# Unit 7 Cooling System

Contents

## Learning Objectives

- To learn about the air and water cooling techniques involved in two stroke and four stroke engines.
- To learn about various cooling components like cooling fan, cooling water, radiator and water jacket.

## 7.0 AIM

In internal combustion engines due to the combustion of the fuel air mixture, enormous heat is liberated inside the combustion chamber. From the total heat released, about 30-35% of the heat is transferred as useful mechanical work at the engine's crank shaft. Approximately 30% of heat is carried out by the burned gases. About 25- 30% of the heat is rejected by the cooling medium and the remaining is considered as the unaccounted loss which is due to the friction, radiation etc., The temperature of the combustion products immediately after the combustion of the fuel reaches the value which is even more than 2000°C. Due to the very high temperature the engine components are subjected to very high thermal stress and get expanded due to the more heat of the products. This leads to the burning of engine lubricating oil and more carbon will get deposited inside the combustion chamber. In order to avoid the damage of engine components and burning of lubricating oil the cooling system is essential which helps in sending the heat to the surroundings.

**The following are effects of overheating of the engine components.**

- Damage of the piston and piston sticking on the cylinder wall.
- Lubricating oil burning and formation of carbon deposits and on the combustion chamber parts and the valves.
- Burning of the engine valves (mainly the exhaust valve)
- Occurrence of Pre ignition, knocking and detonation
- Reduction in viscosity of the engine lubricating oil
- Wear and tear of the engine components
- More fuel consumption.

**The following are effects of over cooling of the engine components.**

- Power loss
- More fuel consumption
- Reduced Thermal efficiency
- Increase in viscosity of the engine lubricating oil
- Reduced mechanical efficiency

**Characteristics of the efficient cooling system:**

- From the overall heat produced, the cooling system must reject sufficient amount of heat about 28-30% from the overall heat produced from combustion of the fuel.
- Cooling system should be designed in such a way that the heat to be rejected quickly when the engine is operated at very high temperature.

- During starting, the cooling system should reject only less amount of heat.
- It should transfer the maximum (i.e. sufficient) amount of heat from the engine combustion chamber.

## 7.1 AIR COOLING SYSTEM

In this type of cooling system, the engine cylinder should be kept in such a way that more air should be in contact with the outer region of the cylinder block. Cooling fins are provided on the outer wall of the cylinder so that the contact surface areas for heat transfer to be more. These arrangements are mostly seen in all motor cycles, scooters and in small engines. Figure 7.1 shows the air cooling system.

When the vehicle moves forward, the air passes over the fins and removes the heat on the engine components and hence the engine gets cooled. In some large engines, blower arrangement is made so that the blower sucks the air from the surrounding air and blows on the surface of the cooling fins of the engine.

The efficiency of the air cooling system depends on the following characteristics,

- The speed of the air which flows on the fins
- Area of the fins that is in contact with air
- Thermal conductivity of the cylinder walls

