BMW E46 M3 Radiator

TOP SECRET

MISHIMOTO
RESEARCH & DEVELOPMENT

MISHIMOTO ENGINEERING REPORT

Testing the Mishimoto BMW E46 M3 Performance Aluminum Radiator

Figure 1: Test vehicle: Notice the additional heat exchangers in front of radiator.

Test Vehicle:
2004 M3 with SMG Transmission

Modifications:
Supercharged, intercooler, methanol injection, full exhaust. Professionally tuned @550 whp on pump gas.

Cooling System Upgrades:
13-row oil cooler for supercharger located behind the kidney grills. Front-mount intercooler (FMIC) located in the front air dam. Upgraded clutch fan that spins faster than stock clutch fan.

DO NOT COPY

MISHIMOTO

RESEARCH & DEVELOPMENT

BMW E46 M3 Radiator

TOP SECRET

Testing conditions:

Temperature range 82˚F–85˚F and 70% humidity

Testing Location:

Orlando Speedworld, 3/8 mile oval track, in Orlando, Florida

Figure 2: Orlando Speedworld track

Apparatus:

For temperature monitoring, Mishimoto chose the PLX sensor modules driven by the Kiwi WiFi plus iMFD. This is a wireless system from the sensor modules to an iPad or laptop computer. The software used was the Palmer Performance Scan XL pro, which has full data logging capabilities. Sensor locations were installed inline with the upper and lower coolant hoses.

Figure 3: Mounting locations for temperature sensors AFR curve.

Figure 4: PLX sensor modules were used to monitor engine pyrometers.

Background and Experiment:

Mishimoto engineers wanted to test the new Mishimoto radiator in short-track and low-speed track conditions to determine the impact of the increased density of the radiator core. Engineers needed to confirm that the radiator would push enough air through the core to cool the engine and not cause overheating. A dense core design rejects more heat in a higher-speed environment, so testing the radiator in a worst-case scenario was paramount to confirm effectiveness.

Core Information: Compared to the stock core, the Mishimoto core has several changes to improve the conductance of the radiator. Improvements include decreasing fin height, which allows for more coolant tubes, increasing fin pitch, which will aid heat transfer, and increasing overall core thickness. The two figures below represent these changes. Overall capacity in terms of volume for the stock radiator is 0.65 gallon, while the Mishimoto radiator showed a 25% increase to 0.87 gallons.

MISHIMOTO
RESEARCH & DEVELOPMENT

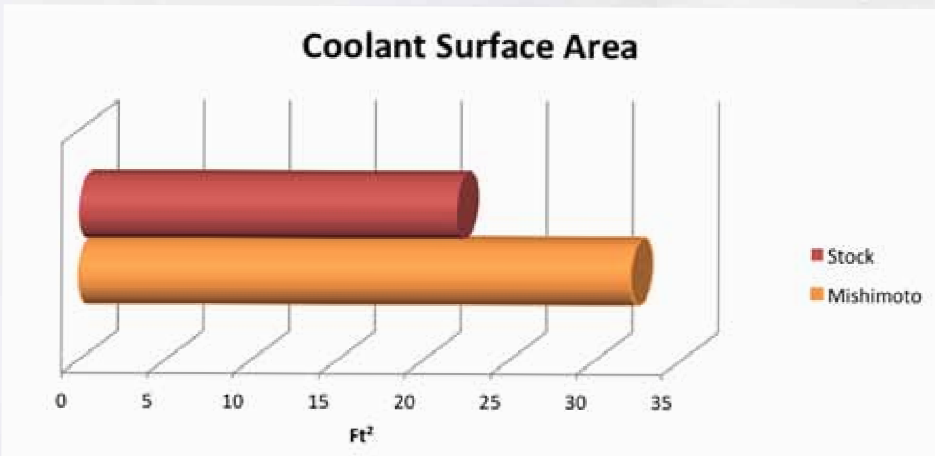

Figure 5: Coolant surface area (tubes) increased by 32%..

