cp-e™, Inc.
6802 Mid Cities Avenue
Beltsville, MD 20705
www.cp-e.com

CUSTOMPERFORMANCE engineering

MZR 2.3 DISI Xcel™ Intake

Key Intake Design Considerations V.S. Our Competition

By: Jordan M. Gartenhaus

The purpose of this information is to thoroughly explain why we make our intakes the way we do. Contrary to popular belief, properly designed cold air intakes are not just pipes with filters on the end. Rather, as OEM automotive technology advances, so must aftermarket product design. That is of course, if the parts are expected to work in concert with each other. Because there is much more to our intakes than what meets the eye, we thought it would be beneficial to illustrate some of the design elements that make our intakes so unique. So we'll start from the beginning.

The Basics:

Your mass air meter is located in the intake tract, and it is what tells the computer how much air the engine is ingesting. It is also arguably the most critical sensor on your entire engine because its signal is the basis for many other engine control calculations. The Desno mass air meters in the MZR 2.3 DISI, use a hot and cold wire sensor to indicate the mass flow rate, or the mass of air entering the engine per unit time. One wire in the sensor is kept at ambient temperature as a reference, and the other is heated by electric current (like a toaster filament). As air flows past the hot wire, the air naturally pulls heat away from the wire, and the PCM (Power train Control Module, or engine controller) senses an increase in current through the wire since temperature and electrical resistance are coupled properties (as temperature drops, so does electrical resistance). The change in electrical current is proportional to the incoming mass airflow. Through calculations and experimentation, the engineers at Mazda came up with a look-up table for the PCM that indicates, "If the mass air meter measures an airflow rate of "X," then inject "Y" quantity of fuel to create a stoichiometric air/fuel mixture." This ensures that every molecule of fuel has a molecule of oxygen to react with, which is ideal (in most driving situations).

Now, the readings from the mass air meter are more of an approximation of the incoming airflow than a direct measurement, so there will be some error (no measurement is perfect). Anytime there is error in the mass air meter's reading, the result is some deviation from a stoich air/fuel mixture. The oxygen sensors will detect this deviation from stoich and tell to the PCM to add or remove fuel in order to bring the mixture back to stoich. This addition or removal if fuel is the "Fuel Trim", and it is indicated as a percentage.

The root of the problem here is that you can easily and inadvertently fool the mass air sensor into a false reading. This is because the mass air sensor doesn't measure the incoming airflow directly; instead it just relies on a change in intake air velocity. This makes sense, as mass airflow through a pipe increases, then so does the air velocity.

So, consider if you were to increase the size of a pipe while keeping the mass airflow rate the same. What happens? By conservation of matter, an increase in pipe diameter must be met with a corresponding decrease in flow velocity. So even though the same amount of air is passing through the pipe, the velocity has changed because the cross-sectional area of the pipe increased. So if you were to change the size of the mass air sensor housing from stock, then the sensor would be indicating to the engine that it is ingesting a different amount of air than it actually is! This is the issue we aim to address, but more on this later.

Now, when you install a cold air intake, it will never sample the air exactly the same way it did in the stock airbox. This is due to the intricate changes in flow due to the unique geometry before the mass air meter. That and airflow is almost always purely chaotic, and is impossible to model exactly. All you can really do is make sure that the flow velocity past the mass air sensor is the same, or close, between your stock intake and your new cold air intake. This will help ensure that the resulting fuel trims are as close to stock as possible (read: little fuel correction), which means the fueling and tables that the PCM references will be most accurate.

"But the PCM has the ability to adjust fuel if the mixture isn't exactly at stoich, so who cares the fuel trim if off a little bit?"

Because the computer has a finite fuel trimming ability. If you exceed the computer's trimming ability, then it'll set a check engine light or cut fuel to the engine. As you modify your vehicle you're changing your engine's efficiency (primarily fuel conversion and volumetric efficiencies), which in turn changes the resulting air/fuel ratio using the stock maps. That means as you add performance parts your vehicle's tune will inevitably degrade, which means your fuel trimming will increase. Since you can only trim fuel so much, you'll want to keep your fuel trims as close to stock to begin with as to allow more room for adjustments as you add more modifications.

