## Fuel Delivery System Requirements

Adequate fuel delivery is generally the greatest problem that we have encountered when tuning and calibrating EFI systems. We cannot stress enough how important it is to have adequate, consistent fuel pressure, **and** volume to the injectors. The use of a properly sized fuel line from the tank, fuel rail and return hose is imperative. Measures must be taken to eliminate excessive pulsations in the fuel rail so the injectors get even fuel flow. These instructions will review the entire fuel delivery system in the following section to help you design your own comprehensive fuel delivery system. On vehicles using the PNP version of the AEM PEMS, all of the essential elements for adequate fuel delivery are designed into the stock fuel system. If you are using a PNP system on a vehicle that is heavily modified (forced induction, nitrous oxide, etc.) pay close attention to the following information regarding fuel delivery, as the OE fuel delivery system may not be capable of supplying an adequate amount of fuel.

## Fuel Tank or Fuel Cell

In most cases the stock fuel tank is acceptable for street use. Most OE fuel tanks have internal baffles to reduce fuel slosh in the tank, which reduce the chances of intermittent fuel delivery.

Fuel cells are the best means of fuel storage because they eliminate the chance of fuel slosh by using a foam liner that dampens the fuel travel. Fuel cells also have the fuel pick up placed in a position that is at the lowest portion of the tank—or in the case of a drag racing car—in the rear of the tank where the fuel shifts to during acceleration.

In either case, the tank must be vented to provide air for displaced fuel as the engine consumes it. The tank must also have provisions for fuel return. It is important that the fuel return be placed as far away from the pick up as possible to prevent foaming or bubbles at the inlet.

## Fuel Pump Sizing

To achieve proper fuel delivery, you must select the right fuel pump for your vehicle. In most cases, where the engine has been modified only with "bolt on" performance items, there is rarely need for a larger fuel pump or larger injectors. Vehicle manufacturers typically design a "safety factor" into the fuel pump to accommodate the deterioration of the fuel system over time. This safety factor is intended to compensate for a fuel filter that is nearing the end its life, or for deposits in the injector orifice. Our research has revealed that generally there is about a 15%-20% oversize in most factory fuel pumps.

If the engine is enhanced via forced induction or nitrous oxide, the stock fuel pump is inadequate. **If the engine's power is increased more than 15-20% fuel delivery must increase as a factor of the power gain.**

The way to determine the proper-size fuel pump is based on the desired brake specific fuel consumption (BSFC) of the engine. This term refers to how much fuel in pounds per hour (pph) the engine consumes per horsepower and is a measure of the efficiency of the engine. It is a useful term in determining the total fuel requirement of the engine.

On vehicles equipped with forced induction or nitrous oxide, higher BSFC's are required as an added measure of safety to prevent detonation or high combustion chamber temperatures. Below is a guide of BSFC's with standard CR that AEM uses for various engines that run on gasoline:

- Naturally Aspirated engines have a BSFC of .48 to .50
- Forced Induction engines have a BSFC of .65 to .68

Methanol (alcohol) powered engines require twice the amount of fuel so the BSFC's are doubled.

Calculating the total fuel requirement of an engine requires simple equations that we outline in the following section. You must know how much power the engine is anticipated to make and we recommend that you guess on the high end. The fuel requirement will be determined in pounds per hour of fuel flow. Since most pumps are rated in gallons/hour you must know the weight of your fuel/gallon. (The vast majority of gasoline based fuels run at 7.25 lbs./gallon.)

The equations to determine your fuel requirement is as follows:

- **(Power x BSFC) x (1 + Safety Margin) = pounds/hour**
- **Pounds/hour / 7.25 = gallons/hour.**

An example of this equation is:

- 500 hp gasoline engine using moderate boost with a 30% safety margin
- (500 x .625) x 1.30 = 406.25 lbs./hr.
- 406lbs/7.25 = 56 gallons/hour.
- If the pump that is being considered is rated in liters per hour, use the conversion factor of 3.785l/gallon. The pump described above would be rated at 56 gallons **x** 3.785 liters = 211.96 liters/hour.

In the fuel pump sizing, always use a safety margin greater than 20%.

## Fuel Pump Location

The fuel pump should be located at a level that corresponds the lowest part of the fuel tank. This does **NOT** mean that the pump should be in a vulnerable position such as hanging below the tank. The pump should also be positioned so that it is protected from the road hazards (speed bumps, curbs, road debris etc.). In the event of an accident, the vehicle structure around the fuel pump should not deform to a point where the pump and its electrical connections are compromised.

The wiring for the fuel pump **MUST** be rated for the amperage of the pump. As with all high current wiring, a fuse rated for the amperage of the pump should be used. It is always better to err on the large side for the wire size. The ground for the pump must be the same size as the power lead and be mounted to a location that is clean and clear of any undercoating or paint.

