# TRADE OF HEAVY VEHICLE MECHANIC

PHASE 2

**Module 3**

**Engine**

**UNIT: 4**

# Cooling System

# Table of Contents

# 1. Learning Outcome

**By the end of this unit each apprentice will be able to:**

- Explain the need for a cooling system to control the expansion and contraction of solids and liquids that make up a mechanical engine
- Convert between the various temperature scales using tables and conversion factors
- Recognise hazards associated with working on a hot pressurised cooling system
- State causes and effects of engine overheating and overcooling
- Remove and replace cooling system components and pressure test the system for leaks
- Test the operation of:

  a) a radiator pressure cap

  b) a thermostat

- State the operating principles and function of air and water cooling systems
- Check the concentration of a coolant (antifreeze) with a coolant hydrometer, drain the system, and refill with the correct concentration
- Check the operation of the thermo-switch, temperature sensor and electric cooling fan

## 1.1 Key Learning Points

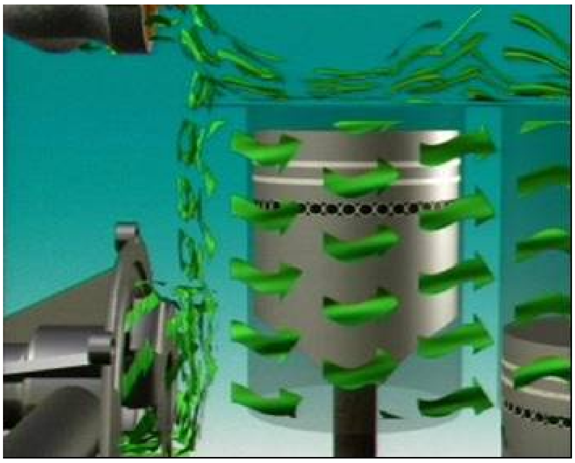
- Need for engine cooling and regulation
- Function and operation of a cooling system and its components
- Use of specialised equipment, to test various pressurised cooling systems and various components, radiator cap, thermostat
- Comparison of water and air cooling systems
- Cooling system dismantling and assembling procedures
- Hazards: associated with hot pressurised cooling systems, boiling water, cap removal, rotating parts etc
- Causes and effects of overheating and overcooling, engine seizure head distortion, excessive fuel consumption, hard starting
- Procedures for testing electrical components, fan, thermo switch coolant temperature sensors
- Coolant (antifreeze) concentration ( ratio of coolant to water), use of coolant hydrometer, properties and the use of corrosion inhibitors

- Effects of pressure and anti-freeze on boiling and freezing point of
- coolant
- Exposed cylinders, fin design to increase surface area, fan type (axial-flow or centrifugal type), ducting and thermostatic controls as used on air cooled engines
- Draining, flushing and reverse flushing procedure
- Introduction to Centigrade, Fahrenheit and Kelvin scales. Use of conversion tables and related formulas
- Use of a thermometer for temperature measurement
- Definition of heat transfer, i.e. conduction, convection and radiation
- Expansion and contraction of solids and liquids due to alterations in temperature and its effects on engine parts and systems, seizure, distortion, excessive fuel
- Definition of specific heat capacity
- Definition of sensible heat, latent heat, changes of state

# 2. Cooling Fundamentals

## 2.1 Cooling systems

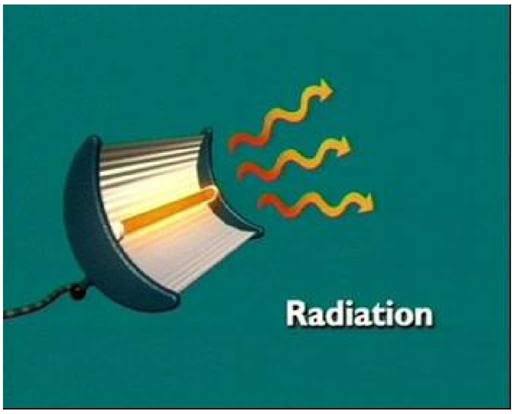
Combustion of the air-fuel mixture in the cylinders generates heat which produces high pressure, to force the piston down in the power stroke. Not all of this heat can be converted into useful work on the piston, and it must be removed to prevent seizure of moving parts. This is the role of the cooling system. Most engines are liquid-cooled.



A liquid-cooled system uses coolant - a fluid that contains special chemicals mixed with water. Coolant flows through passages in the engine, and through a radiator. The radiator accepts hot coolant from the engine, and lowers its temperature. Air flowing around, and through the radiator takes heat from the coolant. The lower-temperature coolant is returned to the engine through a pump.

Air-cooling is common on smaller internal combustion engines. Some engines use cooling fins. Their design makes the exposed surface area as large as possible, which allows more heat energy to radiate away, and be carried off in convection currents in the air. Some engines also use a fan to direct air over the fins.

## 2.2 Heat transfer




The internal combustion engine works by changing heat energy into kinetic energy. There are many ways to do this, some better than others. But no matter how efficiently it is done, and no matter the size of the engine, the heat energy generated never completely changes into kinetic energy. Some energy is always lost.

This is certainly true in internal combustion engines where only about a third of the heat generated is transformed into the mechanical energy that moves the piston and turns the crankshaft. Another third goes out the exhaust, wasted. The rest tries to spread round the engine.

Heat travels in just 3 ways.

- The way it moves through solids is called conduction.
- Through liquids and gases, it is called convection. It follows paths called convection currents.
- Through space, it moves by radiation.

## 2.3 Vehicle coolant

Coolant prevents an engine from overheating in use and from freezing when idle.

The amount of heat generated by an engine is the equivalent of that required to heat a large house in winter in very cold climates. As engines and vehicles become smaller and more powerful they generate even more heat in a confined space, and aerodynamically efficient body designs tend to direct air away from, rather than into, the engine bay.

When an engine stands idle in cold weather, water in the cooling system will expand as it freezes, and this can have sufficient force to crack the engine block or radiator.

A concentrate, usually made of Ethylene Glycol together with some protective additives, is mixed with water to produce coolant. Propylene Glycol, which is non-toxic, is sometimes used in the mixture, as well as, or even instead of, the more toxic Ethylene Glycol. Glycol does not absorb heat as effectively as water, but when added to water it has the ability to lower the fluid's freezing point as well as raise its boiling point.

A common Glycol to water ratio used is 50:50. This will lower the freezing point of the fluid to minus 39°C – minus 38°F, or 70 degrees below freezing – and raise the boiling point to 108°C – 226°F. Manufacturers can recommend other specific mixture ratios, but below 33% Glycol the coolant will give inadequate freeze protection, and above 65% Glycol the mixture has inadequate heat absorption.

There are three types of additives used in coolants: conventional, or inorganic additives; organic additives, and a hybrid mix of the two.

