THE EXPERT
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, Stu has worked for a Ford Rallye Sport dealer, a well-known fuel-injection specialist and various tuning companies.

Eight 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 is the creator and administrator of **www.passionford.com**, which he started in 2003. It has 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 importantly how they can be improved.

TECH

ENGINE COOLING

PART ONE

STU STARTS HIS SERIES ON HOW TO CONTROL ENGINE TEMPERATURES WITH A LOOK AT THE ROLE OF WATER.

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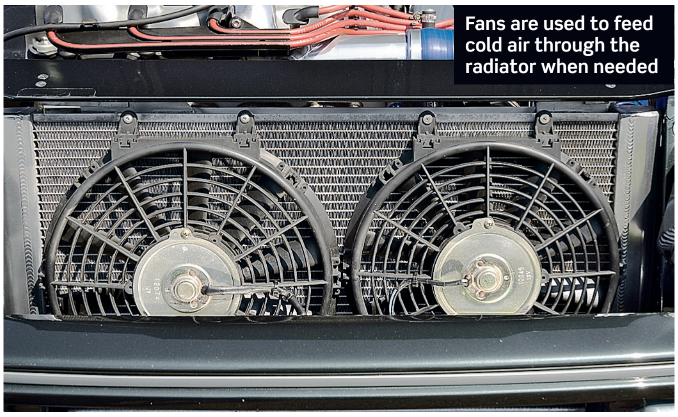
It occurred to me that if I asked 100 Ford owners what fluid cools their engines, I expect around 90percent would reply with water. If I ask the same 100 people what water temperature is ideal for an engine, I think just 20percent will know that 80 to 90 degrees Celsius is an averagely accepted ideal temperature. I also think that very few would know what the maximum allowed temperature is for their engine.

Most Ford owners would be surprised to know that their engines have two separate liquid coolants in them and that the most important of the two is the fluid they probably didn't even know was a coolant at all – the engine oil! So for the next few months we'll be looking at engine cooling, starting with water.

Most of you will know that your engines run hot, and you've no doubt burnt a finger or two over the years on hot engine parts. How much thought have you given to how that heat is generated, how it's harnessed and controlled or indeed just how hot is too hot?


Fans are used to feed cold air through the radiator when needed


Insufficient cooling systems can cause a lot of mess

WHERE HEAT COMES FROM

The internal combustion engine converts fuel into rotary energy at the crankshaft via heat and, as a rule, it is only around one third efficient. This means that the fuel is converted to heat and approximately one third of that heat is converted to energy at the crankshaft, another third goes safely out of the exhaust and the final third is lost into the water jacket of the engine. It is this final third that needs to be dealt with by the cooling systems.

IF WE DON'T REGULATE THE ENGINE'S TEMPERATURE IT WILL ULTIMATELY OVERHEAT.

The combustion process generates a large proportion of the heat, but there is also a lot of heat generated by friction of rotating components such as the crankshaft, connecting rods, camshafts, and linear operating components such as valves, followers and pistons. The heat generated by these moving items is kept in check by the engine's lubricating oil. The oil transfers the heat away from the heat source. These heat sources are items such as the crankshaft journals, camshaft bearings and lobe to follower contact points. Wherever there is mechanical contact, there will be heat, and this heat needs to be collected by the oil and moved to the water jacket or the sump where it can be dissipated into the airstream one way or another.

Have you ever wondered why items such as sumps, gearboxes and differentials often have cooling fins cast into their cases? Well now you know. We are going to look at oil and its cooling in much more depth next month, so for now let's continue with the water cooling system of your engine.

WHY WE NEED COOLING

If we didn't take control of the heat generated within an engine, it would soon destroy itself as the excess heat would lead to metal expansion and gasket failures. Expect either a piston to seize in the bore as the fine tolerances between the two components were made smaller by heat expansion, or a gasket to blow as it can no longer deal with the coolant temperature or pressure.

WHY USE WATER?

Water is a very good conductor of heat. When it comes into contact with heat it absorbs it. This means that we can pour cold water over a hot item and it will cool it down, and in the process become hot.

There are other fluids that don't conduct heat as well, such as oil, which is only 50percent as efficient as water. Most fluids have a documented rating for their ability to transfer or absorb heat. This efficiency is known as its specific heat capacity.

Water has a very good specific heat capacity so it is universally used as engine coolant. There are better fluids, but when allied to the fact that it is extremely cheap and in plentiful supply, water is unbeatable.

HOW DO WE MOVE IT AROUND?

The coolant mixture is moved around your engine by a pump. Normally this is a mechanical belt driven pump but increasingly we are seeing electric water pumps. These have the advantage of speed control irrespective of engine speed, and they can be left running when the engine stops. This is an excellent benefit over conventional systems as it controls the build up of heat and stops hot spots forming after hard use.

WHY DO WE KEEP THE COOLANT UNDER PRESSURE?