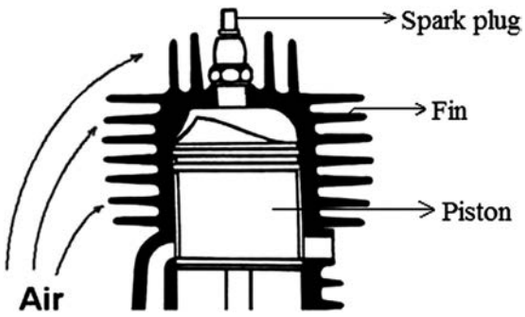



**Figure 7.1 Air cooling system**

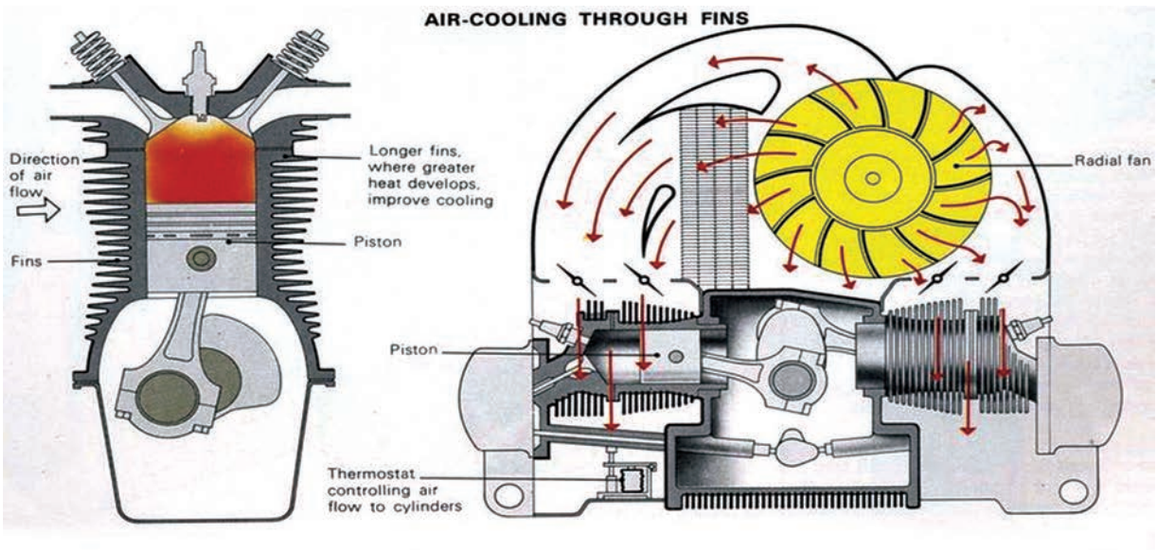



**Figure 7.1(a) Air cooling system**

- The temperature of the engine fins and the temperature of the cooling air

**Advantages and disadvantages of air cooling system:**

**Advantages:**

- In this type due to the absence of radiator fan and pumping unit, engine weight is considerably reduced
- Due to the absence of radiator arrangement, rust and deposits formation are avoided
- Engine occupies only less space
- As the engine needs no water jacket, design of the engine is simple
- The system need no water filling in the radiator
- The engine can be operated at all operating conditions (cold and hot regions)
- Freezing and evaporation of water do not occur as in case of water cooling system

**Disadvantages:**

- Air cool system is not suitable for CSMO cylinder engines
- As this type of engine is cooled by air, the efficiency of engine decreases
- More noise is produced
- Heat transfer rate is lower with air cooling as compared to water cooling
- Blower arrangement is needed for bigger size engines

## 7.2 WATER COOLING SYSTEM

In this method, the water is circulated inside the water jackets of the engine cylinder block and the cylinder head and rejects the heat in the cylinder block and head. As the water absorbs the heat from the cylinder it gets vapourized. It may cause insufficient water to be present in the cooling line. Hence excess water must be added to overcome the vapourization loss. In order to overcome this difficulty radiator arrangement is used to cool the hot water coming out from the engine water jackets. There are three types of water cooling systems followed in engines which are,

1. Direct (or) non return cooling system
2. Thermosyphon or natural circulation cooling system

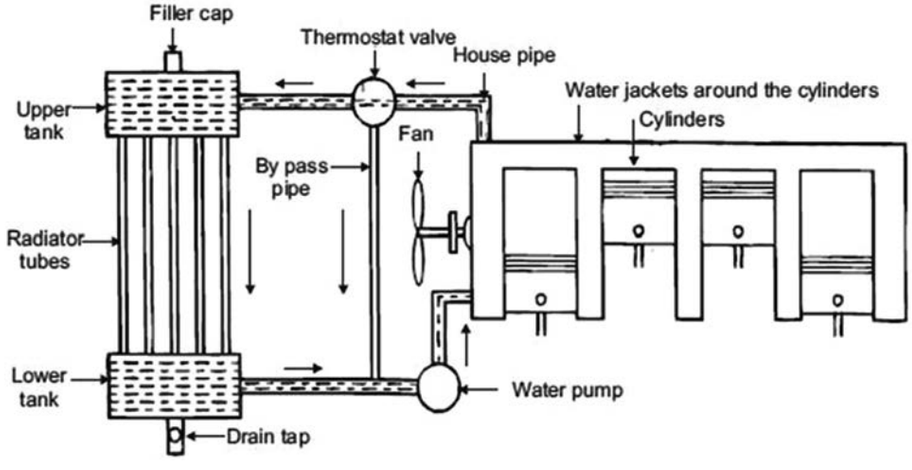



**Figure 7.2.1 Water cooling system**

3. Pressurized or Pump circulation cooling system

### 7.2.1 Direct (or) Non-Return System

This method is mostly used where availability of water is more such as in big industrial engines, marine engines etc., In this method the water from the storage tank is sent to the water jackets of the engine where the water absorbs the heat and the hot water is sent out through the outlet path. The pump in the marine engines pumps the sea water into the water jacket and sends the hot water out. This type is not recommended for automotive engines.

### 7.2.2 Thermosyphon System

We know that the density of hot water is less than that of the cold water. Thermosyphon cooling system works on the principle of circulating water by the density difference in the water. Figure 7.2 shows the thermosyphon system.

In Thermosyphon cooling system, when the engine runs, the hot water in the engine water jacket moves upwards due to the reduction in density. It moves further to the radiator through the hose provided and it is cooled in the radiator. The cold water at the bottom of the radiator enters into the engine and pushes the hot water upwards and occupies the place of the hot

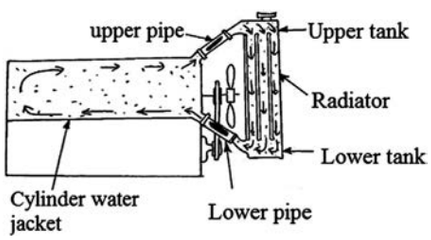



**Figure 7.2.2 Thermosyphon system**

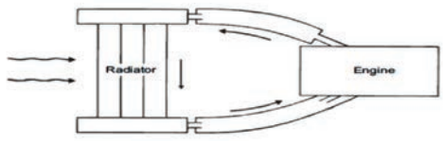



**Figure 7.2.2 Thermosyphon system**

water. This is called as conventional flow of water. In this type of cooling systems the radiator is placed just above the engine. When the water level is less and when the vehicle claims up or down this system does not work properly. Hence this type of cooling system is not is not used in modern automobiles.

