

Intake Manifold Design & Testing

BY MARTIN MUSIAL (WWW.AMSTUNED.COM)

There are some basic parts of an intake manifold that determine the effect it will have on engine power. The Plenum is the common collector that the throttle body feeds and all intake runners draw from it.

HERE IS A TOPIC we see very little information about, Intake Manifolds. How to do you know what's good for your car? Intake manifold tuning is a topic that very few know about and even fewer understand. Following the bigger the better theory really can hurt street performance in this situation. Car companies design intake manifolds to provide good power in the RPM range that the engine and car are intended for. Many of the changes we as tuners introduce are not drastic enough to require a big enough change in intake manifold design. As you know, an engine is a carefully tuned instrument and

all things must work together in harmony in order to produce the best power output.

BASIC DESIGN PARAMETERS

There are some basic parts of an intake manifold that determine the effect it will have on engine power. The Plenum is the common collector that the throttle body feeds and all intake runners draw from it. The plenum volume and shape can be varied to provide different power outputs and engine response. The intake



T/E/C/H/ INTAKE MANIFOLD

runners draw from the plenum and deliver air to the intake ports of the cylinder head. The length and shape will also determine the engine power and RPM range.

OPTIMIZING THE DESIGN

The first thing to determine when choosing an intake manifold is what RPM range your engine was designed or modified to run at. Are you building a street car that you will be using at the autocross course or are you building a drag racer? Your desired RPM range should correspond to how your engine will be designed. Obviously you will want that low RPM torque with solid midrange power for autocrossing

and decent midrange with a top end charge for drag racing.

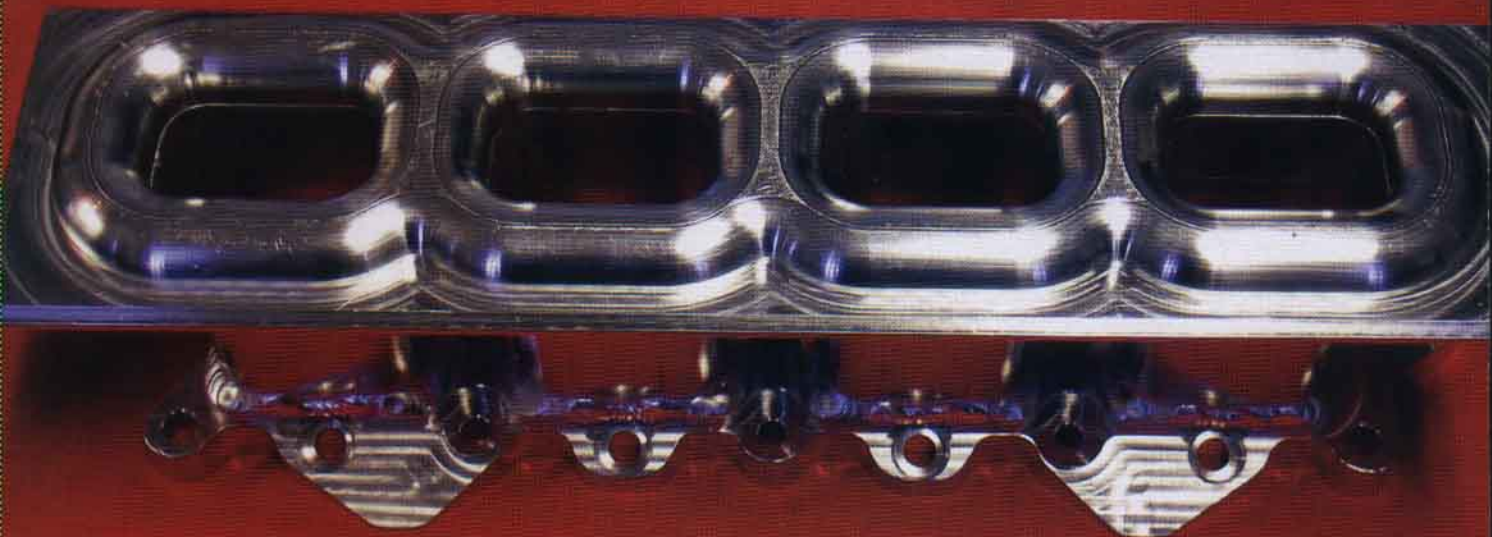
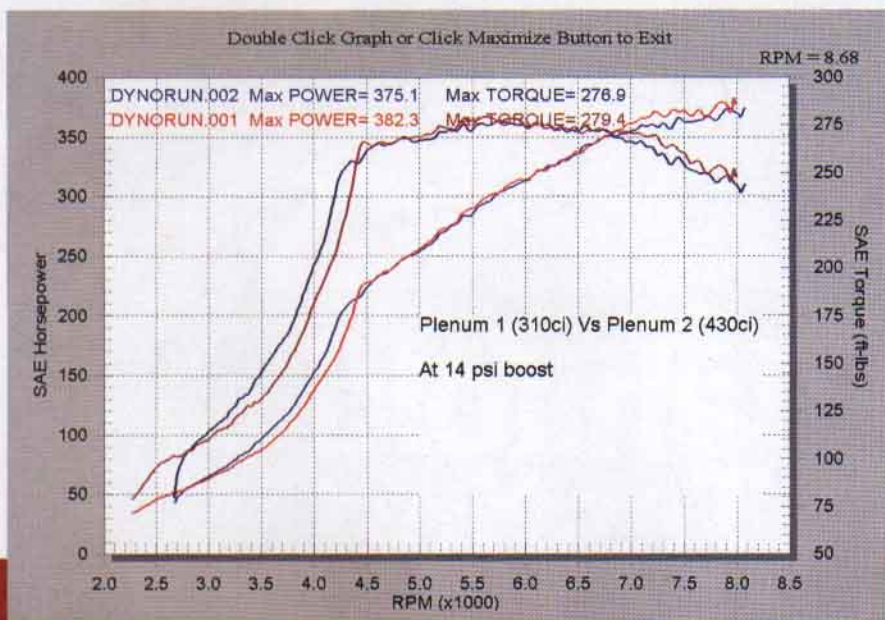
PLENUM DESIGN

