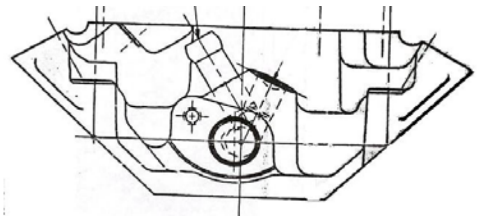
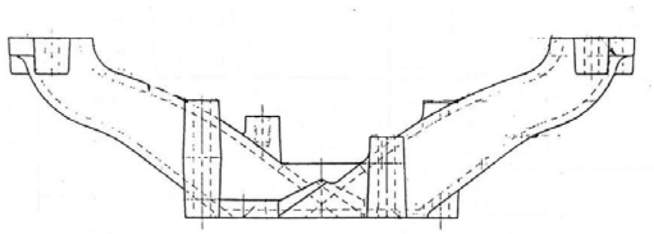
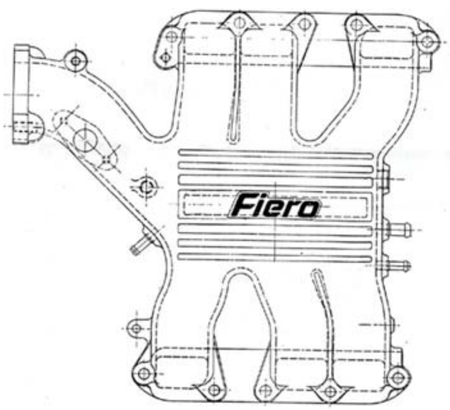
Tech Articles

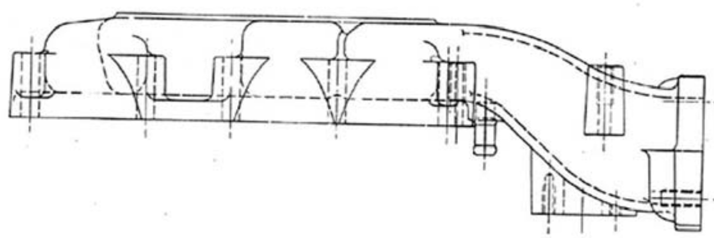
Intake Manifold Design and Function

by: Ryan Gick









This article is in the current Fiero Focus Magazine and is being put on the website because there was no room for the images.

The job of the intake manifold is to deliver air (and sometimes fuel, depending on design) into the cylinder head intake ports on the engine. On gasoline engines, a throttle body meters air flow. In this issue of Gick's Garage, I'm going to touch on the different designs of intake manifolds and how those different designs impact engine performance; however the main focus of this article is going to be about intake runner length and cross-sectional area and the effects of each on engine performance.

Before we get too deep into this topic, it is first important to understand the principle that the engine is really not much more than an air pump. Therefore, the more efficiently it can draw air in and pump air out (at a given crankshaft RPM), the more power it will make. The engine does not pump air at a constant rate. Intake valve opening and closing events, coupled with movements of the pistons, creates a varying speed and volume of air flow into the engine at a given RPM. Because of this, an important rule applies: bigger is not always better.

The early 1980's were a transformational period at GM Powertrain. Nearly every engine produced by GM before the early 1980's was carbureted. But GM-designed fuel injection was introduced in 1982 on a production vehicle in the form of dual, single-barrel throttle body injection units, which saw use on the Corvette and F-body V8 engines. This was not a good design from a performance standpoint, but GM was already working on a multi-port fuel injection manifold design, which would influence the designs that would be used on most of their production engines for the next decade.

The common throttle body injection units were designed to take the place of carburetors, and in most cases require the use of intake manifolds that were designed for carburetors. These were introduced to save cost in design and packaging and rarely were associated with performance. In carbureted and throttle body injection systems, the fuel is introduced into the intake manifold at the throttle body itself, which creates a heavy air/fuel mix. This needs to be able to flow thru the intake's runners and ports so it could make it into the engine. The use of a single point of fuel and air delivery into the intake manifold also means the lengths the air/fuel mix must travel to get into the cylinder head intake ports differ from cylinder to cylinder. The manifold must be designed so the fuel cannot pool, or fall out of suspension of the air flow, as it travels into the engine. Several compromises in design are required in order to use a setup like this, and these compromises hurt drivability, fuel economy, and performance. When multi-port injection was introduced, it allowed many more creative intake manifold designs because these new designs no longer had to be constrained by carrying both fuel and air into the cylinder head ports. With injectors positioned at every intake port, each cylinder now got the same amount of fuel. And this allowed the intake manifold to be designed so the air going to each port would be able to travel the same distance from the intake plenum. This helped balance the power produced by every cylinder. This is what makes multi-port fuel injection system superior to carburetors and throttle body injection setups.