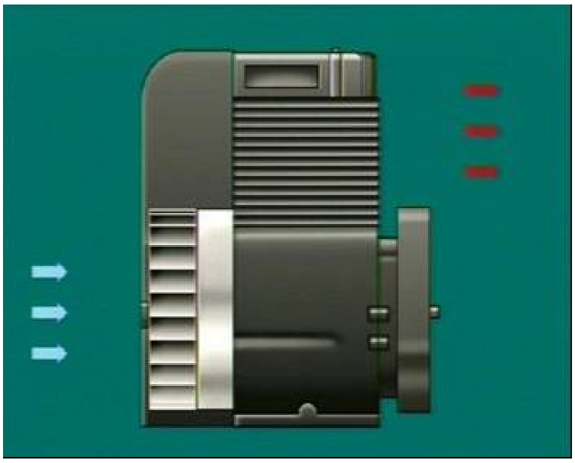
A fully formulated coolant is comprised of a careful balance of ethylene or propylene glycol with rust inhibitors, corrosion inhibitors, scale inhibitors, pH buffers for the acid to alkali balance, anti foaming agents, and reserve alkalinity additives.

## 2.4 Environmental Aspects - Coolant

When disposing of used coolant care must be taken not to cause pollution. Storage of used coolant must comply with the currant law regarding environment protection. Coolant must be disposed of by an authorised waste disposal company.

# 3. Cooling systems

## 3.1 Air cooling



Air-cooling is common on smaller internal combustion engines. They may be small but they still generate a lot of heat.

It's the air that does the work of keeping them cool, so an air-cooling system is usually simple. That's useful on an engine where weight is important, and it works best on the engine that are exposed to a high airflow.

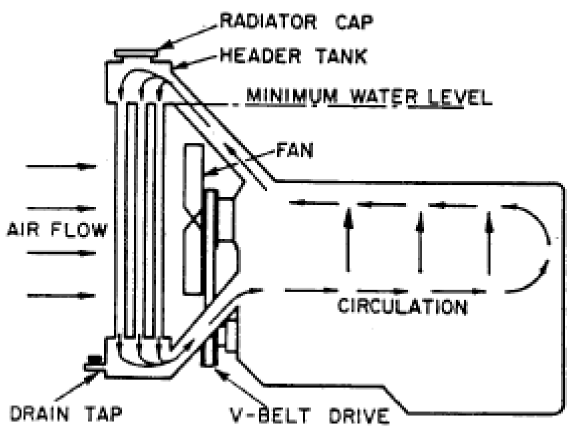
Almost all motorcycles used to be air-cooled but modern motorcycles are larger and more complex, and some are now liquid-cooled.

Some engines use what are called cooling fins. Their design makes the exposed surface area as large as possible, which allows more heat energy to radiate away, and be carried off in convection currents in the air. The more air flows over the fins and more heat is carried away. For a vehicle moving at speed, airflow over the engine is high. At low speeds or during idling, heat builds up. Then the engine can use some help. Air should always be able to flow over the engine effectively. One way to remove heat is to use a fan, with shrouds and ducts to direct air to the cylinders.

There are many places to mount a fan and many ways to drive it. For instance, in some engines it's on the flywheel, driven by fan-belts off the crankshaft.

## 3.2 *Liquid cooling*

This section examines liquid-cooling systems in gasoline and diesel engines.




*Thermo-syphon system.*

In this very basic liquid-cooling system, a coolant is stored in a radiator, and in the engine. As the engine heats up, a natural circulation starts, as coolant rises through the engine block by convection. It passes through the top hose, and into the radiator. Inside the radiator, heat is removed from the coolant as it falls from the top to the bottom. When it reaches the bottom, it returns to the engine through the lower radiator hose.

In modern cars, the engines are more powerful, and radiators are low and wide, and a thermo-siphon process couldn't move the coolant quickly enough.

Instead, a water pump forces it through passages called waterjackets in the engine block. It collects heat by conduction, and becomes hot itself. Heated coolant then returns to the radiator for cooling. And the cycle is repeated. Heat is removed from the engine, and dispersed. Preventing overheating is one function of the cooling system

It also helps the engine reach its best operating temperature as soon as possible. Every engine has a temperature at which it operates best. Below this temperature, ignition and combustion can be difficult. Most engine wear occurs during this warm-up period and most pollution too.

One function of the thermostat is to shorten the warming-up period. It operates according to coolant temperature. When coolant is cold, it is closed.

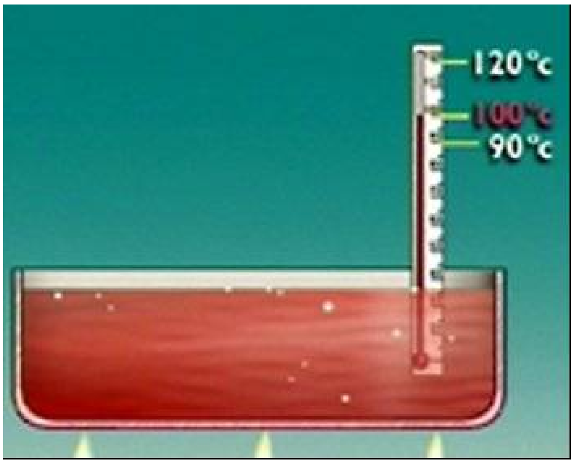
When a cold engine starts, coolant circulates within the engine block and cylinder head and through a coolant bypass to the water pump inlet. It can't get to the radiator.

As the engine warms up, the coolant trapped in the engine gets hotter and hotter.

This starts to open the thermostat, allowing hot coolant to flow to the radiator.

# 4. Cooling system components

## 4.1 Boiling point and pressure




Water at atmospheric pressure at sea level boils at 100 degrees Celsius or 212 degrees Fahrenheit. That is it's 'boiling point'.

If the water is put under pressure, higher than atmospheric pressure, it would boil at a higher temperature. If the pressure is decreased below sea level atmospheric pressure, it would boil at a lower temperature.

Therefore, raising pressure above atmospheric pressure increases the boiling point. Lowering it below atmospheric pressure lowers the boiling point. Changing water pressure changes the temperature at which it boils.

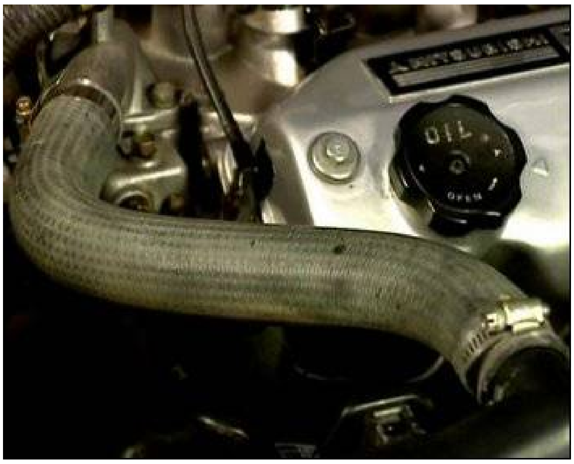
## 4.2 Centrifugal force

Centrifugal force is a force pulling outward on a rotating body.

A vehicle turning a curve is a similar system to this rotating body, so it is subject to centrifugal force too. Centrifugal force resists turning, and tries to keep the vehicle moving in a straight line. Centrifugal force is also the force that causes an out-of-balance wheel to vibrate.

