Words: Stewart Sanderson

CHILL OUT

Stu gives us the lowdown on intake air cooling for turbo-charged cars.

Most of you will have at least heard the words intercooler or chargecooler, even if you don't know what they are or what they do. So, I thought it would be nice to cover them in some depth this month to help you understand one of the most basic requirements of successfully turbo or supercharging.

Air is such a simple thing, none of us can survive without it and, just like humans, an engine won't run without it either. Is it as simple as that; is air just air? As always, no it's not just air at all, it's actually far more complex than that. Apart from being a number of different chemicals, it is also very susceptible to changes in temperature, and that's where it complicates our life when looking at engines...

When a normally aspirated (not force fed air) engine breathes in its air, it does so via a series of pipes and manifolds, but ultimately its air supply comes through an air filter of some form inside an air box, which is normally fed with outside air. There is nothing on the air's journey into the cylinders that will really heat it up very much at all, so, in this country at least, chances are it will be pretty bloody cold when it reaches your combustion chamber, especially when you consider just how fast the air is moving inside those pipes. It doesn't stay around very long to induce much of the latent heat found inside these components. Forced induction however is a different scenario altogether...

STEWART SANDERSON

Having worked as a tuner for 17 years, Stewart 'Stu' Sanderson is one of the most-respected names in the business.

A Level 5-trained fuel-injection technician, in the past Stu has worked for a Ford Rallye Sport dealer, a well-known fuel-injection specialist and various tuning companies.

Then seven years ago he joined forces with Kenny Walker and opened up Motorsport Developments near Blackpool (01253 508400, **www.remapping.co.uk**), specialising in engine management live remapping, as well as developing a range of Evolution chips which are now sold all over the world.

He was also jointly responsible with Webmaster, Petrucci for **www.passionford.com**. Started in 2003, it's grown rapidly from a few friends contributing, to one of the biggest Ford communities on the web.

Stu's enviable knowledge of the workings of modern-day Ford performance engines means that every month he's just the man to explain how and why things work, and most importantly how they can be improved.

Fitting a front-mount cooler is not that hard. Well, if Dan and Neil can do it...

TURBOCHARGED AND SUPERCHARGED AIR

When we force air into the engine with a supercharger or a turbocharger, we heat it up quite dramatically by sending it through a compressor. This device as its name suggests, takes in air, compresses it and sends it back out at higher pressure. It's the fact this air is compressed that allows us to make more power as we can force more air into any given space instead of relying on it being sucked in as per normally aspirated applications, this means we can have 4 litres of air in a 2-litre space for example, this is why a 2-litre turbocharged engine will often produce power outputs of engines twice or more its size.

Unfortunately, compressing the air doesn't only do good things for us, it has many negatives. One of the main ones is that it introduces a large amount of heat into the air that we are sending into our engine. This heat is one of the biggest things we struggle with when force-inducting an engine, as many of the gains we get from the extra air are lost due to the heat itself.

