Aeromotive, Inc. Technical Bulletin #202

From: Aeromotive Technical Department

Date: 12/8/14

Re: **EFI Fuel Pressure Regulators, Vacuum and Boost Reference:**

EFI engines with Aeromotive bypass regulators: On understanding and using vacuum/boost reference:
All Aeromotive, EFI bypass regulators allow intake manifold pressure, vacuum and boost, to affect the regulated fuel pressure . When a fuel pressure regulator is referenced to manifold pressure, it acts to mirror manifold pressure changes with equal changes in fuel rail pressure. The result is lower fuel rail pressure with manifold vacuum and higher fuel rail pressure with boost. The effect occurs on a 1:1 ratio, where the regulator raises and lowers fuel pressure in sync with the change in manifold pressure. In other words, 1 PSI of positive or negative manifold pressure, applied to the regulator through the vacuum/boost port in the regulator cap, raises or lowers fuel rail pressure by the same 1 PSI. See Figure 1.

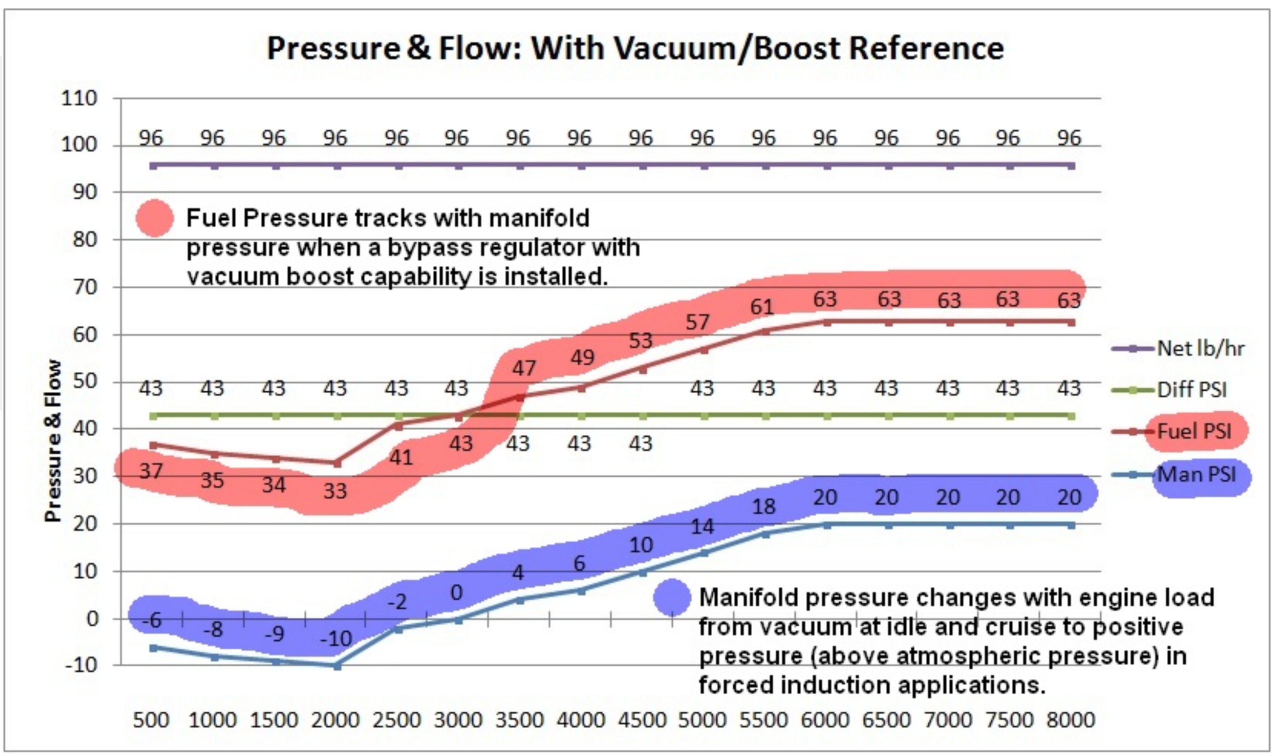


Figure 1

Note: Pressure can be measured on a number of scales including bar (BAR), kilopascals (KPA), inches of water ("H2O), inches of mercury ("HG) and pounds per square inch (PSI). We'll employ the most common pressure scale used in the US, which is PSI, for both positive and negative pressure, but the end result is the same whatever scale is used. It is also common for vacuum or negative pressure to be expressed in inches of mercury ("HG). The conversion is 2.036 "HG = 1 PSI or roughly 2:1. In practice, an engine that idles with 12 "HG vacuum has negative (-)6 PSI of manifold pressure.