The plenum should be of sufficient size to allow even air distribution to each intake runner and not hamper engine response. If a plenum is too large the engine will respond slower to throttle inputs. I believe that in forced induction applications there is more of a need for larger plenums. The large plenum acts like a surge tank, or boost reservoir that lets each runner draw from the large volume. A good rule of thumb is to have the plenum volume be at least 1.5-2 times the engine displacement.

For example, a 2.0L engine would need an intake manifold with a plenum of 3L to 4L displacement.

RUNNER DESIGN

The engine has different air requirements at different RPMs. The engine is not at steady state airflow, therefore, air is not simply flowing constantly from the air filter through the engine, and out of the exhaust. There are valves that are opening and closing and a combustion process that can produce over 2,000psi of pressure in the cylinder. These events produce pulses and pressure waves and the whole system is dynamic. Many times you cannot simply predict the performance of an intake manifold, exhaust manifold, and even head flow, on a flow bench. A flow bench only simulates steady state flow, which is not what is going on in your engine. A flow bench will give some insight as to what is going on but must be used by someone with experience to extract good horsepower. Good velocity is the key to keeping a good powerband in an engine. For larger ports and runners, the slower the velocity. Larger ports can flow more air but at the expense of velocity. Unless a peak horsepower number is important, many times the power under the RPM curve is lost when using a severely opened up head and short, large runner intake manifold. Runner length and shape determine velocity and correlate to what is called a ramming affect on the engine. Air is usually thought of as weightless, but that



T/E/C/H/ INTAKE MANIFOLD

is not the case. Get enough air moving at a high speed and it will have significant momentum and kinetic energy. This energy can be used to our advantage. If the intake runners are tuned correctly, this kinetic energy pulse can be timed to actually help force air past the intake valve and into the cylinder, almost like forced induction. This ramming effect will raise volumetric efficiency (how well a cylinder fills with air) and in turn, increase horsepower and torque. Longer runners will have the effect of increasing power and torque at lower RPMs, while short runners will increase high RPM power and torque. How do we figure out what length we need then? Unfortunately the complexity of this subject is beyond this article and often real life testing is required to establish the design. Complex mathematical formulas and advanced engine simulation software can establish a range of runner lengths that will work for a particular engine design, but empirical testing is needed to confirm the results.

Another important design parameter to consider is the transition from the plenum to the runner. Avoid sharp corners! A well-designed intake manifold will have large 'radiused' edges leading into the runners or even better yet, velocity stacks. Sharp edges produce poor

flow coefficients. The idea of the velocity stack, or air horn, is to catch smooth air from the plenum, as air near the floor of the plenum can be turbulent or even stagnant.

INTAKE MANIFOLD EXPERIMENTATION

The 4G63T engine in our EVO VIII was used to design, build and test an intake manifold. With the first design, I wanted to establish a plenum volume. I used 6-inch long runners with only a 2.5 deg taper per side and CNC'ed inlet horns. The first plenum was small, 3-inch diameter with a volume of 163 cubic inches, slightly larger than the displacement of the engine. Baseline runs were performed at different boost levels and then larger plenums were fitted. We doubled the plenum size to roughly 313 cubic inches and then 435 cubic inches. Power increased with the larger plenums over the first design. The power difference was negligible between the 313 and 435 cubic inch design, but response was affected. The largest plenum design showed slower throttle response and slightly lower boost response. This showed us that the plenum size was too large and was starting to affect the drivability

of the car. I chose the 313 cubic inch design and then varied the runner parameters. The length of the runners stayed at a maximum of 6.5-inches, as this was the physical constraint in the car. I couldn't fit anything longer in the space provided, even though a longer runner length might have performed slightly better. Since length was fixed, I altered the taper angle and the inlet geometry of the manifold. The runner taper angle was changed to 5 deg per side and the air horns were removed. The plenum base transitioned into the runners with a radiused entry. This design went back on the dyno and was tested at three different boost levels to compare with the previous design. Conventional thinking deems the manifold with the larger tapered runners to make more power, but we found out this wasn't the case. At 14psi, 21psi, and 28psi, the less tapered and air-horn equipped manifold outperformed in every aspect. Horsepower and torque were greater at every RPM point and the engine came on boost slightly faster. At 28psi, I noticed that the horsepower did start to converge at higher RPMs. There are two possible reasons for this. The turbo I was using will only make about a maximum of 620whp so we were starting to approach its limits. This flow limitation in the





