CUSTOM PERFORMANCE engineering

MazdaSPEED6 Front Mount Intercooler

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The cp-e™ ΔCore™ intercooler kit is a front mount intercooler upgrade for the MazdaSPEED6. It features a 3" bar and plate intercooler core with 2.25" piping, good for up to 450hp. The kit comes complete with all clamps, hoses, brackets, and hardware required for a complete installation.

The stock intercooler core is a finicky unit, as it is extremely sensitive to heat input and boost pressure. But we found these limitations to be necessary evils that were probably engineered into the system from the factory.

First, the stock intercooler is surprisingly efficient despite its small size and restricted airflow. Making this intercooler efficient in the SPEED6 is quite a challenge, but the Mazda engineers accomplished this feat with a couple band-aids to get the job done.

The band-aid is actually the core design itself. The stock core is a vertical flow unit, with a generous 20" pathway from end tank to end tank. This long air pathway keeps the air in contact with the intercooler for a long time, which increases the total heat transfer. The downside to this approach is that by using long passages within the intercooler you create excessive friction, which saps energy from the air. The result is a cool air charge, but at the cost of boost pressure. An ideal intercooler should have good thermal efficiency without an excessive pressure loss. So, cp-e™ set out to design an intercooler that is thermally efficient, has a low pressure loss, and is designed specifically for the SPEED6 community.

Simply moving an intercooler to the front of a car from the engine bay is advantageous in and of itself. So, designing a front mount intercooler was a no-brainer. By doing so, the intercooler is no longer responsible for removing heat from the engine bay, combined with the boosted air charge. It also opens the intercooler up to a tremendous supply of cool air.

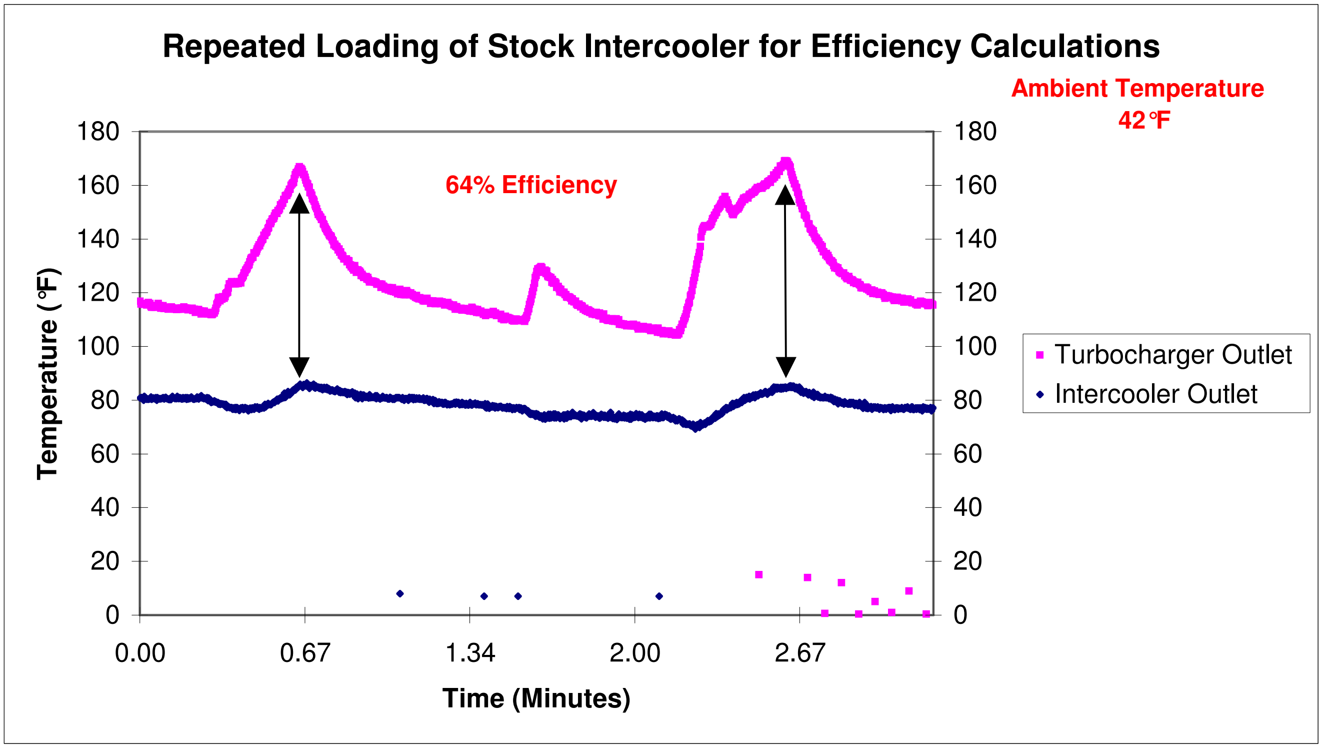
Next, we set out to find the ideal core for the project. cp-e™ chose to use a wide, vertical flow core for several reasons. First, a vertical flow core allows for very compact packaging, and is an ideal shape for the front of the SPEED6. That means less intake piping, and subsequently less throttle lag. It also eliminates one 180° bend required for a horizontal flow unit.

