Keeping your Mini Cool
The Workings of the Coolant System

Engine swaps or modifications are amongst the top few in the Mini owner's list of desires for their car. Little thought or consideration is given to the cooling system when either of these upgrades is carried out - largely because very few understand just what the cooling system does and how it does it, and that shortfalls in compatibility between the cooling system's capability and the power output of the engine can spell disaster for the new engine. All this is obviously exaggerated in the case of racing engines. Questions along these lines are popular -- in most cases too late to be of use, so a little explanation should go a long way …

Cooling system functions

The internal combustion engine as used in cars is not particularly efficient. Burning a fuel/air mixture produces energy, but because this method of energy produces high levels of heat, much of the energy produced must be dissipated. This is essential to prevent component failure through thermal fatigue. The components most susceptible to failure in this manner are the pistons, piston rings, cylinder walls, cylinder head, valves and associated parts; although excessive heat will eventually cause more wide spread failures. The energy/heat level is regulated by the cooling system, passing into the coolant from the combustion chamber in the head, and partially via the cylinder walls to the radiator, then to atmosphere.

The combustion chamber are must be cooled sufficiently to prevent pre-ignition and detonation, problems that are exaggerated by current low-octane, unleaded fuels, and the ever-tightening legislation on lower emissions and lean burn engines. Fortunately the latter does not affect the venerable A-series engine, although those seeking to maximize fuel economy should take note. If an inefficient or inadequate cooling system is used, further losses will be experienced. The higher the combustion chamber temperatures are, the more the ignition has to be retarded to avoid the onset of the aforementioned pre-ignition and detonation. This causes a reduction in engine output; particularly torque that is the mainstay of driving the car. Further torque losses are caused when an engine is running too hot by increased inlet temperatures, creating a less dense fuel/air mixture. Heat dissipation and temperature control are regulated by the cooling system. A thermostat is fitted to keep the temperature constant and consistent at the required level. Heat dissipation is largely by thermal conductivity. The coolant passes over the hot metal surfaces inside the cylinder head and water jacket around the cylinders where heat is transferred to it as it is at a lower temperature. The coolant then passes into and through the radiator where the heat is passed into the cooler air.

The coolant explained

Water is the most common form of coolant used in car engines. It has excellent heat transfer properties in its liquid state and does and extremely good job when properly controlled. It does have one or two shortcomings though. The worst from a cooling point of view when not controlled is its very high surface tension – the thing that allows bugs to walk around on it without sinking.

This surface tension limits its ability to ‘wet’ the metal surfaces of the water jacket, forming a sort of barrier. Because of this, hot-spots can be caused – particularly around the combustion chambers where temperatures are highest. These hot-spots form vapor bubbles by boiling the water despite the fact that the bulk of the passing water is well below boiling point. The bubbles formed on the metal surfaces then act as an insulator around this area, greatly impeding heat transfer. This in turn reduces the cooling system’s efficiency, thereby increasing the combustion chamber temperature.

The eventual result is component failure, the piston usually being the first to go, or maybe the spark plug, then the exhaust valve, inlet valve, and so on. The speed at which this can happen can be alarmingly quick, and is governed by the severity of the hot-spot and the dynamic loads on the engine (i.e. foot hard down = max load = blisteringly quick melt down if there is a hot-spot present).

Anti-freeze is widely used as an additive to water in car cooling systems, and is indeed essential where freezing temperatures are to be experienced. It also raises the boiling point slightly, as well as providing some lubrication for the water pump seals and reduces the formation of rust on the iron surfaces. The reduction of corrosion helps prevent blockages in the radiator. It does not, however, increase the cooling capability or the system. Many people are under the false impression that adding more anti-freeze will solve over-heating problems. Nothing could be farther from the truth.

No more than is absolutely necessary to provide sufficient protection in the environment in which the car is used should be added. Follow the manufacturer’s instructions to the letter. Although as standard, all road cars have a larger cooling capability than is required to allow for a fairly strong anti-freeze/water mix, bigger or more powerful (tuned) engines will soon render it inadequate.

Water, as previously mentioned, has amazing heat transfer properties, far better than almost any other liquid cooling medium within a vast majority of spheres. It is certainly superior to a mix of anti-freeze (usually glycol based) and water. In fact, water has up to two-and-a-half times greater thermal conductivity to, say, a glycol-type coolant given the same operating capacity. As the cooling system works by conductivity – from hot metal to a cooler liquid (as in the engine water jacket) then from hot liquid to cooler metal surfaces (as in the radiator), the coolant’s thermal conductivity is of ultra importance. Tests carried out by major motor manufacturers have concluded that the improvement of glycol’s thermal conductivity is of ultra importance. Tests carried out by major motor manufacturers have concluded that the improvement of glycol’s thermal conductivity is practically directly proportional to the amount of water added to it. Just to illustrate this, a 50/50 water and glycol mix has about 70% of the thermal conductivity of water on its own.