But wait, there's more! The engine also has a timing table, which is used to determine how much ignition advance to apply under certain engine loading conditions. An engine under high-load (think wide open throttle) will require much less timing than low-load conditions (think cruising down the highway) since the in-cylinder operating pressures in either scenario will be vastly different. Too much timing can cause knock, and too little timing will reduce power output and engine efficiency. So it is absolutely vital that the engine runs the proper ignition advance.

The problem is that the PCM uses the mass air sensor to calculate how much load the engine is under. So if you alter the mass air meter's sampling accuracy, as you would when you install an aftermarket intake, then your load tables are no longer ideal. This is just another reason why we're so serious about making the mass air sensor happy!

In summation, an inaccurate mass air sensor will not only diminish your available fuel trim window (and eventually set CEL's or cut fuel), but it will also skew your ignition advance! So clearly, ensuring that the mass air sensor is accurately sampling the incoming air is of the utmost importance for proper engine operation.

The cp-e™ Difference:

When our competitors manufacture their intakes, they typically just use standard sized aluminum pipe for their mass air meter housings. When we say standard pipe, we mean 2.5", 2.75", 3". They'll tap threads into the top of the pipe and just mount the sensor on top of it. Some may go so far as to swage the pipe to some diameter other than a standard pipe size, but swaging holds very poor tolerances. But the point here is that these methods are quick, cheap, and easy to perform, which is why the big name, high volume companies take this route. However, *the size of the mass air housing greatly influences the accuracy of the sensor*. So if a particular vehicle requires, say a 2.623" mass air housing, then our competitors may just choose the 2.500" pipe because it's the closest match. But *closest* isn't *ideal*, and this is where drivability and reliability issues crop up.

So what exactly does cp-e™ do that's so different from the other aftermarket companies out there? Being a true performance parts manufacturer, we have the sophisticated machine equipment required to properly design and fabricate ideal mass air meter housings.

We perform various real-world tests in order to determine the optimal diameter for the mass air housing so that the resulting fuel trims are nearly perfect. Once we find that ideal mass air sensor housing diameter, we machine our mass air housings from billet aluminum so we can custom tailor the housing to satisfy the requirements of each unique vehicle. In fact, our process is so exacting that we can hold tolerances of +/- 0.002", which is roughly the diameter of a human hair! This ensures that the sensor accurately samples the incoming air, and the resulting fuel trims are almost identical to stock.

Real World Testing:

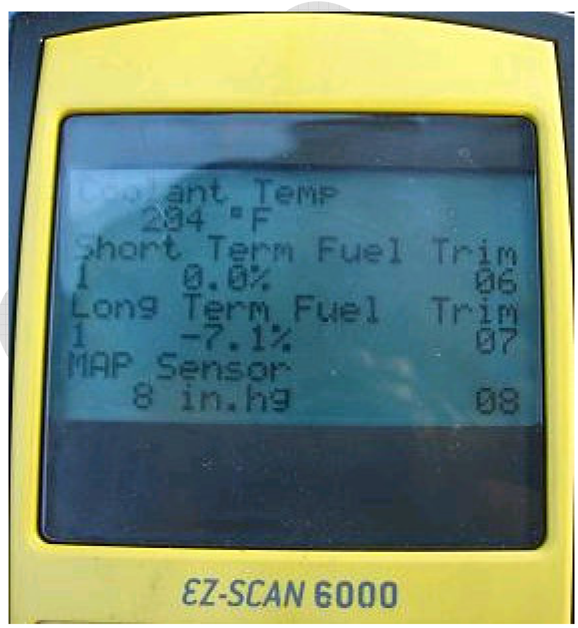
To demonstrate just how effective our mass air housings are as compared to the competition, we set up a test. We measured the fuel trim at idle on a stock MazdaSPEED3 and then compared it to our Xcel™ intake, and another competitor's intake. We aimed to show that our Xcel™ intake keeps the fuel trims closer to stock than our competition. We are the only company that offers machined mass air housings!

Our testing began with the stock airbox. We disconnected the battery while we installed the stock airbox, and that gave the computer enough time to clear its memory. We then took the vehicle out for a drive to warm it up and brought it back to the shop to record some fuel trim data. Because the fuel trims are always changing, we took some data, took the car out for a spin, and then checked the numbers again. We did this about a dozen times, and the long term fuel trims settled at about -4.7%.

