressure gauge to the injector. However, the realities of plumbing results in the kluge you see in the figure.

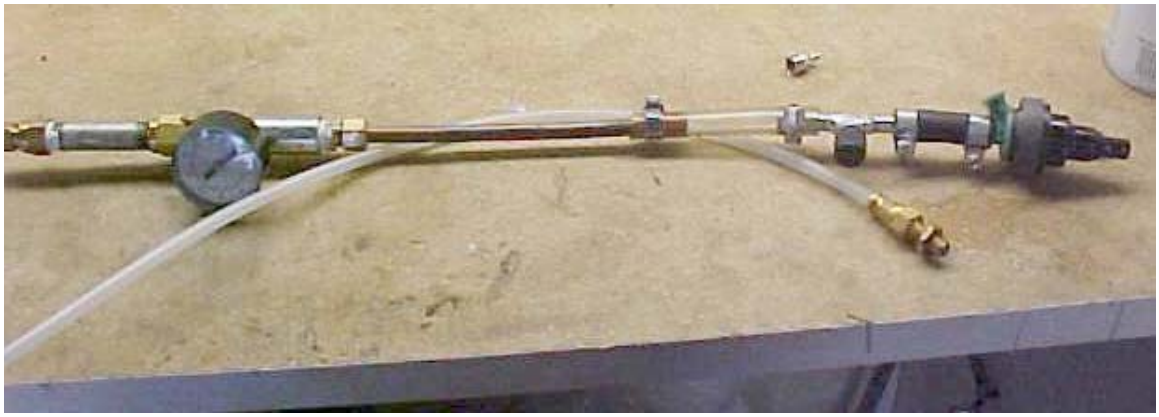

Figure 1 Pressure test rig.

To connect to the pump you need a Schrader fitting. I got one designed for air-shocks, as used in the RV industry. Try a local RV repair or supply shop. Another source of Schrader fittings is the junk yard. Find some fuel injected car and look around for a test port on the rail. These look like a bicycle tire valve stem, and screw into the rail with a 1/8" pipe thread.

In my rig the Schrader valve connects to hard polyethylene tubing (the milky white stuff at the hardware store), as seen at the right end of the photo. The tubing is long enough to reach from a bicycle pump on the floor to my workbench. It is connected through various brass fittings and a short length of ¼" galvanized pipe to an air pressure gauge, purchased at Home Depot in the air tools department. A length of 5/16" copper tubing is fitted to the gauge outlet. I have clear PVC tubing clamped to the copper tubing, but obviously normal FI hose would do as well. For leak testing with air only you can fit the injector directly to this tubing. In the photo you can see that I have an additional fitting in between. This is a 5/16" aluminum test port, purchased at an automotive AC supply house. It can be used to feed fuel into the injector for other operations, e.g., liquid leak testing, cleaning, and spray pattern testing.

Note that I use a bicycle pump to pressurize the rig. There is not much volume in the rig, so you could easily over pressurize it if you attempted to use shop air.

Leakage Testing with Air

To test an injector simply clamp it into the test rig, connect your bicycle pump to the other end, and pump it up to the desired test pressure. I test at 40-60 PSIG. A spray bottle with a dilute solution of dish soap is used to spray the injector tip. Any leakage will show up as bubbles at the injector tip. Also, if all joints in your test rig are leak free (test them with the spray) you can watch for decay in the gauge reading over 10-15 minutes.

It is worthwhile to note that molecules of the constituents of air (N_2, O_2, etc.) are quite a bit smaller than those for gasoline. Therefore an injector that passes this test will not likely leak any gasoline. Moreover, an injector that leaks a little air may be leak free with gasoline. I hedge a bit here because although I have done some checking and asking around, am not absolutely certain on this point. If anyone has contradictory experience, please let me know. In my case nine were leak free in the air. Three produced very slight bubbling. Rather than rejecting these as bad, however, I took them to the next stage of testing.

Testing with Fuel

To test injectors with fuel you need to feed a bit of fuel to the injector tip. While you may think you could do this with an eye dropper it doesn't work. First, it's hard to find an eye dropper theses days. The real problem is that air in the injector, together with fuel surface tension, prevents the fuel from flowing to the tip. The solution I found was to energize the injector coil with 12v to open it, allowing the air to be displaced with liquid fuel.

Note: With gasoline on the bench you do not want to do this by touching live wires to the injector electrical contacts!

Instead, construct something like I show in Figure 2. This is simply a pair of leads with an injector connector at one end and alligator clips on the other, and a momentary contact button switch in one of the leads. The clips and button are Radio Shack items and the injector connector is NAPA part #2-17411 (one required) and #2-17414 (2 required). For a power supply I use an idea from Sean Straw's Web site (http://jaguar.professional.org/tools/Electrics.php), Figure 3. It plugs into the cigar lighter and provides a convenient 12v anywhere near the car. (Unfortunately, mine is not quite long enough to reach my workbench so I wound up doing some testing on the garage floor.)