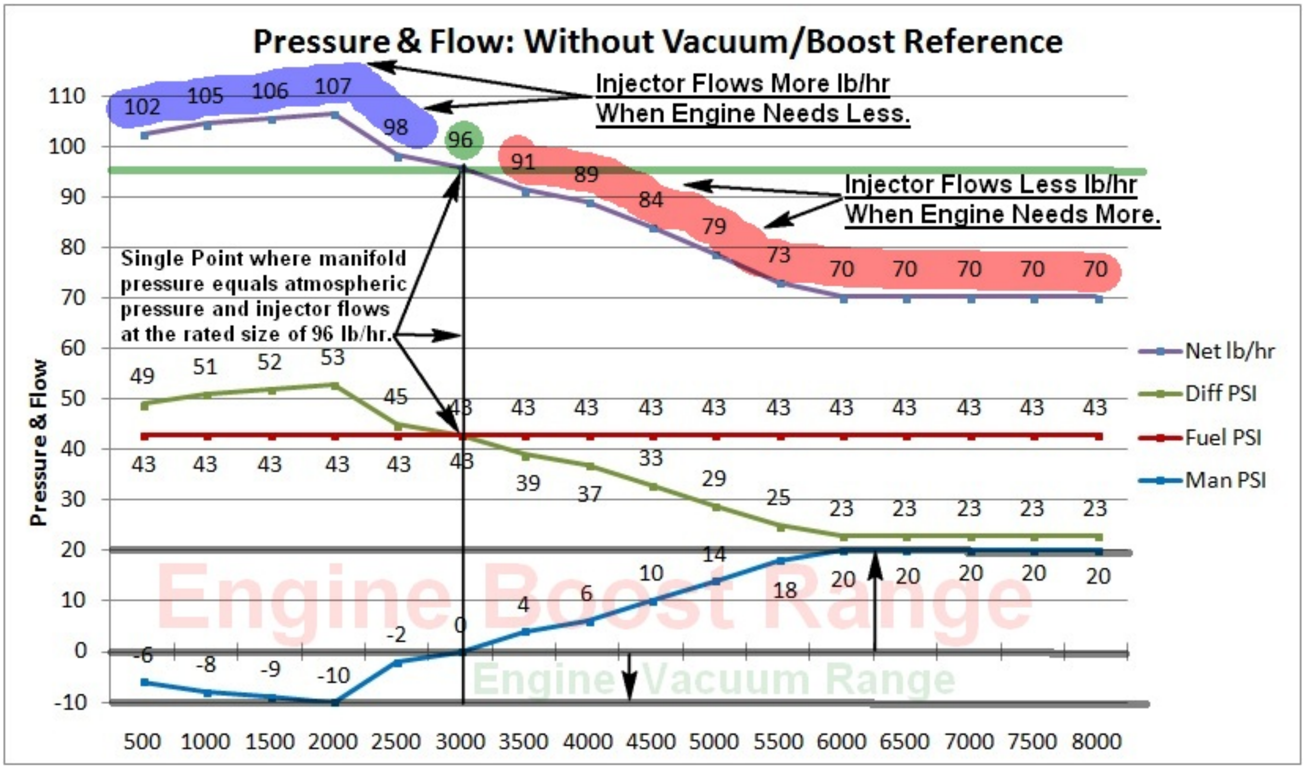


Figure 2

Many enthusiasts mistake the purpose of boost referencing the regulator. The belief is that increasing fuel pressure with boost will make the injector larger, when in fact it really just prevents the injector from getting smaller, as illustrated in Figure 2 above. This may seem to be an unnecessary distinction, but when calculating the injector size needed for a forced induction engine, it's critical to account for boost reference, or the lack of it. Failing to account for a shrinking injector flow rate (because a bypass regulator with boost reference is not installed) could cause an unexpected lean condition in boost.