A vertical flow core takes full advantage of the limited area in the front of the SPEED6. If you pull your bumper cover off, you'll see a steel structural bumper in front of all the cooling equipment. Since the steel bumper cannot be removed (without cutting of course), we set out to take advantage of all the open area we could. A large, square intercooler would be shrouded by the bumper, so we chose a very wide, and short intercooler. This style intercooler core has excellent pressure loss qualities, and also utilizes all the available open area in front of the car for superior cooling. The result is an efficient intercooler with very little pressure loss.

INTERCOOLER EFFICIENCY:

Intercoolers can be rated on how well they expel heat by using a standard formula. More significant than a simple temperature drop calculation, the intercooler efficiency formula takes into account ambient conditions, which can greatly affect overall cooling effectiveness. But generally speaking, the larger the temperature drop, the more power the end-user will make.

$$IC_{eff} = \frac{T_{in} - T_{out}}{T_{in} - T_{ambient}}$$



But using these calculations are not as straightforward as one might think. A well-known tactic in drag racing is to "ice down" the intercooler before a race. This artificially raises the intercooler efficiency since it will drop the core temperature below ambient. So, the temperature of the core is also of great significance, as it will affect the efficiency calculations. So, we opted to perform several runs to illustrate this point, and to show how sensitive the stock core is to temperature.

