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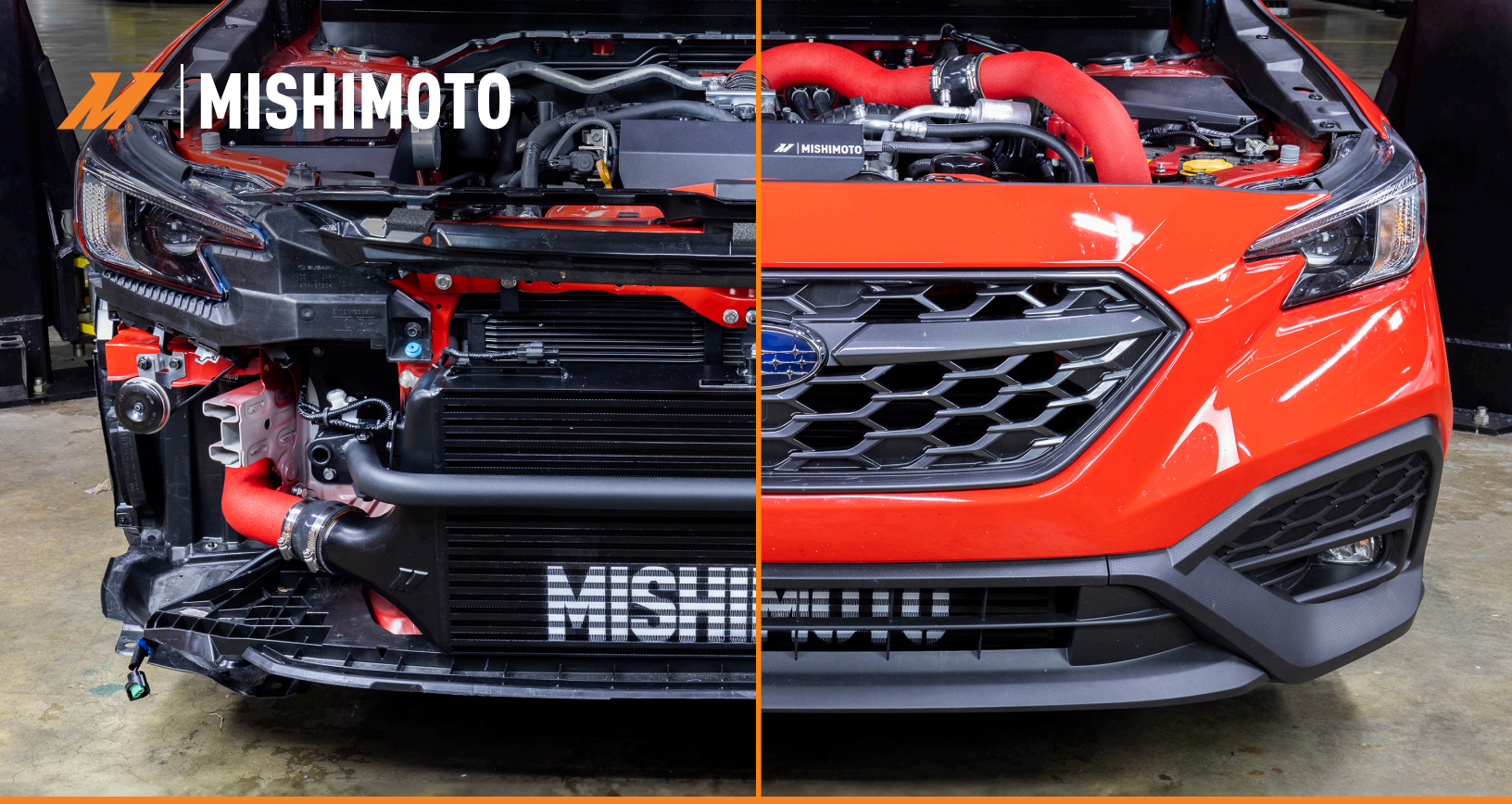

ENGINEERING REPORT

2022+ Subaru WRX Performance Front Mount Intercooler Kit | SKU: MMINT-WRX-22

By: Mitch Levy, *Mishimoto Product Engineer*

REPORT AT A GLANCE

- **Goal:** Design a front mount intercooler kit that maintains a consistent low charge air temperature without adding significant pressure drop. The design must incorporate a replacement bumper bar with accommodations for the factory tow hook and maintain the side-front impact support bars.
- **Results:** The Mishimoto Front Mount Intercooler kit saw peak power gains of 8.3 horsepower and a max power gain of 12 horsepower while maintaining charge air temperatures that peak at only 6 degrees above ambient, 7 degrees lower than the factory intercooler system. The average pressure drop through the system stayed about the same as the factory intercooler system despite having a significantly larger flow path and cooler size.
- **Conclusion:** The Mishimoto Front Mount Intercooler system is a great package to get the most performance and consistency out of the WRX.

