Unit 21686

Demonstrate knowledge of automotive cooling systems

Level 2
Credit 2
Version 2

I will pop up through this workbook to give you a hand with some of the words that you might need a hand with, and at other times to see if you are ok.

Make a point of stopping to read the words and / or do the tasks, it will probably help you understand.

If you find other bits of writing you don't understand let your tutor know so I can fix it for the next students.

To successfully complete this unit you will need to;

- complete this workbook
- complete the self-tests
- complete any activity sheets linked to CDX
- complete any practical workshop tasks assigned
- complete the written assessment

Tutor	Date

get your tutor to sign off each part as you complete it.

The next page has the elements and performance criteria for this unit; basically all this stuff is what you will be covering and what you will need to know before an assessment.

Modern vehicle cooling systems are AWESOME.

How can we run an engine over a variety of conditions, loads and environmental conditions and get to be reliable while maintaining a constant operating temperature that is above the boiling point of water.

This is the challenge.

To begin to understand the cooling system we need to understand how heat transfers.

Term	Definition	Example
Radiation	radiation is a process in which heat energy waves travel through a medium or space	Heat reaches us from the sun through radiation
Conduction	Conduction is a mode of transfer of energy within and between bodies of matter, due to a temperature gradient.	It we heat one end of a steel bar the heat will be conducted along the bar, so the whole bar heats up.
Convection	the transfer of heat by the circulation or movement of the heated parts of a liquid or gas.	Convection ovens use air flow over a hot object to heat another object.

Watch all of this video, it shows some animations of these methods of heat transfer. [Eureka 29 - Radiation Waves.mov - YouTube]

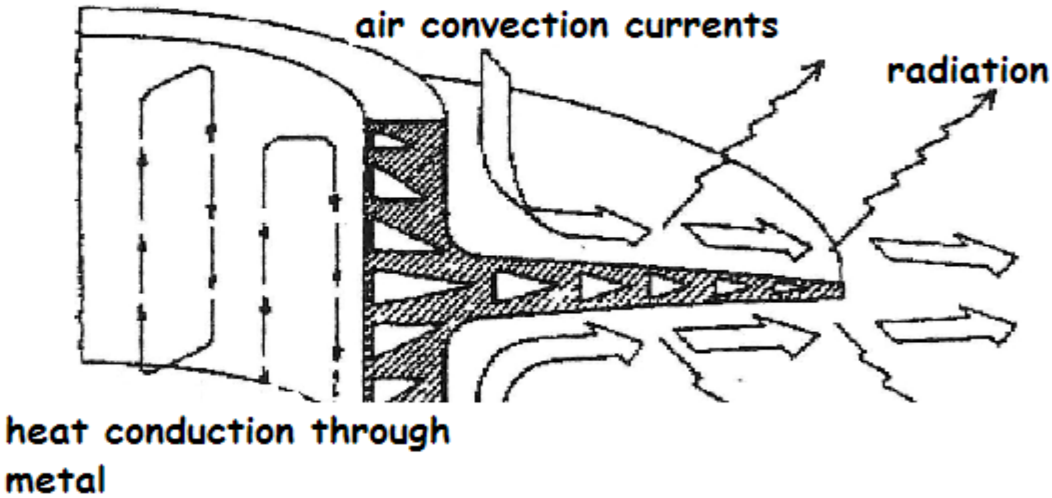
Without going on further, think of an example of each of these heat transfer methods that would relate to and automotive cooling system.

Conduction –

Convection –

Radiation –

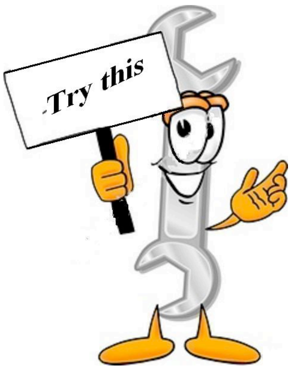
Below is an example of all three heat transfer methods acting on a cylinder fin of an engine.



Conduction occurs as the piston and burning air / fuel in the cylinder produce heat in the cylinder. This heat is conducted through the cylinder fin.

Convection occurs as air flows over the fin, in a motorbike this would happen as the bike moves through the air, or in a lawnmower engine as the fan blows air over the cylinder, as examples.

Radiation occurs as heat energy leaves the cylinder fin.



Draw over this radiator, show where/how the 3 methods of heat transfer happen here.

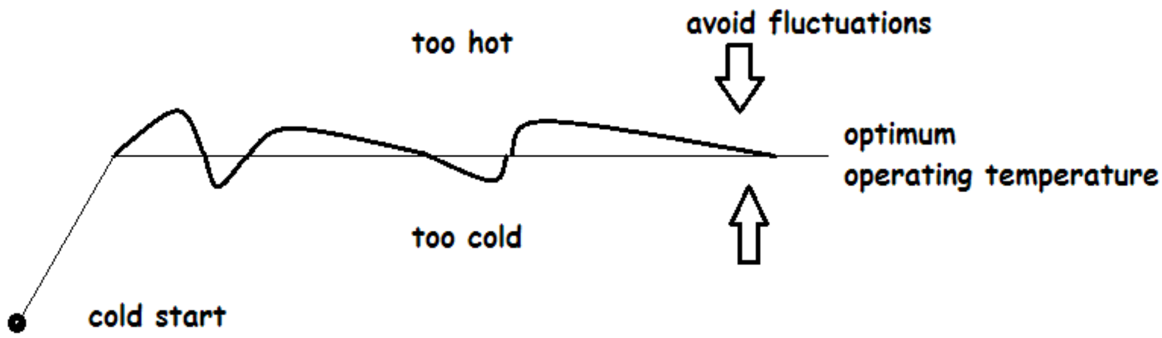
From the last couple of pages you should be starting to get your head around heat transfer and relation it to our automotive engines.

It is probably useful to see the requirements of the cooling system.
There are 3 main ones that you need to know.

1/ **To get the engine to its normal operating temperature as quickly as possible**. If the engine runs below normal operating temperature it is in-efficient meaning it doesn't perform at its maximum level, uses more fuel than it would at its normal operating temperature, parts of the engine have not expanded to their correct clearances, and the lubricants are not at their best operating temperature. We need the engine to get to its operating temperature as soon as possible, manufacturers do this by a variety of methods, more later. At this point it is interesting to note that some specialised vehicles have electric heaters in the sump to keep temperature in the engine at all times, Fire engines and ambulances are like this so they can be driven hard from start up.

2/ **Once the engine reaches its normal operating temperature it needs to be kept there**. Although this sounds easy it is in fact very difficult to do. Think about the different loads on an engine from accelerating up a long hill on a hot day to gliding down a long hill on a cold day, idling at traffic lights for a long time, being in a line of traffic with little air flow over the vehicle.

3/ **Provides a means of heating the passenger compartment.** The cooling system provides a useful medium to assist in heating the passenger compartments, usually by incorporating another small radiator connected into the cooling system and mounted inside the passenger compartment. Electric fans and ducting guide this heated air around the vehicle.



So what if the engine exceeds its temperature, it gets too hot. What happens to the engine?

- Engine parts expand past their normal specifications and begin to seize and bind together.
- Lubricating oils break down and do not reduce friction between moving parts.
- Lubrication oils overheat and fail to do their part in cooling the engine.
- The engine uses more energy (fuel) to remain operating.
- Once the temperature gets too hot the cooling systems ability to reduce the temperature an okay level is not possible.
- It costs heaps to repair engine damage.

So what if the engine remains under the required operating temperature?

- Engine parts do not get to their required operating sizes and tolerances.
- Lubricating oils operate at below their temperature so liquid friction is higher than it should be.
- The engine uses more energy (fuel) than it would at normal operating temperature.
- The passenger heating system is not very efficient.

Any prolonged high or low temperature operation of the engine will damage engine components.

Back to some more basics.

Some engines are air cooled and some are liquid cooled.

We need to try and get clear about **water cooled** engines. It is **not** a good idea to call the system **WATER** cooled, get yourself in the habit of calling it a **LIQUID** cooled system. It might sound picky but you need to get the terms right, the system no longer just contains water, there can be a number of additives in the coolant so get used to calling this a **liquid cooled system**.

Air cooled engines are just that. Engines are cooled by air passing over the engine parts either by moving the engine through the air or forcing the air over the engine with the aid of a fan system.

Advantages of air cooled engines are that they are light, have less moving parts and maintenance requirement are usually less, and usually get to their operating temperature quickly.