## Fuel Injectors

The AEM PEMS requires the use of "saturated" or high-impedance fuel injectors. **If "Peak and Hold" or low impedance injectors are to be used, an injector resistor must be used or you will damage the ECU.** Resistors can be purchased from AEM. The PNP version of the AEM PEMS is configured for the stock injectors and no additional parts are required.

To determine the size of the injectors, the total engine power must be estimated or known. The fuel pump calculations and BSFC information mentioned in the previous section provides a good understanding of the fuel requirements for an engine. The following equation will allow you to determine the requirements of your injectors:

Using the same engine as above:

- **((Power x BSFC) x (1 + Safety Margin))/Number of Injectors = pounds/hour**
-

An example of this equation is:

- 6 CYL. engine rated at 500 hp on gasoline using moderate boost with a 15% safety margin on the injector
- 500 x .625 = 313 lbs/6 = 52 lbs/hr/ injector. 52 x 1.15=60lbs/hr/ injector

If we take the flow of the injector (60 lbs/hr) and multiply it by the number of cylinders (6), we arrive at a total of 360 lbs/hr of flow. As you can see, the fuel pump described above has enough capacity to feed the engine with a little room to spare.

It is a good idea to know the maximum operating pressure of the fuel injectors. In some cases the fuel injector will not open if the fuel pressure exceeds the design limit of the injector. Also, at the higher pressures the injector fuel flow may become non-linear and cause inconsistent fuel delivery, usually creating a lean condition. Most injectors can withstand up to 70 psi. Many of the pintle style injectors can withstand higher pressure.

In the fuel injector sizing, always use a safety margin between 15-20%.

## Fuel Hoses & Routing

Even with proper injector and fuel pump sizing, a fuel system will not flow adequately unless the hoses that deliver the fuel to the fuel rail are of sufficient size and are routed properly. On systems that use the PNP version of the AEM PEMS, there is no need to replace the fuel delivery hoses unless the engine is heavily modified.

**NEVER** route fuel hoses through the interior of a car. Put bluntly, this is a **dangerous** thing to do. Whenever possible, use a delivery tube to make the connection from the pump discharge to the filter in the front of the car. The lines should be rated to withstand at least twice the maximum pressure of the EFI system.

Using the above parameters of our sample engine with moderate boost, we expect to see pressures in the 65-70 psi range. This will require a line with at least 140-psi rating (most AN hoses exceed this by a large margin). When routing fuel lines, it is imperative that they are protected from road hazards and the exhaust system. The fuel line should **NEVER** be routed near battery cables. Use clamps to secure AN hose every 15 inches, or 24 inches if a rigid tube is used.

The following table will help you determine which hose size is correct for your application: These sizes are based on a nominal fuel pressure of 40 psi.

## Fuel Delivery Hose Sizes

### Gasoline Powered Engines

Up to 499 HP .344” hose -6AN
500 - 799 HP .437” hose -8 AN
900 – 1100 HP .562” hose -10 AN

### Methanol Engines

Up to 499 HP .437” hose -8 AN
500 - 799 HP .562” hose -10 AN
900 – 1100 HP .687” hose -12 AN

The above table should be used for typical passenger car applications. However, for custom applications the hose run length will affect fuel delivery. If you have a long hose run, then the actual flow will have to be determined by running the fuel pump into a graduated cylinder, then measuring the flow vs. time and calculating the flow in gallons per hour (g/h). Also note that if fuel banjos are used in the system be sure they have adequate fuel flow capability.

The fuel return hoses should be one size smaller than the delivery hose. For the sample engine described above, we would use a .437” (-8) delivery hose and a .344” (-6) return hose.

## Fuel Filter and Fuel Rail

Often overlooked in EFI installations, the fuel filter must have the capacity, filtering efficiency and burst strength to withstand the pressures of an EFI system. It must be able to flow the amount of fuel that matches the maximum fuel pump output. The filter is always located after the fuel pump, however it does not matter if it is positioned in the front or rear of the vehicle (we prefer to put it toward the front for easy serviceability). AEM carries fuel filters for high-powered engines, which use an easy to find, high volume, replaceable element.

It is imperative that a pre-filter be mounted to the fuel pick up in the tank. These filters are very high volume and create very little pressure drop. The use of a pre-filter ensures long fuel pump life and can eliminate low flow conditions caused by debris entering the pump inlet.

The final link in the fuel delivery system is the fuel rail. The fuel rail should be consistent with, or larger than, the hose size. The additional capacity of a large-diameter fuel rail helps to dampen the pulsations created by the fuel injectors and ensures even fuel delivery under all conditions.