Stock airbox long term fuel trim (at idle): -4.7%

We performed the same procedure on our Xcel™ cold air intake with the machined MAF housing and the airflow straightener. After several runs we got a long term fuel trim of -7.1%, which deviates from stock by -2.4%.

cp-e™ Xcel™ intake long term fuel trim (at idle): -7.1%



Since we don't have direct access to our competitors' products, we used data from a message board member who was kind enough to record this data.

Long term fuel trim with competitor's intake: +5%

In summation:

Stock long term fuel trim: -4.7%
Xcel™ long term fuel trim: -7.1%
Competitor's long term fuel trim: +5%

So what does all of this mean? These percentages are indicating how much fuel was added or removed from the mixture as a result of mass air sensor sample error. You'll notice that the stock fuel trim was not 0%. Why? Because at idle the fuel vapor purge valve is in its open position and the fuel vapor displaces some oxygen, which makes the car run slightly richer. So the computer compensates by removing 4.7% of the fuel in order to bring the mixture back to stoich.

The important point here though, is that our intake deviated from the stock value of –4.7% by -2.4%, whereas our competition's intake deviated from stock by nearly 10%. That's nearly five times as much error! Since the computer only has so much fuel trim adjustability, running our competitors intake essentially narrows the window in which you can safely modify your car without a proper tune. This fuel trim deviation also indicates that the timing tables are no longer ideal. In fact, this positive fuel trim value indicates that the PCM thinks the engine is under a lower load than it actually is. That means the ignition advance is going to be too great, and the chance of knocking is greatly increased. Not good!

If you're curious about checking your fuel trims, you can perform this check with any OBD-II scanner that has the ability to log sensor data in real time. We used the AutoXRay EZ-Scan 6000 for all of our tests.

Frequently Asked Questions:

Q: My cold air pipe has a constant diameter, whereas yours necks down at the mass air meter. Doesn't that mean that my intake has less flow restriction than yours?

A: For our intents and purposes, the answer is no. Following that logic, a 4" pipe will have less restriction than a 5" pipe. Although this is true to an extent, if you haven't tapped the flow potential of a 3" pipe, increasing the diameter isn't going to appreciably affect flow resistance. In other words, the power levels (and corresponding airflow rate) on the SPEED3/6 isn't great enough to tax the flow potential of our mass air housing.

Q: My friend told me that these cars run very rich, and that my intake leans my car out. This is good because I'll make more power, and get better gas mileage, right?

A: Leaning a car out by changing the diameter of the mass air housing is called mechanical tuning, but it is not recommended on these cars. The proper way to tune an engine should involve some kind of sophisticated engine control software!

First, mechanical tuning skews your timing tables, which brings you closer to your knock threshold. That means you could start knocking under load, and could potentially harm your engine. You're right that you will make slightly more power if your intake leans your car out, but the resulting problems outweigh the benefits. If you're interesting in tuning your car, use a device like our Standback engine controller.

Secondly, mechanical tuning will not increase your fuel mileage over our cold air intake because *your PCM always tries to target a stoich mixture while cruising*. In fact if you deviate too far from a stoich mixture the computer will trigger a check engine light because you will have exceeded your fuel trim window. Your argument might be valid if your car had the ability cruise at a mixture leaner than stoich, but it doesn't.

Q: I saw a dyno where your intake made 5hp, and a competitor's intake on another car made 10hp. What gives??

A: The SPEED vehicles are notoriously difficult to dyno accurately because of the innumerable variables associated with the testing. Any comparison testing should always be conducted on identical dyno's, on identical days, and on identical cars. This is because these cars are so sensitive to environmental changes.

For instance, the electronic throttle never opens 100%, and its instantaneous position is based on several calculations, which include data from various engine sensors. So one car's throttle may open 60% at wide open throttle, whereas another may only open 50% on a given dyno run.