Disadvantages are that air cooled engines tend to be noisier, (because of the need for greater engine clearances) are more difficult to maintain an optimum temperature, are less fuel efficient.

Car manufacturers do not now produce air cooled vehicles; it's just too hard to meet emission requirements. **Ask Porsche.**

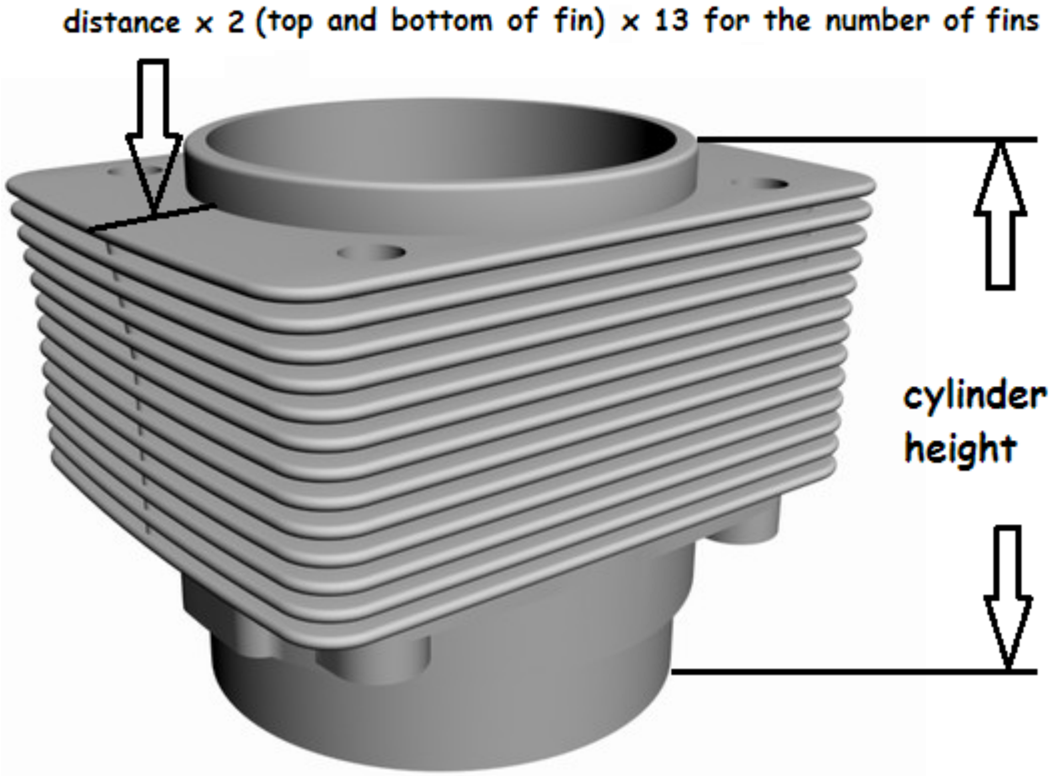
Air cooled engines now tend to be limited to motorcycles and small engines (lawnmowers, chainsaws, weed eaters, stationary engines etc.)

we need to have a closer look at air cooled engines.

Check out the fins on this cylinder.

What is their purpose?

Look at the height of the cylinder and compare the distance around the fin.



See how the overall distance is around the fins is far greater than the distance of the cylinder height and the surface area of the fins is huge compared to the surface area of the cylinder.

The purpose of the fins is to increase the surface area of the cylinder that is exposed to the air currents flowing over and around the cylinder.

You will find the cylinder head is also heavily finned for the same reason, along with other engine parts like crankcases and engine covers.

All these fins work fine provided the engine is moving through the air, like on a motorbike, but what if it stops and is idling and not moving? the air flow stops so the cooling efficiency goes out the window as well. This results in high engine temperatures and ‘hot spots’ around the engine.

Imagine this Ducati moving through the air, the fins on the cylinders, cylinder heads and sump fins are lined up to allow the air to flow over them but it the bike stops moving and is still running then air flow becomes nothing.

Remember at the start of this unit we discussed how the cooling system is required to keep the engine at as close to a constant temperature as possible so you should be able to see from this motorcycle just how difficult that is for an air cooled engine that relies on air flow only.

Even more difficult for small engines like a lawnmower, you would have to sprint around the lawns to get some sort of air flow over the engine.

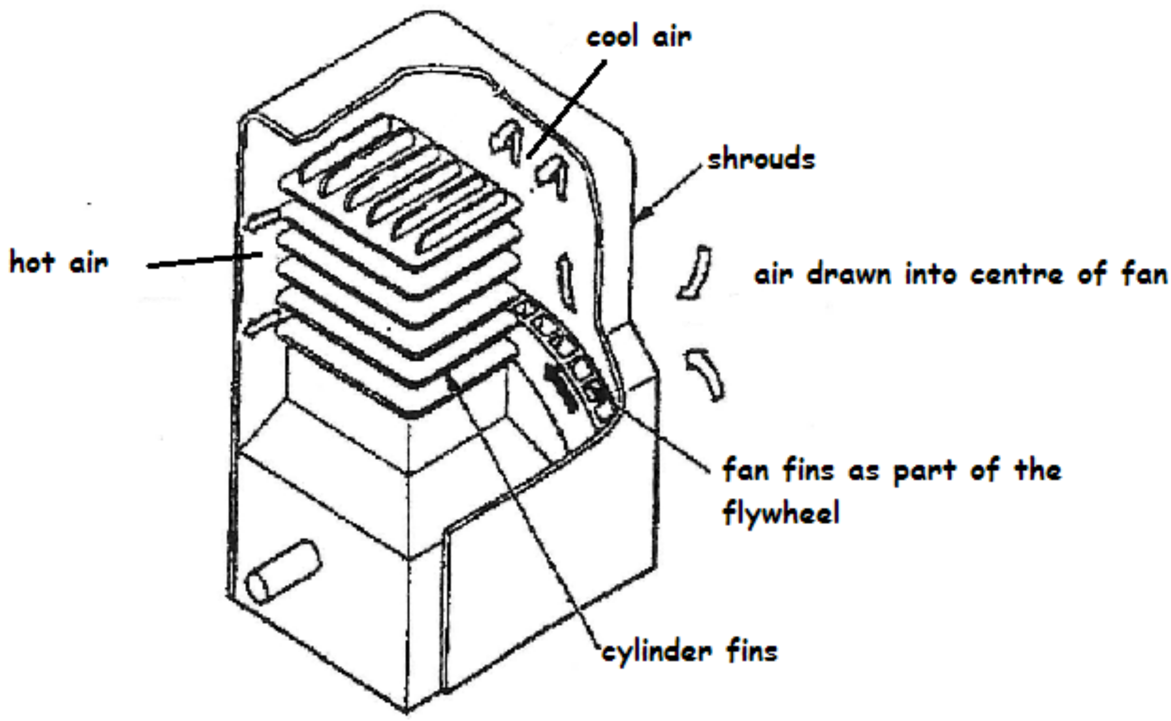
So how else can we cool the engine using air only?

Term	Definition	Example
Centrifugal	moving or directed outward from the center	The engine uses a centrifugal fan to force air over the cylinder

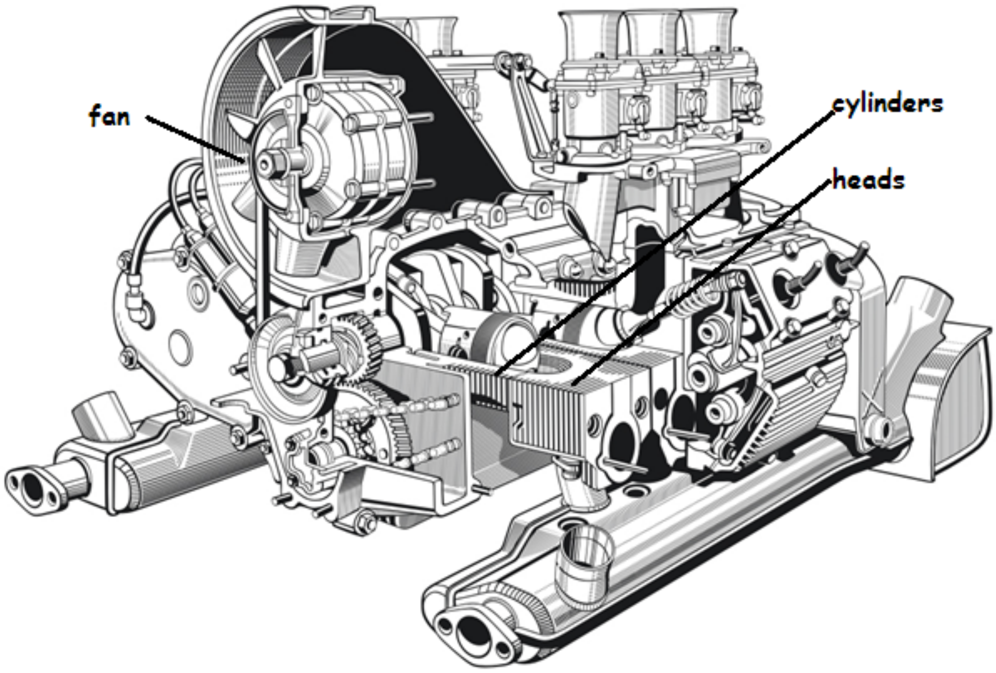
Shroud	something that covers or conceals	Engine shrouds cover engine parts and direct air to particular areas.