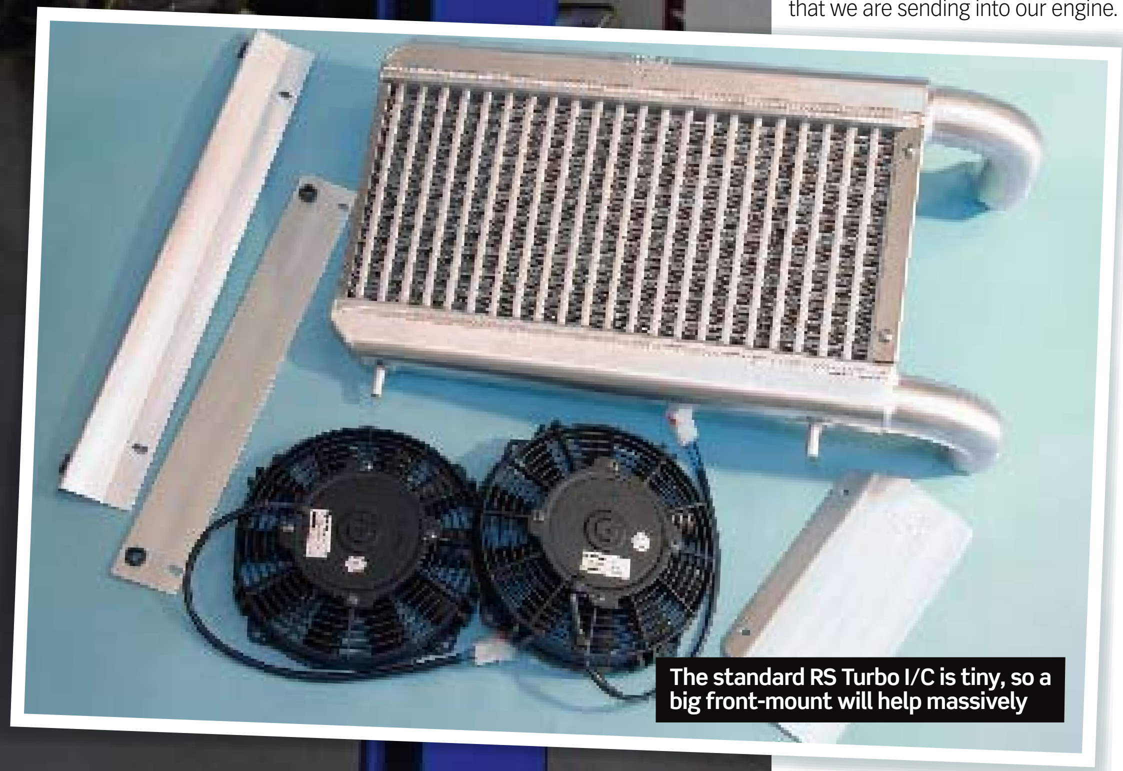
AIR TEMPERATURE

Warm air is less dense than cool air; this means that it weighs less by volume. A good way to visualize a volume of air is to imagine a 1m square box full of nothing but air. The colder the air is the more the air in that box will weigh and importantly, the more actual oxygen will be present in it.

It is important to know that an engine's power capability is determined largely by the mass of oxygen present in the air we feed it and not the overall volume of air itself. So, if the engine is being fed warm, high pressure air, the maximum power possible is significantly lower than if it is inhaling cold, high pressure air and this is due directly to the amount of oxygen present in the cylinders.

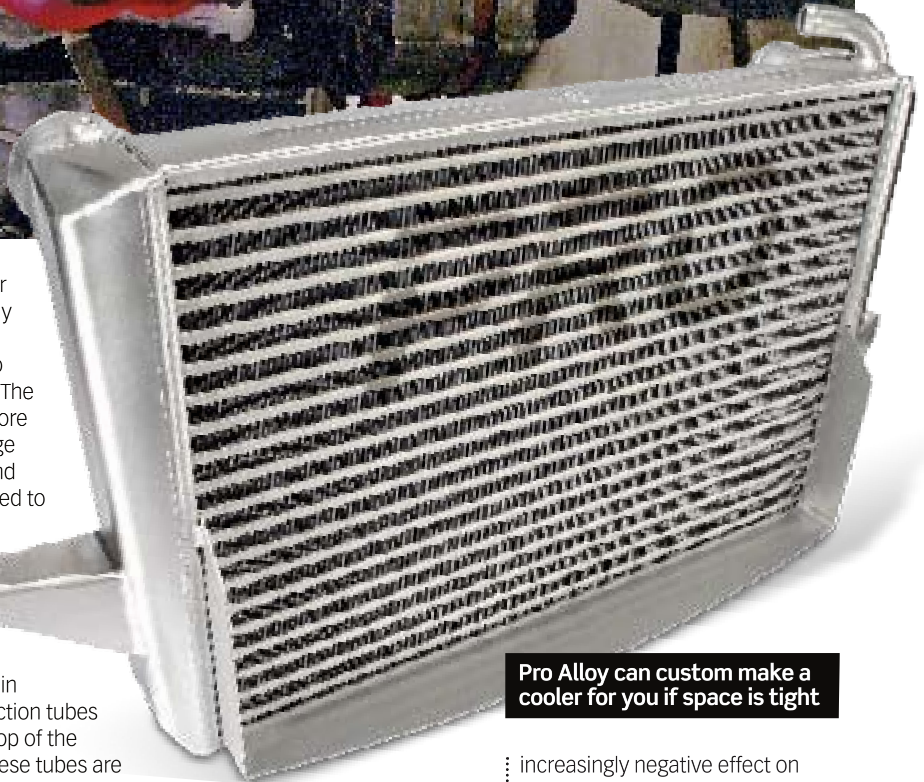
The second problem with an engine breathing warm air is that the likelihood of detonation is increased. Detonation is a very unstable and uncontrolled burning of the fuel mixture that can destroy a very expensive engine in only a few seconds. Damage to the pistons, piston rings and cylinder head and walls will occur very quickly and without any real noticeable or easily audible warnings.

