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Testing of the 2015+ Subaru WRX Performance Air Intake

Figure 1: 2015 Subaru WRX 6-Speed used for R&D and testing

Test Vehicle

2015 Subaru WRX 6-Speed

Modifications

None, fully stock

Objective

To make a direct-fit, performance air intake that produces more power than the stock setup without harming the engine

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2015+ Subaru WRX Performance Air Intake

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Testing conditions

All testing was performed in a climate-controlled garage that maintained an average temperature of 85°F and 35% humidity.

Testing Equipment

To test the effects of different intake setups, a DynoJet dynamometer was used to measure the power output. An EcuTek ProECU Programming Kit was used to monitor and log different sensors and aspects of the testing vehicle.

Goals and Metrics

Before development began on the 2015 WRX performance air intake, goals and metrics were defined for the project. First and foremost, we set out to create an intake that would make more power without potentially harming the engine and without the need for a tune. To accomplish this, air-fuel ratios (AFRs) were closely monitored to ensure that enough fuel was being supplied to the engine. Another goal was to create an intake that was isolated from the radiating heat of the engine bay. Cold air is denser than hot air and therefore creates a larger combustion, so the ideal intake would draw in as much cool air as possible. This can be achieved by placing the intake away from the engine and close to the cool air coming in through the front bumper. The final goal for this intake was to ensure that no permanent modification is necessary when installing it. This means that it should be a direct bolt-in part without any cutting or grinding required.

Research and Development

The first step in developing the Mishimoto Performance Air Intake was to choose a location for the filter. The stock intake setup utilizes a scoop that allows ambient air to flow directly into the airbox. The Mishimoto filter was designed to sit directly in front of this scoop, enabling it to route as much ambient air into the system as possible.
An optional intake box was also designed to work with the stock scoop and Mishimoto intake. This box isolates the filter from high engine temperatures and ensures that the only air entering the filter is coming from the ambient scoop. Once the filter location was chosen, piping was fabricated with as few bends as possible. The Mishimoto intake also uses a larger internal pipe diameter over the stock setup. This increase in piping diameter along with an increase in filter surface area allows for greater mass airflow (MAF), which will help with power gains. For the final step we needed to choose an appropriate

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internal diameter for the pipe that has the MAF sensor mounted to it. We knew from previous intake development that this dimension is crucial and directly affects the AFRs (and subsequently the power output) of the engine.

Experiment and Results

MAF Housing Design

For our first experiment we chose to test three different-size MAF housing pipes to determine the effects they would have on overall power output and AFR readings. Throughout this experiment the internal diameter of the MAF pipe was the only variable. The air filter, primary piping, and engine tune all remained constant. It was immediately clear that the WRX's ECU was very particular about this dimension. Of the three designs tested, only one gave an increase in power while the other two prototypes caused the ECU to pull a significant amount of timing, which led to a drastic decrease in power. Even though these prototypes might have worked once the ECU was tuned, they were deemed unacceptable since the Mishimoto Intake must work safely on a fully-stock WRX. Figure 2 shows a comparison between one of the prototypes that was rejected and the final design selection.

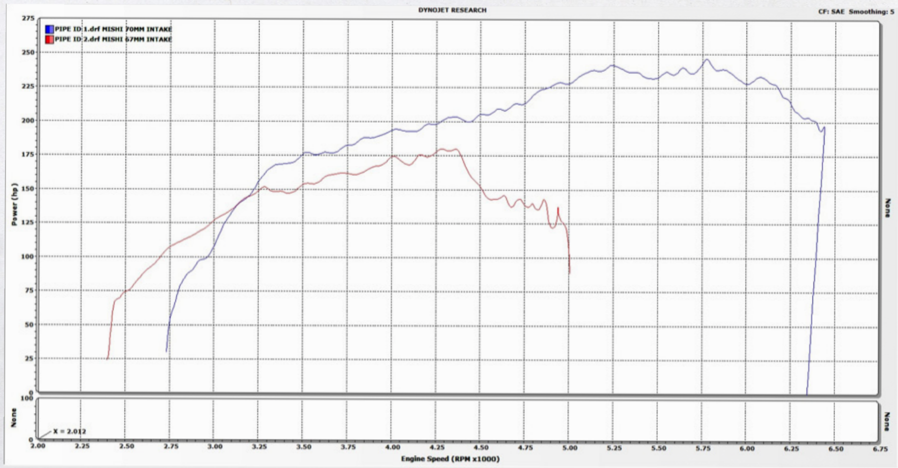

Figure 2: Comparison between the selected pipe prototype (blue) and a rejected prototype. The rejected prototype caused the WRX to run so poorly that the run had to be stopped before redline.