### 7.2.3 Pump Circulation System

In this system a water pump is used to circulate the water. Hence this method is also called as pump circulation system. Nowadays, in many vehicles this type of cooling system is followed. In this system the conventional flow of water and the pressure of the centrifugal pump are combined and hence the system has the added advantage. Fig 7.2.3 shows the pump circulation cooling system.

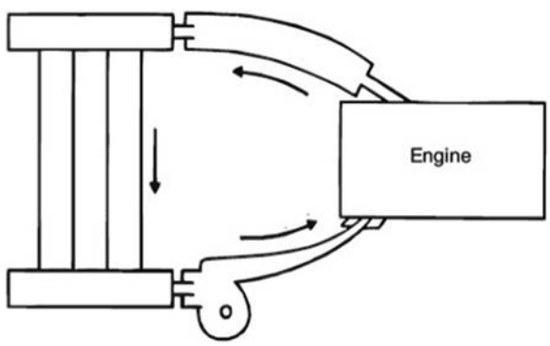



**Fig 7.2.3 pump circulation system**

The pump present in this system pumps the water into the water Jacket of the engine quickly. The pumped water takes away the heat from the engine cylinder and goes to the radiator. The hot water in the radiator is cooled as it enters into the shells of the radiator and also due to the opposing air coming from the atmosphere. As the air passes through the gaps of the shells,by touching the fins in the radiator the heat is removed from the water. The cooled water is again sent to the engine water jackets by the pump. By this way the pressurised or pump circulation cooling system rejects heat. The power to the water pump is taken from the V-pulley belt drive.

**The important components of this system are as follows,**

1. Water jacket
2. Water pump
3. Radiator
4. Thermostat valve
5. Fan and fan belt
6. Radiator hose

**The following are the Advantages of the water cooling system:**

1. The engine noise is reduced and runs smoothly
2. Cooling rate is high
3. The engine can be operated for more time than other type of cooling system engines
4. This is mostly used for multi cylinder engines
5. Temperature is controlled as per the requirement of the engine

**Draw backs:**

1. Maintenance is difficult
2. Maintenance cost is higher than air cooled engines
3. Water pump, water jacket, radiator and the radiator fan are the components needed.
4. Purified water has to be used.
5. Deposits and corrosion of the engine water jackets are possible when using impure water in this system

## 7.3 PARTS OF THE WATER COOLING SYSTEM

1. Radiator
2. Pressure cap
3. Thermostat
4. Water pump
5. Fan

### 7.3.1 Radiator

Radiator consists of three main parts such as upper tank, core and lower tank. The radiator core and connecting tube are placed in between the upper tank and lower tank. In a radiator the upper tank is connected to the upper surface of the engine through a separate hose. The lower tank is connected with the water pump through a separate hose connection.

The hot water coming out from the engine goes to the upper tank of the radiator through the hose connection. The water reaching the lower tank from upper tank of the radiator is cooled by the radiator core. Before reaching the lower tank the water is cooled by the air passing through the fins of the radiator core by the atmospheric air. The atmospheric air is sucked by the radiator fan and hence the hot water is cooled.

