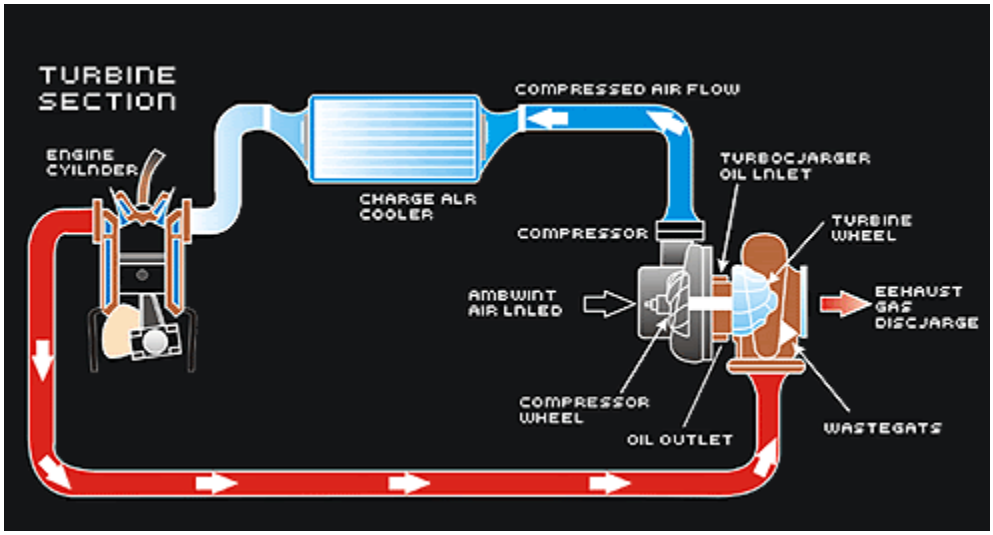
An intercooler's “magic” centers on air density. During compression, charge air is heated and with this heat comes a decrease in air density. Density can be viewed as the amount of molecules in a given volume of air. Intercooling reverses the heating trend and endeavors to recapture some of that density.



The amount of density regained depends on the ambient temperature of the air (in air-to-air units), the efficiency of the compressor (max boost, wheel efficiency etc.) and the cooling capacity of the intercooler.

A properly sized turbo that operates at or near its peak efficiency will not heat the charge as much as a mismatched unit that has to overspeed to generate the desired boost. This extra effort results in a chopping of the air, which nets high outlet temperatures.Because of its charge chilling capabilities, the intercooler also ups the detonation threshold and, as a general rule, a good intercooler will allow you to run three to four more psi without experiencing any detonation.

Tube-Fin Intercoolers

Let’s look at the tube-fin designs. These include the higher end companies of GReddy, HKS, and PWR. The lower end ones , which require a lot of surface area in order to cool, are the CX Racing, Johnny Race car, Godspeed, etc.

Typical tube-and-fin units utilize extruded tubes with fins pressed into place. In order to achieve strength, a thick, extruded tube must be used.

The picture below shows a fin comparison with the popular low-pressure drop, high-speed plain square fin used in CX Racing, (right) and an offset fin design used in GReddy (left) . The offset fin will allow the air to travel slower through the core (more pressure drop) but the air will have more time in the core for heat exchange. Apexi’s Delta Design also uses an off-set design that works extremely well.

The tube-and-fin core is held together and its seal is created at the joints at the end of the plates, which is usually .125 inches thick. The width of the tubes is less than the width of the side plate. Space is lost where the joints for sealing are used. So a 3.5-inch core will have tubes only 2.87 inches wide. Tube and fin has a larger leakage rate compared to bar-and-plate cores. Furthermore, tube-and-fin cores are more susceptible to road damage from rocks and debris than bar-and-plate cores; big trouble in front-mount applications. The oval tubes are extruded from thin-wall material and any sort of extreme pressure can cause these tubes to 'balloon.' But that is extremely rare, and only if the quality is ridiculously poor.

But they are very inexpensive to make, and given the right amount of surface area, can do a great job of cooling. But they have to be pretty tall in order to do it correctly. The smaller ones under 7" in height really only can do about 350whp, then its about done. Even the taller ebay ones have to be big to work properly.... but they *can* work properly provided it was constructed without leaks.