So, if the temperature of the air can be reduced after it exits the turbo or supercharger then the engine will have the potential to develop a higher and safer power output. We have to be prepared to try and cool the air down before it gets to our combustion chamber if we wish to force our engine with air from a turbo or supercharger.



The standard RS Turbo I/C is tiny, so a big front-mount will help massively

Compressing air with a turbo or supercharger makes it get bloody hot



Pro Alloy can custom make a cooler for you if space is tight

HOW HOT?

It's worth knowing just what sort of temperatures we are talking about here, and there are a lot of variables to take into consideration. If we look at a relatively standard turbocharged car running around 15psi on a turbocharger with a 70 per cent efficient compressor, you would expect to see around 110 degrees C on the output side of the compressor, if we are inducing air at around 15 degrees C into it. That is a large increase in heat, so how do we cool it down?

INTERCOOLING

The first option is to install a heat exchanger of some description. The most common and easiest to fit is an air-to-air intercooler, which is technically simple, very rugged and reliable. An air/air intercooler is normally constructed out of three main parts: two end caps and a core. The end caps make the core airtight and allow large robust connectors and hangars to be mounted to the core.

The way an intercooler works is simple. The induction air passes through thin rectangular cross-section tubes that are stacked on top of the other. Often inside these tubes are fins that are designed to create turbulence in order to improve the heat exchange. Between the tubes on the outside are more fins to maximize the cooling potential from the outside air. These fins are normally formed in a zig zag shape.

Air/air intercoolers are almost exclusively constructed from aluminium. The induction air flows through the many aluminium tubes and is exposed to a very large surface area of conductive aluminium that absorbs and transfers the heat through the metal, where it is dissipated by the outside air being driven through the core by the forward motion of the car.

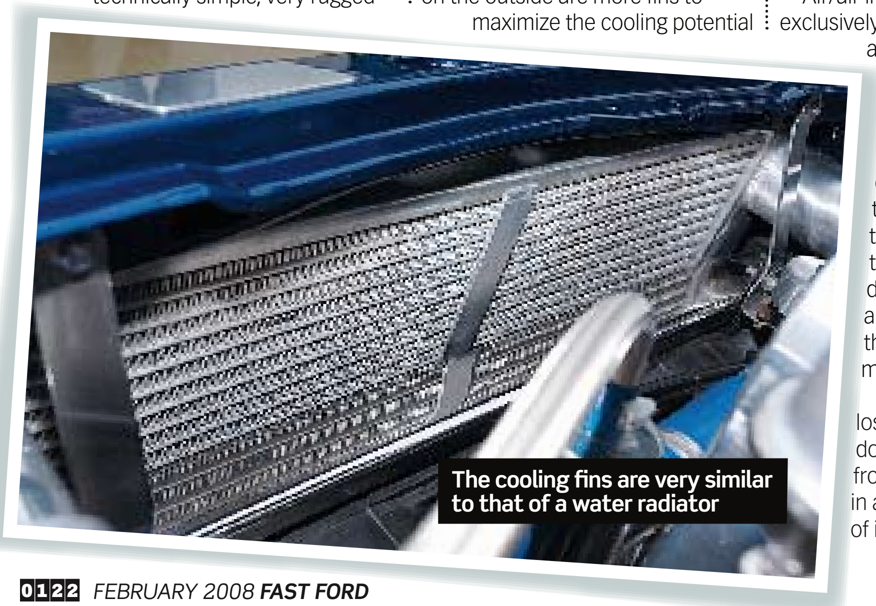
The heat is ultimately lost to the atmosphere, no doubt we will be hearing from the green party soon in a bid to rid the world of intercoolers due to our increasingly negative effect on global warming…

There does need to be a way of connecting these cores to the intake and outlet pipes on our engine, and a way to bolt the core to the car, so the end tanks normally accomplish these missions for us. They also perform the important role of determining whether a core is single or double pass, so some cores have the inlet and outlet tanks at one end separated by a divider and at the other end the air does a U-turn and heads back to the same end it came in on. Most cores are single-pass, with the inlet at one end of the core and the outlet at the other.