Boost reference makes sense, but what is the point of referencing vacuum? The argument for reducing fuel pressure with manifold vacuum is the same as for raising it with boost; it works to keep injector flow consistent. The use of a vacuum reference is applicable to both naturally aspirated and boosted engines, but works to reduce fuel rail pressure when the manifold is in vacuum. This prevents injector over-flow (injector acts larger than it's rated) when the engine need less fuel.

Installing an Aeromotive EFI bypass regulator and connecting the vacuum/boost port to the intake manifold allows the regulator to take dynamic control of the fuel rail pressure. This enables the regulator to monitor manifold pressure and change fuel rail pressure as needed in order to maintain the necessary difference, or what is called "differential pressure".

Understanding what "differential pressure" is and how it affects fuel flow through the injector, is important. It can change what size injector will be needed to support peak horse power, what fuel pump and regulator are suitable. It can even change how the fuel system is installed in the vehicle and how the ECU is calibrated to achieve optimal performance.

So, what is "differential pressure"? It's simply the difference between two pressures, in this case between fuel rail pressure and manifold pressure. It is found by comparing the two pressures and subtracting the lower pressure from the higher. It can get tricky when dealing with vacuum in the intake, as this is a negative number. For example, take an engine with base pressure of 43 PSI and -6 PSI vacuum (12" HG). The equation looks like this: 43 PSI - (-6 PSI) = ?? PSI. The rule is, when subtracting a negative number from a positive number, add the two numbers together (change the two minus signs into one plus sign) The answer is 43 + 6 = 49 PSI differential. Calculating the difference with boost is simple subtraction.