Bar & Plate Intercoolers

Ok.. Bar & plates.. Everyone's favorite. Many companies started doing Bar & plate intercoolers after Spearco and Garrett (and their vendors) rocked the house with their designs. They started improving their designs even more as of 2008-2011, but in the meantime, companies like Precision (who used to use Spearco), Mishimoto, Treadstone, and some private labels.
On the ambient side, where oncoming air streams through the unit, fin design is equally important. Fin density here also impacts cooling performance but there is often the vehicle's cooling system to consider.

This is a louvered fin system from a Garrett. The first versions for years had two rows of these fins in between the plates of the intercooler. Recently, they've been changed to where it has 3 rows of these fins sandwiched in.

Side Split Fin - Used on Some Bar & Plate Intercoolers

A *Plain* Square find design from Mishimoto, Treadstone, & Precision. ETS uses this design, but uses *3* rows instead of two like the other companies

According to Wang, Spearco pioneered the bar-and-plate core design. True, the bar-and-plate design is a bit heavier than tube and fin, but this is actually advantageous. A bar-and-plate core can take the damage of front-mount life and endure high boost without flinching. Sealing is superior in bar-and-plate units because the bars and brazing sheets run the length of the unit, providing a 100-percent seal between the ambient and charge sides. A key advantage of bar and plate is its extraordinary variety of fin designs on both sides of the cooler. Further, the height of the passages can be changed by using taller bars and fins, which dramatically expands the possibilities for the intercooler designer. A 3.5-inch thick core gets a 3.5-inch row of fins, not the 2.87 inches found in tube-and-fin designs.
Here's the difference.

Also, a tube-and-fin design has a lot of room between rows where a bar-and-plate unit can get more rows into a given area with more area per passage which means more cfm and a more efficient unit. As far as big boost goes, the ability of a bar-and-plate core to handle high boost is determined by the thickness of the braze sheets, fins, side bars and top plates. For Tube and fin, its much more about surface area that determines Horsepower capability.

The thickness (and the type of fins used) dictates how quickly the charge air will move across the unit while the surface area affects how quickly ambient air will flow across the cooler. The curveball here is fin density. The number of fins per inch will dramatically impact the cooling characteristics of the unit.

Mr. Wang states that Fin combination is very crucial when designing an effective core with a very low pressure drop, and that although a dense fin design offers superb heat transfer, this design also creates high ***pressure drop***. ***Pressure Drop*** is a phenomena in which the amount of boost lost by the system as it pumps the charge air through the intercooler. The type of fin-plain, offset, louvered or bump-each has its own unique heat transfer characteristics.

So How Do You Pick which one works for you?

When choosing any intercooler, the key is that a balance is met where the effectiveness is attained and a low-pressure drop is achieved.

For example, a plain fin design offers an exceptional low pressure drop but does not provide great heat transfer compared to a louvered fin or an offset fin. The air moves quickly over/through the plain fin (low pressure drop), but is so fast it may not be in the core long enough to maximize heat transfer. Consequently, air moving through a louvered or offset fin takes longer to move through the core (more pressure drop), but it also has more time to transfer heat.

Surface Area vs. Intercooler Thickness

So now that you have the right *type* of intercooler figured out, the question one asks themselves without snickering thinking about an ENZYTE commercial, which is better? To be thicker? or have a larger height? Think of *this* rule of thumb

"Bigger is better. More surface area means more cooling potential".

However,a larger surface area is favored over a thicker core. A larger surface area provides more cooling face for the ambient air where a thicker core might be less effective.

As the core gets thicker, the ambient air traveling through the core is heated by transfer and the farther through the core it travels the hotter it gets. By the time the ambient is at the back side of the unit, it's lost a good percentage of its cooling capacity. Beyond that, thick cores cause an ambient pressure drop, which means less air will make its way to the radiator causing overheating issues Wang agrees with this concept. He states that when it comes to area, achieving the maximum height is more beneficial than widening the unit.

The main reason for this is pressure drop is greater when the charge air has to travel through longer passage compared to a shorter passage. It should be noted that pressure drop through a longer-passage core can be compensated for, to a certain extent, via fin design.
With bar and plate being so superior, one has to wonder why even bother with Tube/Fin setups. Its very simple; It's all about cost. The tube-and-fin core is much cheaper to produce and is often used in OE applications, which inherently run lower power levels. Some OEMs get it wrong and get use an intercooler largely prone to heat soaking.

So remember, intercoolers do a lot more than look good behind a custom bumper cover. Their atmospheric magic is the result of technical factors such as area, thickness, fin design and fin density. Controlling the flow compromises and cooling advantages of these factors will determine the ultimate driveability of your turbocharged beauty.