To labor the point so that you are left in no doubt about this, other factors such as the viscosity of the coolant, and the convection coefficient of the coolant in a tube (a complex relationship between the thermal conductivity, viscosity, tube diameter – as in a radiator core tube – and turbulent flow of the system) influence the effectiveness of the system. A 50/50 glycol/water mix has roughly four times the viscosity (thickness) of water alone and, as previously mentioned, about 70% of the thermal conductivity. A trial using these factors established that this mix had approximately 50% of the convection coefficient of water only. Or to put it in

English, water on its own as a coolant is capable of TWICE as much heat transfer as the 50/50 mix. Hopefully this has exploded the ‘more anti-freeze will help’ myth once and for all.

Capability improvement options

So … what can be done, and when is it needed? The last thing you need to do is install your mega-hyperpower engine with a cooling system that is a wild guess at best, to find that it is woefully inadequate, causing the early demise of your pride and joy. To given an illustration of the standard system’s capability, even the Cooper S having its radiator with increased ‘gills per inch’ would over-heat at anything but a steady 70 mph. To all intents and purposes, if you put a 1275 engine in where there used to be a 998, put an up-rated radiator in as well. The standard 998 radiator will cope with the application of a stage one kit, but going to a decent modified head and fast road cam will sorely test it if it is in any other condition than A1 perfect.

It is common practice to remove the thermostat and fit a blanking sleeve in a bid to improve cooling. If this is done, you must blank off the bypass hose, otherwise stagnant areas of water will occur causing the dreaded hot-spots. However, the danger with fitting a blanking sleeve is that the engine may not reach proper operating temperatures, and this can be every bit as bad as running a little too hot. I would strongly advise using a thermostat in ALL road cars, of at least 82 degrees to make sure the correct running temperatures are achieved. A blanking sleeve is not the answer to over-heating problems. I always run a thermostat in my race engines unless bound for foreign shores where high ambient temperatures are experienced. Many folk think they have to fit a blanking sleeve if they are blanking off the by-pass hose. Not so. Blank off the troublesome by-pass hose then fit a thermostat that has had six or eight eight-inch holes drilled around the periphery. These holes allow water to circulate before the engine is up to temperature and the thermostat opens.

Fitment of an auxiliary radiator will help if the two-core is not enough – say on a race or rally car. Use the matrix out of the heater box, and plumb this in going from the heater tap take-off, into the back fitting of the matrix, then out of the front fitting and into the bottom hose. Mount the matrix behind the grill for maximum benefit – around fifteen degrees temperature drop can be expected. If you pass the water coming out of the heater tap take-off down the front of the matrix first, you will be blowing hot air across the water going back out of the matrix and into the engine. It is important to know that not taking water out the heater tap take-off will increase the temperature that the number four cylinder runs at substantially due to reduced flow around that chamber. Some folk make the mistake of taking the water out of here and connecting it back to the bottom hose. This is putting un-cooled water straight back into the engine. If you do not want to run an auxiliary radiator or internal heater, plumb the hose from the heater take-off into the top hose. This is the least that should be done.

Further assistance

Ensure you always use the water pump with the deep impellor. These are fitted to everything as standard these days, but 850/998/1098 engines before about 1975-ish had the old shallow impellor type. The shallow impellor protrudes from the gasket face by 7.9mm (5/16”) and the deep impellor by 15.75mm (5/8”). All Metros also have the bypass hose blanked off in the casting, as do the very late Minis. The exception to the rule here is the 850, there is rarely enough material in the block to be able to run these. If fitting to an old 998/1098 block, it may be necessary to grind some of the cylinder wall away to clear the deep impellor. To help engines that will be run mainly at high rpm, use the Metro 1275 large diameter water pump pulley (4.725” diameter), as this will slow the pump speed down, reducing the onset of cavitation.

There are a couple of alternative fans available, the old two-blade type (that is usually run double up to make a four-blade), or the six-blade export type fan. I am ignoring the old metal multi-blade type, as they are not generally available and not that good. The fourblade is very noisy but very good, the six-blade much better than the standard plastic one, but a little noisier.

Apart from this, make sure your hoses are in good condition, and you have the right hose for the right engine, particularly when going from a 998 to a 1275 based engine. The top hose is very much different – the 998 looking like a boomerang, the 1275 one shaped like a question mark. Using the 998 one on a 1275 will put a kink in the hose that will cause a severe restriction. It will also be necessary to change the top radiator bracket. This is caused by the thermostat housing pointing sideways on the 998 and forwards on the 1275. The Cooper S top hose and bracket, or 1275GT versions, are the ones to use.

Author unknown