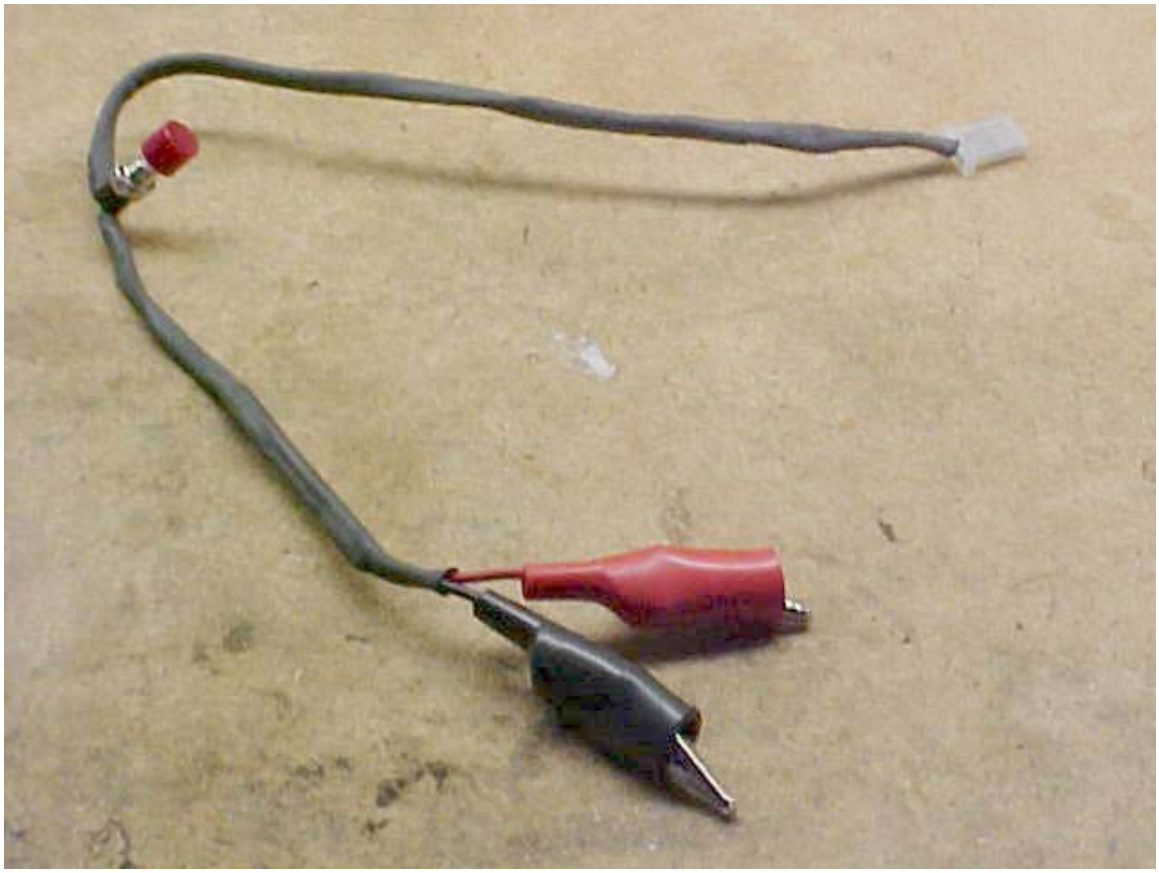

Figure 2 Injector test energizer rig.

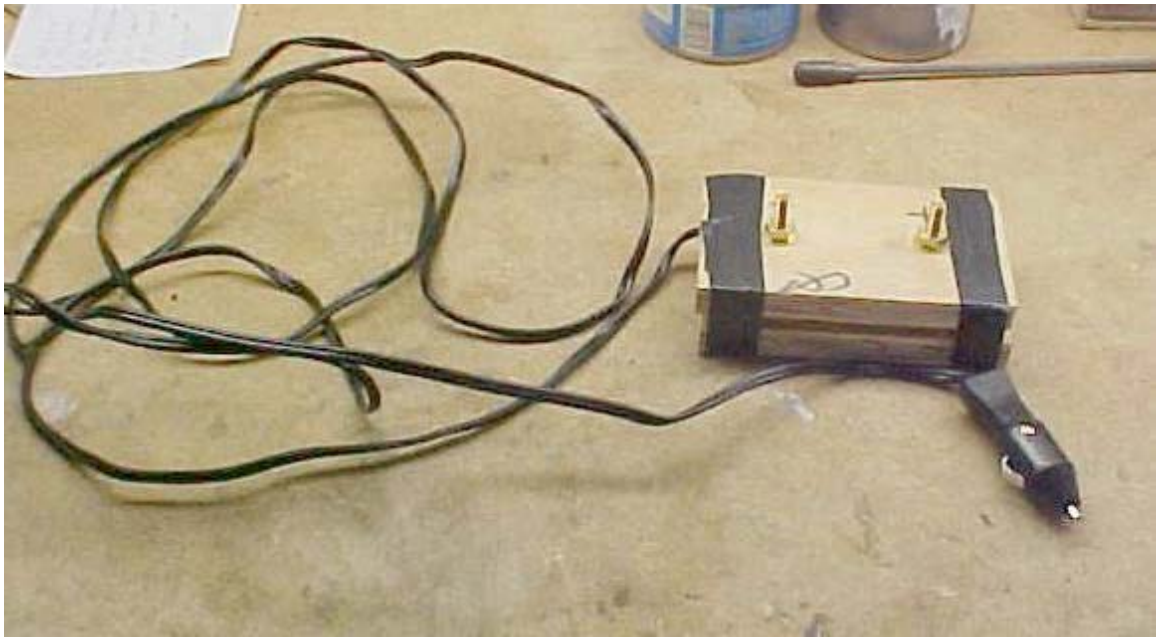

Figure 3 Power supply (credit to Sean Straw)