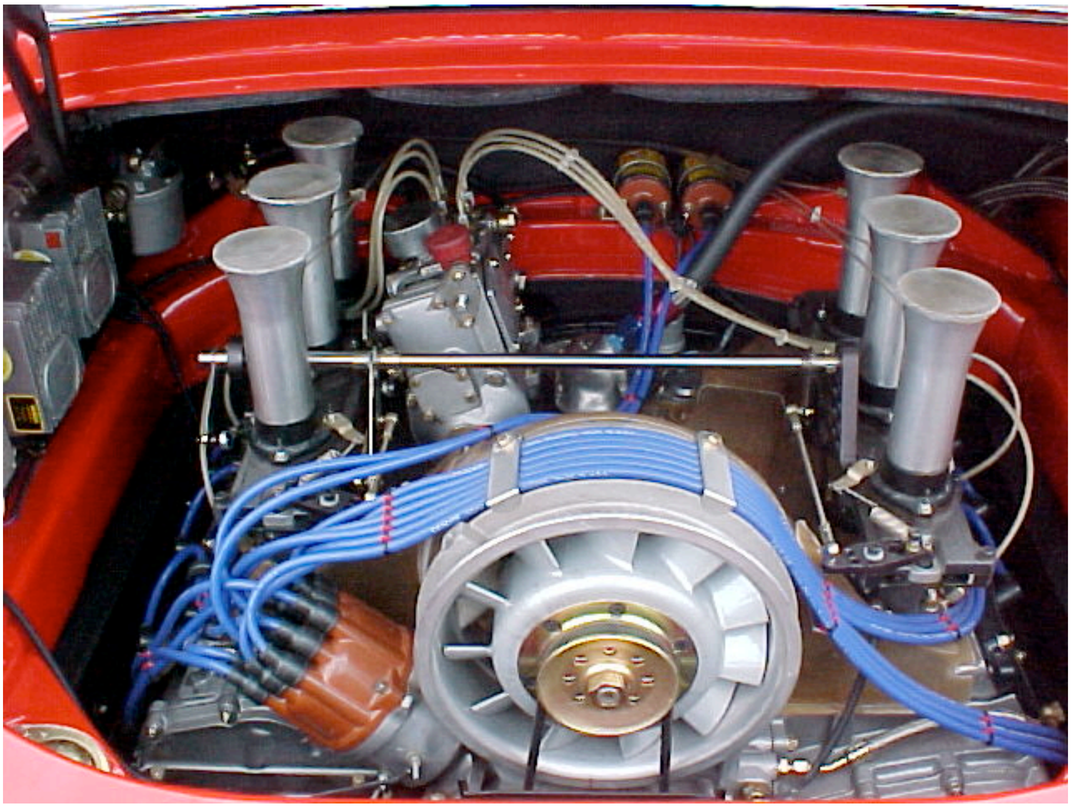
Most direct air cooled engines especially small engines in mowers, chainsaws, weed eaters, scooters and smaller motorcycles use some form of centrifugal fan to draw air into the engine, speed it up and force it through shrouds to critical engine parts. This overcomes the problem of air flow over the engine as air speed is high because of the operation of the fan.

Check out the basic picture below, cool air enters the centre of the fan which is part of the flywheel. The air is sped up and forced outwards from the flywheel. The fan shroud now directs the air across the cylinder and cylinder head and exits the engine.



Although no longer in production because of the inefficiencies of air cooled systems, manufacturers like Porsche and Volkswagen used direct cooled for many years with larger displacement engines and high performance engines. These larger displacement engines often had additional flaps that operated in the cooling shrouds to open and close to help control the engine temperatures.





How good is this!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

Watch this video right through, the guy has some good stuff.
[How engine air cooling works - YouTube]

Go into the workshop and find yourself a lawnmower, sure it's only a lawnmower but check out the cooling system.

Think about this: The shape of the fan blades,

The shape of the shrouds

Are there any vanes or flaps inside the shrouds?

How does the air exit the engine?

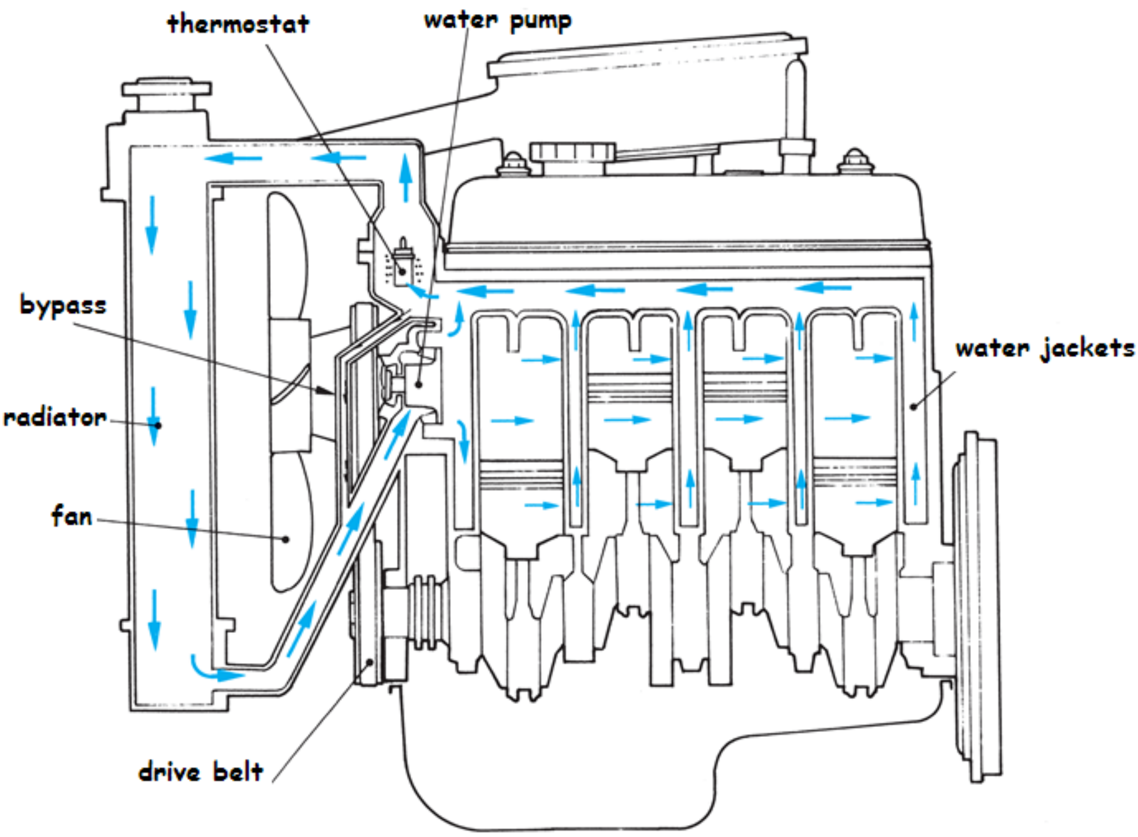
What happens if any grass goes into the fan?

The next step is to check out a Porsche (yeah right)

On to liquid or indirect cooled engines.

First thing we need is to get familiar with some of the names of the various key parts.