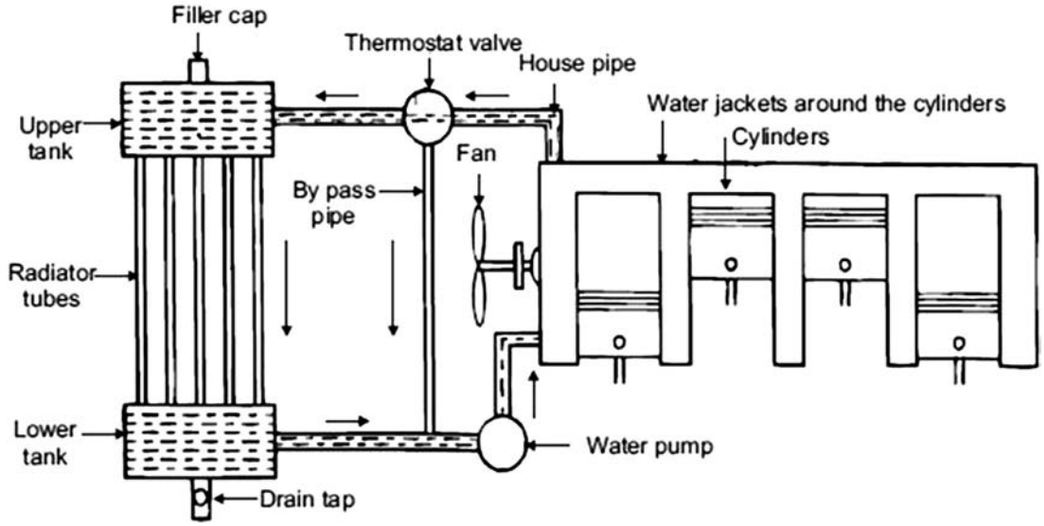



**Figure 7.3.1 Radiator**

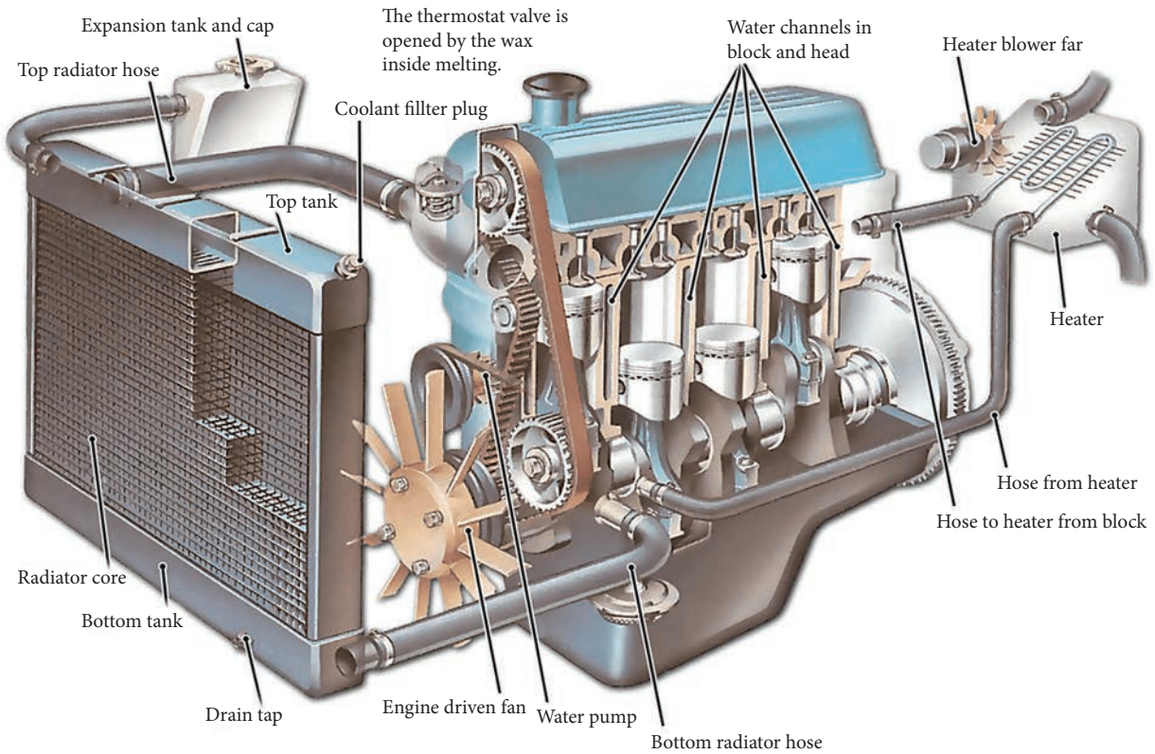



**Figure 7.3.1(a) Radiator**

**Types of radiator:**

We can classify radiators in to two types: they are

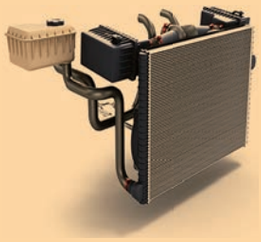
1. Tubular type radiator
2. Cellular type radiator (or) honey comb type radiator

DO YOU KNOW?

**What is a Radiator?**

Radiators are heat exchangers used to transfer thermal energy from one medium to another for the purpose of cooling and heating.

In automobiles it is responsible for preventing the car engine from overheating. It uses coolant (water or oil) to keep the engine running at a healthy temperature.



### 7.3.1(a) Tubular Type Radiator

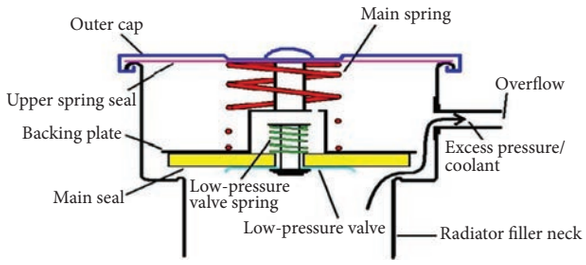
Small diameter tubes are used for connecting the upper and lower tank in the radiator. Water gets cooled by flowing through the number of tubes. The outside of the tube walls are attached with cooling fins. The fins and tubes are made up of pure copper. The fins are arranged horizontally with each other. In this type of radiators the cooling process is affected for the entire distance of tube if there is any blockage inside the tubes. This type of radiator is lower in weight and simple in structure and hence used in most of the vehicles.