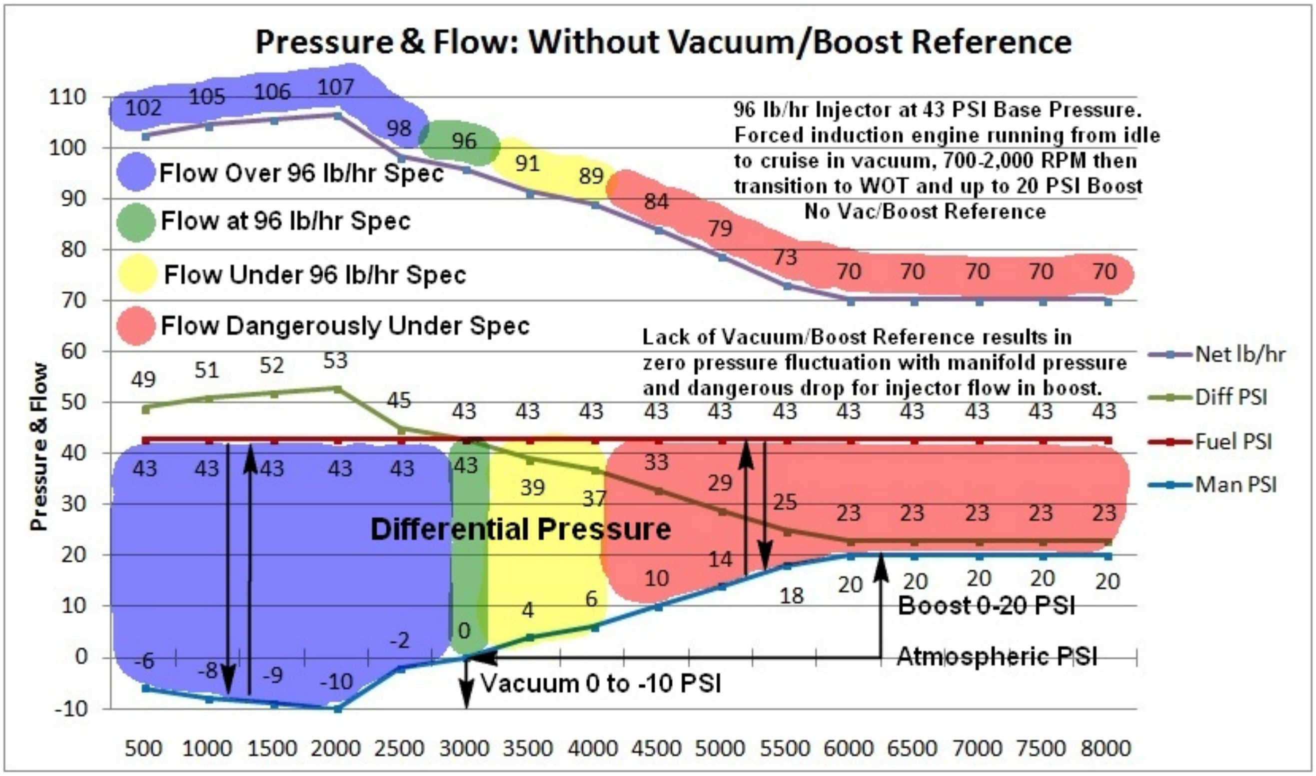


Figure 3

For example, if baseline fuel pressure is 43 PSI, and the engine makes 20 PSI of boost, we find the difference by taking base pressure of 43 PSI minus boost pressure of 20 PSI for a differential of 23 PSI. Figure 3 above shows fuel rail pressure is only 23 PSI higher than manifold pressure at full boost. In this example, without the benefit of boost reference, real injector flow capacity falls 27.5%, from 96 lb/hr down to 70 lb/hr. If the engine requires a 96 lb/hr injector to support peak HP, running without boost reference would require installation of a 132 lb/hr injector to make up the shortfall. Note: Any size injector would suffer the same 27.5% drop in flow if differential pressure fell the same amount. Serious business indeed.

This topic has special application for today's "returnless" EFI fuel systems, none of which have a bypass regulator that is (or can be) vacuum/boost referenced. In 1999 the OEM was faced with meeting new, and much stricter EPA EEC (Evaporative Emission Control) standards, aggressively tightening the maximum allowed vapor emissions from the vehicle. Some manufacturers responded with a very sophisticated "returnless" system that uses pulse modulation and a pressure sensor to create and control pressure by varying the speed of the fuel pump. Most however kept the bypass regulator, but moved them to the back of the car, or in the tank with the fuel pump. For these reasons today's fuel systems are not referenced to manifold pressure, instead new calibration tables in the ECU compensate for the varying injector flow rate illustrated above.

Yes, calibrations tables can be (and are) used to compensate for these significant variations in injector flow... but there's no ECU programming magic that can preserve the physical size of the injector, 100% duty cycle is 100% duty cycle. Differential Pressure is Differential Pressure, and you either maintain it, or you don't, and live with the consequences. Without vacuum/boost reference, games have to be played with injector sizing, base fuel pressure and engine management calibration. Forced induction applications with a blower or turbo are especially disadvantaged without boost reference, but all engines are affected one way or another. The Bottom line is when compromises are made, consequences are inevitable.