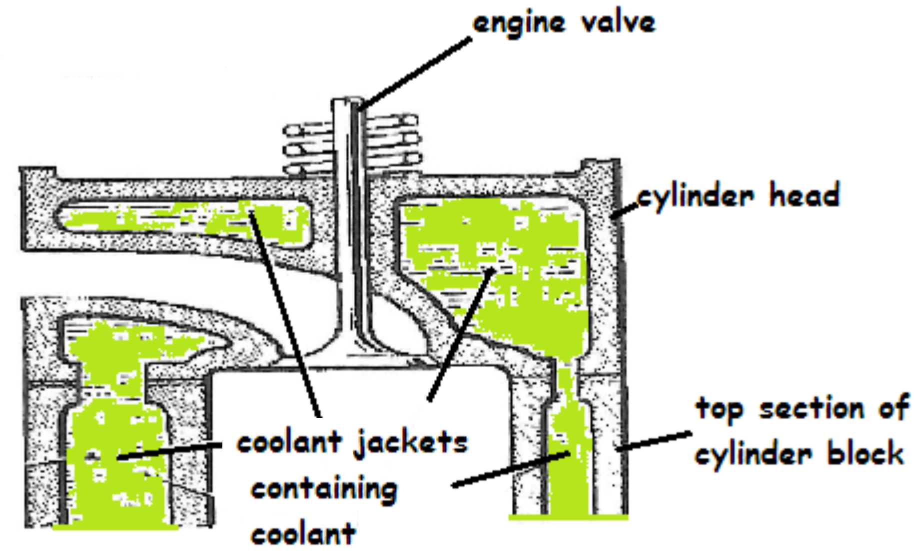
Term	Definition
Thermostat	A temperature operated valve that opens at temperature and allows coolant to flow around the system, closing when the coolant cools.
Water pump	Belt driven centrifugal pump that circulates coolant through the system.
Water jackets	Passages cast into the block and heads to allow the coolant to circulate around the engine parts.
Bypass	A passage to allow the coolant to circulate in the block when the thermostat is closed.
Radiator	A series of fine water passages containing fins
Fan	A belt or electrically driven air pump
Belt drive	A system of belts and pulleys taking drive from the engine crankshaft to engine auxiliaries



We need to look at these parts closely.

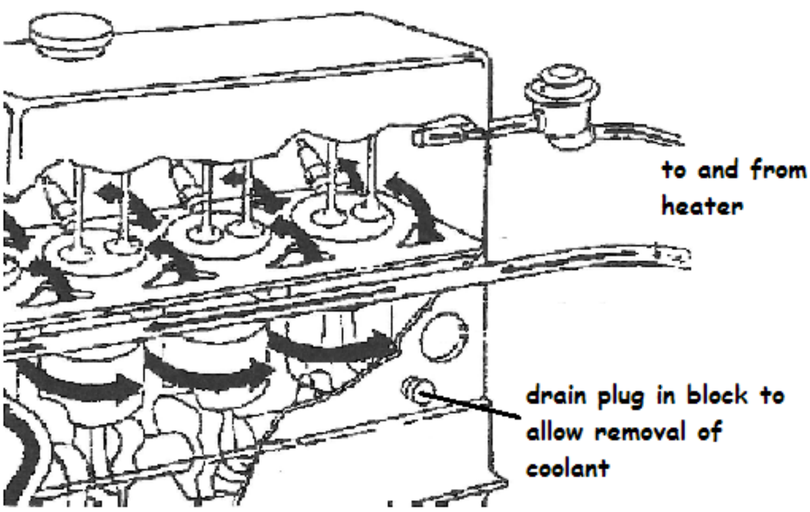
Coolant jackets are cast into the cylinder head around the valves and ports, more so the exhaust due to the extra heat in this area.

The area around the cylinders also contains coolant jackets, particularly toward the tops of the cylinders where the engine temperature is higher than at the lower ends of the cylinders.



The black arrows indicate the circulation of the coolant around the jackets.

One of the functions of the cylinder head gasket is to seal the coolant jackets between the cylinder head and block.



The **water pump** or more correctly **coolant pump** has undergone numerous updates through its automotive life.

Early automotive engines didn't use a coolant pump, they relied on a 'thermo syphon' system where the water heated up and rose to the top of the radiator from the engine, cooled as it flowed down through the radiator and entered the lower jackets of the engine.

The coolant pump was a major advance in the cooling system as it forced the coolant around the system leading to more even circulation of the coolant and avoiding 'hot spots' around the engine where the coolant is not moving.

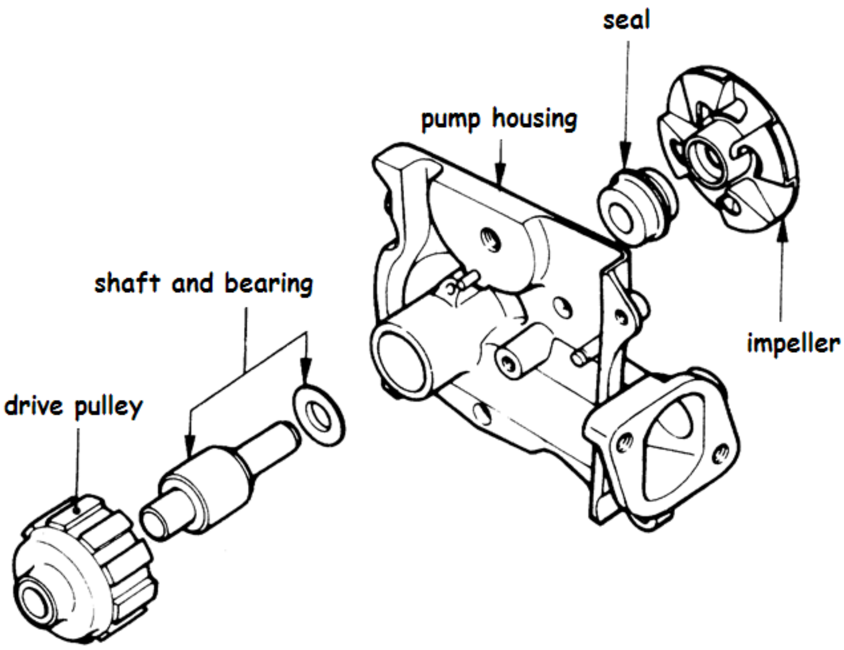
The water pumps main part is the **impeller**

Note that the shape of the impeller blades are like those you have seen on the flywheel of an air cooled lawn mower engine or a turbo turbine.

As the impeller is spun coolant enters the centre of the blades and is thrown outwards. This gives us the pumping action.

The coolant pump can be driven by a system of pulleys and belts taking the drive from the crankshaft of the engine, or electrically by an electric motor.

Modern trends are to electrically drive the coolant pump as this reduces the power drag of driving the pump from the engine.



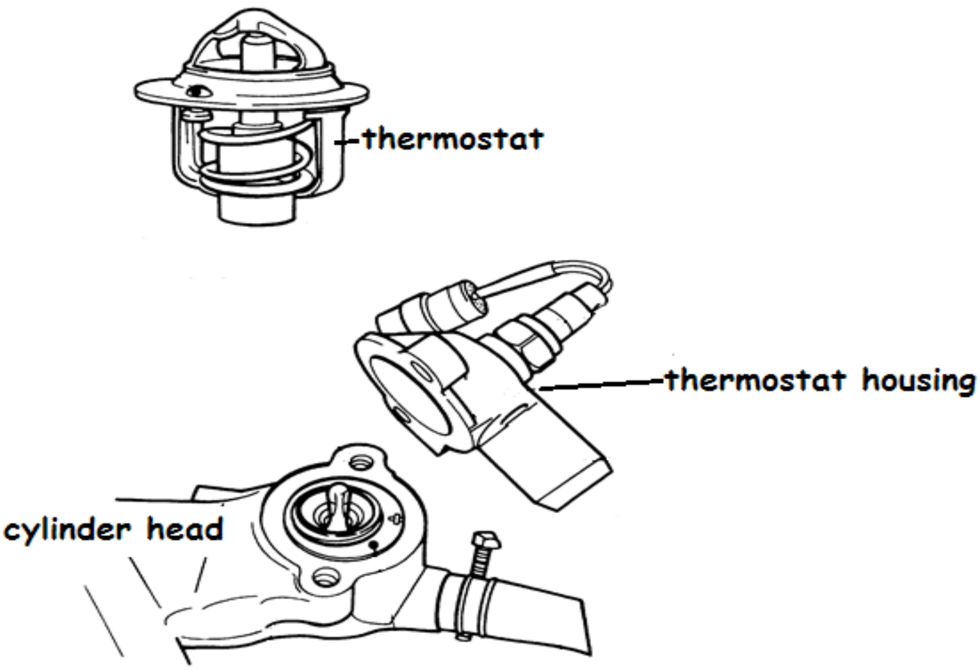
Click here for some water pump info, check out the impeller. [Water Pump Fail - YouTube]

The Thermostat: for some reason this coolant valve gets the blame for most cooling system faults.