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Before the Mishimoto prototypes were tested, the WRX was put on the dyno to see how much power a completely stock setup made. Once five consistent pulls were made it was found that the average result was a peak of 213 whp and 244 wtq. The chosen Mishimoto intake design was then run on the dyno until five consistent pulls were made. The average plot chosen from these runs shows a peak result of 240 whp and 261 wtq. Figure 3 below shows these findings.

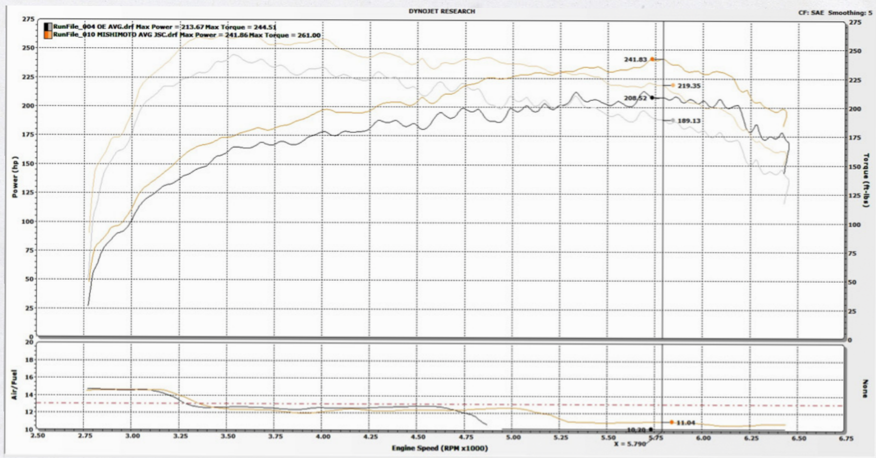

Figure 3: Gains of approximately 28 whp and 16 wtq are seen when the Mishimoto Intake is compared to the stock intake.

A gain of 28 whp while maintaining safe AFRs is impressive for a bolt-on intake and certainly shows that the additional airflow helps the FA20 achieve more power. Before this number was set in stone, however, we set out to do additional testing to ensure accuracy.

ECU Learning (Self-Adjustment)

Once an intake design was selected and dyno tested, the next task was to determine if this power increase would remain constant. The age of bolt-on power without tuning is slowly fading as modern ECUs are programmed to contantly adjust themselves. In general, the goal of these adjustments is to provide a proper balance between power and engine safety. Since these adjustments aren't always instantaneous, it's possible to see a sharp increase or decrease in power when a component such as the intake is changed. This is because the WRX ECU seems to pull or add timing based on whether it detects engine knock. An example of this can be seen below in Figures 4 and 5.

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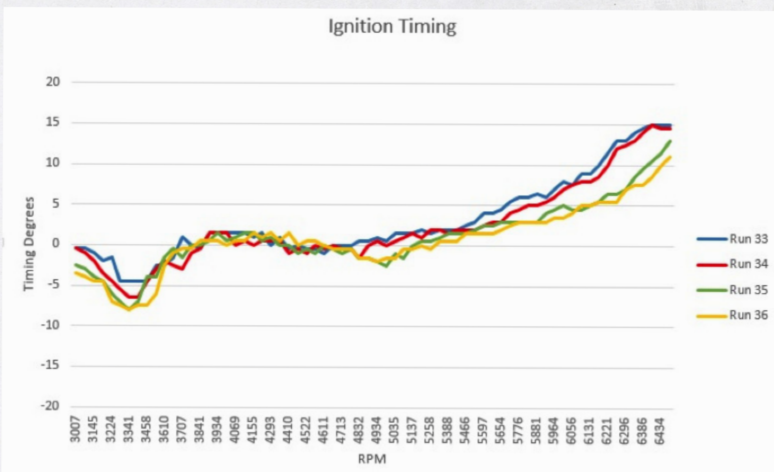

Figure 4: Ignition timing is pulled as the ECU tries to learn itself.