Centrifugal force can also be useful. When coolant enters the center of this pump, and the rotor spins, centrifugal force moves the liquid outward.

## 4.3 Cooling system hoses

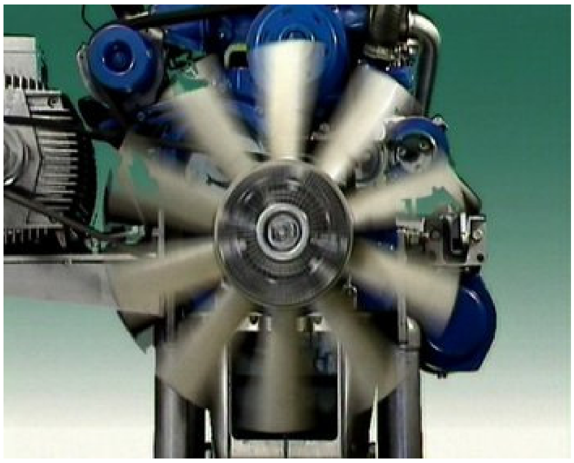


Coolant is transferred throughout the cooling system by hoses.

Most vehicles have the engine mounted on flexible mountings to reduce noise and vibration. Since the radiator is mounted to the vehicle body, flexible hoses are needed.

Coolant is also carried to the heating system which is usually inside the cabin of the vehicle. Coolant hoses vary in diameter depending on the volume of coolant that passes through them. Heater hoses carry a smaller volume. All hoses are subject to hot coolant and high under-bonnet temperatures, and they can deteriorate and fail.

## 4.4 Cooling fans



In a vehicle moving at high speed, airflow through the radiator cools the coolant, but at low speed or when the engine is idling, extra airflow comes from a fan.

Fans can be driven in different ways. More and more modern vehicles now use an electric fan. Air-conditioned cars often have extra fans.

Electric fans can be behind the radiator, in front, or both. This arrangement would be difficult with a belt-driven fan. Some fans can be driven from the crankshaft.

When an engine is mounted longitudinally, its fan is usually mounted on the water pump shaft. The drive belt then turns the water pump and fan. Fan blades can be rigid or flexible. Rigid blades tend to be noisy and use more energy. This noise can be reduced by using irregular spacing of the fan blades.

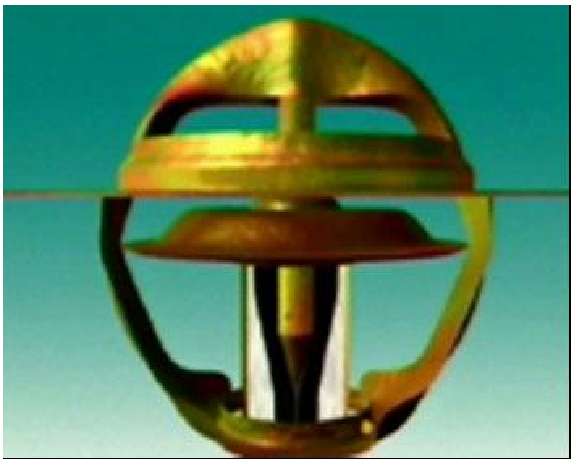
Some vehicles use a shroud to direct all of the air that the fan moves, through the radiator core. At high speeds, plenty of air is already flowing through the radiator. If the fan is always working at full speed, it's a waste of energy. And since the engine drives the fan, it's a waste of fuel too. What's needed is some way to control the fan.

A heat-sensitive switch in contact with the coolant can work like a thermostat, and turn the fan on and off according to coolant temperature.

Another way to alter the speed of the fan is with a viscous hub.

This type of fan slips when it is cold, but as the engine heats up, it grips more and more.

## 4.5 Cooling system thermostat



The thermostat helps an engine to warm up. It's fund in different positions on different engines.

It is a valve that operates according to coolant temperature. When coolant is cold, a spring holds the valve closed.

When a cold engine starts, coolant circulates within the engine block and cylinder head and through a coolant bypass to the water pump inlet. It can't get to the radiator. As the engine warms up, the coolant in the engine gets hotter and hotter.

This thermostat has a wax-like substance that expands as the engine nears its operating temperature. This starts to open the valve. Coolant starts to flow to the radiator.

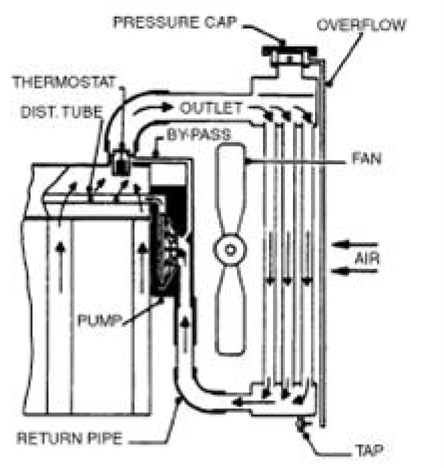
Thermostats have a small hole or valve to let out air that was trapped in the engine block.. A jiggle pin is fitter in this hole to prevent it from getting blocked.

Heated coolant is pumped from an outlet in the cylinder head. It goes into the upper radiator hose, then to the radiator.

## 4.6 Radiator

Many radiators are mounted at the front of the vehicle in the path of greatest airflow. The air carries heat away, cooling the liquid before it returns to absorb more heat from the engine.

Where a radiator is mounted also depends on space - how the engine is mounted. A header tank can be mounted away from the radiator, where it provides a coolant supply, stored above the engine. It can be made of sheet metal, or hardened plastic.



*Impeller-assisted system.*

The radiator has 2 tanks and a core.

The materials used in the radiator must be good heat conductors like brass or copper. Brass and copper are often used for tanks, combined with a copper core.

Modern vehicles often use plastic tanks combined with an aluminium core. This saves weight but still provides good heat transfer.

The core consists of a number of tubes that carry coolant between the 2 tanks. The tubes can be in a vertical downflow pattern, or a horizontal crossflow pattern.

A crossflow radiator fits more easily under a steeply sloped bonnet.

In the core, small, thin, cooling fins are in contact with the tubes. The shape of the fins increases the surface area exposed to the air.

Where coolant touches tube walls, and where the tubes touch the fins, heat is removed from the coolant by conduction, then by radiation and convection at the surface of the fins. Air rushing by carries the heat away.

Liquid emerges cooler at the bottom of the radiator. It travels through the lower radiator hose to the water pump inlet, then through the engine again.

## 4.7 Radiator pressure cap

If a coolant boils, it can be as serious for an engine as having it freeze.

Boiling coolant in the waterjacket becomes a vapour. No liquid is left in contact with the cylinder walls or head. Heat transfer by conduction stops. Heat builds up, and that can cause serious damage.

One way to prevent this is with a radiator-pressure cap that uses pressure to change the temperature at which water boils.

As coolant temperature rises, the coolant expands and pressure in the radiator rises, and that lifts the boiling point of the water.

Engine temperature keeps rising, and the coolant expands further. Pressure builds against a spring-loaded valve in the radiator cap until at a preset pressure, the valve opens.