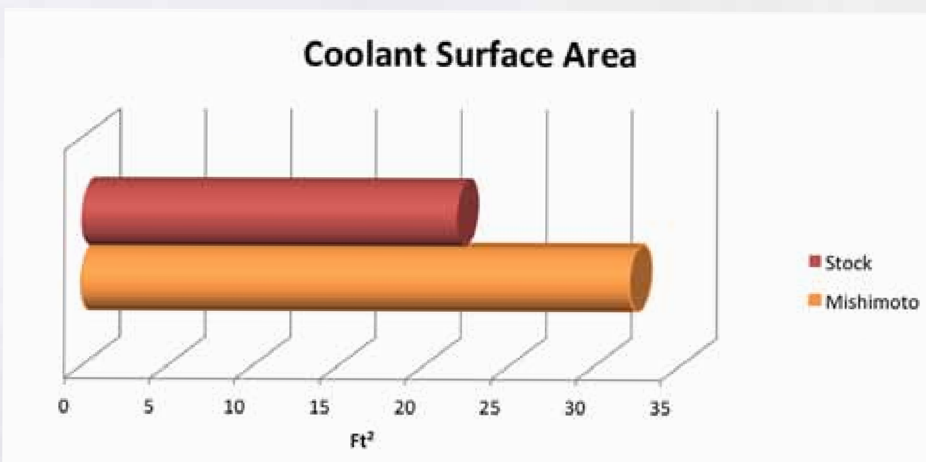

Figure 6: Air surface area (fins) increased by 15%.

TOP SECRET

MISHIMOTO
RESEARCH & DEVELOPMENT

Track Scenario One:

First we drove a few laps around the track to get the engine and tires warmed up. Next, we drove full-speed laps for about 7–10 minutes, or until the temperature data reached a stable condition. Since the track is an oval we can explain the details of a lap fairly easily. For a typical lap under scenario one, Mishimoto engineers chose to run the car in 3rd gear for the entire lap. The straight section would see an acceleration from 3,000 rpm to 5,000 rpm, or about 40¬–58 mph, then hard on the brakes down to about 35 mph. As we passed the apex, the car was given partial throttle up to about 40 mph out of the bend; then we accelerated again up to about 58 mph, braked, and repeated. The graph below shows the results of testing under this condition for about five minutes of driving. The temperature data from both radiators show that the car can handle this type of driving without any issues. Oil temperatures under these conditions were approximately 233˚F as observed from the stock gauge.

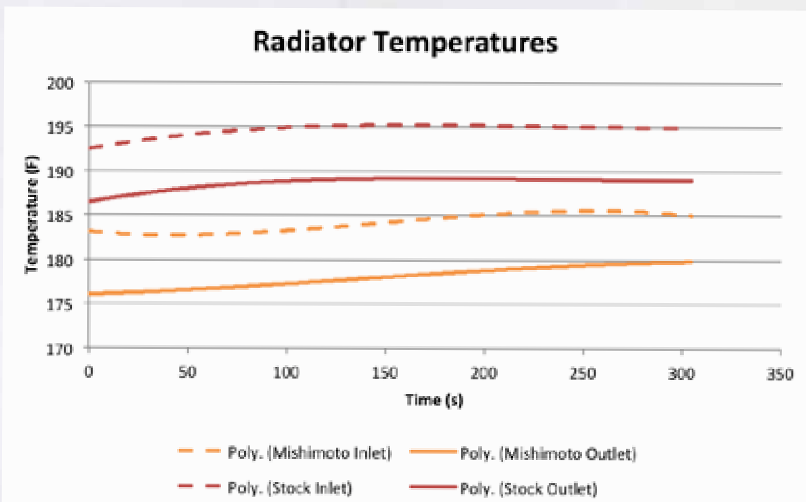

Figure 7: Overall coolant temperatures are lower with the Mishimoto unit. Pure distilled water was used for all tests. If a 50/50 mixture is used you can expect to add around 10˚F to all plots.

DO NOT COPY

CONFIDENTIAL

MISHIMOTO

Heat rejection is approximately equal for the stock and Mishimoto radiators under testing conditions for the first scenario. This is expected due to the governing laws of thermodynamics, i.e., energy output of the engine into the cooling system equals heat rejected from the radiator when under steady state. Figure 9 shows a difference of approximately 200 Btu/min, or 6% between the stock and Mishimoto radiators. The difference in total error is due to a combination of lack of testing repeatability and lack of sensor accuracy.

Figure 8: Rate of heat dissipated

$$Q = \varepsilon \times C_{min} \times (T_{h,i} - T_{c,i})$$

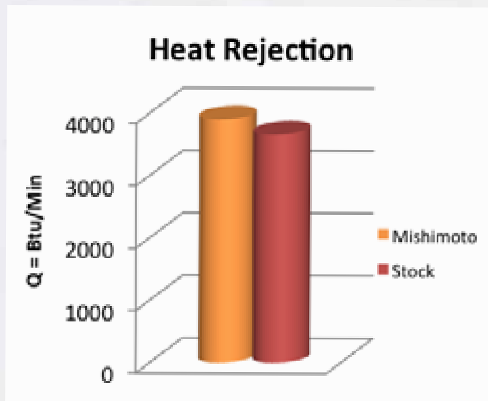

Figure 9:: Measured heat rejection

Scenario One Results:

Both the stock and Mishimoto radiators were able to stabilize temperatures under the conditions stated for this scenario. One important difference to note is the reduction in the engine output temperature. For the stock radiator the engine output temperature was 195˚F; for the Mishimoto radiator the engine output temperature was 185˚F. Using this information we can calculate the air-to-boil (ATB) temperature. The ATB temperature is the maximum ambient air temperature reached before the engine outlet temperature of coolant will boil, which would result in overheating and engine failure (see Figure 10). For scenario one, the outside ambient temperature would have to be 140˚F for the stock radiator to overheat, while the Mishimoto radiator could allow an ambient temperature of 150˚F before overheating.