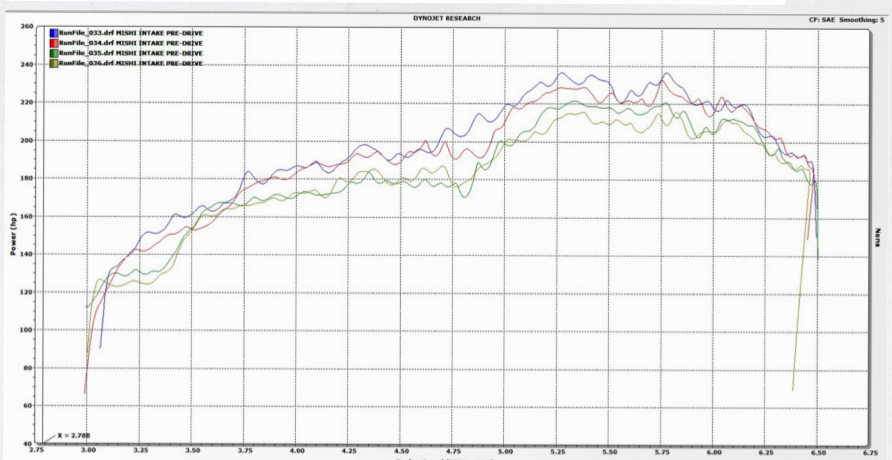

Figure 5: This decrease in ignition timing leads to a decrease in overall power.

Dyno pulls 33 through 36 were made directly after the Mishimoto intake was installed and the ECU was reset (by disconnecting and then reconnecting the battery). It's clear that once the ECU's memory is cleared, it then goes through a "learning" or self-adjustment period after the vehicle is started again. In order to test the Mishimoto Intake after this learning period has been completed, the vehicle was taken off the dyno and driven on the streets for some real-world testing.

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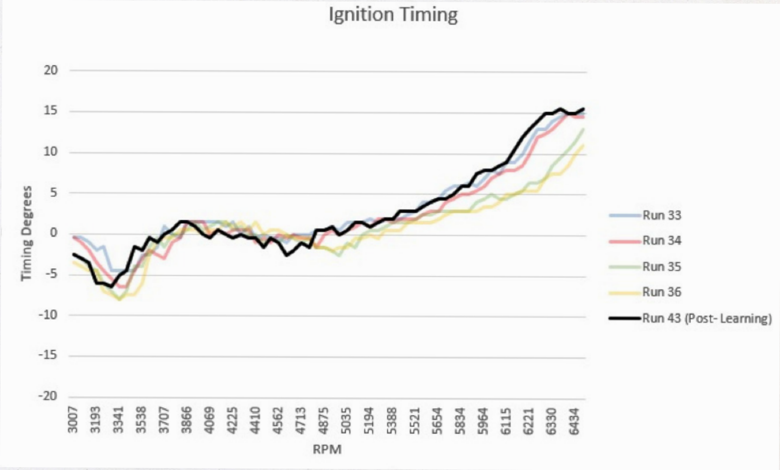
For the first round of street testing, the WRX with stock intake was driven on a highway for approximately 120 miles. The vehicle was again put on the dyno, and after five to six pulls that produced inconsistent plots, it was clear that this amount of driving time was not enough for the ECU to learn itself. After some research it was concluded that the vehicle needed more time on the road and to be driven at higher RPMs. Since most of the first test was highway driving, we believe the ECU didn't have a chance to fully adjust, particularly at high rpm and high load. The vehicle was then taken off the dyno and driven on the road for approximately 200 miles. This time, special attention was given to be sure the ECU saw all rpm values and engine loads numerous times. The vehicle was then brought back onto the dyno and retested. This time our dyno plots were consistent, so we believe the ECU had found its ideal timing and fueling values. After we obtained five consistent dyno runs, we found that this completely stock WRX made an average of 210 whp and 235 wtq, which is very similar to the results we obtained during the initial round of testing.

Once the appropriate stock values were found, identical testing was performed with the Mishimoto intake installed. We knew that the power would start out strong and eventually taper down a bit (as shown in Figures 4 and 5). However, the final result was a bit surprising. It seems the ECU quickly pulled timing to compensate for this new intake, but then over time it slowly added more timing. This observation is shown in Figure 6, which compares the timing curves in Figure 4 to the timing curve of the ECU once it had learned itself. After the vehicle was driven for 200 hard miles it was put back on the dyno and we obtained very consistent pulls. On average the WRX made 235 whp and 254 wtq, which is a 25 whp and 19 wtq increase over stock. AFRs stayed at a relatively safe level (on 93 octane gas) as shown below in Figure 7.

Figure 6: Timing curves from the four runs shown in Figure 4 are compared to the timing curve of the ECU after the WRX was driven for over 200 miles.