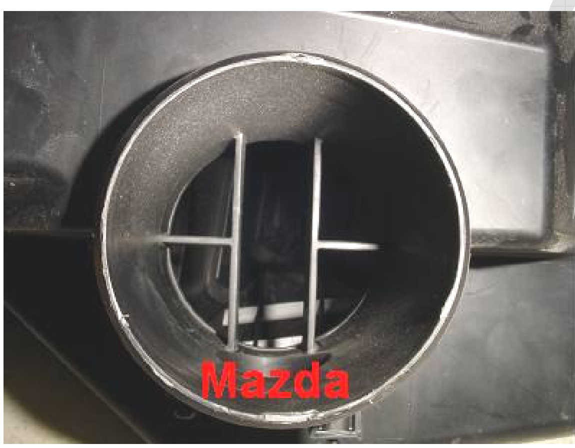
Different dyno's also have vastly different calibrations, despite being considered a "traceable measurement tool." You can take a car and dyno it on different dyno's and get variances of up to 30% (inertia versus brake dynos).

These cars are also very susceptible to intercooler heat soak due to the top mount intercooler, and the intensity of the cooling fan on any dyno can greatly influence power output, especially on consecutive dyno runs. Simple things like having the hood open or closed also greatly affects repeatability.

We worked very hard to dyno our products as honestly and accurately as possible, so resist the temptation to compare unlike dynos. There are too many variables to draw an accurate conclusion. We encourage people to dyno their vehicles after the addition of cp-e™ products, but be cognizant of the various factors that can affect the results of your dyno test.

Q: Few of your competitors actually include an airflow straightener in their cold air kits, so they're probably not needed, right?

A: We can't even begin to fathom why our competitors decided to omit the airflow straightener, even though it's present in the stock airbox! The Mazda powertrain engineers felt that it was a necessary addition from the factory, yet our competitors obviously disagreed, or decided that it wasn't worth their effort.



We, on the other hand, machine stock style airflow straighteners from aluminum, and they're included in all of our SPEED3 Xcel™ intakes. Why did we include them? After testing the stability of the mass airflow meter with and without the airflow straightener, we found the precision of the meter was vastly improved with the straightener installed. So we went through the extra effort to include them for a more reliable mass air meter sample.

Q: My Mazdaspeed cold air intake is probably better than yours because it was actually designed by Mazda. Moreover, it also retains the factory warranty.

A: Believe it or not, the Mazdaspeed cold air intake is actually manufactured by AEM, and is simply private labeled by Mazdaspeed. In other words, the engineers at Mazda had nothing to do with the development of the Mazdaspeed intake, and Mazdaspeed just bought the design from AEM!

You should be aware of your rights as an automotive enthusiast. You have every right to modify your car without voiding your warranty. Anyone who tells you otherwise (including dealers) probably isn't being honest.

If it were true that aftermarket parts voided your vehicle's warranty, where is the line drawn? Do aftermarket windshield wipers void your warranty? How about high performance tires or a high performance air filter? The fact is that you can modify your vehicle and retain your factory warranty as long as the installed aftermarket part didn't cause the warranty claim.

In 1975 a federal statute was enacted that stated:

"Under the Magnuson-Moss Act, a dealer must prove, not just vocalize, that aftermarket equipment caused the need for repairs before it can deny warranty coverage. If the dealer cannot prove such a claim — or it proffers a questionable explanation — it is your legal right to demand compliance with the warranty. The Federal Trade Commission administers the Magnuson-Moss Act and monitors compliance with warranty law."

http://www.ftc.gov/bcp/conline/pubs/buspubs/warranty.shtm

Q: I heard short ram intakes are better than cold air intakes. Is that true?

A: There can be more than one tool for any particular job, and modifying cars is no different. Short ram intakes are cheap and easy to service for sure, but their benefits stop there. Short ram intakes are placed in the engine bay and as such they're going to suck up the hot engine air, and this is especially true if the short ram doesn't have a corresponding airbox. Although many might downplay this issue it does seriously affect performance. If you look at a stock SPEED3 intake, Mazda designed their factory airbox to grab cold air so they must have been on to *something,* right?

The fact is that every 8°F increase in air intake temperature is met with a 1° reduction of ignition advance as commanded by the factory ECU. Since your under-hood temperatures can be as much as 100°F above ambient air temperature, you run the risk of seriously retarding your ignition timing, which makes the car feel very flat. Cold air intakes don't have this problem, which is why we chose to go that route.