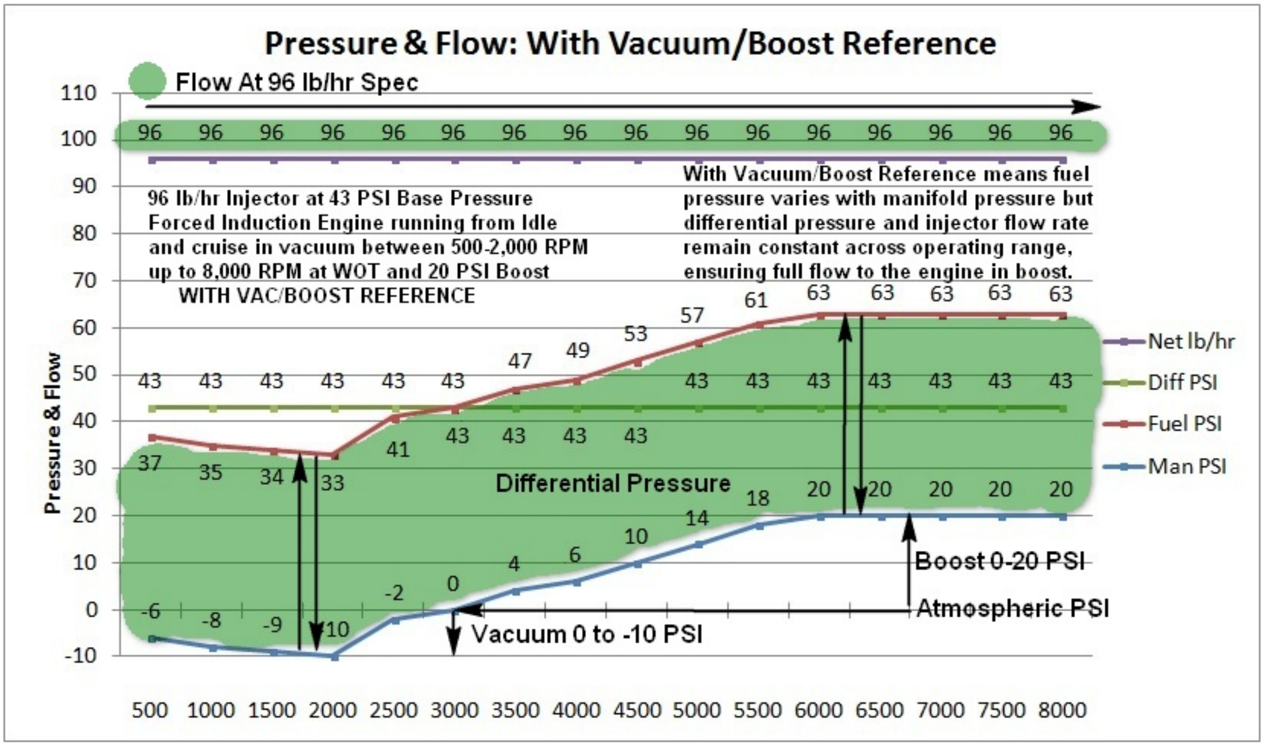
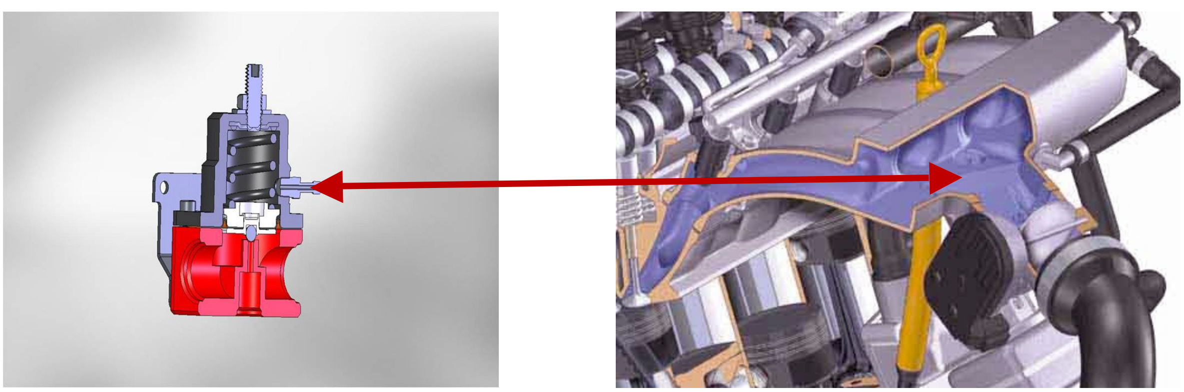


Figure 4

Don't compromise fuel delivery to your engine, especially if high performance is your goal. Examining Figure 4 above, the impact of referencing the regulator to vacuum and boost is obvious. It's easy to see why fuel pressure should be dynamic in order to maintain linear injector flow capacity, and how this benefits fuel delivery across the board. This is a proven approach for controlling fuel pressure in concert with manifold pressure, ensuring fuel delivery is always spot-on and the injector's flow capability is fully protected, regardless of throttle position and engine load.

The proper vacuum/boost connection for an Aeromotive bypass regulator requires a length of 5/32" vacuum line to be routed from the intake manifold plenum, after the throttle body, to the port in the regulator cap. Be certain to set base fuel pressure with the vacuum/boost line disconnected when the engine is running. For TBI engines where the injector is above the throttle blade(s), the vacuum/boost port should be left disconnected and open to atmosphere, never blocked or plugged.



Aeromotive EFI Bypass Regulators with vacuum / boost compensation are available with a wide range of base pressure adjustment and options capable of handling an extremely wide range of flow. Contact your Authorized Aeromotive Dealer or visit our website at www.aeromotiveinc.com for more information and technical support.