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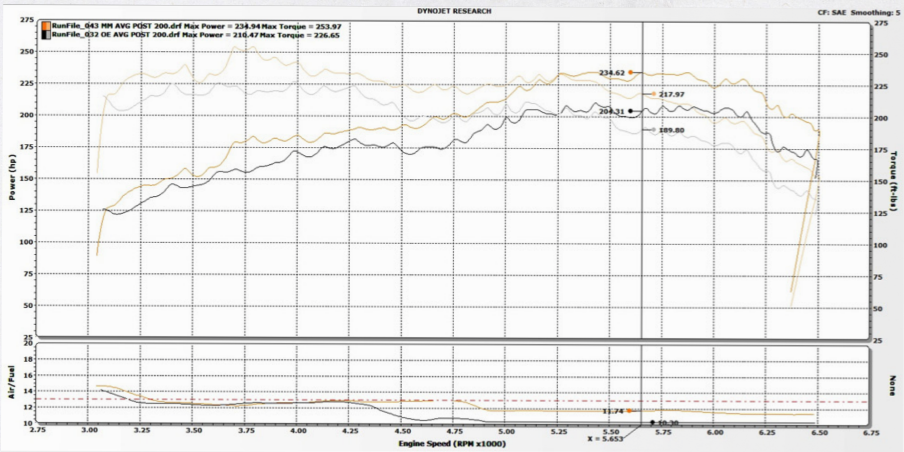

Figure 7: Stock intake vs. Mishimoto intake after the vehicle was driven for 200 miles and the ECU was fully adjusted.

Once this test was completed, the ECU was reset (by disconnecting and reconnecting the battery), and the vehicle was run on the dyno again. Our results showed the identical pattern as the previous testing: The vehicle slowly began to pull timing and reduce power and then eventually came back up and leveled out.

From these tests on ECU learning we can conclude that when the intake is originally installed, it will need approximately 200-300 miles of hard driving before the ECU will finish adjusting itself. During this time the vehicle should be run at different loads (or throttle positions) and engine speeds. This will give the ECU a chance to alter the timing and fueling to create a safe and efficient power curve. We can also conclude that the WRX will make up to 25 additional wheel horsepower by adding the Mishimoto intake. Since the power output is heavily dependent on how the ECU adjusts itself, each vehicle will be slightly different and may see a bit more or a bit less than 25 whp gains.

Intake Air Temperature Testing

As previously mentioned, a goal for this intake was to allow the coolest air possible to the filter to provide a dense air charge, which can result in more potential power. To accomplish this, the stock air duct was used in conjunction with an optional intake box to isolate the filter from the engine heat. The intake air temperatures were then recorded using the EcuTek ProECU data logging software.

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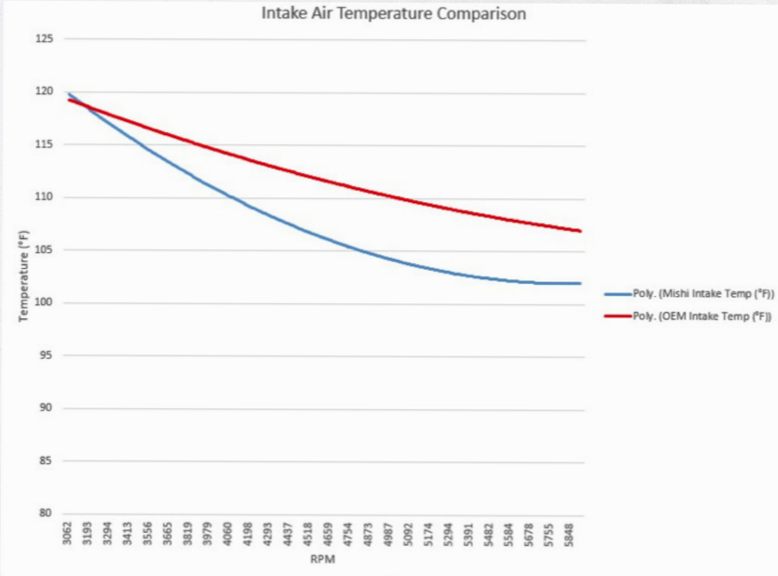

Figure 8: Comparison of stock and Mishimoto intake air temperatures

As shown in Figure 8 the Mishimoto intake with optional box reduces air temperatures by approximately 5˚F when compared to the stock setup.