Earlier in this unit we discussed some of the functions of the cooling system were to get the engine to the manufacturer's specified temperature as quickly as possible. This is mostly the task of the thermostat.

The thermostat is usually fitted on a high position on the engine, usually on the cylinder head. In this position the thermostat acts like a cat door, remaining shut when the engine is below the correct operating temperature trapping the coolant in the cylinder head and block which allows it reach the required temperature quickly.

As the temperature of the coolant in the cylinder head and block reaches its required level the thermostat (cat door) opens allowing the coolant to circulate around the system.



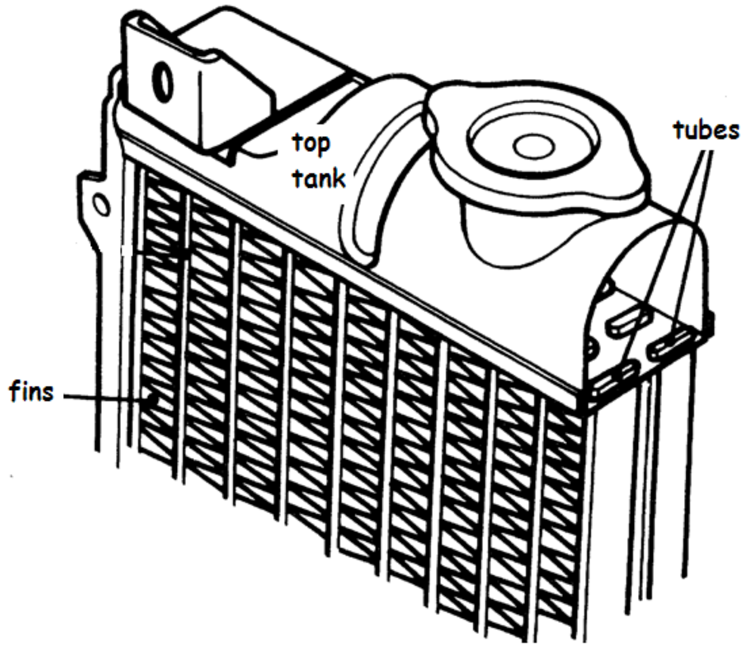
Unit standard 21717 will look at testing the thermostat operation.

watch all this video, at the end it shows the opening of the thermostat, but seeing how it's made will help you understand its operation.
[Auto Thermostat - YouTube]

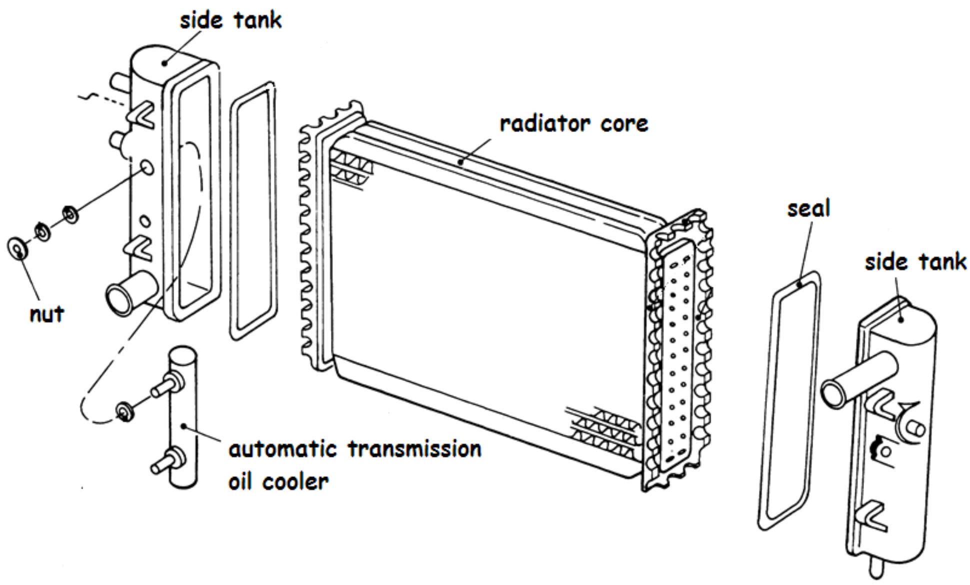
On to the **radiator:** This is another component that has undergone major change over time. Firstly, most radiators are now made of plastics with alloy tubes and fins forming the cooling surface whereas radiators were constructed of copper tanks with copper tubes connecting them.

Traditionally the radiator is mounted vertically with the top and bottom tanks connected by the vertical tubes. The older metal radiators have the tanks soldered to the core containing the tubes and fins.

Newer plastic radiators crimp a seal between the core and the tanks.



Note on the radiator below the tanks are at the sides of the core, not the top and bottom.



Now check this out. It’s a bit old school as the radiator is being made of copper, also the presenter has a cool accent when she says radiator.
[How It's Made - Car Radiators - YouTube]

The **Fan.** This part can be a real pain. At times the engine doesn't need it and would be better off if it was not there, while at other times it is critical in keeping the engine alive. The fan started its life as a set of blades bolted to the pulley end of the water pump. This meant that whenever the engine is operating so is the fan.

Think about this for a moment, how much horsepower does it take to turn an aeroplane propeller?

The fan is a propeller.

We know that when the vehicle is moving through the air the fan is not needed but when the vehicle is moving slowly or is stationary then engine temperatures require the fan to force air through the radiator.

NOTE: on some industrial and earthmoving engines the fan pushes air through the radiator from the engine to the outside.

Most fans are now plastic (lightweight) and easy to manufacture.
Take a close look at any reasonably modern fan and you will probably notice the fan blades are not evenly spaced around the fan.

Have a close look at this picture.

Why is this?

Having uneven spacing of the fan blades tends to make less wind noise from the fan and reduce the eddy currents around the tips of the fan blades.

Google 'fan vortices' or something similar if you want to find out more about these.

Term	Definition	Example
Viscous	of a glutinous nature or consistency;	The viscous properties of water and honey are very

Manufacturers tried different methods of being able to stop the fan when the engine doesn't need its help, the most common of these and the one you are most likely to find is called the **Viscous Coupling** fan unit.

You may have noticed some engines have the fan mounted to an aluminium hub shaped like two saucers joined together. This unit is the **viscous coupling.**

You have probably heard the word viscous when oils are being talked about (viscosity). The viscous hub contains a silicon paste that thins when it warms and thickens when it cools.

The viscous hub bolts to the water pump pulley and the fan is attached to the viscous hub.

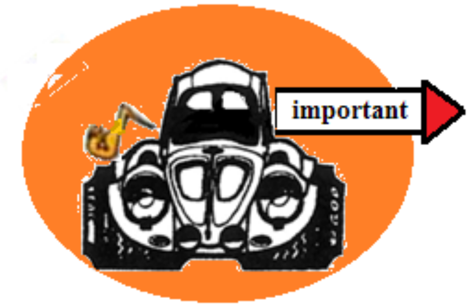
Probably the easiest way of sussing out how the viscous coupling works is to watch the following video. The video shows a high tech viscous coupling, not all have the electronics in them that this one does but it shows the technology that is in there.

BorgWarner Visctronic - YouTube

You have probably already figured out **"why not use an electric fan".** Good call.