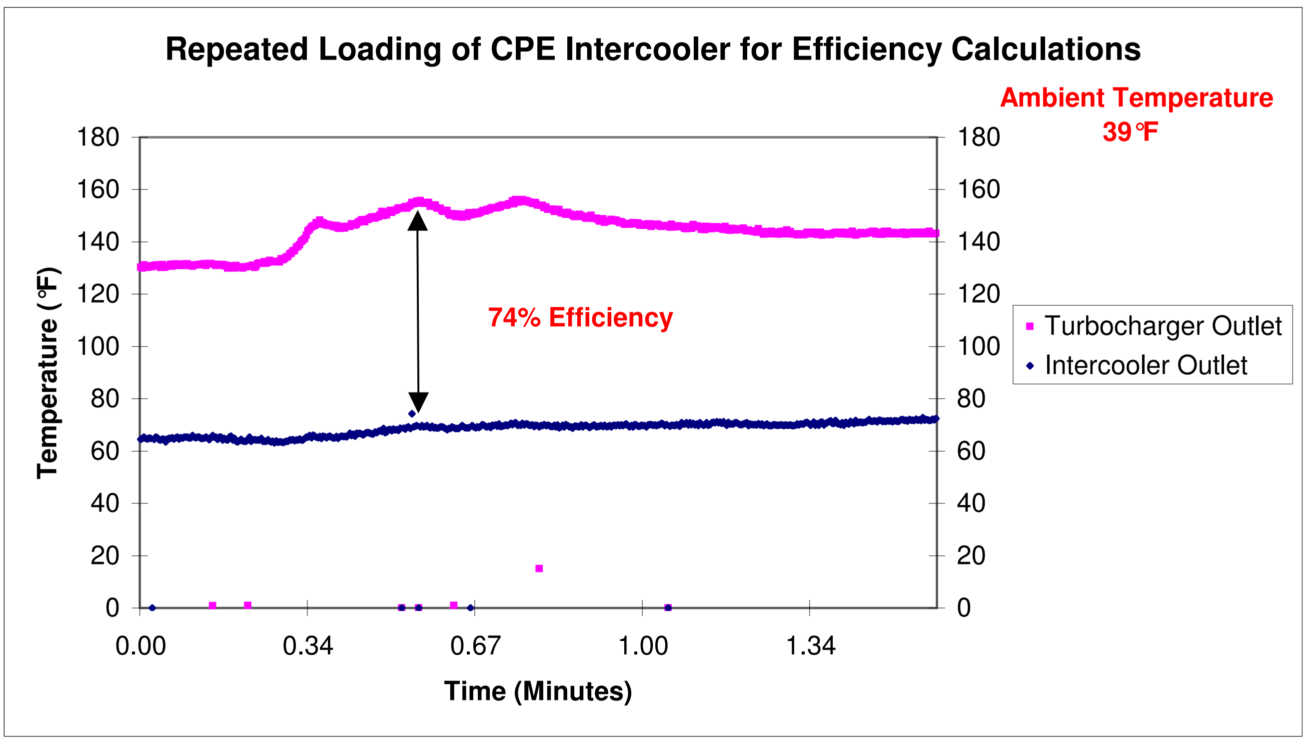
Normal Start		
Turbocharger Outlet Temperature	167	°F
Intercooler Outlet Temperature	86	°F
Ambient Temperature	41	°F
Efficiency	64	%

Hot Start		
Turbocharger Outlet Temperature	219	°F
Intercooler Outlet Temperature	132	°F
Ambient Temperature	71	°F
Efficiency	58	%

What's interesting is that the stock core performs well despite its small size and restricted airflow. But why? If there were no pressure drop across an intercooler core, then there would be *no cooling*. Generally speaking, as the pressure loss increases, so does the cooling efficiency. This is because pressure loss is a function of air turbulence in the core, and the more turbulence there is, the more the air is coming in contact with the fins and walls in the intercooler. More contact means more heat transfer. The problem however, is that a large pressure loss means that your turbo is working harder than it needs to, which subsequently adds unnecessary heat to the intake charge, and limits the amount of boost the engine actually receives.