**Figure 7.3.1(a) Tubular type radiator**

### 7.3.1(b) Cellular (or) Honeycomb Type Radiator

In this type of radiator, the hot water coming from the upper tank is allowed to pass through the tubes which are in honeycombed structure and gets cooled before reaching the lower tank. Two honeycombed structure tubes are connected in between the water flowing passage. By this structure, any block occurs inside the tube will not reduce the cooling performance. This type of radiator is mostly used in racing cars. They are costlier than tube type radiators. The figure 7.3.1(b)shows the picture of the honeycomb radiator.

**Fig 7.3.1(b) Honey comb type radiator**



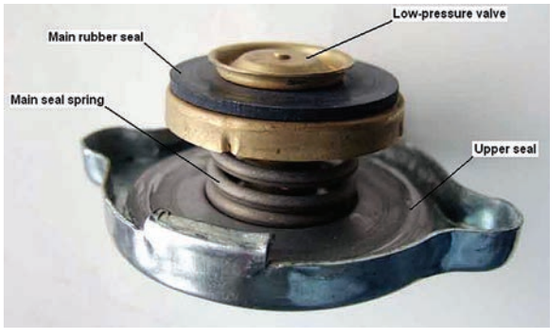




**Figure 7.4 Pressure Cap**

## 7.4 PRESSURE CAP

The component used to close the upper tank of the radiator is called as the radiator pressure cap. This cap prevents the flow of evaporated water (steam) outside from the upper tank. It also helps in avoiding flow of water outside the tank when the vehicle is traveling on any bumps and pot holes. In cold climatic countries water inside the radiator gets cooled naturally when the engine is at rest. In such condition vacuum may occur inside the tank. In such situations the exterior air comes inside the tank and replaces the vacuum area. The pressure in the pressure cap is released from the pressure valve by opening the pressure cap when the pressure inside the water tank is increased. When water is cooled the vacuum vale is opened and air is allowed to enter in to the radiator for protecting it.

## 7.5 THERMOSTAT

A specified temperature must be maintained in the cooling system to operate the engine safely and efficiently. This temperature is generally in the order of 70 deg to 80 deg for petrol engine and 80 deg to 85 deg for diesel engines. To maintain the temperature a thermostat arrangement is used. It blocks the coolant supply until the engine is warmed up. The thermostat valve is placed in between the engine and upper tank of the radiator. Thermostat housing consists of an inlet and outlet valve. Inside the housing the thermostat is placed. There is a bypass line arrangement for passing cooling water after the engine is started and until it reaches the required temperature. Cooling water starts to flow through the tubes by opening the thermostat valve when the engine reaches its specified temperature and the cooling water is sent to the upper tank in the radiator.

Basically there are two types of thermostat valves used in automobiles, they are

1. Bellows type thermostat
2. Wax type thermostat

### 7.5.1 Bellow Type Thermostat

In this type of thermostat, there is a frame in the upper side and valve in the lower side which is attached to the bellows. Bellows are filled with either alcohol or acetone which is easily evaporating chemicals. These chemicals have lower boiling points such as 70 deg to 80 deg. When the engine's coolant(water)

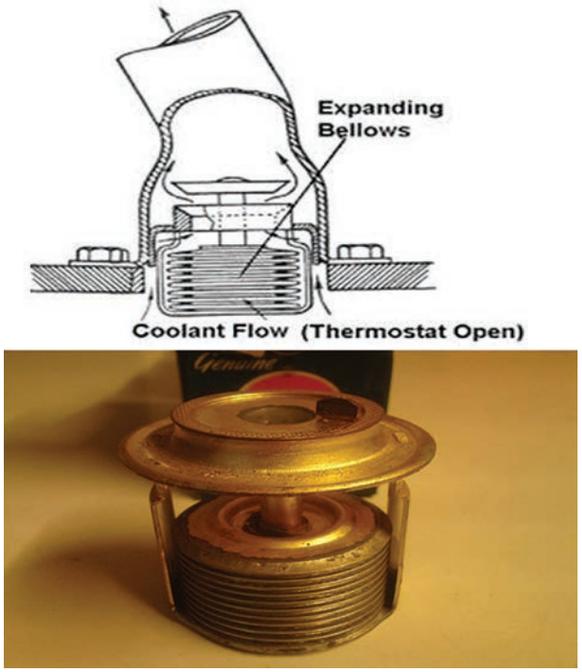



**Figure 7.5.1 Bellows Type Thermostat**

temperature reaches 70 to 80 deg Celsius, the chemicals inside the bellows get evaporated and allow the bellows to get expanded. The valve connected to the bellows now open and the water from the engine is sent to the upper tank of the radiator. When the cooling water temperature is reduced to 80 deg Celsius the chemicals inside the bellows get cooled and shrink. Now the valve connected to the bellows gets closed by this shrinkage. By this way thermostat controls cooling water circulation. The figure 7.8 shows the arrangement of the bellows type thermostat.