There are only really two specifications available for an intercooler, those being the pressure drop at a rated airflow and the cooling effect available, normally expressed as a temperature drop at a given intake temperature and outside air speed. However, in my experience most intercooler manufacturers have no data available on either of these factors! The fact is bigger will be better as long as it can be sited correctly within the airstream and it doesn't significantly affect the engine's cooling by blocking the air stream to other heat exchangers such as coolant radiators and oil coolers.

Many factory-fitted intercoolers are incredibly undersized. Air/air cores smaller than this magazine can be found in most turbo cars with under 200bhp. Cars so equipped can be held at peak power for only a very short time in warm ambient before the increasing inlet air temperature causes the ECU to retard timing or decrease boost.

A car fitted with this type of tiny factory intercooler is almost impossible to dyno test repeatedly. Intake air temps rise so fast on most dynos, due to their tiny fans, that rarely can more than one or two consecutive runs be made before the intake air temp is so high that the engine detonates, or the ECU starts to take control and drops boost or ignition. These cars gain greatly from bigger intercoolers, mainly in the ability to maintain power in a more consistent manner, but they do tend to show more power on the rollers, for the reasons mentioned above.



The cooling fins are very similar to that of a water radiator

If space is tight then a chargecooler will be what you need

Chargecoolers have their own radiator for cooling the water

CHARGECOOLERS

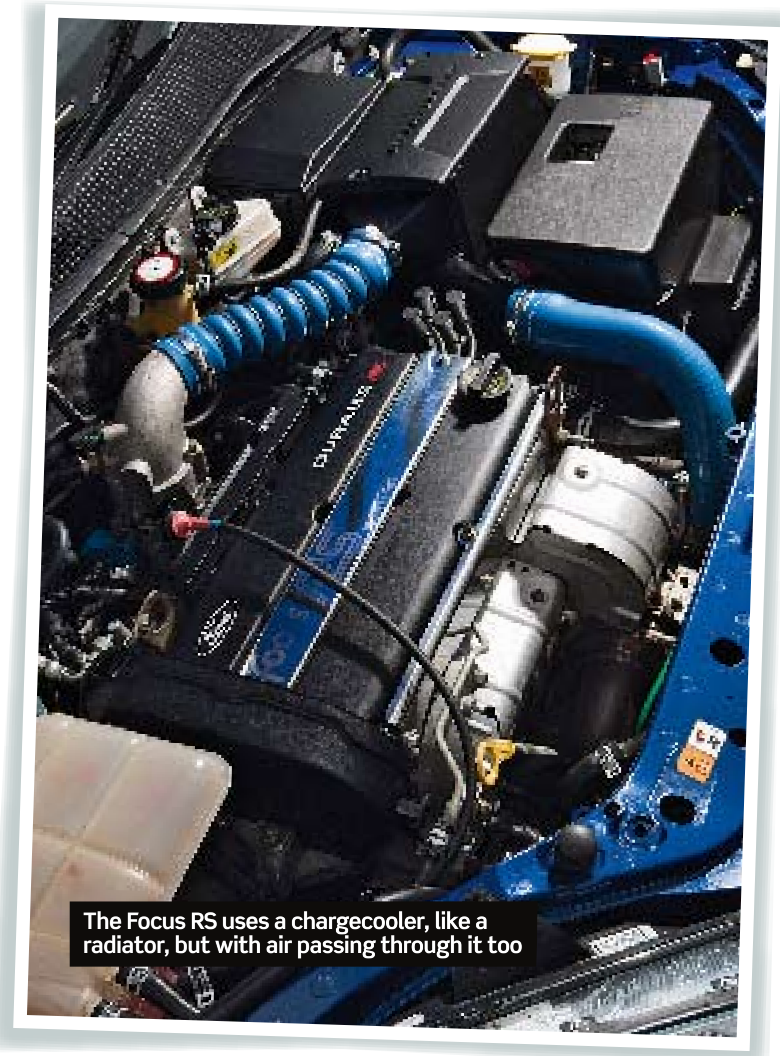
Chargecoolers essentially work the same way as the intercooler, in that the air flows through a core, but the difference is this core is cooled by water instead of air. Water/air intercooling is used less frequently than the air/air approach but it does have several benefits, especially in the tighter engine bays. This may go some way to explaining why Ford used it in the Focus RS, even though some marketing idiots labelled it as an intercooler!