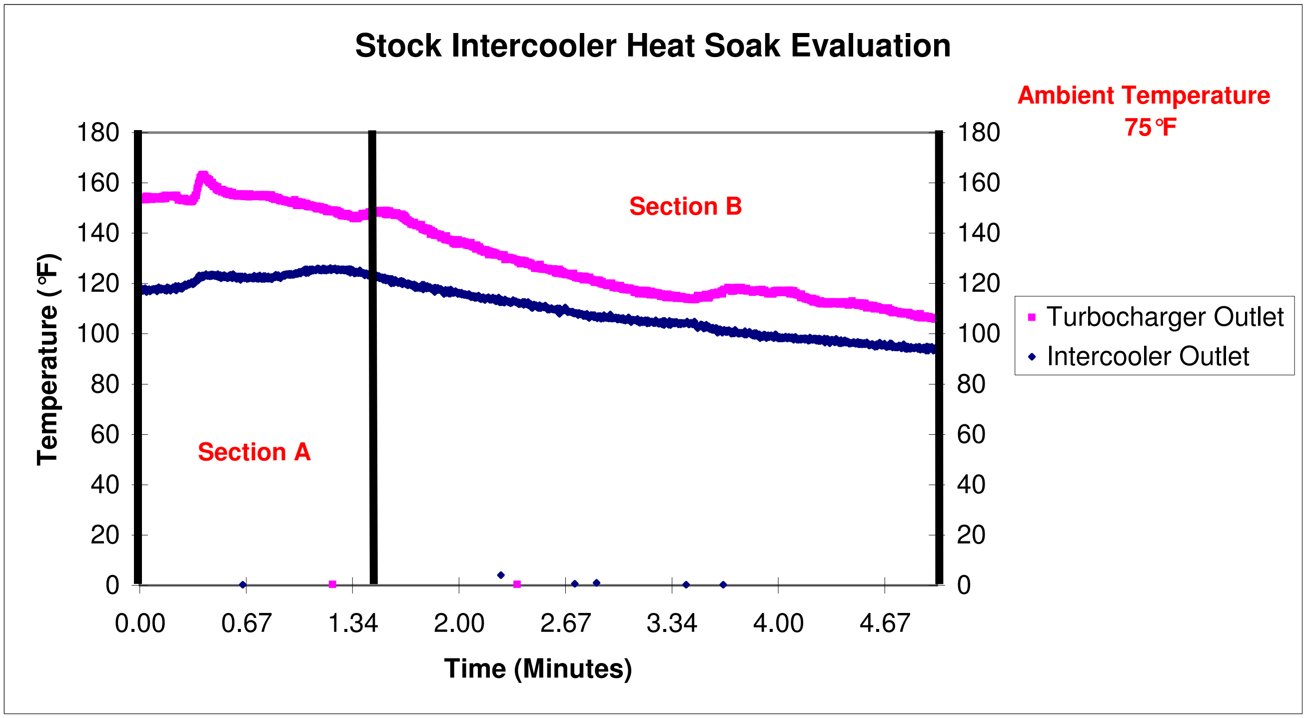
But the problem with the stock core is exposed once it starts heating up. Even though it has a large pressure drop across the core, which aids in cooling the stock core is relatively small, and is bolted to a hot engine. Once the core gets hot, it reaches a point where the heat coming into the intercooler is exceeding the heat being expelled. This is indicative of an intercooler that is inadequate for a particular application. The result is a steady increase in temperature of the air that enters the engine. If left unchecked on modified engines, this could lead to dangerous turbocharger impeller speeds, or excessive intake temperatures.

Compare the stock intercooler's efficiency to the cp-e™ intercooler:



The cp-e™ intercooler found the fine balance between cooling efficiency and pressure loss. Because our core doesn't sap as much energy from the air, simply adding this core to a stock car would allow nearly a three-pound increase in boost pressure to the engine. Moreover, our intercooler is much more stable than the stock unit, as it is not as sensitive to heat input. You can beat the turbocharged MZR for all it's worth, and our intercooler will maintain its 70%+ efficiency rating.

STOCK INTERCOOLER HEAT SOAK DATA:



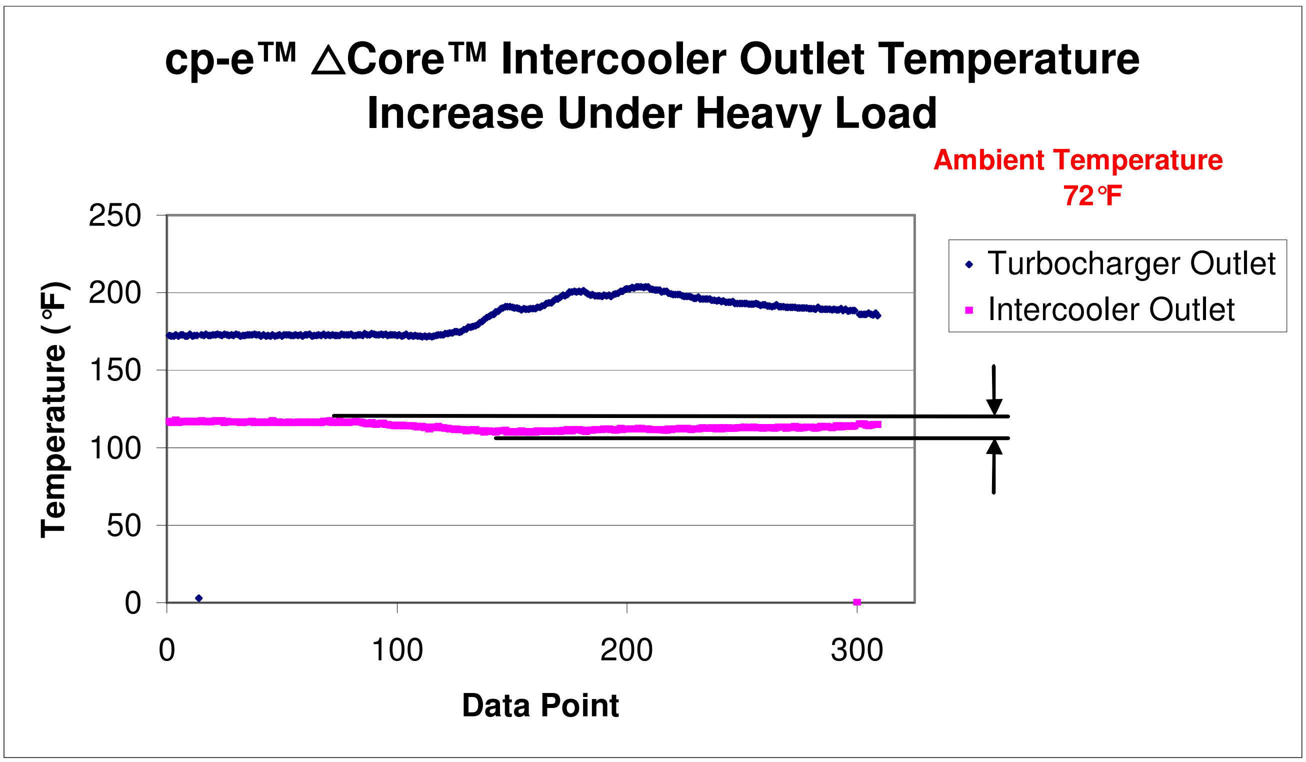
Section A:
Section A illustrates what happens to the stock intercooler under heavy heat load. The engine was loaded under wide-open throttle for about 10 seconds (the blip on the pink curve just before 0.67 minutes) and was then allowed to drive under low load for several minutes. You can see both the turbocharger outlet and the intercooler outlet temperatures were at steady state (both lines were flat) before we loaded the engine. But after the engine was loaded and the turbocharger started cooling off, the intercooler outlet temperature kept rising! But think of what's happening under the hood. The radiator fans turn on when the engine gets hot and blows hot air over the engine. The oil cooler is releasing heat to the engine bay. The transmission and differential are creating excess heat. And the hot valve cover is radiating heat up towards the intercooler. So, now the intercooler is responsible for not only cooling the air charge, but it also has to bleed off the heat generated by the engine itself.

Section B:
Section B illustrates how long the intercooler takes to cool off under low load. This test could be representative of how long an intercooler would take to cool off after a drag race. A good intercooler should cool to nearly ambient conditions in about a minute since they're made of aluminum and have fresh cool air rushing past them. This isn't the case for the stock intercooler, as it has a constricted air path and also has to expel heat conducted from the engine. You can see after about 4 minutes of driving, the outlet temperature of stock intercooler has only dropped by about 20°F under virtually no boost at all. So, once the stock intercooler gets hot, it takes a lot to cool it back off.

THERMAL LOADING:

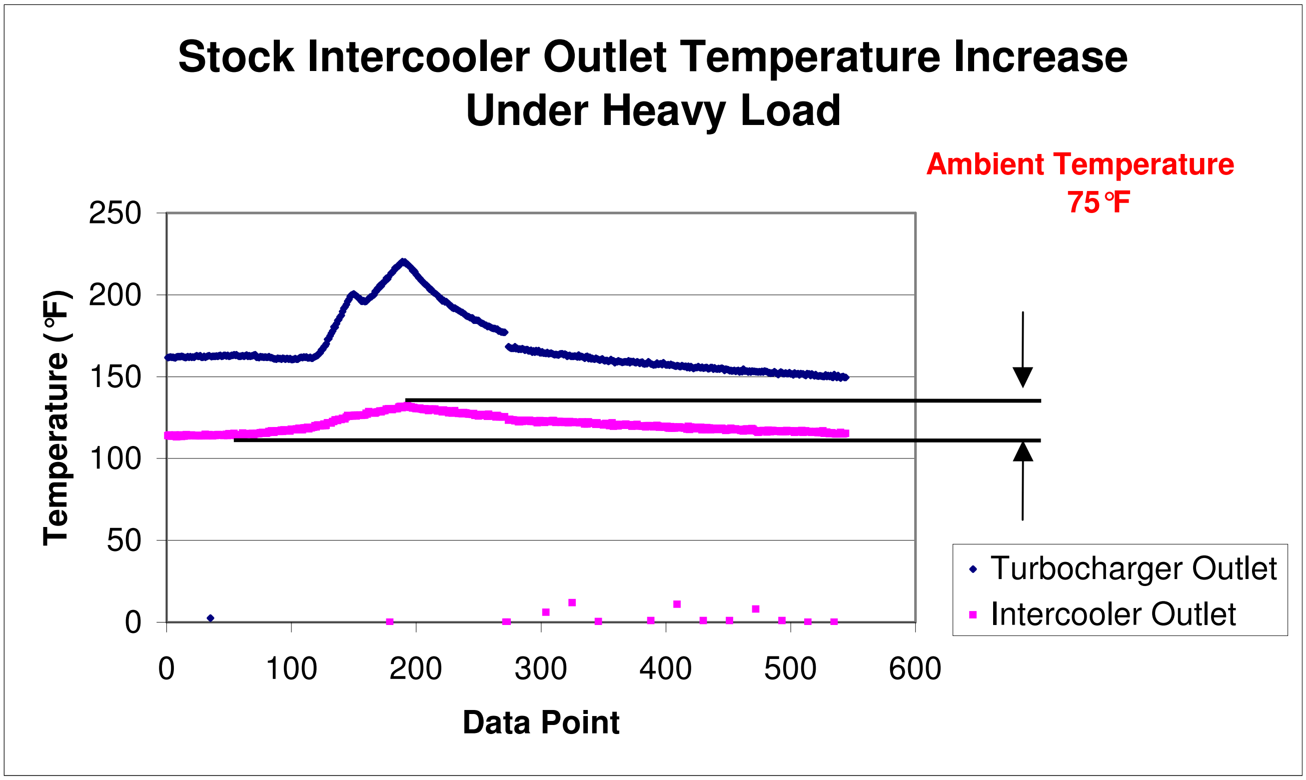
Similar to the previous test, the last empirical data shows that the stock core is in fact undersized, even in stock form. A properly sized and well-ventilated core should be able to expel any heat that the turbocharger is capable of producing. When the core is under a thermal load, like at wide open throttle, the air entering the intercooler heats up quickly. In turn, the intercooler's core temperature will increase to some degree, but the magnitude of the increase says a lot about how capable the core is at removing heat from the boosted air.

The only caveat, is that we were not able to reproduce the same turbocharger outlet temperatures as the stock core, since the turbocharger is always pushing about 3psi more boost than when we ran our cp-e™ core. So, even though the engine is seeing the same amount of boost, the turbocharger has to pump an extra 3psi of boost to account for the boost loss across the stock core. The data at least demonstrates the thermal loading capabilities, even if not a perfect comparison.



Notice the temperature increase of both the boosted air before and after the intercooler. Despite a 40°F increase in boosted air temperature, the temperature of the air exiting the cp-e™ intercooler is almost unchanged! In fact, the intercooler outlet temperature seems to *drop* once the throttle is pinned. This is probably due to the increase in air speed while the throttle was applied.

Compare this to the stock core (next page).