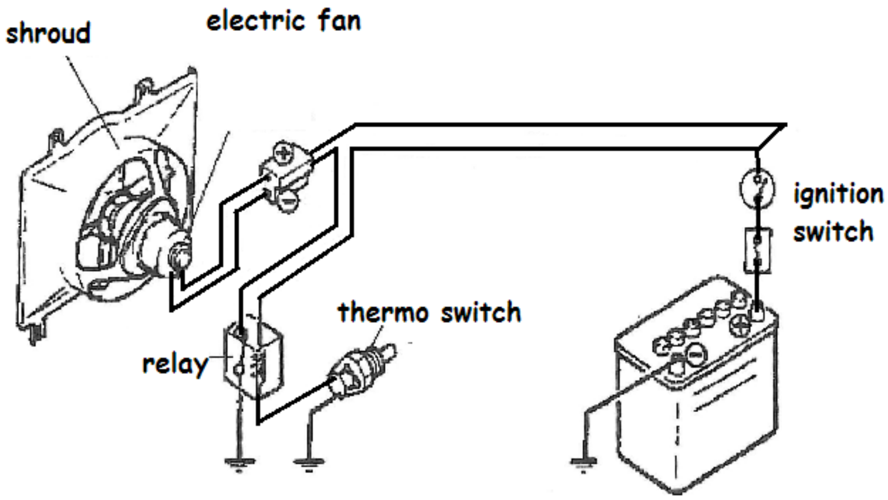
The electric fan is now fitted to most vehicles.

The electric fan puts no mechanical load on the engine and with modern electronics can be operated at various time and speeds to suit the engine.



Be careful when you are working in the engine area as the fan or fans can operate at any time. The engine does not need to be running and the ignition does not need to be on.

The basic circuitry for the electric fan uses a thermo switch (temperature operated switch fitted into the coolant) connected to the electric motor of the fan. More modern systems use the engine ECU to drive the fan or fans.



To understand the **radiator cap** we need to go back to some physics.

You are probably aware that the coolant is under pressure in the system, but what happens to the properties of a liquid once it is pressurised?

Water boils at 100^0 Centigrade (C).

Here's the bit that matters:

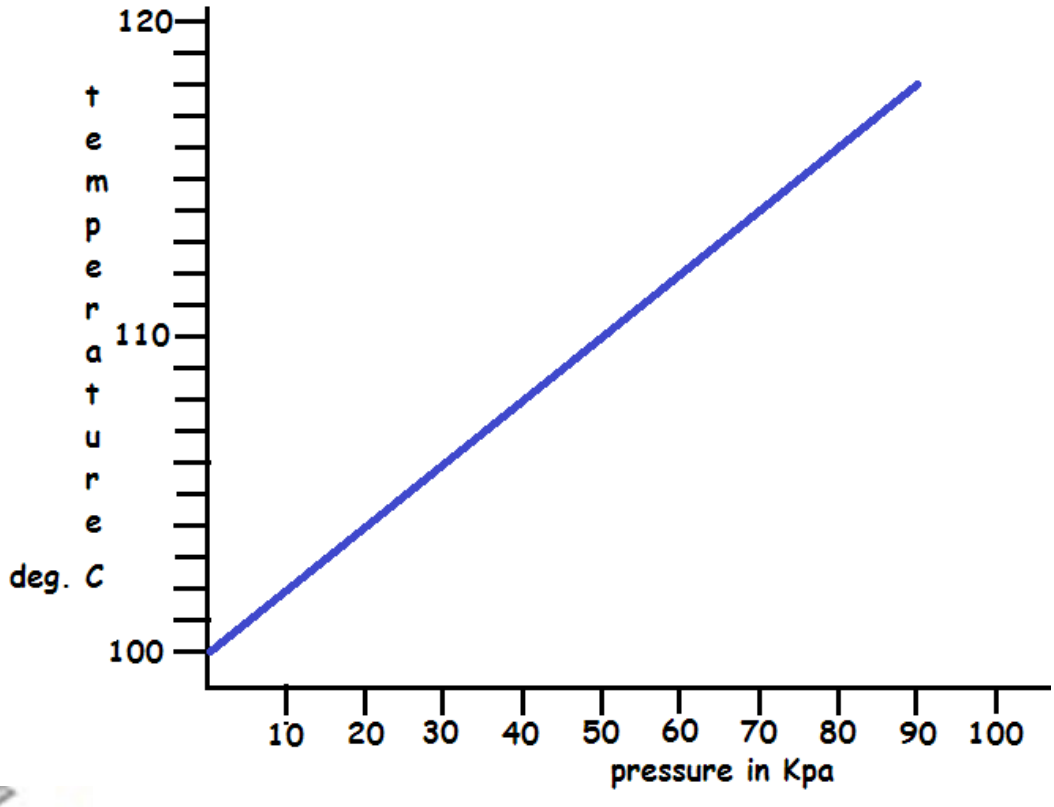
For every 5 kpa of pressure the boiling point increases by 1 degree.

That may not sound much, but if we have a look at the pressures cooling systems are operating under then the numbers start to get bigger.

90 Kpa is a common specification for coolant pressure in the system.
So: divide 90 by 5 -

5/90 = 18 so if the coolant boiling point is 100^0 and we apply 90Kpa of pressure to that system then the boiling temperature will now be 100 + 18 = 118^0

the basic graph below shows the effect of pressure on the boiling point of a liquid.



So what happens when you (the technician) remove the radiator cap when the engine is at normal operating temperature?

Finish the story: Not just in a couple of words, describe what happens to the pressure, the temperature, the coolant and you.

Show you tutor your answer; you need to get this right.

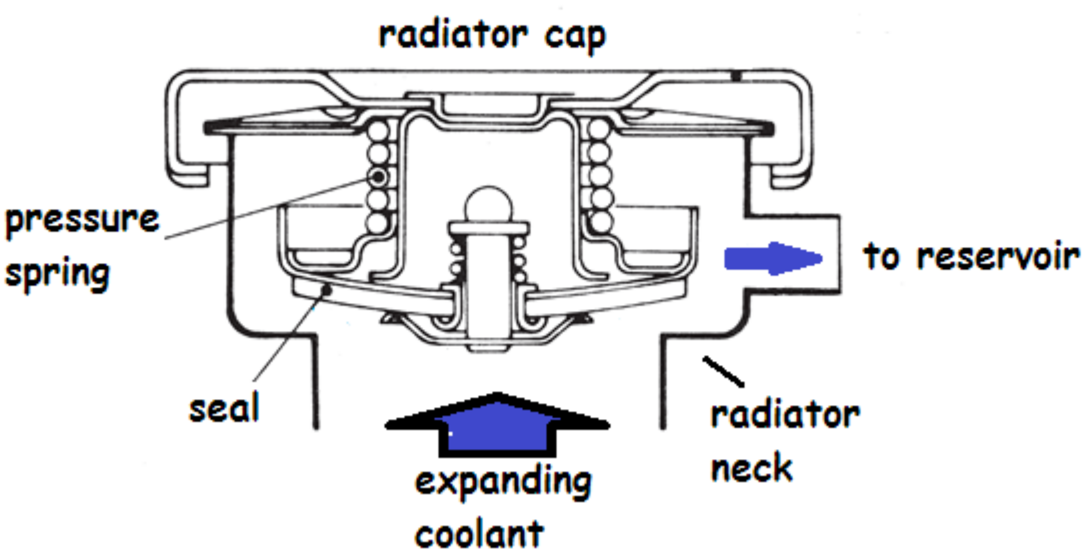
Removing the radiator cap when the engine is at normal operating temperature will

Back to the radiator cap.

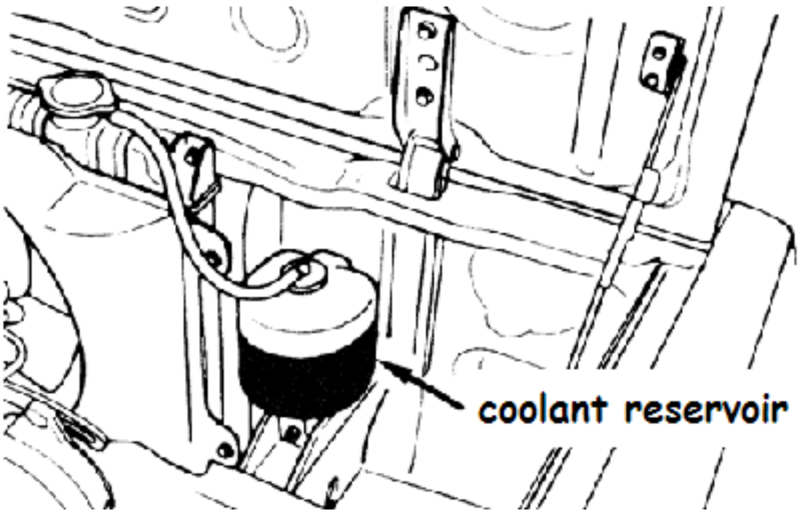
As we heat a substance it expands (easy eh)

If we heat a bucket of water then the water expands, in fact it may expand that much it begins to turn to steam.
So if we heat the coolant in the cooling system then it also expands. If the coolant is in a confined area then it cannot expand and simply builds up pressure. This is exactly what we want in the cooling system as it allows the coolant to be kept at a temperature above 100^0 c without boiling.