CONTENTS

Figure 1: *Rendering of the Mishimoto Front Mount Intercooler Kit.*

DESIGN OBJECTIVES

- Create an intercooler that performs better than the stock intercooler
- Minimize the pressure drop normally associated with a front-mount intercooler kit
- Include replacement bumper bar with a location for the factory tow hook
- Direct fit kit with minimal trimming required
- Allow for fitment of aftermarket front strut bars

DESIGN AND FITMENT

The factory intercooler system on the 2022+ WRX includes a top-mount intercooler system that is mounted to the engine and throttle body and is fed cool air through the hood scoop and ducting. In the design of a WRX front mount intercooler system, we must compare both the factory top mount intercooler as well as top mount intercooler upgrades. In this case, we will use data and comparisons to the Mishimoto top mount intercooler upgrade. The top-mount intercooler systems benefit from having a short path from the turbo to the throttle body, which minimizes the opportunity for pressure drop and generally has a quick response to the driver's input. However, the top mount intercooler can suffer from heat soak due to its location as well as limited heat exchange ability due to the limited size of the hood scoop and accompanying ducting. The front mount intercooler kit relocates the intercooler core to the front of the vehicle, in front of the radiator, allowing greater airflow, less heat soak, and a larger core.

Figure 2: *2022 WRX with Mishimoto top mount intercooler upgrade installed.*

To design a precise and efficient kit, the vehicle was 3D scanned using Mishimoto's Faro 3D laser scanner. Utilizing the 3D data, we were able to establish the most efficient pipe routing as well as figure out what size core would fit behind the bumper, without needing to trim the bumper or surrounding components. In addition, the new bumper beam could be designed to fit closely with the bumper and have a precise tow hook receiver location.

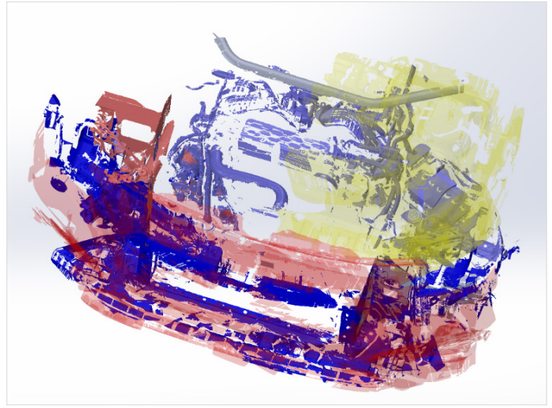

Figure 3: *3D scan data includes the bottom of the hood and inside of the bumper to ensure proper fitment of every part.*

The final core size was 675mm x 308.5mm x 100mm, which is approximately 318% larger than the factory unit with a 159% frontal area increase. While the core is very large, the sleek end tank design and internal fin specification were designed for maximum flow and minimum pressure drop. Two different core configurations were tested, varying the internal fin specification, so that a core could be chosen with a balance between cooling capacity and pressure drop. The core was designed to utilize the full front grille in addition to peeking up through the upper grille for maximum frontal area exposure. The robust bar and plate design is both efficient and strong enough to resist any rocks and debris that it may encounter at the front of the vehicle. This core is also significantly larger than the Mishimoto top mount intercooler as well, for those looking for extra charge air cooling over the already great performing top mount intercooler upgrade.