In a recovery system, the hot coolant flows out into an overflow container. As the engine cools, coolant contracts and pressure in the radiator drops. Atmospheric pressure in the overflow container then opens a second valve, a vacuum vent valve, and overflow coolant flows back into the radiator.

This system stops low pressure developing in the radiator, and that stops atmospheric pressure collapsing the radiator hoses.

## 4.8 Recovery system

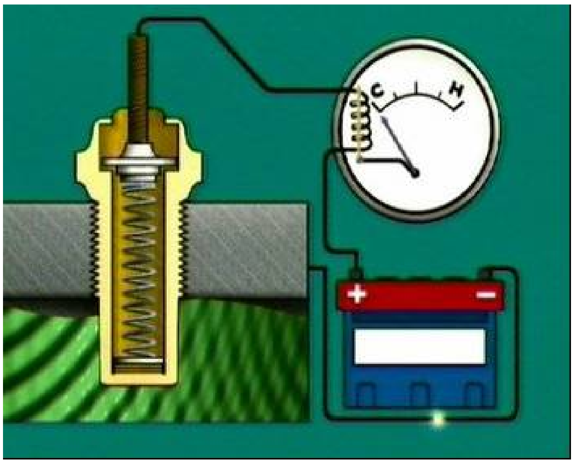
A recovery system maintains coolant in the system at all times.

As engine temperature rises, coolant expands. Pressure builds against a valve in the radiator cap until, at a preset pressure, the valve opens. Hot coolant flows out into an overflow container.

As the engine cools, coolant contracts and pressure in the radiator drops. Atmospheric pressure in the overflow container opens a second valve, and overflow coolant flows back into the radiator.

## 4.9 Temperature indicators

Overheating can seriously damage an engine, so having warning of trouble is obviously useful.




A device that's sensitive to engine temperature sends readings to a temperature gauge or a warning lamp. To give an accurate reading this sensor must always be immersed in liquid.

Indicators that measure coolant levels can give warning if the level falls too low.

## 4.10 Thermo-switch

A thermo-switch opens and closes according to pre-set temperature levels. Some are mechanical, others are electrical. It may be designed to switch off when temperature rises above a certain level, or it can be made to switch on, when the temperature reaches a certain level.

Heat switches can operate on the bimetallic strip principle. It consists of two different metals or alloys attached back-to-back. As different metals and alloys heat and cool, they expand, and contract, differently. That means that if they are joined, and then heated, the faster expansion of one will force the whole strip into a curved shape.

As the strip changes shape, it can be designed to complete a circuit, and a resulting electrical signal can then do a range of tasks, or it might have a mechanical effect, simply opening a passageway.

Cooling then produces the opposite effect. Breaking the circuit, and closing the passage.

## 4.11 Water pump

The water pump is usually in front of the cylinder block, belt-driven from a pulley, on the front of the crankshaft. A hose connects it to the bottom of the radiator where the cooler liquid emerges.

It has fan-like blades on a rotor or impeller. Coolant enters the center of the pump. The rotor spins, and centrifugal force moves the liquid outward. It is driven through the outlet into the cooling passages called waterjackets. Waterjackets are passages in the engine block and cylinder head that surround the cylinders, valves and ports. Coolant can be also directed to hot spots such as the exhaust ports in the cylinder head, to stop local overheating.

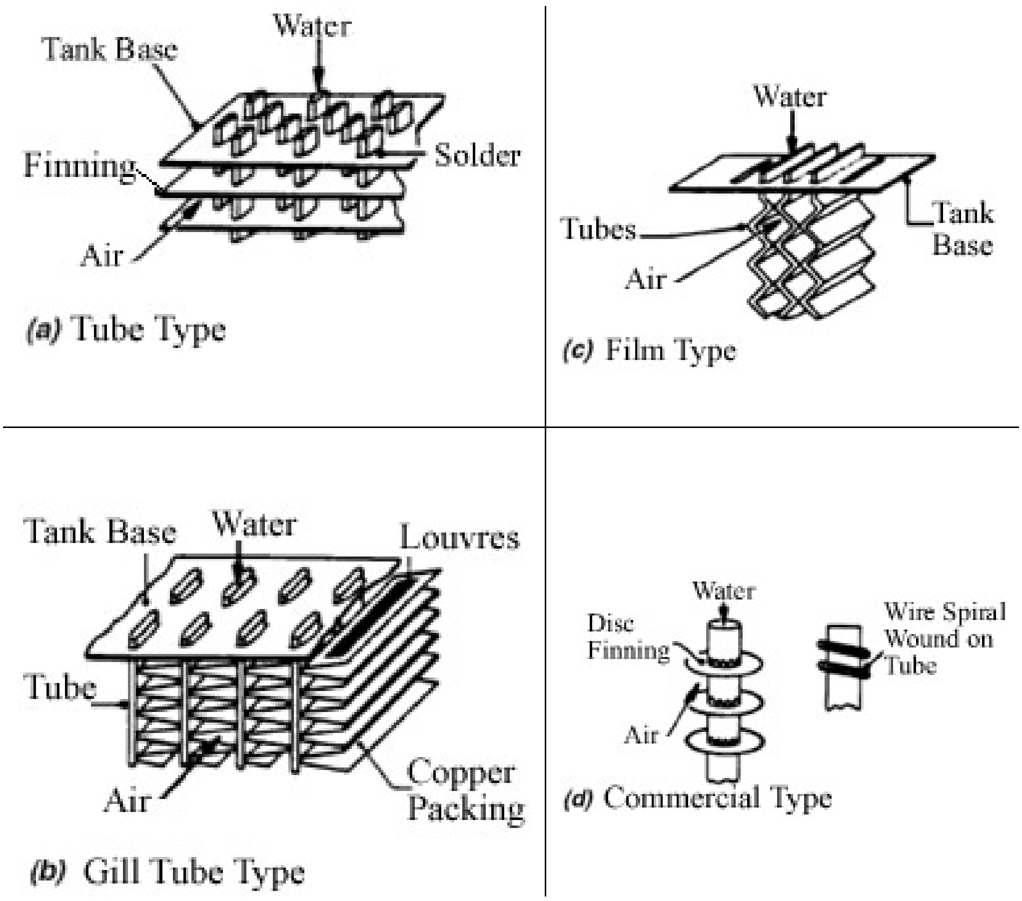
## 4.12 Radiator

**Function:** The radiator is designed to expose to the airstream as large a cooling area as possible in as small a frontal area as possible. It also acts as a tank for some of the water carried.

**Construction:** The usual form of construction is that of sheet steel or brass pressings which are formed into top and bottom tanks. They are connected by brass or copper tubes fitted with finning to increase their surface areas. The block of tubes is some times termed the core and in the radiator of cars and the lighter commercial vehicles the core may be of the tubular or of the film type. Radiators must have a filler cap and an overflow or vent pipe and often have a drain tap fitted to the bottom tank.