The water in modern cooling systems is kept under pressure when hot. The reason is twofold. Pressurised water is harder to boil because the boiling point of water increases with every psi of pressure it is compressed by. Secondly, water flows around the engine a lot easier under pressure, which helps to get the water through the tiny radiator cooling channels and around the extreme reaches of the engine cylinder block and head.

The pressure is created by the actual action of the water getting hot because it is expanding as it heats. As long as the cooling system is sealed we will end up with pressure in the expansion tank. The expansion tank pressure cap maintains this pressure, and runs to around 1bar.

Radiators don't have to be mounted at the front of the car, just as long as they get enough airflow

HOW TO COOL THE WATER?

Water flows around your cylinder head and cylinder water jacket, all the time absorbing heat from the components and getting hotter. How do we cool it back down? This is where the radiator comes in. The radiator is always mounted somewhere in the airstream, normally at the front of the car. A radiator is a simple water-to-air heat exchanger that works the same was as an intercooler, but instead of the airflow cooling the air inside the exchanger, it is cooling water.

The radiator is normally made of aluminium or copper and contains a series of small tubes that are attached to heat sinks. The coolant flows through these tubes and is cooled by the air flowing across the heat sinks. The heat is taken from the water and transferred to the air. The more airflow we have the better the cooling action. When a car's stationary the radiator doesn't work as it needs air flowing through it in order to operate, this is why engines get hot fast when the vehicle is stood still and is why cars are fitted with cooling fans.

The cooling fan should come in at very slow vehicle speed and draw air through the radiator, essentially forcing it to operate as though the car was moving at normal speed. Radiators are simple things. The three things that really stop them working properly are:

1) Water leaks.

2) Blockages in the small pipes. Usually caused by rust.

3) The heat exchange fins perishing and starting to fall out.

Water constantly flows through the radiator and back into the engine, keeping the water in a cyclic mode of heating and cooling. If all is functioning well, the radiator will be able to remove more heat than the engine puts into the water. So what stops the water ending up too cool again? Well, the device in charge of maintaining the temperature of the coolant mixture is called a thermostat.

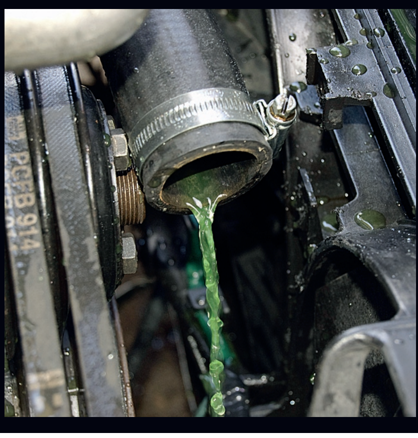
ANTI-FREEZE

Water used as coolant in all engines is mixed with anti-freeze, normally at a ratio of around 50/50. Why? For one it raises the boiling point of the water. This is very important as if the water boils air pockets are introduced into the system. This can be deadly for an engine as it disrupts water flow and causes localised overheating.

The last thing you want in your engine is the water freezing. When water freezes it expands and can crack whatever it happens to be in, such as your head, block, radiator, pipes, etc.

When we mix water with anti-freeze at around 1:1 we will ensure that the coolant will remain liquid to around -40c and will not boil until in excess of 110 degrees Celsius.

The anti-freeze also works well as a lubricant for pump bearings and inhibits corrosion in steel, iron and alloy components.



CONTROLLING WATER TEMPERATURE

If we don't regulate the engine's temp it will ultimately overheat. The cylinder walls and combustion chamber areas of the head need to ideally be maintained around 90 degrees Celsius to gain maximum efficiency from the combustion process. Most engines run with a coolant temperature of around 88-90 degrees Celsius, a thermostat regulates this temperature.

It's worth mentioning that not all engine parts need to run at that temperature. For example, the inlet plenum and manifold need to stay as cool as possible as does the turbocharger's inlet compressor housing on turbocharged cars. Normally these items are in permanent contact with the incoming air. These are essentially air-cooled items anyway so are fine and don't need any cooling as such, bar intercooling.

THE THERMOSTAT

The thermostat is a valve that is controlled by temperature. When it senses that the water behind it is getting to optimum temperature (this varies from engine to engine, but for this article let's use the common 88 degrees), it opens and allows that water to leave the engine and head down to the radiator where it will be cooled, and allowed back into the engine to be heated up all over again. When it senses the water is too cold it will close. This allows an engine to get to full operating temperature as fast as possible, giving fast warm ups in the morning. The thermostat can cause three main problems if it develops a fault:

1) Slow warm up: Thermostat doesn't close properly so the coolant is always being cooled.
2) Overheating: Thermostat stuck closed so the coolant is always being heated.
3) Engine always too cold: Thermostat stuck open so the coolant is being cooled too much.

Sudden drops in engine efficiency, power and fuel economy can often be traced to the thermostat. They are cheap to replace so always bear it in mind. I personally change these every year as service items. Keep your eye on temperature gauges for signs of problems.