A water/air intercooler uses a compact heat exchanger located under the bonnet and normally placed just before the throttle body. The heat is transferred to water which is then pumped through a dedicated radiator mounted at the front of the car in the airstream. This radiator is cooled by the airflow that is generated by the car's forward movement, just like the intercooler was. A water/air intercooler system consists of three main components: the heat exchanger itself, the radiator and the pump.

Technically, a water/air intercooler has some distinct cooling advantages on road cars. Water has a much higher specific heat value than air. The specific heat value is an indicator of how much energy a substance or material can absorb for each degree of temperature it rises by. A substance good at absorbing energy has a high specific heat value, while one that gets hot quickly has a low specific heat. An item or substance with a high specific heat value can obviously absorb lots of energy, and this is good for cooling down air.

The cooling air we use in an intercooler has a specific heat value of 1.01 whilst water weighs in at 4.18 so for each increase in temperature of one degree, the same amount of water can absorb over four times more energy than the air can. It's also worth noting another positive by-product of this is the fact we can get the same job done heat exchange-wise but will need vastly less radiator area to get it done. Great news in confined engine bays where we can't fit a massive front-mounted intercooler.

The high specific heat value of water has another real advantage due to its heat sinking affect. An air/water heat exchanger designed so that it has a reasonable volume of water within it can absorb a great deal of heat during a boost spike. Even before the water pump has a chance to transfer in cool water, the heat exchanger has absorbed considerable heat from the intake airstream. It's this characteristic that makes a water/air intercooling system as efficient in normal urban driving with the pump stopped as it is with it running!



The Focus RS uses a chargecooler, like a radiator, but with air passing through it too


Chargecoolers are just as efficient as intercoolers, but can suffer heat soak when the engine is shut down

The water in the heat exchanger absorbs the heat from the boosted air, feeding it back into the airstream once the car is off boost and the intake air is cooler. I'm not suggesting that you don't worry about fitting a water pump, but it is a reminder that in normal driving conditions the chargecooler works in a quite different way to how it needs to perform during sustained full throttle. However, the downside of this is once the water in the system has got hot, such as when you have been driving for a while and then parked up, it takes some time for the water to cool down again once you've driven off and applied some cooling air to the core's radiator.

NATURAL SELECTION

Both air/air and water/air systems have their own advantages and disadvantages.

The intercooler (air/air) systems are generally lighter than water/air systems, especially once you have filled them with water. An air/air system is less complex by far and if something does go wrong such as developing a leak in the core, you will normally notice it quite quickly as you will lose boost, and air flow meter-equipped cars may not even start and run properly. If a water/air system sprung a water leak or the pump ceases to work it will not be immediately obvious.

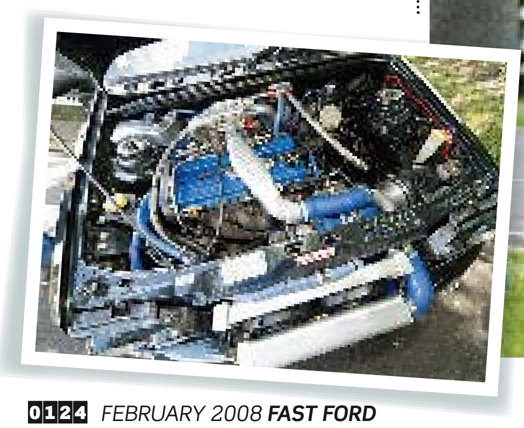
An air/air intercooler uses much longer intake ducting and it can be difficult to package a bulky air/air core at the front of the car while getting all the ducting in place and fitting nicely. If selecting on price alone, you would choose air/air.

A chargecooler is suitable where the engine bay is tight. Getting a couple of flexible water hoses to a front radiator is easy and the heat exchanger core can be made quite compact. A water/air system is suitable for a road car, with the thermal mass of the water meaning that temperature spikes are absorbed with ease. However, if driven hard and then parked, the water within the system will normally become quite warm through underbonnet heat soak. This results in high intake air temperatures after the engine is re-started as the hot water takes some time to cool down. These systems are also quite expensive compared to air/air.

So, there you have it, hopefully now you know why the air gets hot, and what we hope to achieve by lowering the temperatures of the air, as well as what options are available to do so. See you next month.

NEXT MONTH

The differences between a normally-aspirated engine and a turbocharged one. What you need to do to convert one to the other.



Getting good air flow to your 'cooler is vital to keep the temps low