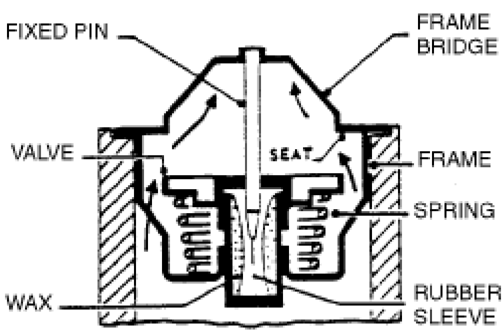
**Operating Principle:** Hot water from the engine rises to the top tank, as it passes down the Wubes of the core it is cooled by air travelling through the core drawn in by the fan when the vehicle is stationary or forced in by the truck travelling in a forward direction.

## Radiator construction:



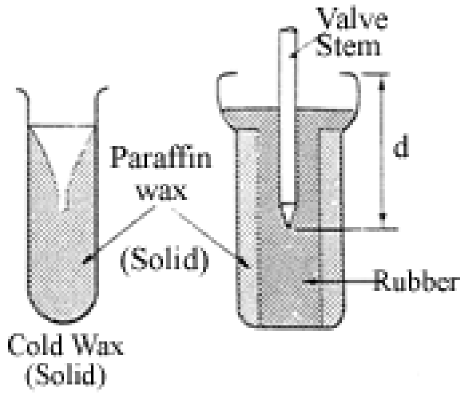

# 4.13 The wax thermostat

Thermostat capsule as used in cooling system thermostat valves.

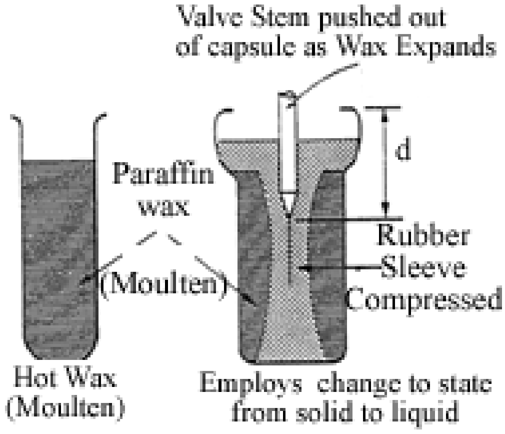



*Thermostat: wax type.*

The valve is opened by the force produced by relatively large expansion of a special wax as it changes from solid to a liquid state.




The valve is arranged below the seat and is forced towards the seat by a strong spring. A bridge over the seat and the mounting flange has a taper ended thrust pin attached to it and the lower end of this pin is surrounded by a cylindrical rubber sleeve, itself surrounded by wax. The wax and sleeve are both enclosed by and sealed into a very strong metal capsule to which the valve is attached. The lower part of the capsule and the lower end of the spring are supported by a frame secured to the mounting flange.




## Operation:

**Engine Cold:** When the water in the engine is cold the wax has its least volume and the valve is forced up on its seat by the spring. No water can pass from the engine to the radiator.

**Engine Hot:** As the water in the engine absorbs heat, the wax begins to melt and expands. Because of the construction of the capsule the powerful expansion force of the wax is directed into compressing the rubber and so forcing the thrust pin upwards out of the capsule. As the pin is attached to the bridge and cannot move, the capsule and the attached valve are forced to move down from the seat so opening the valve.

Failure of this type is usually due to the rubber sleeve being damaged by either age or mechanical means.

**Jiggle pin:** A jiggle pin is fitted to prevent air locks forming when the cooling system is being refilled.

Thermostat testing: The failure of the thermostat results in one of the following symptoms:

(a) Engine overheating, when the thermostat fails to open.

(b) Engine slow to heat up, thermostat remains open.

To test a thermostat, place the thermostat in a container of water heated to the opening temperature of the thermostat. If the thermostat fails to open it will have to be replaced.

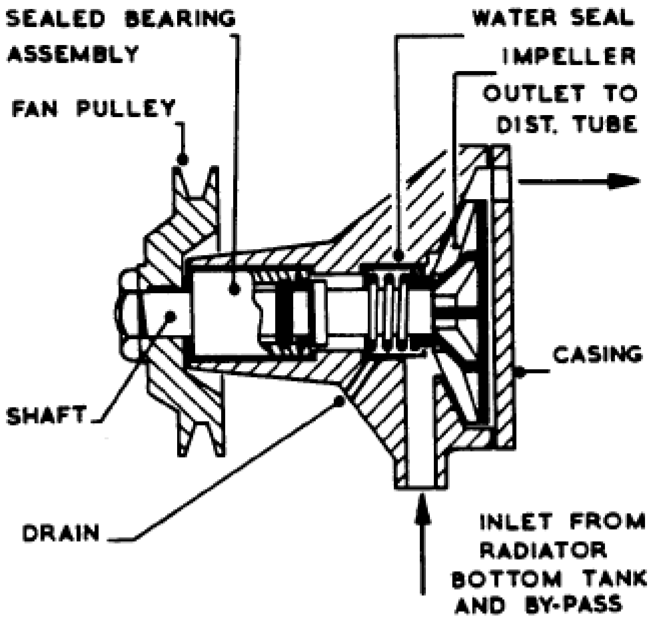
*Thermostat testing*

## 4.14 Water Pump

**Function:** The impeller pump is bolted to the front or side of the engine and is used to speed up the circulation of the water through the system. This makes possible the carrying of less volume and mass of water, the use of smaller and lighter radiator (the position of which is not critical) and the directing of the coolest water to the most heated area.

**Construction:** The pump consists of an impeller in the form of a disc with integral tapered blades on one side. The blades may be straight or curved according to the degree of centrefugal force required and are deeper at the impeller centre. The impeller is secured to one end of a shaft carried in a prepacked and grease sealed bearing. The other end of the shaft carries the drive pully and the fan, and is driven by a vee belt from the crankshaft. The shaft assembly is mounted in a castiron or aluminium casing which also surrounds the impeller, the bearing being protected from the water by a spring loaded carbon sealing ring.

The water inlet from the bottom tank of the radiator leads into the centre of the impeller and an outlet from a point at the edge of the impeller directs the water into the distributor tube in the cylinder head.




*Impeller pump.*

**Operation:** The impeller is rotated as the engine starts and the water at its centre is impelled along the blades by the action of the centrefugal force. The water is then thrown off the edge of the impeller and directed to the outlet by the casing. The centre of the impeller (low pressure) is refilled with the water displaced from the radiator and the circulation continues for as long as the impeller is rotated. Should the thermostat valve be closed, the water leaving the pump is returned to the pump inlet through an internal or an external by-pass.

## 4.15 Water Pump Inspection

A faulty water pump can be diagnosed by one of the following symptoms:

(a) High pitched noise when the bearings are failing. (This may be due to an over tightened fan belt).