A pressure spring on the radiator cap could control the amount of pressure in the system by sealing the neck of the radiator until the pressure increases to a level it overcomes the spring pressure of the radiator cap.



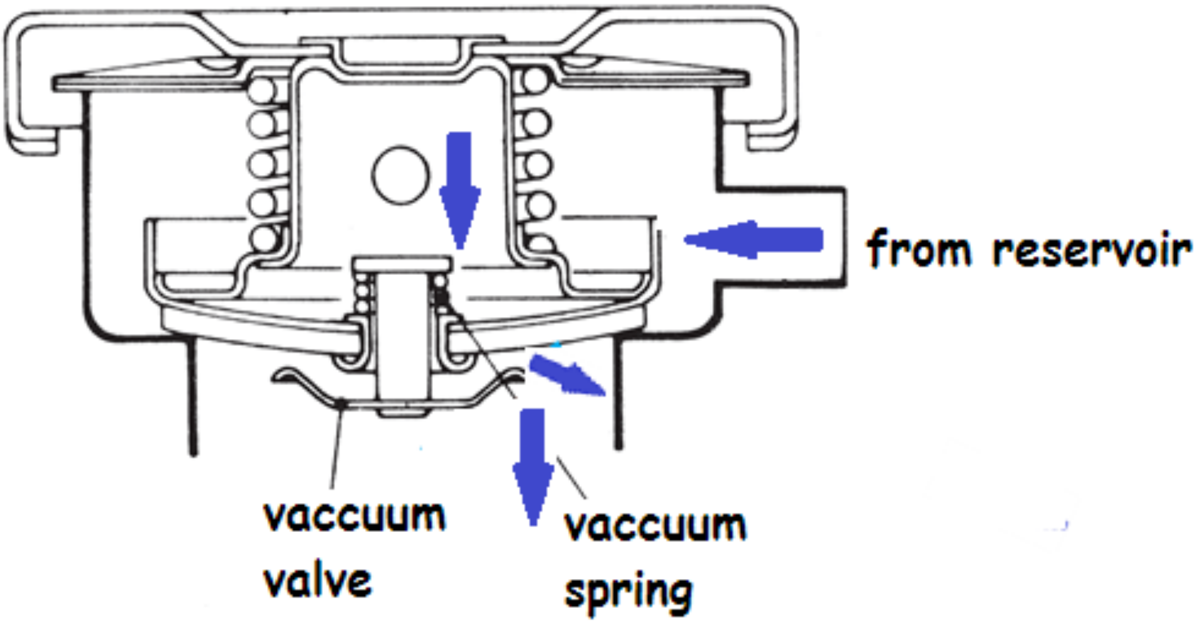
As coolant escapes the radiator past the cap seal it is collected in the reservoir bottle or header tank as it is sometimes called.



The pressure spring in the radiator cap is able to maintain the coolant system pressure at the specified level, **but now what happens** when the engine is switched off and cools down?

We just discussed how the coolant expands (increases in volume) as it is heated so it must contract (reduce in volume) as it cools.

The radiator cap has a second valve in it that will be opened by the action of the coolant contracting. This valve opens in the reverse direction to the pressure valve allowing coolant to return from the reservoir to the radiator.



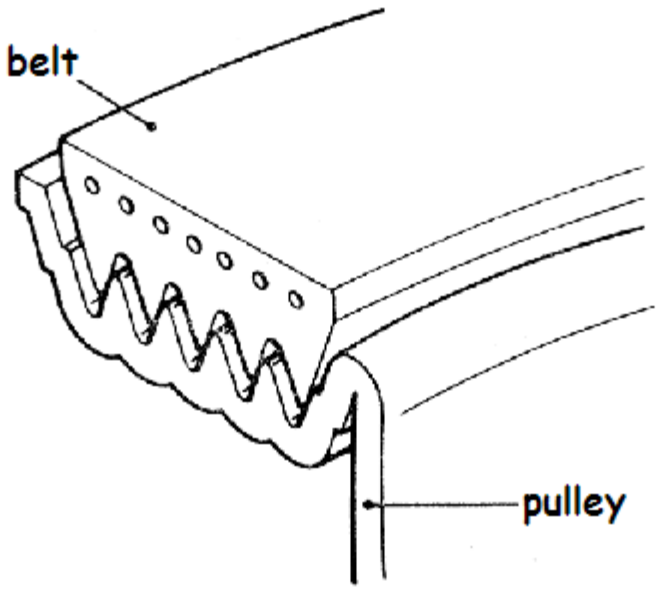
A major benefit in regard to this system is that air is eliminated from the cooling system, any air in the system would alter the temperatures and pressures.

Also the radiator does not need to be opened to add coolant and the coolant level in the reservoir is easily checked through the plastic container.

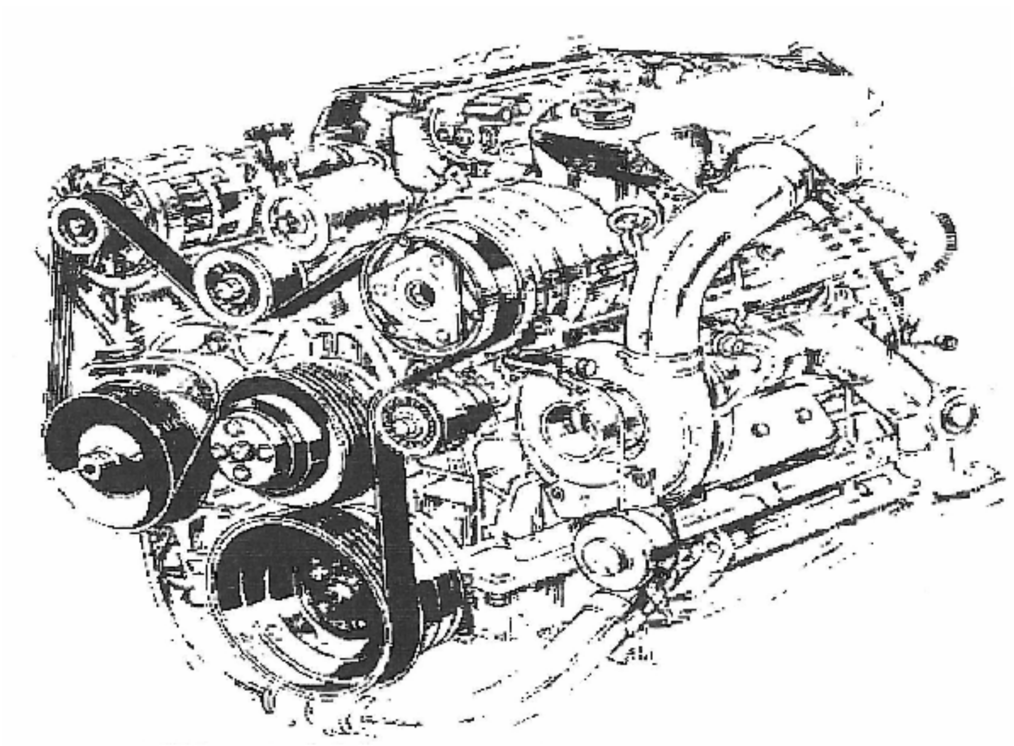
The drive belt or belts are the link between the engine and the water pump.

Most drive belts are **serpentine** belts. This is a fancy name for a belt that is thin in profile, has a flat surface on the back of the belt and longitudinal ribs on the underside of the belt.

These belts are able to drive on both sides, this means the rib side of the belt drives in pulleys and the back side of the belt can run in idlers or tensioners. Because the belt is of a thin profile it can work around small diameter pulleys which are also an advantage.