Figure 10: Air-to-boil temperature

$$ATB = T_{bp} - (T_{c,i} - T_{ai})$$

MISHIMOTO

Track Scenario Two:

First we drove a few laps around the track to get the engine and tires warmed up. Next, we drove the car at full speed using only 3rd gear for 7–10 minutes, just as we did for scenario one. Since the track is an oval we can explain the details of a lap fairly easily. For a typical lap under scenario two, Mishimoto engineers chose to run the car in 2nd gear for the entire lap. The straight section would see an acceleration from 4,200 rpm to 7,800 rpm, or about 40–62 mph, and then hard on the brakes down to about 35 mph. As we passed the apex the car was given partial throttle up to about 40 mph out of the bend; we then accelerated again up to about 62 mph, braked, and repeated. The graph below shows the results of this condition for about five minutes of driving. This driving condition was extreme for the car, so we ended the test after about four minutes of driving. Oil temperatures for the supercharger were extremely hot, and oil began to seep and bubble from the oil pump. Engine oil temperatures were approximately in the 255˚F–260˚F range.

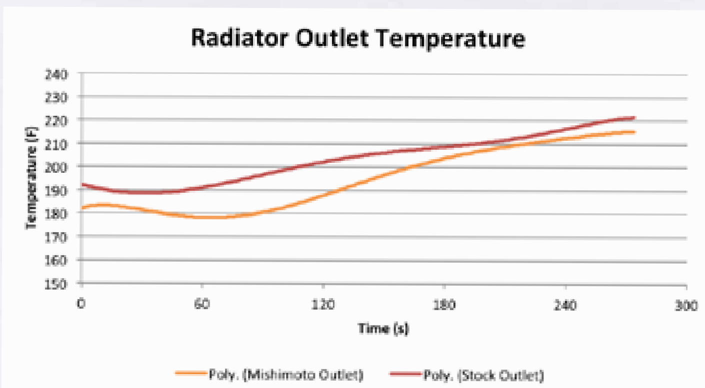

Figure 11: Mishimoto radiator revealed overall lower outlet temperatures when compared to the stock

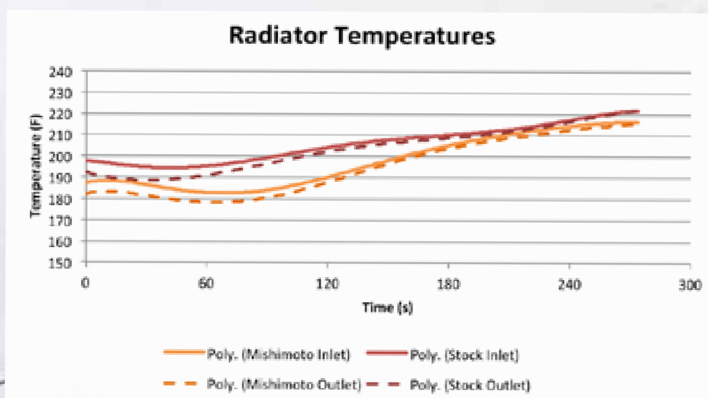

Figure 12: Inlet and outlet temperature comparisons. The change in temperature averaged about 3˚F for both radiators.

TOP SECRET

Inlet temperatures for both the stock and Mishimoto radiators were 2˚F–4˚F hotter than the respective outlet temperatures. Although the temperature difference between the inlet and outlet was slightly less than in the first test, flow rates of the water pump increased with engine speed, and the heat rejection for both radiators resulted in about the same rate as seen in Figure 9.

Scenario Two Results:

Heat rejection for both the stock and Mishimoto radiators seemed lower than what the engineers expected. After some calculations the engineers found that the ideal heat rejection from the stock and Mishimoto radiators for both scenarios would be around 6200 Btu/min and 7400 Btu/min, respectively. This Q ideal or theoretical number would indicate perfect conditions, for example: airflow through the radiator core would equal the vehicle speed, and flow of both the coolant and the incoming air would be distributed equally throughout the core. Engineers concluded that the losses from the FMIC, AC condenser, SC oil cooler, pusher fan, and other shrouding lowered the incoming airflow to the radiator by a significant amount. According to the test data, average measured track speed for one lap was 42 mph. Engineers found that airflow was 19 mph instead of the ideal 42 mph. Other losses came from the presence of the FMIC and oil cooler, which increased the incoming air temperatures that enter the radiator, resulting in a lower rate of heat rejection for the radiator.