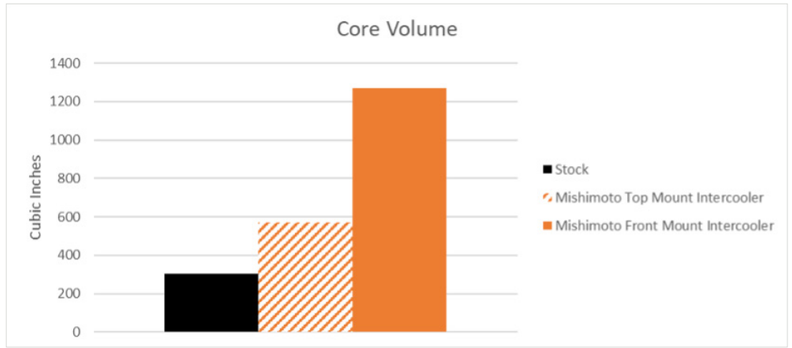

Figure 4: *Core volume comparison shows a 318% increase over the stock intercooler.*

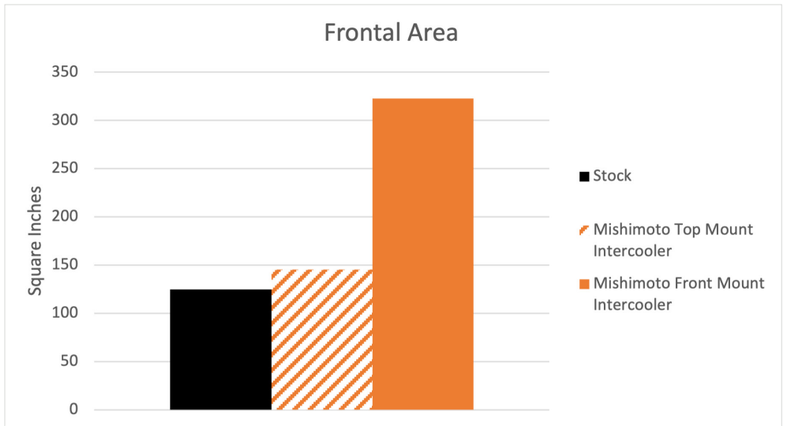

Figure 5: *Frontal area comparison shows a 159% increase over the stock intercooler.*

Several design features were utilized to minimize pressure drop throughout the system. With a clean sheet design for the intercooler end tanks, the inlet and outlet sizes are matched to the inner diameter of the 2.5" charge pipes going into and out of the intercooler, allowing for uninterrupted flow through the intercooler. This same principle was used at the throttle body adapter for maximum flow. In addition, 2.5" piping was used as much as possible, except for the turbo outlet pipe. The outlet of the turbo is only 41mm, so jumping straight to the 60mm inner diameter of the 2.5" pipe was not ideal. The CNC machined turbo outlet adapter transitions the 41mm adapter to the 54mm ID of the turbo outlet pipe and then transitions to 60mm ID at the first pipe transition and stays that way until the throttle body adapter. The throttle body adapter design also allows for a smooth, tapered transition from the adapter into the inlet of the throttle body.

Figure 6: *Intercooler inlet and outlet have a matched internal diameter to promote smooth flow.*

Figure 7: *This cutaway of the throttle body connection shows the inlet matches the internal diameter of the charge pipe and an outlet that matches the internal diameter of the throttle body to promote smooth flow.*

To fit the large core in the front of the car, the factory bumper bar would no longer fit. In its place, this front-mount intercooler kit includes a fabricated bumper bar that is also designed to mount the intercooler as well. It is important to replace the front bumper bar to maintain the structural rigidity that the bumper bar provides in addition to safety and crash protection. In addition, the Mishimoto bumper bar has provisions for a factory tow hook, in the factory location. This is important for roadside recovery and safety as well as being necessary to be able to race in many racing leagues and tracks. Furthermore, Subaru added side-front impact bars on the WRX models starting with the previous generation WRX (2015-2021). While these bars make the pipe routing significantly more difficult, it is important to keep this safety feature, to maintain safety in the event of a crash. To achieve this, the charge pipes for the inlet and outlet of the intercooler are very precisely routed around the bars, with brackets and rubber grommets to keep the charge pipes in place and still allow for engine movement and chassis flex. On the passenger side, the Mishimoto kit includes a kit to relocate the windshield washer reservoir fill neck to allow more room for the charge pipe to snake through the chassis.

Figure 8: *Front view of the intercooler system shows the included bumper beam and the retention of the side-front impact supports diameter to promote smooth flow.*

Figure 9: *Side view of the intercooler and intercooler outlet pipe shows the tight precise fitment of the charge pipe to allow the retention of the side-front impact supports.*

The location of the intercooler core creates another issue: the ambient air temperature sensor is now located behind the intercooler core. As a result, the ambient air temperature sensor will now read higher than the actual temperature as it reads the air after it goes through the intercooler and picks up heat from the core. To solve this issue, the Mishimoto intercooler core includes a bracket that allows the ambient temperature sensor to sit above the core with access to fresh air to be able to read accurately.