When talking about intake manifold designs, two main factors need to be considered: port size (cross-sectional area) and runner length. The smaller the port size, the faster the velocity of air flow through it; but also the less amount of air flow it can ultimately support. Smaller port size intake manifolds will offer increased low-RPM torque production and better engine response, but usually at the cost of upper RPM performance. Too large of ports can stall air flow at lower engine RPMs resulting in poor lower-rpm performance and response. Runner length (the length of the port from the intake plenum to the cylinder head intake port) impacts the power band as well. As a general rule, longer runners produce better low RPM performance while shorter runners produce better upper RPM performance. The reason for this is because air flow through a port is not constant on a running engine. Valve opening and closing events create pressure waves that travel thru the runners. A multi-port intake's runner length can be designed, or tuned - so it can create a supercharging effect on a specific engine at a specific RPM range of operation. This is where the Tuned Port Injection system got its name.

The TPI intake was originally designed for the 305 V8 SBC engine. The design of the TPI intake took place at a time where the 305 was considered to be the biggest engine the company was going to produce for use in any of its cars (including the Corvette). As history shows, that plan was never implemented. But the TPI intake's design was such a success that it was used on both 305 and 350 engines. The length and size of the runners on the TPI intake allowed this design to take advantage of the pressure waves produced by the valve events in the engine to create a supercharging effect at a certain RPM range of engine operation. In a nutshell, pressure waves are generated by the opening and closing intake valves and these waves travel between the intake plenum and intake valve at different speeds depending on engine RPM and airflow. In a tuned-port designed intake, during optimal RPM operating ranges, a pressure wave would be generated by a closing intake valve, bounce back and start traveling towards the intake plenum. Once it reached the plenum, it would encounter a higher pressure zone generated by incoming air, and bounce back and travel back down the runner and arrive at the intake valve right at the moment it opened. This effectively forced air into the cylinder at increased pressures. This design was one of the few produced by GM that achieved over a 100 percent volumetric efficiency without the use of an external super or turbocharger. Volumetric efficiency is the amount of air the engine can hold (based on displacement) vs. the amount of air the engine is actually consuming. Having a volumetric efficiency of less than 100 percent means the engine cannot completely fill its cylinders with air, and this is typically what happens in all engine designs that do not use tuned port intakes or forced induction. The more air you can fill the cylinders with, the more power the engine will produce.

But there was a tradeoff. Having been designed for the smaller 305 V8 engine, when the TPI intake was used on bigger displacement engines, it did help the engine produce outstanding low-RPM torque numbers, but choked off upper RPM performance considerably. If trying to use this same intake on an even bigger displacement engine (such as a 383 or 400 cubic inch V8), the effects would be even more pronounced. Now you may be asking what does this have to do with the Fiero (besides those few cases where TPI engines have been swapped into Fieros)? It has a great deal to do with Fieros. If we take a look at the design of the MPI intake used on the stock Fiero 2.8L V6, we can see that it was also modeled after the V8 TPI design, as it too has long intake runners. This helps the 2.8L V6 produce outstanding low-RPM torque and response, but as many of you know, the 2.8L V6 is not known for its upper RPM performance.

For those of you wanting to enhance the upper RPM performance of your engine, a way you can do that is to use an intake manifold that has shorter intake runners (if available), or runners that have a larger cross-sectional size. As a side note, one of the interesting things I discovered when Fred Bartemeyer acquired his first Fiero PPG Pace Car, was its engine had a modified upper intake manifold. By all appearances, a stock Fiero 2.8 upper intake manifold was modified for use on the PPG car engines, and these modifications reduced the total length of the intake runners. This modification, coupled with many others, allowed these PPG engines to produce about 40 more HP than stock Fiero 2.8L V6's. If you take a look at a '93-'95 Camaro 3.4L SFI V6 intake, it uses basically the same intake as the Fiero 2.8L, but the stock upper plenum was replaced with a split plenum design that had no runners in the upper plenum portion (the stock Fiero 2.8L upper plenum has a few inches of intake runners cast into it). This design change gave the 3.4L's power curve more favorable performance in the mid-upper RPM ranges.

It should be noted, however, that whatever intake you end up using needs to match, and work well with, the other parts you are using on the engine, such as the cam and cylinder heads. Trying to use an intake designed for high-rpm performance on an engine that has a low-rpm cam and economy-minded heads won't produce good results. Likewise, trying to use a long runner intake on an engine that has a high-rpm cam and heads with large ports will probably choke off the upper-RPM performance of this engine. Looking at the entire picture, you need to match parts that work well together in the total package so the engine produces power where your car can best use it for the application you are using it in. If you have an automatic transmission and use your Fiero as a daily driver, you are probably better off just leaving that stock long runner intake on there. If you have a manual transmission or a high stall converter and short gears in your automatic and you want some more upper-RPM performance, then using an intake with shorter or larger runners may be of benefit.

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