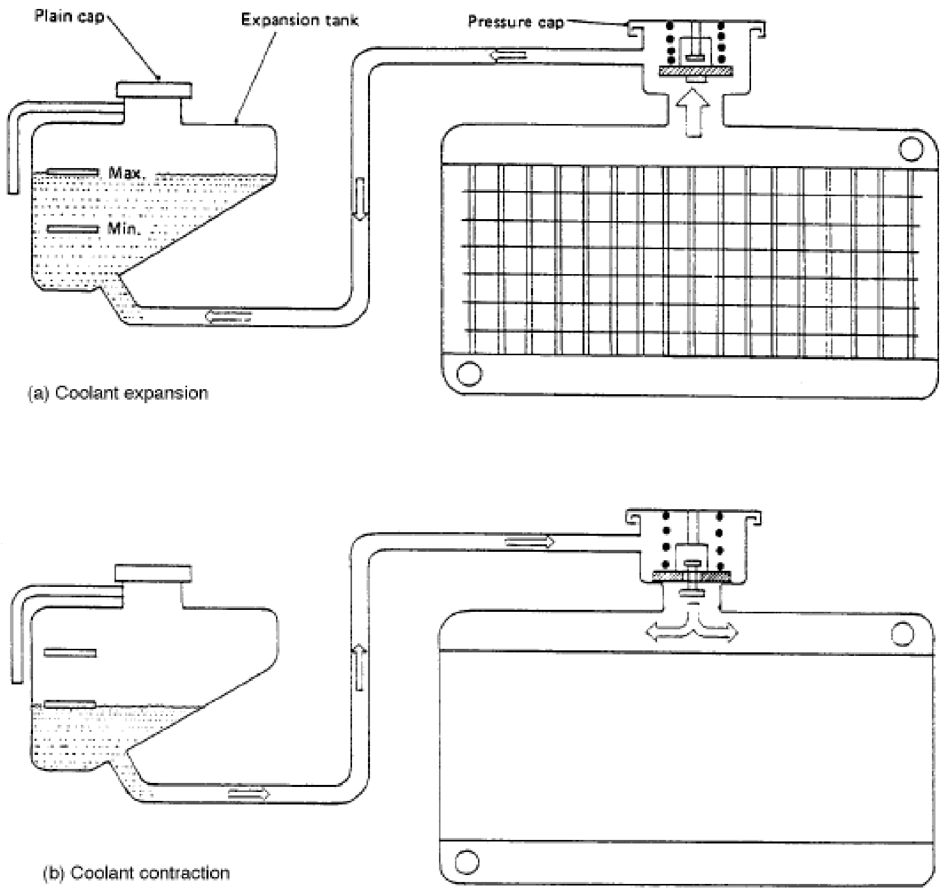
(b) Water coming from the drain hole as a result of the carbon seal cracked or worn.

**Note:** Water may drain from the drain hole on a new pump until the carbon seal is run-in.

## The Sealed System

In the system previously described the expansion of the coolant and air in the system results in small losses of coolant through the radiator overflow pipe. Over a period of operation the level may fall enough to stop the correct circulation and so the level of coolant in the radiator must be checked and topped up at fairly frequent intervals. This service operation is avoided or reduced by the use of a sealed system.

**Cooling system incorporating an expansion tank**




**Vented Expansion Tank**

## Pressurised expansion tank

A more popular layout has the pressure cap fitted on to the expansion tank, which is connected to the top of the radiator by a pipe. The radiator is completely filled with coolant, and a small amount of coolant is also initially put into the expansion tank.

As the system warms up, coolant expands and overflows into the expansion tank which then becomes pressurised. When the temperature in the system drops, the coolant contracts and the pressurised expansion tank will now force coolant back into the main system in order to keep the system completely filled at all times.

The pressure cap on the expansion tank will operate just as if it were fitted directly on to the radiator filler neck.

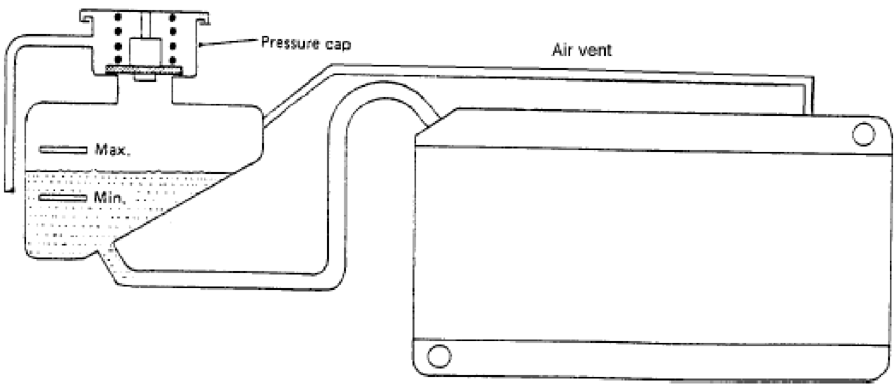
## The advantages of incorporating an expansion tank

(a) It eliminates periodic cap removal and topping up with fresh coolant.

(b) It prevents the loss of excess coolant due to expansion.

(c) It reduces the deterioration of the antifreeze and corrosion of the coolant jackets, as air is excluded from the system.

(d) It enables smaller radiator header tanks to be used and permits the lowering of the radiator height relative to the engine.




**Pressurised Expansion Tank**

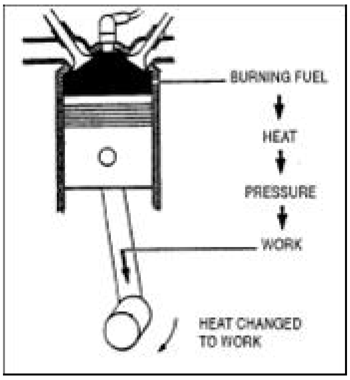
## Cooling system faults

| Fault | Possible Cause |
|---|---|
| External leakage | 1. Loose hose clips.<br>2. Defective rubber hose.<br>3. Damaged radiator seams.<br>4. Excessive wear in the water pump.<br>5. Loose core plugs.<br>6. Damaged gaskets.<br>7. Leaks at the heater connections or plugs.<br>8. Leak at the water-temperature gauge plug. |
| Internal leakage | 1. Defective cylinder-head gasket.<br>2. Cracked cylinder wall.<br>3. 3. Loose cylinder-head bolts. |
| Water loss | 1. Boiling.<br>2. Internal or external leakage.<br>3. Restricted radiator or inoperative thermostat. |
| Poor circulation | 1. Restriction in system.<br>2. Insufficient coolant.<br>3. Inoperative water pump.<br>4. Loose fan belt.<br>5. Inoperative thermostat. |
| Corrosion | 1. Excessive impurity in the water.<br>2. Infrequent flushing and draining of the system.<br>3. Incorrect anti-freeze mixtures. |
| Overheating | 1. Poor circulation.<br>2. Dirty oil and sludge in the engine.<br>3. Radiator fins choked.<br>4. Incorrect ignition timing.<br>5. Incorrect valve timing.<br>6. Low oil level.<br>7. Tight engine. |
| Overcooling | 1. Defective thermostat.<br>2. Inaccurate temperature gauge. |

# 5.0 Heat

Heat is internal energy and is capable of doing work.