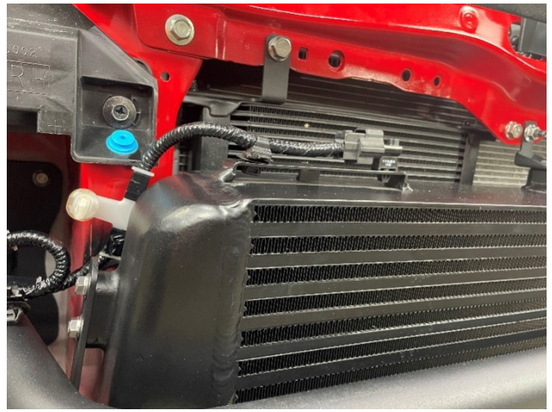

Figure 10: *The Mishimoto intercooler relocates the ambient temperature sensor for accurate readings.*

APPARATUS

For hardware, Mishimoto chose to use the AEM AQ-1 driven by the AQ-1 Data Acquisition system with OBD-2 data acquisition. Air temperatures were taken with Rife intake air temperature sensors. Air pressure was taken with Rife 4 Bar manifold pressure sensors.

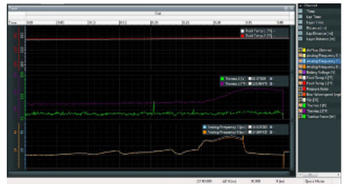

Figure 11: *AEM Data Acquisition Software*
Figure 12: *AEM AQ-1 Datalogging System*

The pre-intercooler sensors were placed close to the turbo outlet, in the turbo outlet charge pipe, and the post-intercooler sensors were placed right before the throttle body. This setup allows Mishimoto to get data that accounts for the pressure drop of both the intercooler and the charge pipes, as well as accounting for any heat the air might pick up in the cold side charge piping. In addition, these sensor locations are like those used during the top mount intercooler system testing, so that the data can be compared with significance.

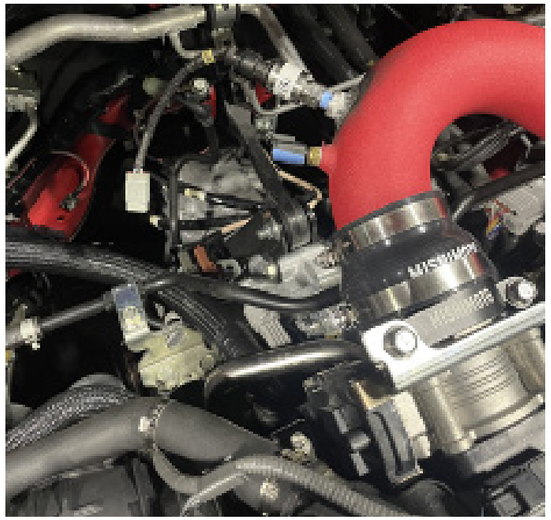

Figure 13: *Temperature and pressure sensors located in the charge pipe, close to the throttle body.*

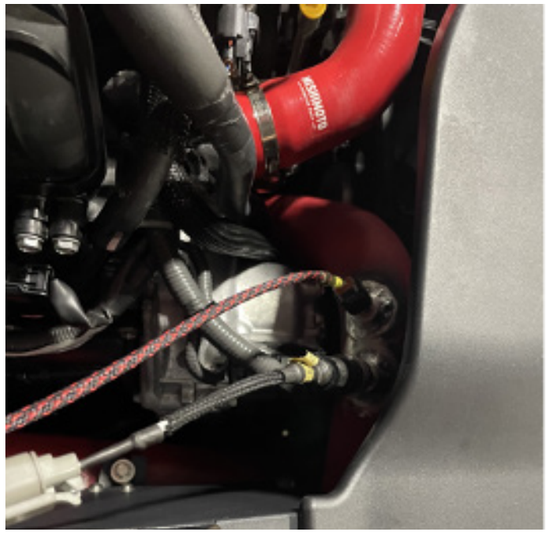

Figure 14: *Temperature and pressure sensors located in the turbo outlet charge pipe, to accurately measure the air leaving the turbocharger.*

PERFORMANCE TESTING

A 2022 Subaru WRX (6-speed manual) was used to test the front mount intercooler setup. The vehicle was tested with the following modifications: Mishimoto Thermostatic Oil Cooler Kit, Mishimoto Radiator, Mishimoto Radiator Hoses, and Mishimoto Air Intake

System. The ambient temperature was recorded by both the vehicle's ambient temperature sensor and the dynamometer's built-in sensors. The ambient temperature ranged from 73-80˚F (23-27˚C). To test the performance of the front mount intercooler system, a Dynapack™ dynamometer was used to conduct consistent ramp tests.