One additional note worth mentioning is the recovery time of the radiator after the hot lap. Immediately after the test we began cool-down laps by cruising around the track at about 40 mph to cool down the engine. For the stock radiator we needed about two to three minutes before the temperatures would return to about 190˚F, while the Mishimoto radiator needed only about one and a half minutes. In hindsight engineers should have recorded rather than merely observed this information. If we test the radiator again, we will be sure to gather this additional information.

Fan Testing:

Due to the increased density of the core, engineers wanted to test how the stock fan worked with the new core when compared to the stock core. The test was conducted in the Mishimoto garage and was simply a constant idle over 20 minutes to confirm that the engine would not overheat. Below are the results.

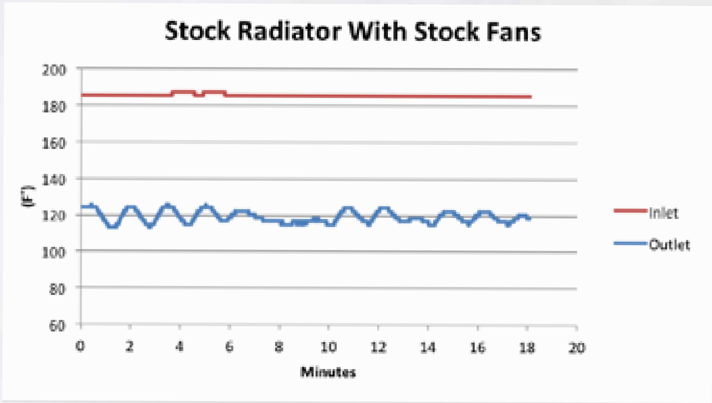

Figure 13: Stock radiator maintained an outlet temperature of approximately 120˚F.

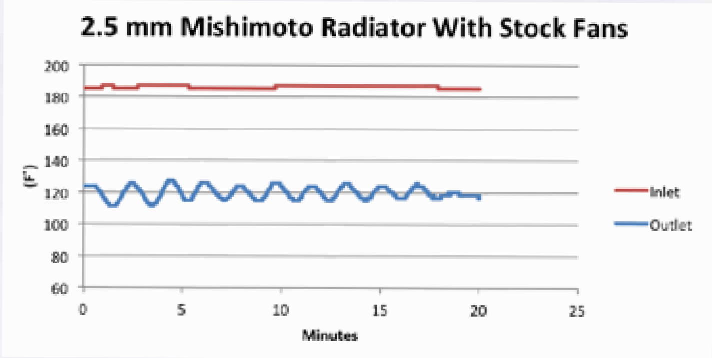

Figure 14:Mishimoto radiator maintained an outlet temperature of approximately 120˚F.

Idle Test Conclusion:

The idle testing shows that the stock and Mishimoto radiators perform alike under the same testing conditions. Compared to the stock radiator, the Mishimoto radiator will not add any extra stress on the engine at idle.

Overall Conclusions:

Mishimoto engineers calculated that the test vehicle heat output was 3,700 Btu/min for scenario one and 5,500 Btu/min for scenario two. In scenario one the 550 hp car was able to maintain temperatures with the coolant, engine oil, and supercharger oil.
In scenario two the vehicle was not able to maintain a stable condition. The engine

TOP SECRET

output (5,500 Btu/min) was higher than the radiator heat rejection (3,600 Btu/min). This means that it would be only a matter of time before the car would overheat. For scenario two, the supercharger oil and soon-to-be engine oil overheated before the radiator did. Scenario two was an extreme environment when factoring in all the conditions: extra 250 hp vehicle, FMIC, supercharger oil cooler, and very low-speed track. (Note: This is why oval track racecars use such large radiators.) Mishimoto engineers calculated that the Mishimoto and stock radiators would have needed wind speeds of 32 and 36 mph, respectively, to reach the front of the radiator so that scenario two conditions could be maintained.

The idle test showed that the increased density of the Mishimoto core does not impede airflow enough to cause higher idle temperatures. This is important to note because some cars might not be able to support idle temperatures that are higher than stock temperatures.

The Mishimoto radiator is designed for higher speeds, but it outperformed the stock radiator in all tests, proving that the newly designed Mishimoto radiator will be an improvement over the stock radiator under all conditions. (Note: Performance will vary depending on vehicle modifications, environment, racing conditions, and coolant type.) Special thanks to Precision Sport Industries located in Winter Park, Florida, for donor vehicle and shop space.

Kevin McCardle
Product Engineer

DO NOT COPY