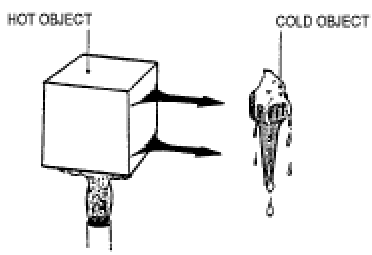
Heat engines obtain their power by burning fuel - the chemical energy in the fuel is released by ignition to make the gas very hot. This causes a force which pushes the piston down the cylinder.




**Heat changed to work**

## Heat flows from a hot to a cold surface

A hot object placed beside a cold surface will cause the heat to 'flow' until the two things are at the same heat.




*Heat flows from a hot object to a cold object*

**Heat flows from a hot object to a cold object**

# 6.0 Temperature

The temperature of a body is: **the degree of hotness**

This is different to the heat contained in an object, e.g. more energy will be required to heat four litres of water than that used to heat one litre to a similar temperature.

**Temperature is measured by a thermometer**

## Temperature scales

Most temperature scales are based on two fixed points given by the temperature of:

(a) steam from water boiling under standard atmospheric pressure;

(b) pure melting ice.

**Celsius scale:** In this case the freezing point of water is marked 0°C and the boiling point 100 C; temperatures below zero are given negative values.

**Fahrenheit scale:** A scale used in Britain until fairly recently. The upper fixed point was marked 21 2°F and the lower point as 32°F; the interval between divided into 180 degrees. To convert °F to °C the formula is:

$$C = \frac{5(F - 32)}{9}$$

**Kelvin scale:** The Sl unit of temperature is the 'kelvin'.

This has the same size of degree or temperature interval as the Celsius scale, but has a zero about—273°C. To convert from Celsius to kelvin add 273, e.g.

16°C = 16 + 273

= 289 K

**Note:** The degree symbol is not used with the Kelvin scale.

Value 273 was obtained by noting the behaviour of a gas and this indicated that heat ceased to exist at that temperature. A temperature of —273°C (zero K) is sometimes called the absolute zero.

## State of change

A liquid readily changes its shape to suit the container but resists any change to its volume. A gas has no definite shape or volume and readily fills any container in which it is placed, but in doing so, changes its density.

Heat can change a material from one state to another:

SOLID – LIQUID – GAS

F – Fusion or melting

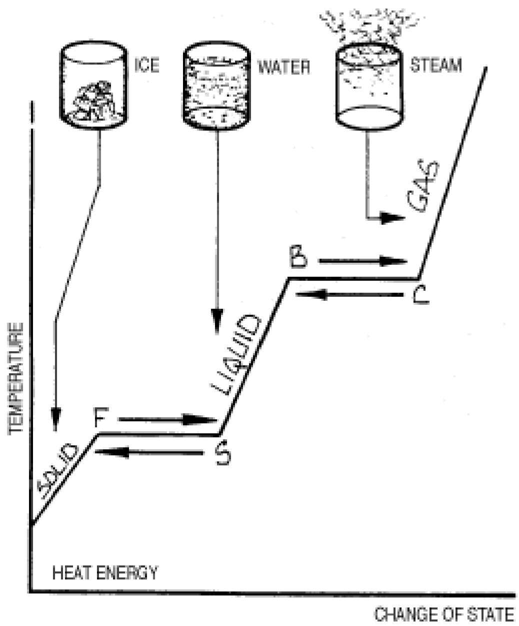
B – Ebullition or boiling

Cooling can reverse the process from one state to another.

GAS – LIQUID – SOLID

C – Condensing

S – Solidifying

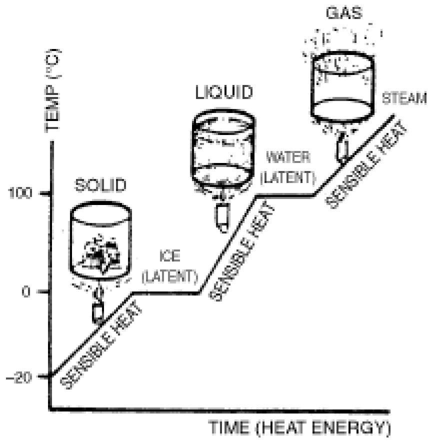



Changes take place at definite temps. in a particular material but at different temps in different materials.

Pure water freezes at a temp. of 0°C or 273K. When exposed to normal atmospheric pressure. During solidification its volume increases slightly.

## Sensible and Latent Heat

**Sensible Heat:** Ice being heated from -20°C to 0°C at constant rate. Temperature gradually rises This is sensible heat.



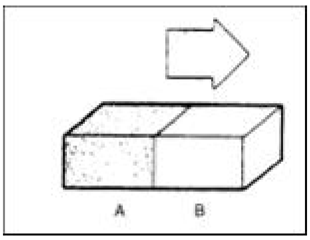

**Latent Heat:** When temp. reaches 0°C there is a lapse or period where further heating does not give a rise in temp. During this period the heat supplied causes a change of state and is known as Latent Heat. (Hidden Heat).

The change from liquid to vapour is called vapourisation: this may take place relatively slowly and from the surface of the liquid only, in which case it is called evaporation: or it may take place rapidly with bubbles of vapour forming within the bulk of the liquid itself and rising to the surface, in which case it is known as ebullition or boiling. The reverse process by which a vapour changes into a liquid is called condensation.

## Heat transfer

Heat transfer (can be by one or more ways):

(a) Conduction.
(b) Convection.
(c) Radiation.

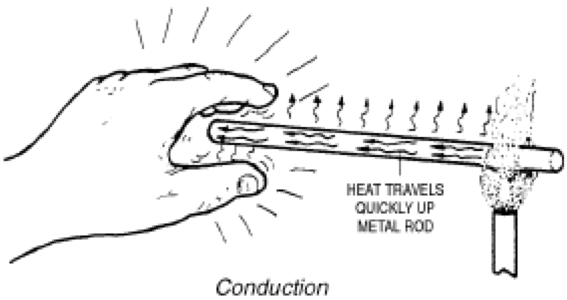



Two pieces of metal (similar)

a) heated;
b) cold.
Placed in actual contact.

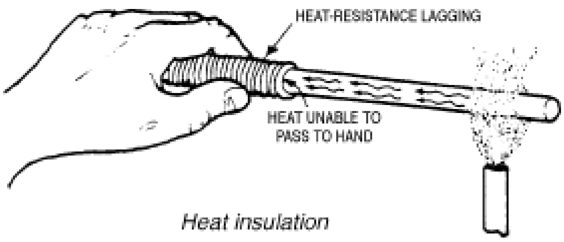
'A' becomes cooler. 'B' becomes hotter. Eventually both attain the same temperature. This is heat transfer by conduction.

Heat travels from molecule to molecule (in contact) until the whole rod is of uniform temperature.