The WRX was warmed up by idling it on the dyno until the coolant temperature reached 190˚F (88˚C). Once the car was warmed up, dyno runs were conducted until multiple consistent runs were recorded. The vehicle was kept running between runs to maintain a consistent coolant temperature for every run. As a final test, 6 back-to-back dyno runs were completed with each intercooler core to simulate heat-soak conditions. The following data given is for the core specification that was chosen for the final production kit. Two different core specifications were tested, and the best-performing core was chosen.

As expected, the large intercooler core did a great job cooling the charge air. During the single wide-open throttle pull, the temperature of the outlet peaked at about 80˚F, which was only 6˚ over the ambient temperature. The outlet temperature decreased during the duration of the pull, ending at 77˚F. By comparison, the stock top mount intercooler peaked at 82˚F, which was about 10˚F over ambient temperatures. The Mishimoto top mount intercooler was in the middle with a 79˚F peak outlet temperature, which was about 7˚ over ambient. The top mount intercooler testing was done on a cooler day, with ambient temperatures averaging 71.6˚F so we use the temperature difference between the outlet temperature and the ambient temperature for comparison. The front mount intercooler cooled the charge air better than the Mishimoto top mount intercooler and significantly better than the stock intercooler on a single pull. At 6000rpm engine speed, the intercooler efficiency was 97%.

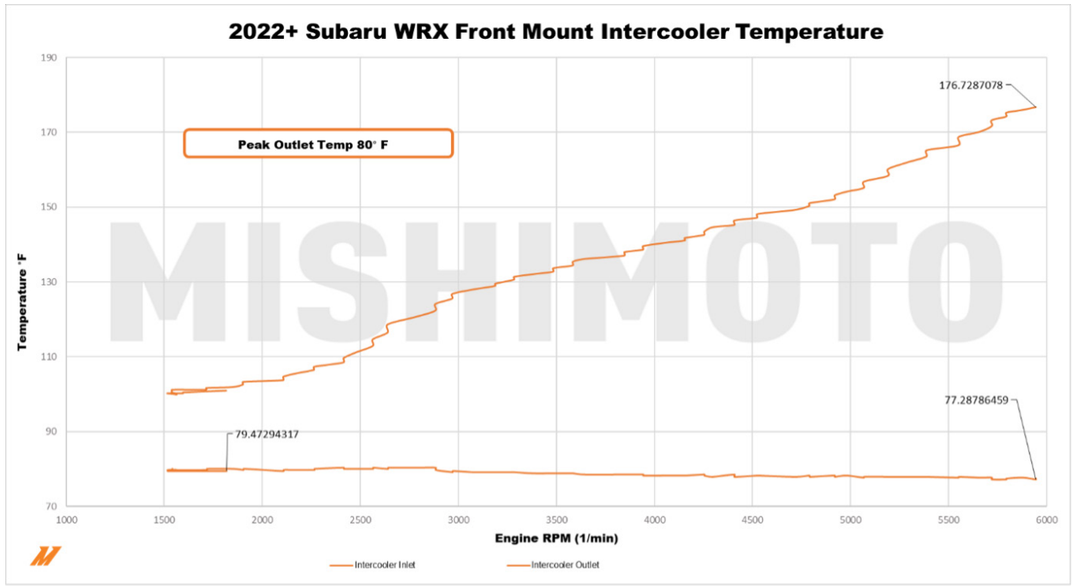

Figure 15: *Intercooler inlet and outlet data show a decrease in outlet temperature through the pull despite the inlet air rising in temperature throughout the dyno pull.*