Now, back to testing with fuel. Grip the pressure test rig with injector in place in a vice, with the injector tip hanging over something to catch the fuel (like a tuna can), Figure 4. Connect the injector to the energizer rig and remove the cap from the test port in the pressure test rig. Now, if you haven't been able to locate an eye dropper, you can use a length of 1/8" hard flex tubing, or a soda straw, to get the fuel into the system . Dip it into a jar of gasoline and hold your finger over the free end. Move the other end over to the test port and release the gasoline into the test port. Do this several time so you have a decent amount in the injector feed tube. At this point it will not be all the way to the tip due to air blockage. Press the energizer button several times for a second or so at a time. (I've read that one mustn't energize continuously for fear of overheating the coil.) Eventually you will see fuel dribbling out the injector tip. A mechanic's mirror under the tip helps you see the tip if you're working on the floor as I am here.

Figure 4 Testing with fuel.

Now that the injector has fuel all the way to the tip you can see if it leaks fuel. Replace the cap on the test port, being sure the little o-ring is in the cap. Pump up the rig to the wanted test pressure, e.g., 40-60 PSIG. Watch the tip carefully for several minutes to see if it gets wet. If it stays absolutely dry you have a good injector. Again, a mirror helps, Figure 5. Any wetness means you have to either toss the injector or try to get it to stop leaking (see Cleaning the Injector below). In my case none of the injectors that leaked air leaked fuel at 40 PSIG. Nonetheless, I took them to the next stage.

Figure 5 Injector tip in mirror.

Cleaning the Injector

Note: This should be done with great care, away from all open flame etc. The spray created is extremely flammable. Do not energize the injector by touching bare wires together or to the injector, as sparking could ignite the gasoline vapor.

If the injector leaks fuel it could be just because there's a bit of something caught in the seat. The easy first try is to pump the pressure up to about 60 PSIG and hit the energizer button to a few times. Be sure you have a catch pan or something because it will emit a strong, fine spray of gasoline. This may be sufficient to dislodge the dirt. Then wipe the tip dry and watch it again for several minutes to see if it still leaks.

If fuel alone doesn't work you can try making a strong mixture of injector cleaner and gasoline to fill the injector and repeat the spray test. If the injector has been in long service without cleaning you may even want to fill it with the solution and let it soak for a day or so. I've never done this, so can't say how effective it will be. You could also try to locate stronger cleaners.

Other Operations with the Test Rig

With a little more effort you could extend the testing with the test rig described here. I have not tried any of these things, so you will be on your own.

As mentioned before, one thing professional injector shops do is checking of spray patterns. You could do this merely by placing blotter paper of some kind a measured distance, perhaps an inch or two from the tip. A quick hit to the energizer button will leave a wet pattern on the blotter. You could then trace around it with pen or pencil to get a permanent record of the pattern. I would not know how to tell a good pattern from a bad, but at least you could tell if some injectors were wildly different from the others. The difficulty I see in doing a good job at this task would be carefully maintaining the same parameters between tests, e.g., tip to blotter distance, pressure, and energizing time for each injector tested. Obviously, the latter would be the greatest challenge, but it should be easy to tell how you are doing just by repeating the test with the same injector. If you get a different spray pattern every time with the same injector something's wrong, most likely the length of button contact time. If this were the case the button could be replaced with an electronic pulse generator. The electronically inclined could probably do this without too much difficulty, perhaps using a 555 timer chip.

If you are really ambitious you could attempt to do flow rate testing too. For this you would surely have to build a pulse generator that generates a series of pulses of some prescribed length over a prescribed period of time. You will also have to somehow measure flow accurately, but that should be easy with a graduated cylinder (is that the right term?) from a high school chemistry lab. The shop that I sent my injectors to several years ago reported flow rates in terms of cubic centimeters of fuel "equivalent to wide open flow for 15 seconds." For my preHE injectors, they reported 61CC to 71CC before cleaning and 75CC after. Since I don't think they energize them for 15 seconds continuously, my guess is that their machine probably uses a series of pulses with a total open time somewhat more than 15 seconds to account for the dynamics of the fluid motion. This subject could easily get challenging if you were to try to really do a good job, but you might be able to do some satisfying comparative tests with modest effort. I probably won't take this further myself.

Finally, you could easily measure the coil resistance for each injector. From the results of earlier professional testing I gather that the preHE injectors should be 2.8 ohms cold and 3.3 hot. One could do this testing with nothing more than an ohmmeter and a heat gun.