Fuel System Testing

All EFI engines require a supply of high pressure fuel with sufficient FLOW to meet the engine power requirement. If any component of the system causes a flow restriction at the rated system pressure then potentially dangerous “lean-outs”, high exhaust temperatures and limited power output will result. All fuel systems should be tested periodically for correct flow and pressure since some system components are subject to wear, and have a finite service life. This is especially important on high power race vehicles where continuous high fuel flow is required.

Typical Symptoms

The following list outlines some of the more common symptoms caused by inadequate fuel flows.

1. Engine runs lean at high power despite all efforts to increase fuel flow using normal computer / controller adjustments. Use the ECU tuning tool to monitor injector flow or measure injector duty using an external meter. Large increases in injector duty with no apparent change in air / fuel ratio is a very common indicator of inadequate fuel flow.
   Note: If the air/fuel ratio is acceptable up to (say) 95% injector duty and then falls off rapidly, then this is more likely to be inadequately sized injectors. See later details for injector selection.

2. Exhaust gas temperature excessively high, as measured with suitable EGT probe. (This may also be caused by relatively retarded ignition so look for other symptoms in conjunction with this.)
   Note: Engine coolant temperature is NOT a suitable indicator since many other factors affect this temperature

3. Engine power/torque tends to “fade” away or starts surging at high power. (Abrupt misfiring is more likely to be caused by ignition rather than fuel. “Lean-outs” tend to be subtle rather than aggressive.)

4. Detonation (knock) is heard, or indicated on suitable instrument. Although detonation has many causes, running a relatively rich air/fuel ratio will reduce the onset or severity of knock. Whatever the cause detonation MUST be eliminated quickly or serious engine damage will result.

Injector Flow Rating

The total injector flow must equal or exceed the amount required to produce the target engine power output. Ideally, each cylinder should have a single, adequately rated injector per port. Multiple injectors per port improve flow but are complicated in terms of space, wiring and plumbing. It is often less expensive to replace low flow items rather than add additional injectors. Injector flow is also a function of fuel pressure but see cautions regarding very high pressure operation in subsequent sections of this text.
Injector flows are best tested on a specialized injector test rig, and must always be expressed as cc/minute (lbs/hour) AT 100% FLOW, at a stated pressure value.
(Flow figures given at other duty cycles or obscure “RPM” values are mostly useless)
The following formulae give power versus flow for typical petrol/gasoline engines expressed in both metric and imperial measure. (Total flow for ALL injectors)

1000 cc (ml) / minute	=	200 Horsepower (147 KW)
97 lbs/hour	=	200 Horsepower

NOTE:	US gallon	=	3.785 litres
	Imperial gallon	=	4.546 litres

When selecting flow rates remember to multiply the individual injector flow by the number of injectors to give total flow.

Fuel Pump Testing

Most EFI systems utilize an electric fuel pump, pressure regulator and return line to provide a constant fuel pressure differential across the injectors. This requires the fuel pressure to vary with manifold air pressure in both vacuum and boost phases of operation, with the excess fuel returning to the tank. Some fuel pumps run at 100% flow (full voltage) at all times while some systems reduce the voltage supply at low power to reduce heat, wear and noise. This is normally controlled by the engine control ECU, but may also have external drive modules or resistors to do the actual power control. In all cases the pump must be run at full voltage when testing the system so some form of controller by-pass may be required.
(Ensure that the system voltage is at least 13 volts during this test. If necessary connect a battery charger or idle the engine to keep the voltage up. The flow ability of the pump is quite voltage dependent.)

NOTE: The system may be checked in-vehicle using a pressure gauge and running the engine at full power. The gauge pressure must rise and fall with manifold pressure, and indicate full (boost) pressure at maximum RPM and boost. A pressure reading that is initially high then falls with increasing RPM indicates a fuel supply problem. In short, the readings must be carefully interpreted.

1. Disconnect the FUEL RETURN line between the pressure regulator and the fuel tank. Redirect the return flow into a suitable container.

2. Apply air pressure to the fuel pressure regulator reference port equal to the highest boost pressure that the system is likely to run. Normally aspirated engines should have the port open to atmosphere only. A “Mityvac” is the preferred tool for this since it provides a metered source of compressed air.

3. Run the pump at full voltage for a measured period of time E.G. 30 seconds, and collect the return fuel.

4. Measure the amount of returned fuel using a graduated measure. Compare the quantity with the required amount and decide if adequate flow is present.

Important Notes:

- The flow will fall off quite quickly with increasing pressure. Ensure the test is done at the full, anticipated boost pressure.
- Simply measuring the flow at zero pressure (straight out of the pump, no pressure regulator) is a complete waste of time.
- If flow is less than expected, replace fuel filters and check for blockages or restrictions in the fuel lines. The fuel pump MUST have some sort of inlet (pre) filter to protect the precision internal parts. A high pressure (post) filter is recommended but not essential.
- A high performance pump will flow at least 3 litres (3000 cc) per minute at a fuel pressure of about 4 Bar (60 PSI). Most factory pumps will do less, typically about 2 litres / minute under similar conditions. It may be necessary to run multiple pumps for very high power applications, in which case the pumps must be connected in PARALLEL (side by side). Never connect the pumps in series (end to end). This will not work.

Increasing Flow by Raising Pressure.

A current trend in performance modification is to increase the fuel pressure above standard to increase injector flow. This works in theory but has a number of pitfalls if not carefully done:

1. The increase in flow is proportional to the SQUARE ROOT of the pressure. This means that if the fuel pressure could be doubled (unlikely) then the increase in flow would be only 41%. A typical system may allow (say) a 20% increase in pressure which will result in a flow increase of about 9%. This is probably a practical limit.
2. Any increase in fuel pressure will decrease the available flow from the pump. In some cases raising the pressure results in less NET flow if the pump is marginal.
3. Increasing pressure may give higher full power flow but will also increase flow at low and medium powers causing the engine to run unnecessarily rich. This is OK if the EFI system is adjustable, but many factory systems will run poorly in this area of operation.
4. “Rising rate” pressure regulators have a non-linear pressure curve which increases fuel pressure more at higher manifold air pressures and have less effect at medium/lower pressures. To date however, such devices have proved to be unstable and erratic in operation. Usage is not recommended at this time.