**CLUTCH & FLYWHEEL
SYSTEMS FOR EVERY
APPLICATION**

**EXCELLENT STREET,
STRIP & TRACK
PERFORMANCE**

**CNC MACHINED
COMPONENTS**

**"SEE MORE"
INCLUDING
LOCAL DEALERS**

www.mod.centerforce.com

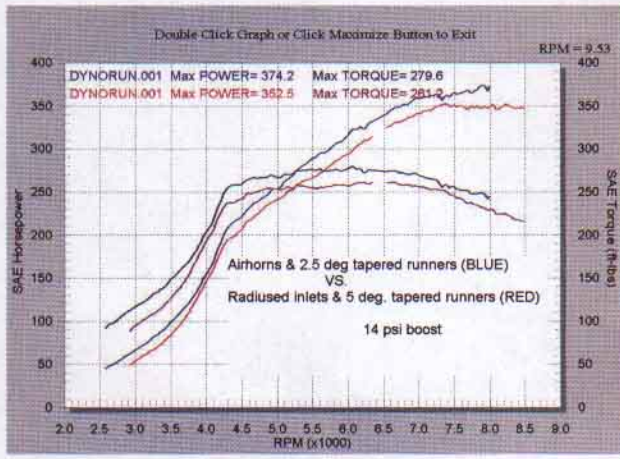
OR BY CALLING

(928) 771-8422

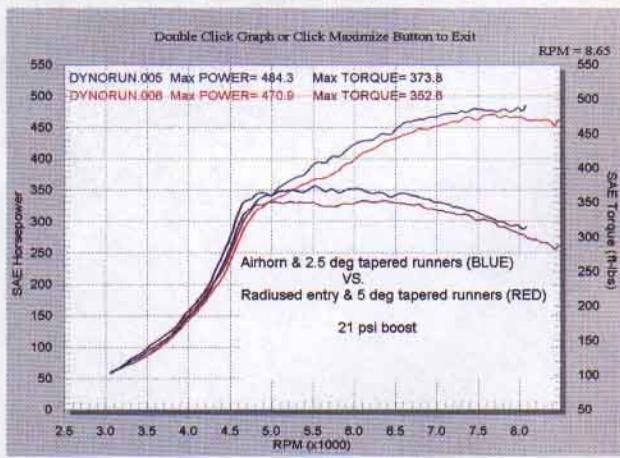
turbo could have been why I started to see the horsepower start to equalize at the higher RPMs at high boost. Also, it could be that the smaller runner manifold was starting to lose flow efficiency at this high airflow rate and the larger runner design was operating efficiently. After examining the data and different dyno curves I think the issue was more of turbo flow than runner design. If the turbo was sized larger and the differently selected camshafts would make power at higher engine speeds, I would venture to say the larger runner design would have made more power at higher RPMs.

Granted, this increase in power would come at 8.5-10K RPM, which for most of us would never be utilized.

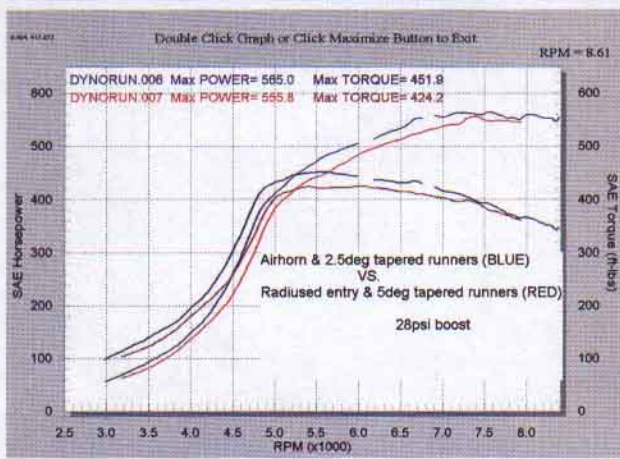
Through the limited testing performed, I learned a few things. Good entry to the runners is important and seemed to help power and torque at all engine running speeds. For street use, keeping velocity high is important, so try to use aftermarket manifolds with long straight runners. For those of you seeking high horsepower for your drag car, it's best to arm yourself with some basic knowledge, use reputable recommendations, and finally test and re-test different designs. ■■■



The airhorn entry & 2.5 deg tapered runners fared much better than the radiused entry 5 deg runners making almost 22hp more and over 18 lb-ft torque at only 14psi.



An impressive 14hp and 21 lb-ft torque were realized at 21psi with the 2.5 deg tapered runners and airhorn entry again showing it is the better design.



The final 28psi test proved once and for all that the airhorn entry & 2.5 deg tapered runners are far superior than the radiused entry 5 deg runners in our application.