*Conduction*

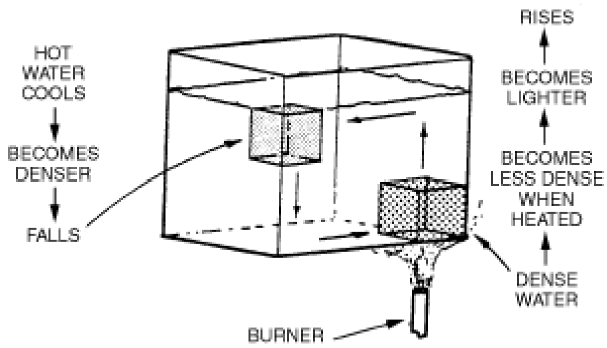
A material that is a poor conductor of heat is said to be a good insulator. Asbestos cord being used in example illustrated.



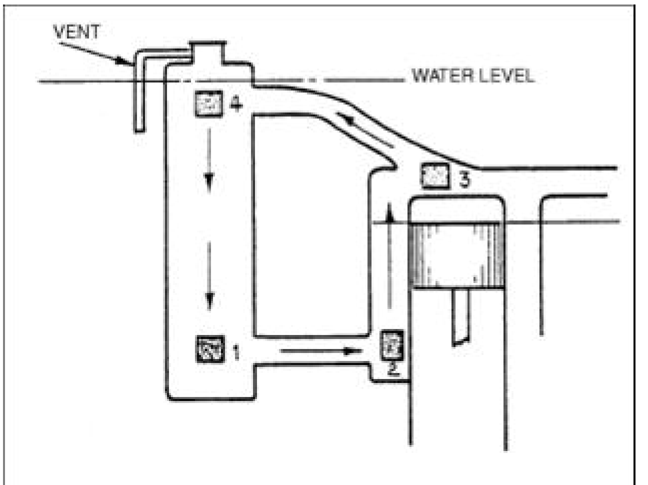

*Heat insulation*

## Convection

Heat transfer due to movement of fluid.



1. Water cold and dense.
2. Slightly heated and less dense (lighter rises).
3. Heated by heat of combustion (less dense rises).
4. Temp. starts to drop (heavier falls).



Thermo-syphon cooling system.

Elementary method of taking heat from "hot zone" cooling the medium and re-cycling to hot zone.

## Radiation

Heat transfer by rays which are similar to light rays. The radiant heat consists of invisible electromagnetic waves which behave similar to light waves:

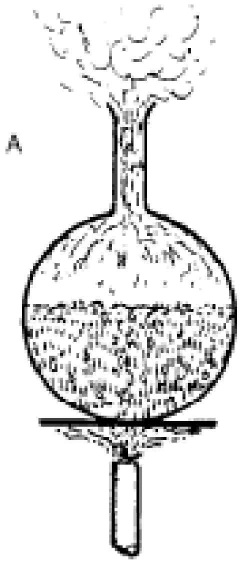
(a) they travel in a straight line.
(b) they can be reflected.

## Pressure and boiling point

**Evaporation** - all liquids tend to form vapour above the surface. Some vapourise more readily than others.

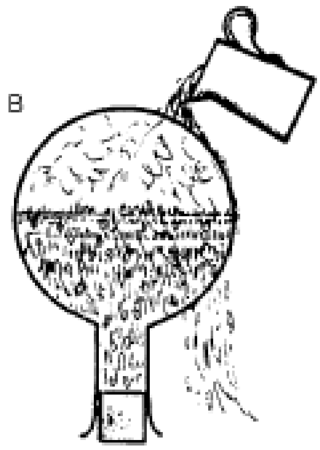
**A:**

1. Heating water causes internal vapour pressure.
2. When this equals the atmospheric pressure the water boils.
3. When boiling vigorously for some time the steam (water vapour) expels some of the air.




**B:**

1. Flask corked whilst steaming and inverted.
2. Trickle of cold water poured over the surface. This condenses the water vapour causing a drop in water pressure or partial vacuum.
3. Water boils vigorously for a few minutes without added heat.

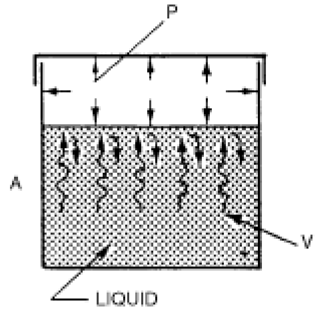



Pressure above water is less than atmospheric and boiling point is lowered.

**Effect of increasing pressure above water.**

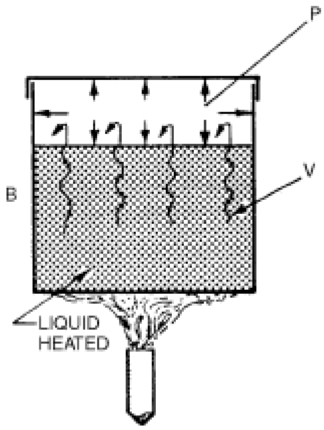
**P:** Pressure resulting from vapour which has escaped from liquid.

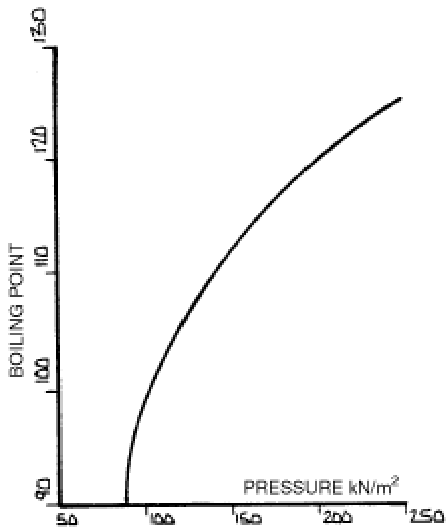
**V:** Vapour unable to escape from liquid because its pressure is too low to overcome the pressure in the air space.




**V:** Vapour pressure now greater and now escaping from liquid.

**P:** Pressure above liquid now greater due to a escaping vapour, (plus expansion of liquid).




**Effect of pressure on the boiling point of water**

If the temp. of the liquid is raised in 'B' the greater internal vapour pressure will enable more vapour to escape from the liquid. In turn this vapour will increase the external press. (P) which in turn prevents more vapour to escape.

Repeating process eventually
V = P and liquid boils.
(Vapour escaping vigorously).

# 7.0 Fans

## 7.1 Cooling fans

Function: The fan is used to draw air through the radiator when the vehicle is moving slowly or is stationary. It must be fairly close to the radiator core and is usually driven by the same vee belt that is used to drive the generator. In m+Ny vehicles the fan and water pump are combined.

## 7.2 Viscous fan drives

Many heavy vehicles are fitted with viscous fan drives that control fan speed in such a way that it only operates when required. When a vehicle is travelling at high speeds there is normally sufficient air passing through the radiator core to provide adequate cooling without the assistance of a fan. Viscous drives are designed to cut out fan operation at high road speeds and high engine speeds if it is not required which gives a saving in engine power and a reduction in fan noise. On the other hand, when the engine is working hard and requires cooling, the viscous drive acts in such a way as to provide adequate cooling.

## 7.3 Electric fan

It is not always essential to have a fan, especially under normal driving conditions, in which case, the fan absorbs engine power unnecessarily and tends to overcool the engine.

An electric fan which cuts in and out through a thermostatic switch activated by the temperature of the coolant, is a better proposition.

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