**Comparison of air cooled and water cooled system:**

| Air cooled system | Water cooled system |
|---|---|
| Air is a medium of cooling | Water is medium of cooling |
| Fins are used | Water jacket, water pump radiator, thermostat like components are used. |
| Construction is easy | Construction is difficult |
| Less space is required for installation. | Needs more space |
| Produces more noise | Less noise |
| It runs with all the climatic changes. | In cold climatic countries water will freeze. So this type is not used in such countries. |
| No sediments or corrosion in the system | Corrosion and sedimentation occur. |
| Cooling process is not affected by any damage of one or two fins | If there is a water leak, it affects the cooling process. |
| This system cools the engine randomly. | This system cools the engine uniformly. |
| Conductivity of temperature is low | High |
| Not suitable for multi cylinder engines | Suitable for multi cylinder engines |
| Production and maintenance cost are low | high |
| Mostly used in two wheelers | Used for Lower, medium and high duty vehicles. |

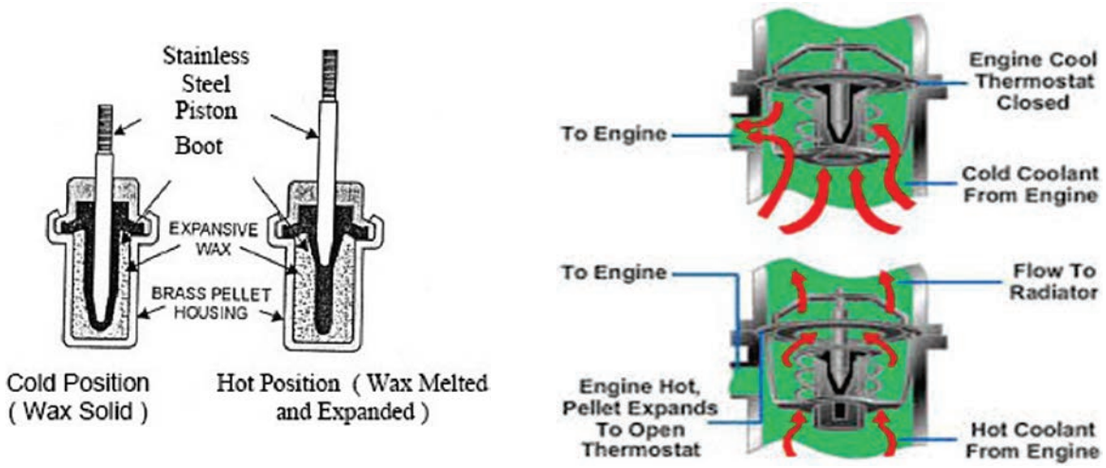



**Figure 7.5.2 Wax Type Thermostat**

### 7.5.2 Wax Type Thermostat

In this wax type thermostat there is a container which is filled with wax. This container is made up of high temperature conducting metals such as steel, brass or coppers as the material. The wax inside this container is fully sealed with rubberised material. A conical shaped movable steel pin with wax at one end and body at another end are connected with this type of thermostat. When the temperature of