When the coolant gets hot and expands the whole cooling system becomes pressurised

MEASURING WATER TEMPERATURE

Most cars nowadays have a temperature gauge for the engine, although recently an annoying few models have slipped into the market without them. The temperature gauge is almost always connected to a very simple sensor, which in component form is called a thermistor. This sensor sits in the water and its electrical resistance changes by a known amount when it is heated. A gauge can be connected to it and the reading converted to temperature.

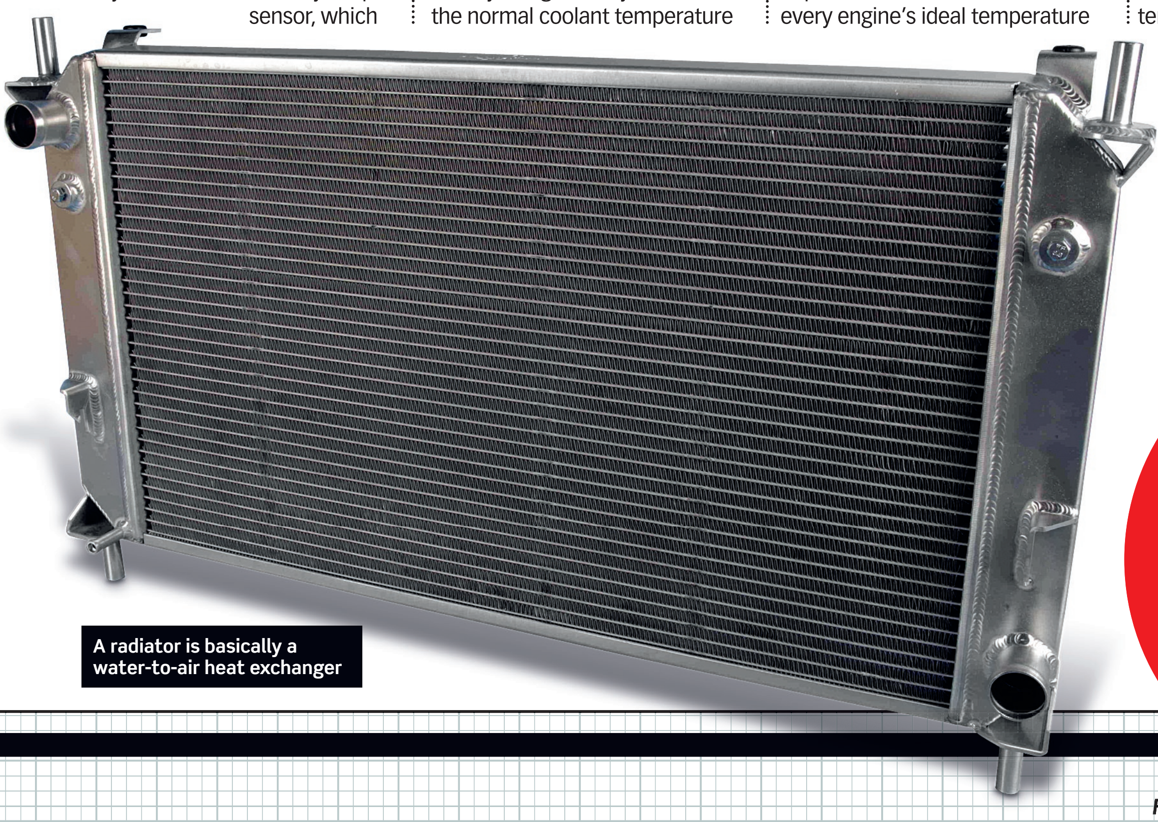
Manufacturers' gauges are usually designed so you don't see the normal coolant temperature swings associated with stop-start motoring, so be prepared to worry a bit if you fit a more sensitive aftermarket unit. It will appear to be very active compared to an aftermarket unit with no 'paranoia soothing features.'

WATER CONSTANTLY FLOWS THROUGH THE RADIATOR AND BACK INTO THE ENGINE

ACCEPTABLE WATER TEMPERATURES

There would be little point measuring water temperature if you didn't know how hot was too hot or how cool was too cool. It's impossible to be definitive here as every engine's ideal temperature differs and it's affected by so many things; materials used and intended engine use etc. You will need to research your own individual engine to be sure. It is worth noting that virtually all cooling fans come on somewhere between 92 and 96 degrees C, so it is fair to say that most engine are operating at their most efficient between 88 and 96 degrees Celsius.

Often a high-performance engine will be run a little cooler due to the massive rise in temperatures when they are used hard, but even these engines will rarely be run below the mid 80s. If they are a loss of power and fuel economy will definitely result. The colder an engine is the less efficient it runs, so running without a thermostat is a ridiculous thing to do. Take note, as I see it all the time…


A radiator is basically a water-to-air heat exchanger

NEXT MONTH
ENGINE OIL AND HOW WE CONTROL ITS TEMPERATURE.