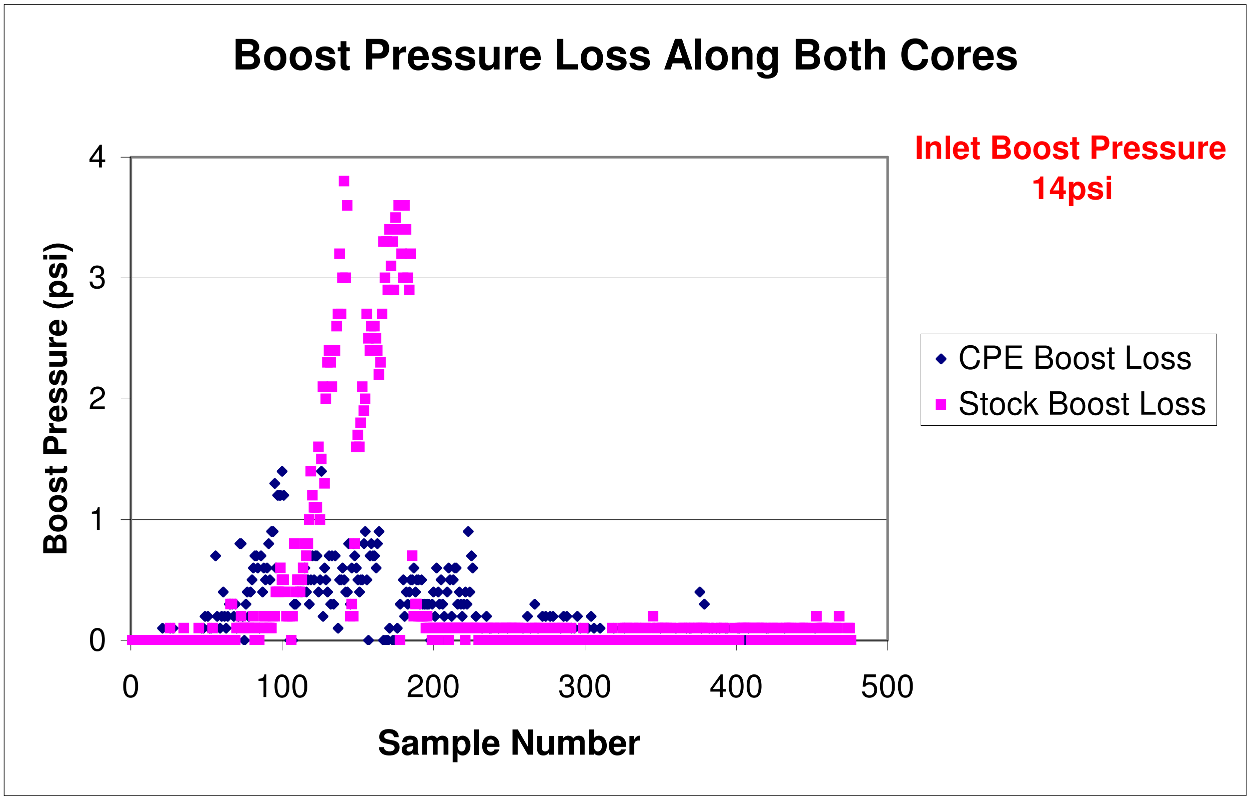


Notice how sharply the temperature of the air coming out of the intercooler increases under boost. Even though the boosted air is hotter than the cp-e™ example, the stock intercooler increases the outlet temperature by as much as 30°F! If we had been able to load the intercooler for longer than a few seconds, the problem would be even more apparent.