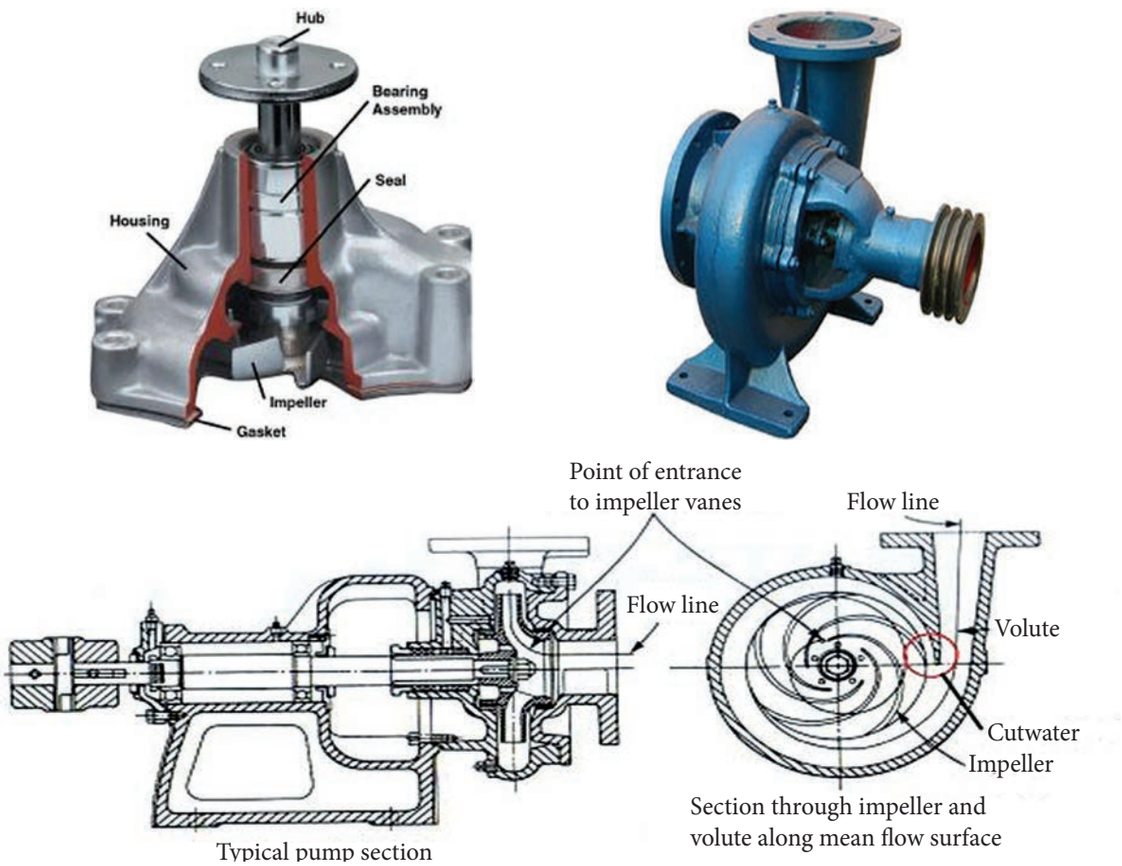



**Figure 7.6 Water Circulation Pump**

water gets increased, the wax gets melted and expands the bottom of steel pin in the opposite direction and pushes the seal. By compressing the seal against spring force in the container, the container valve opens. When container gets cooled the wax shrinks and reduces the pressure acting on the steel pin and the container comes to its original position. Now the container valve gets closed.

## 7.6 WATER PUMP

The water pump is placed in between in front of the engine's cylinder block and the radiator. The Pump impeller consists of a shaft, bearings and water seal which are placed inside the housing. Impeller is fixed to the shaft. The impeller has flat or bended vanes with round shape. Water seal is placed to arrest the leakage with the help of bearings.

**Working:**

When the impeller rotates, the water in between the blades are expelled out due to centrifugal force. The expelled water moves to the engine water jackets through the pipe with high pressure. The power to the impeller is given from the V-pulley arrangement. The water pump increases the circulation of cooling water. Fig 7.6 shows the water pump.

## 7.7 ENGINE FAN

When the vehicle runs, natural air is enough to cool the water. However during heavy load and during stationary conditions, air from the atmosphere coming by natural means to the radiator is not sufficient to cool the water. Hence fan is required to supply more air to radiator and to engine. Fan will be coupled with water pump pulley. The fan sucks more air and passes to the radiator core and then cools the water. There are many types of cooling fans used, which include,

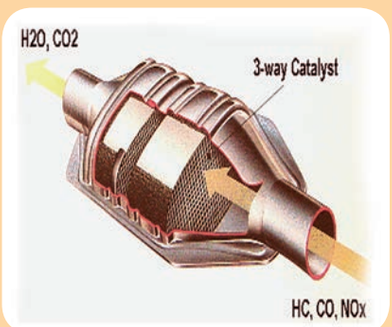
**Figure 7.7 Engine fan**


**What is catalytic converter?**

Catalytic converter was invented by Eugene Houdry in 1930.

Inside the converter, the gases flow through a dense honeycomb structure made from a ceramic and coated with the catalysts.

It reduces harmful NOx and CO emissions into harmless one.



1. Suction type
2. Blower type
3. Electrical type

## 7.8 ANTI-FREEZING SOLUTIONS

During cold climate conditions and at hill stations water generally gets frozen in the water cooling system. Due to this radiator core, water jacket and rubber hoses in the cooling system may get damaged. In addition more power is needed to start the engine. To overcome these difficulties chemical agents are added to the water to prevent it from freezing. These agents are called as anti freezing solutions. Some of the anti freeze solutions used in automobile are,

1. Methanol
2. Methyl alcohol

F5M3P

| Cooling System Capacity ▼ | ANTIFREEZE PROTECTION CHART (°F) — Quarts Required for Low-Temperature Protection ► | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| QUARTS | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 9 | 5° | -15° | -43° | -76° | | | | | | |
| 10 | 10° | -4° | -26° | -54° | -76° | | | | | |
| 11 | 12° | 0° | -14° | -40° | -60° | | | | | |
| 12 | 14° | 5° | -8° | -28° | -51° | | | | | |
| 13 | 15° | 8° | 0° | -14° | -44° | -61° | -76° | | | |
| 14 | 17° | 10° | 3° | -8° | -28° | -44° | -60° | | | |
| 15 | 18° | 12° | 5° | -4° | -14° | -35° | -54° | -76° | | |
| 16 | 19° | 14° | 9° | 1° | -9° | -28° | -44° | -60° | | |
| 17 | 20° | 16° | 11° | 3° | -2° | -15° | -31° | -60° | | |
| 18 | 21° | 17° | 12° | 5° | 0° | -13° | -26° | -33° | -53° | -76° |
| 19 | | 18° | 13° | 7° | 2° | -10° | -20° | -32° | -50° | -60° |
| 20 | | | 14° | 9° | 3° | -6° | -15° | -26° | -33° | -54° |
| 21 | | | 15° | 12° | 5° | 0° | -10° | -22° | -32° | -51° |
| 22 | | | 16° | 13° | 8° | 3° | -5° | -10° | -28° | -33° |
| 23 | | | 17° | 13° | 10° | 4° | -3° | -8° | -22° | -32° |


**Figure 7.8 Anti-freezing solutions**

3. Glycerin
4. Alcohol
5. Ethylene glycol

The above chemical components must have the requirements such as easily soluble in water, should withstand very high temperature, non-corrosiveness and should not deposit on the radiator core and rubber hose.