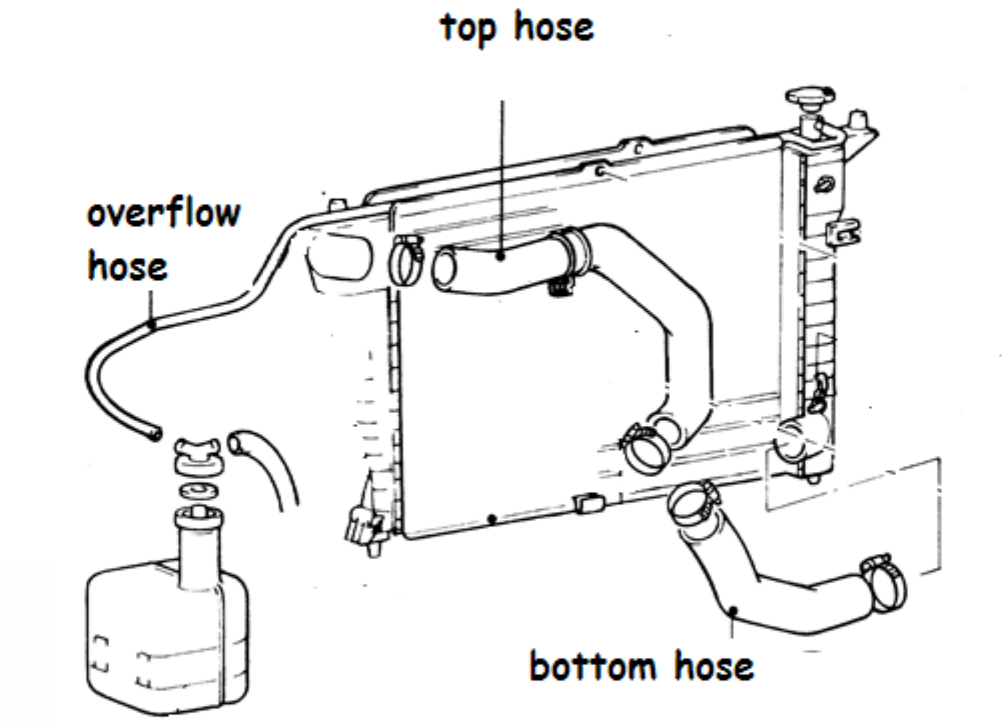


Check out the picture below



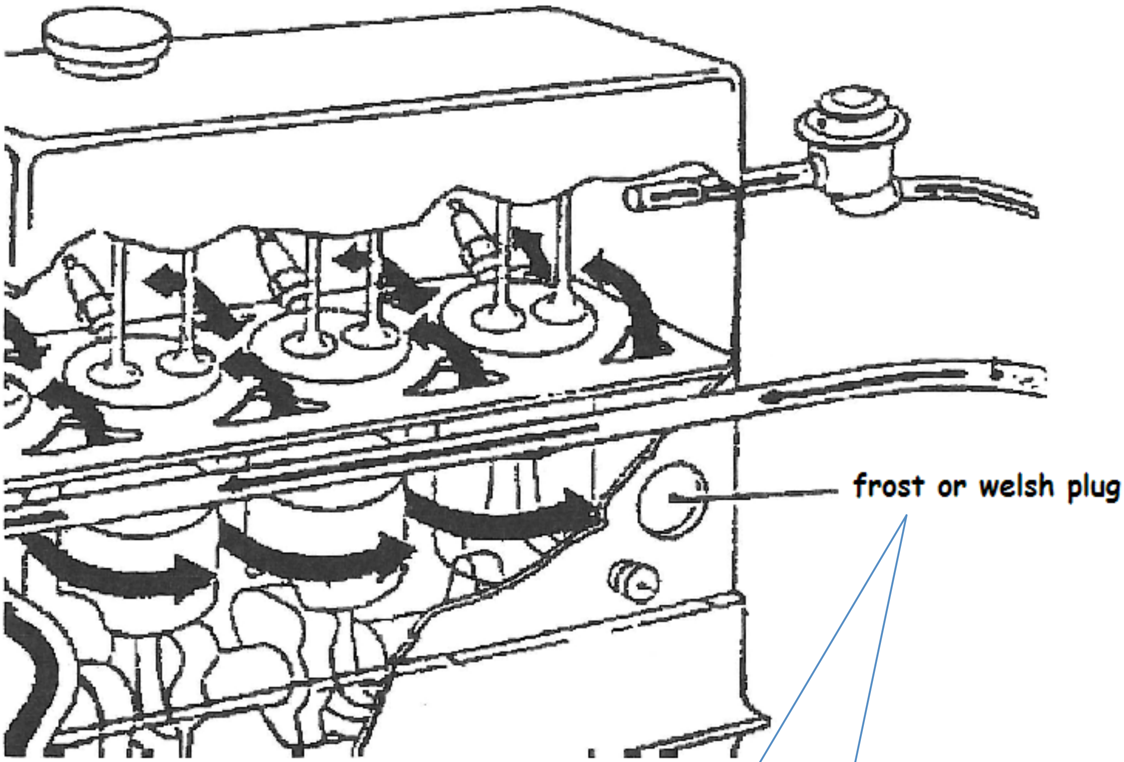
Radiator hoses provide a flexible passage between the rubber mounted engine and the radiator mounted solidly to the chassis or sub frame.

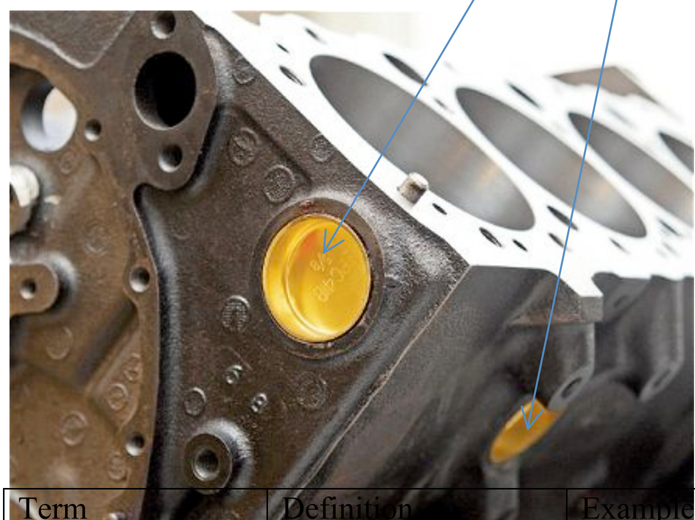
The hoses are made of 2 ply rubber with a woven reinforcing layer between.



Hose clamps are used to secure the hoses to their outlet or inlet fittings.
Additional hoses to the heater will also be fitted.

Frost or **Welsh** plugs are fitted into the block and cylinder head after their manufacture to fill the casting holes from manufacture. These plugs are often into coolant jackets so they are sealing the coolant into the jackets.
In years gone by the frost or welsh plugs also acted as a release area in the castings that would pop out of the casting if the coolant froze.
In automotive reconditioning the frost plugs are removed to allow the cooling jackets to be cleaned out, but in normal use removal and / or replacement of frost plugs is seldom required. Frost plugs are available in various sizes as determined by manufacturers.





Term	Definition	Example
Electrolysis	The formation of electricity in a liquid	An electrical current is produced in the coolant as it

The **coolant** is the final piece of the system.

The coolant is now a mixture (usually 50/50 or half and half) water and an additive made mostly of **glycol**.

Glycol is a form of 'industrial alcohol' which has properties that are beneficial to the cooling system.

Glycol: Raises the boiling point of the coolant
Lowers the freezing point of the coolant
Contains a lubricant that lubricates water pump seals etc.
Limits the effects of electrolysis in the cooling system.

Electrolysis is a byproduct of pumping the coolant around metal passages. This electricity must be earthed to prevent it reacting with the alloy castings of the engine. If unprotected the alloy will rapidly deteriorate, eating away the surface material of the castings to a stage where they fail.

The prevention of the effects of electrolysis is controlled by the glycol in the coolant and connection of good earth cables between the engine and chassis.

Any servicing of the cooling system (maybe changing a cam belt or whatever) that requires the draining of the coolant will require you to refill the system with the correct amount and the correct ratio or strength of coolant.

Any time you are draining a cooling system you need to be very careful with how you dispose of the coolant.

It cannot be poured down a drain; the Recourse Management act 1991 is the legislation that covers the disposal of liquids similar to the coolant.

Check for the procedures in your workshop regarding the disposal of the coolant.

There are a variety of tools available that will identify the ratio of glycol to water in the coolant. This ratio will be specified by the vehicle manufacturer and **must** be followed.

The most common type of glycol (antifreeze) ratio tester is shown here, it looks very similar to a battery hydrometer and contains a number of different coloured pellets which will float at different glycol/water ratios.

Make yourself familiar with the material in this unit standard then go on to the self-test to check your knowledge.