The front mount intercooler kit was able to cool efficiently with minimal pressure drop increase during our testing. During a single dyno pull, we saw a peak pressure drop of 1.5 psi with an average pressure drop of 1 psi. By comparison, the Mishimoto top mount intercooler saw a peak pressure drop of 1.1psi and an average pressure drop of 0.6 psi, and the stock intercooler was 1.5psi and 0.9psi, respectively. When considering the extra volume and distance the air must travel in the front mount intercooler, there was almost no increase in pressure drop through the system over the stock system. This means that when driving the car, the driver will not notice a decrease in responsiveness of the turbocharger and the turbocharger will be able to stay efficient. Often inefficient intercooler systems have a large pressure drop means that the turbo must spin faster to create the same pressure in the intake manifold, which then creates more heat. Mishimoto's intercooler system provides more cooling without any additional pressure drop.

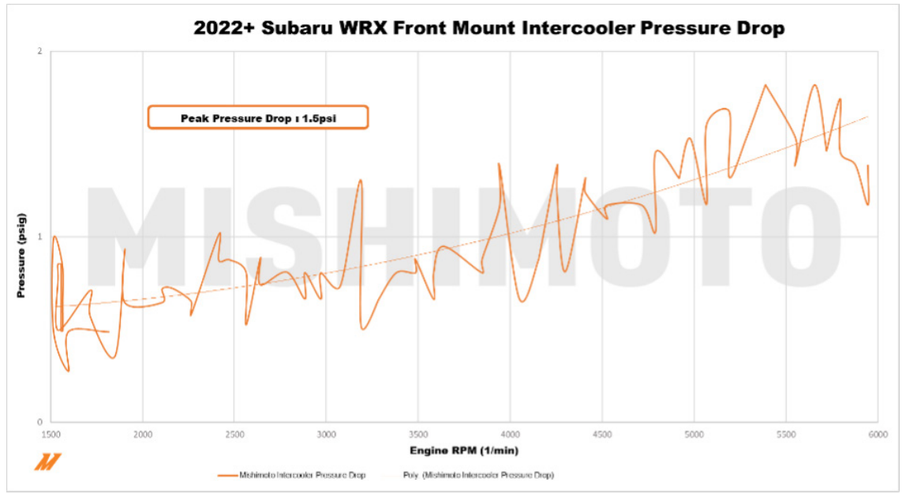

Figure 16: *Pressure data shows an average pressure drop of 1 psi and a peak pressure drop of 1.5 psi from the turbo outlet to the throttle body.*

The front mount intercooler showed promising gains in power as well, with a peak increase of 8.3 horsepower and max gains of 12 horsepower and 11.8 foot-pounds of torque. We saw a very small loss of torque from 2500 to 2800rpm, likely due to the extra volume of the intercooler and charge pipes, however, the vehicle made more power from 4250 rpm until redline. During performance driving applications, the range of 2500-2800 rpm is rarely used, while 4250 rpm to redline is almost always utilized, so the very small losses in torque in the low rpm range are negligible.

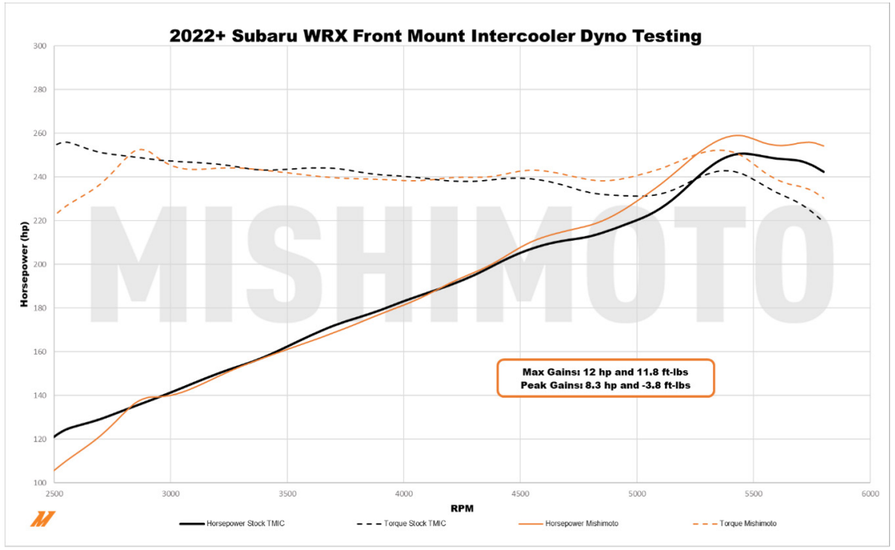

Figure 17: *Dyno results from the Mishimoto front mount intercooler kit versus the factory top mount intercooler show promising gains, especially above 4000 rpm.*