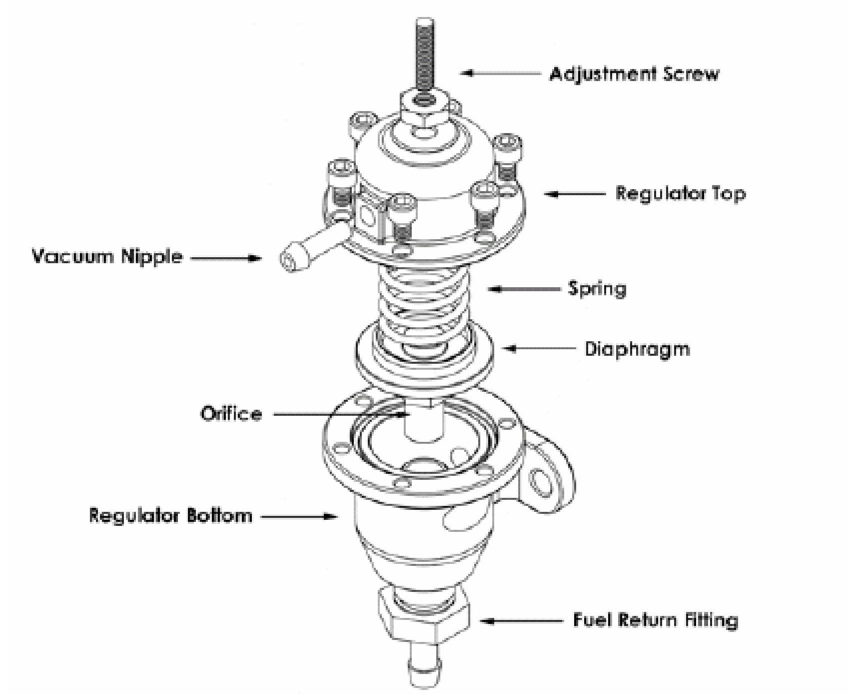


## Fuel Pressure Regulator and Pulse Dampener

The fuel pressure regulator maintains a constant pressure across the fuel injector. The inlet manifold pressure varies with throttle angle, and engine speed. Small throttle angles and high engine speed produce low manifold pressure (high vacuum). While high throttle angles and low rpm give high manifold pressure. In addition to these conditions, low manifold pressure is associated with idle and high manifold pressure is at full throttle. It is the fuel pressure regulators job to keep a constant fuel pressure across the injector(s) regardless of manifold pressure.

Currently, there are several types of fuel pressure regulators in use. Many late model cars use a return-less system where the fuel pressure regulator is mounted in the fuel tank adjacent to the fuel pump (and therefore requires no return line back to the fuel tank). In most naturally aspirated applications these types of systems are adequate. With forced induction or heavily modified engines, an adjustable fuel pressure regulator with manifold vacuum reference must be fitted.

The two common types of fuel pressure regulators used are non-adjustable and adjustable. As the name implies, a non-adjustable regulator is set at a fixed value and is manifold-vacuum referenced (whenever a regulator is said to be vacuum referenced, this means that the inlet manifold vacuum/pressure is ported into the chamber above the regulator diaphragm).




As manifold pressure increases, the pressure in the top chamber of the pressure regulator increases along with it, allowing the regulator to compensate for the increased demand of the fuel delivery system.

Keep in mind that at idle or low throttle openings with high rpm, there is very low manifold pressure (vacuum). This tends to literally draw fuel from the injector. As manifold pressure increases (as the throttle is opened), this vacuum dissipates and it is harder for the fuel to discharge from the injector. The regulator reacts to the differences in manifold pressure to maintain constant fuel pressure across the injector. There is a spring in the vacuum (top) chamber of the fuel pressure regulator. The spring's pressure on the diaphragm determines the fuel system's static pressure. The system's static pressure is the amount of pressure measured with the vacuum hose disconnected or with the engine turned off. The fuel system's static pressure is higher than the fuel pressure at idle or under high vacuum conditions.

When the engine is running, the engine vacuum acts against the spring and the effect of the vacuum diminishes as the throttle is opened. At idle, there is a high amount of fuel returned to the tank because the vacuum is pulling the diaphragm seat off of the fuel return orifice, reducing fuel pressure. As the throttle is opened, the diaphragm seat starts to close off the orifice, restricting the amount of fuel flow through the return line.