91 Octane Testing

It's a well-known fact that the octane rating of the fuel you put into your vehicle will have an impact on how well it runs and how resistant it is to engine knock. Throughout all experiments so far the vehicle has been filled with 93 octane fuel, which is the highest standard octane rating on the east coast of the USA. In California, however, the highest standard octane rating is 91. To ensure that the Mishimoto intake is safe for all users, the 93 octane fuel was drained and the tank was filled with 91 octane gasoline. The ECU was then reset and the vehicle was driven hard for another 200 miles with the Mishimoto intake installed. With the WRX back on the dyno, we saw very similar power gains; however, the AFRs were leaner than desired.

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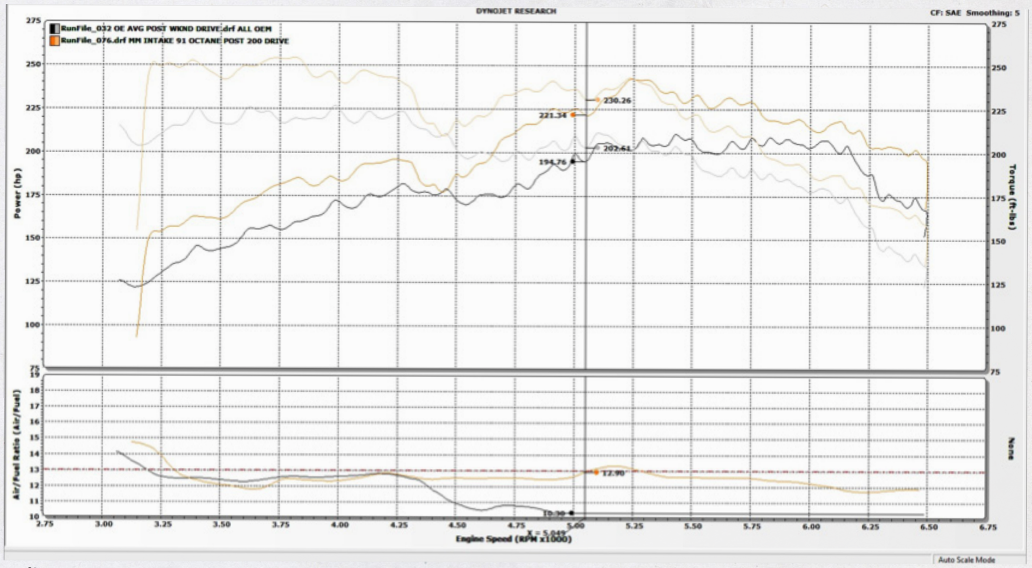

Figure 9: Mishimoto intake ran with 91 octane fuel compared to all-stock setup

As seen in Figure 9, AFR remains upwards of 12.5:1, which is generally considered unsafe.

Figure 6 shows that when running 93 octane fuel, the AFRs taper down to the 11.5:1 range, which is a much more conservative number. Running the motor too lean for extended periods of time can cause high combustion temperatures and pre-ignition, which can lead to premature engine failure. Since the 91 octane fuel causes the engine to run at a much leaner mixture than stock, it is recommended that the vehicle be tuned before driving extensively with the Mishimoto intake installed and when this grade of fuel is used.

Conclusions:

The final Mishimoto intake design successfully met all the goals and metrics set forth before the project began, with the exception of 91 octane fuel users. The overall design proved to make safe and effective bolt-on power even after the vehicle was driven for over 200 miles. Air-fuel ratios remained at relatively safe levels on the factory tune and while using 93 octane gasoline. The AFRs climb to a more risky level when lower-grade fuel was used, so it's recommended that California drivers get the ECU tuned before driving the vehicle under heavy loads.

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The intake also provided better-than-stock intake air temperatures, which will allow for a denser air charge and thus lead to more power. The Mishimoto intake gives off a deep, throaty tone under full throttle, which provides a much more pleasing sound for the driver. Additionally, the lower silicone hose is steel-wire reinforced to eliminate the chance of collapsing under vacuum. Proven safe power gains, aggressive intake tone, and no permanent modification required for installation all make the Mishimoto Performance Air Intake a must-have for any 2015+ Subaru WRX owner.

Steve Wiley
Product Engineer, Mishimoto Automotive

Disclaimer: The power results shown were on a stock WRX ECU without any sort of tune. Additional gains are to be expected once the ECU is tuned for the additional airflow. The gains resulting from a tune can be expected with both 91 and 93 octane fuel.

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