BOOST PRESSURE LOSS:

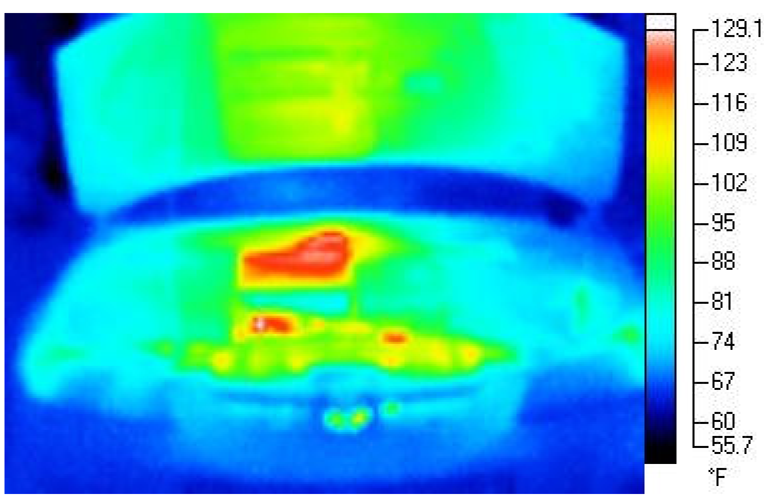
This next chart (on the following page) was constructed to show how much boost is lost when using a stock intercooler, at stock boost levels. A good intercooler should create a balance between cooling efficiency and boost pressure loss, as there is direct correlation between the two. Typically, intercoolers will lose on the order of one to two pounds of boost across the core. You can see on the graph above that the cp-e™ core never exceeds a two-pounds pressure loss, whereas the stock core is nearing a 4-pound loss. That means that the turbocharger must produce nearly four extra pounds of compressed air that the engine will never use. All the extra pumping; turns into wasted heat which the intercooler now has to expel.

This boost loss was acceptable from the factory because the turbocharger was still well within its operating range, and the air-charge was still cooled well despite the core's small size. However, if the end-user wishes to up the boost pressure, they will be disappointed to find that boost loss will only increase as the boost pressure increases.

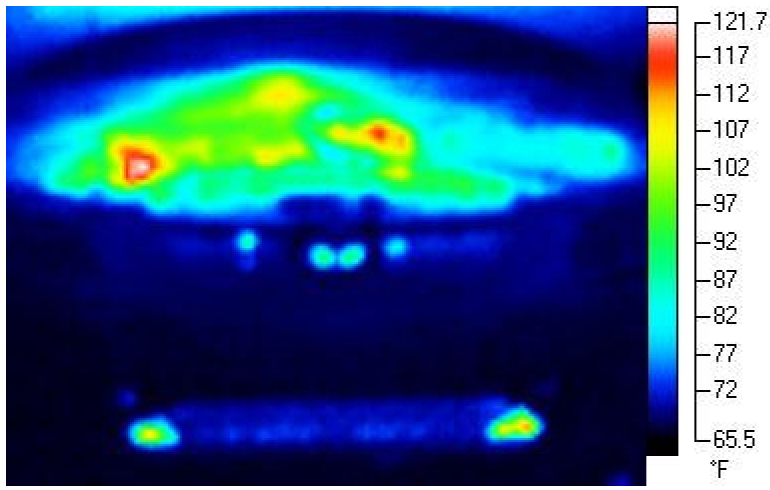


THERMAL IMAGING:

The final test we conducted was the most straightforward. cp-e™ wanted to illustrate what happens to the stock intercooler when the car is simply at idle. So, the SPEED6's hood was propped open, the car was started, and after it warmed up the thermal imager was used to record the temperature of the entire engine bay. Now, since the turbocharger is not producing any boost, any heat the intercooler receives must be a product of conduction or convection from under-hood components. You can clearly see the red and white shades of the top mount intercooler, which represent a temperature of about 120°F.



Since the cp-e™ intercooler is in front of the car, it will receive very little heat transfer. This is ideal as the intercooler is now only responsible for cooling the intake air, as opposed to waste heat from the engine. You can see the blue rectangle behind the bumper, which indicates a temperature of about 75°F.



SUMMARY:

In summation, our project has been a success. We set out to design a core that not only decimates the stock core, but would also be ideal for elevated power levels as well. The end result is a core that has a higher thermal efficiency than stock, has *no* heat soak issues, has a higher thermal capacity, and cuts the boost pressure loss in half! Combine this with zero welding, cutting, or fabrication required to install our front mount kit, and I think it's safe to say that Custom Performance Engineering has developed a serious intercooler from serious engineering.