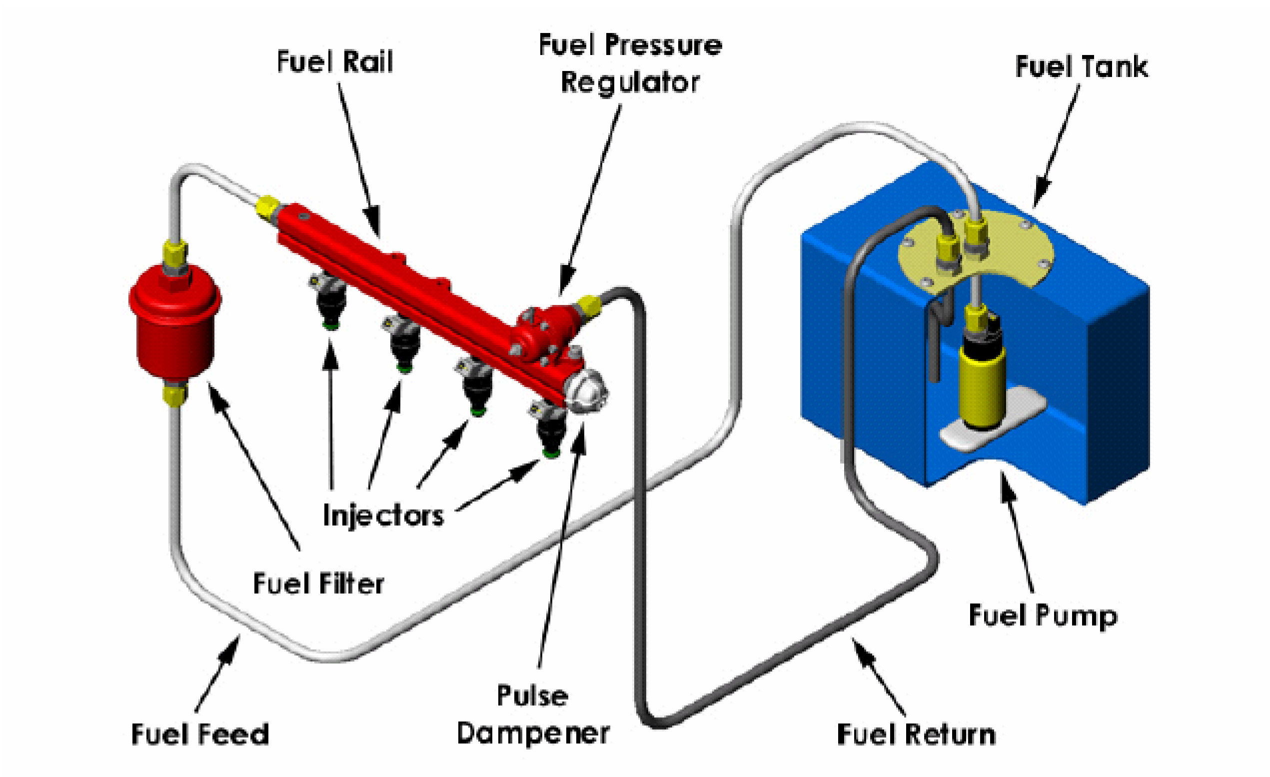
An adjustable regulator allows the static pressure to be raised or lowered via an adjusting screw that acts on the diaphragm spring. On most adjustable regulators, when the screw is turned **in** pressure raises and when it is turned **out** pressure is reduced. Although we highly recommend installing a proper fuel delivery system, raising or lowering fuel pressure *can* compensate for fuel injectors that may not be properly sized for an application.

Most aftermarket fuel pressure regulators (and OE regulators) use a 1:1 ratio of fuel to boost pressure for increasing fuel pressure in applications where forced induction is used. This means that for every psi of boost, fuel pressure is increased one psi. This ensures adequate fuel delivery under boosted conditions.

Many vehicle manufacturers use a pulse dampener to reduce the pulsations in the fuel rail caused by the opening and closing of the injectors (a dampener also reduces the noise of the injectors). In applications where a new fuel system must be installed, a fuel pressure dampener is integral to ensuring consistent fuel flow to the injectors. AEM fuel rails have a provision for a pulse dampener. The dampener assembly part numbers are:

Honda PN: 16680-PE7-661 Dampener
Honda PN: 16705-PD1-003 Inner Gasket
Honda PN: 90428-PD6-003 Outer Gasket
AEM PN: 2-602 Fitting for Rail

Before the fuel system is assemble in the vehicle inspect for debris and damages. Before the fuel system is checked make sure to have a fire extinguisher near by in case of fire. After the fuel system is installed you must inspect the integrity of the entire system. Begin by purging the lines. To do this, run the fuel pump with the hose that connects to the fuel rail placed in a grounded container. This will eliminate any debris left in hose during its manufacturing process. Inspect the fuel rail for cleanliness before starting the engine. Make sure that the fuel pressure is set correctly for your application. Then, reattach all of the hoses and run the fuel pump by switching the ignition to the "ON" position (**DO NOT** turn over the engine at this time), and visually inspect all of the connections for fuel seepage or leaks. If any seepage or leaks are present in the system, repair them before proceeding.


Fuel Rail
Fuel Pressure
Regulator
Fuel Tank
Injectors
Fuel Filter
Fuel Pump
Fuel Feed
Pulse
Dampener
Fuel Return