The benefits of a large intercooler core and front-mounted location are its ability to keep the charge air cool with repeated back-to-back wide-open throttle pulls, similar to what might be seen during track driving or drag racing. A good-performing intercooler system should be able to perform several dyno pulls with minimal decrease in power. In this case, after 6 back-to-back dyno pulls, the vehicle gained about 4 horsepower from the first pull to the last pull, which is a testament to the system's resistance to heat soak. The consistency from pull to pull was remarkable, with a swing of about 6 horsepower from the highest power pull to the lowest or 2%.

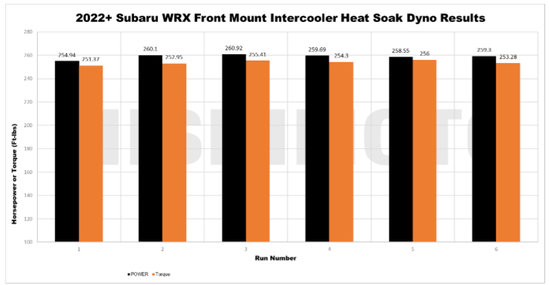

Figure 18: *Peak power and torque from back-to-back dyno pulls show consistency and resistance to heat soak.*

The analysis of the sensor data from the heat soak test showed a remarkable ability of the front mount intercooler system to keep temperatures consistent after many dyno pulls. The intercooler outlet temperature was the same 84°F at the start of the first pull as it was at the end of the 6th pull despite the intercooler inlet temperature rising every pull, with a peak of 230°F. The intercooler temperature differential at the end of 6 pulls was 146°F. The peak outlet temp of 84°F was only 5°F over the ambient temperature during testing while staying below 84°F for most of the test. By comparison, the factory intercooler outlet rose by 14°F with a peak outlet temp 21°F over ambient. Mishimoto top mount intercooler rose by 10°F during the heat soak test with a peak outlet temperature of 16°F over ambient. This test shows that the front-mount intercooler will perform exceptionally well in high-heat racing scenarios, especially when compared to the factory top-mount intercooler.

The Mishimoto performance front mount intercooler for the 2022+ Subaru WRX is designed to install easily, fit well, and perform consistently with a ton of extra headroom for additional performance. The intercooler kit is a perfect addition for those looking to make a lot of power pull after pull without sacrificing the response or safety of the vehicle.

TESTING DONE BY:

Mitch Levy, Mishimoto Product Engineer

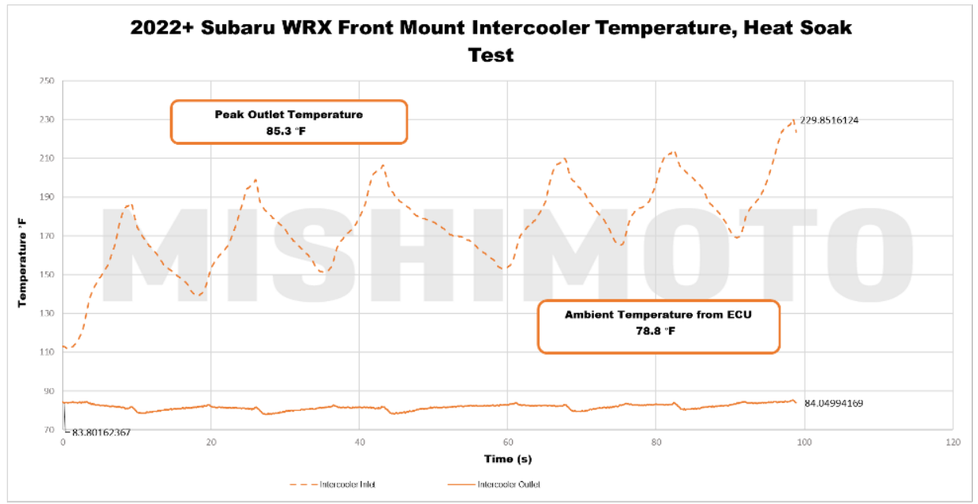

Figure 19: *Intercooler temperature data from the heat soak test show a steady, low outlet temperature despite rising inlet temps with every pull.*

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