## 7.9 MAINTENANCE OF COOLING SYSTEM

The following are the check lists for the proper maintenance of the cooling systems

1. If there is any blockage occurs inside the radiator, water tubes and water jackets they have to be cleaned by flushing process.
2. The fan belt has to be replaced if it is exhausted or cracked.
3. The shape of fan blade has to be checked whether it is ok or not.
4. The cells must be straightened in the radiator if they are blended.
5. If there are any unwanted materials or insects nest are present in the radiator blades, they must be cleaned by using compressed air.
6. If there is any damage or hole occurs in the radiator tubes (rubber), it has to be replaced.
7. Fine tight must be given to the radiators tube clips.
8. Leakage in the radiator pipe, jar, tank, water pump, thermostat valve and drain gauge must be checked and leak proof has to be ensured.

9. Current status of thermostat valve has to be checked.
10. The radiator has to be inspected whether it is fixed properly or not.
11. The radiator gate valve has to be checked for its position which is closed properly.

**Troubles and remedies of cooling system:**

**Loss of cooling liquid:**

| Causes | Remedies |
|---|---|
| 1. Clips in the radiator hose pipes may have released. | Have to fine tight the clips |
| 2. There may be tearing occurred in the rubber tubes. | Has to be replaced. |
| 3. There may be a leakage occurred in the radiator cap portion. | Has to be corrected by using altering process. |
| 4. Cylinder head jacket may get defected. | Hasto change to a new one. |
| 5. Water pump or water seal may be damaged. | Gasket or seal should be replaced with a new one. |
| 6. Thermostat valve may be defected. | Hasto be changed with a new one. |
| 7. Drain gauge in the radiator may be loosen or broken. | Has to be tightened or has to be changed with new one. |

**Engine over heating:**

| Causes | Remedies |
|---|---|
| 1. There may be a reduction in water level in the radiator. | Has to be filled with required quantity of water. |
| 2. There may be water leakage during cooling process. | Leakage should be avoided by repairing the pipe line. |
| 3. Water pump may get damaged. | Has to be repaired. |
| 4. Fan belt may be loosened or teared. | Has to be tightened at loosened area or has to be changed with a new one. |
| 5. Thermostat valve may get damaged. | Has to be changed with a new one. |
| 6. There may be a chance for blockages inside the radiator water tubes. | Blockages should be cleaned by using reverse flushing process. |
| 7. There may be blockages in water jackets due to corrosion and sedimentation. | The water jackets have to be cleaned by removing blockages. |

| | |
|---|---|
| 8. There may be blockages in the radiator fins. | Have to be removed or cleaned. |
| 9. There may be an auto ignition. | Has to be corrected. |
| 10. There may be changes in valve timing and ignition timing. | Has to be corrected. |
| 11. There may carbon deposition in the cylinder head, valves, piston and combustion chamber. | Need to be cleaned by De carbonizing technique. |
| 12. There may be defects in break or clutch | Have to be corrected. |
| 13. The vehicle may be over loaded. | Enough amount of goods to be carried. |
| 14. There may be blockages in the exhaust tail pipe. | Have to be removed. |
| 15. Engine bearing may get damaged or broken. | Has to be changed with a new one. |
| 16. There may be blockages in air cleaner or air inlet manifold. | Have to be removed or corrected. |
| 17. Fuel injection timing may be incorrect. | Has to be checked and corrected. |

**Over noise from water pump:**

| Causes | Remedies |
|---|---|
| 1. Impeller in the water pump may be loosened. | Has to be tightened. |
| 2. Pulley in the pump shaft may be loosened. | Has to be tightened. |
| 3. Impeller may rotate unevenly inside the pump housing. | Has to be fixed at the right place. |
| 4. Bearing in the water pump may damage or lubricating oil may not be there in the bearing. | Oil has to be applied or changed with new bearing. |
| 5. Impeller may be broken. | Has to be checked and corrected. |

**Rapid wear on fan belt:**

| Causes | Remedies |
|---|---|
| 1. Belt may be under over tight | Has to be adjusted for exact tension. |
| 2. Belt may be affixed with improper length. | The belt that is recommended by the manufacturer has to be used. |
| 3. There may be a deposition of oil or grease in the belt. | Clean the belt with petrol and fix it. |
| 4. Belt may not be fixed properly to the pulley. | Affix the belt properly on the pulley. |

**Over noise from radiator fan:**

| Causes | Remedies |
|---|---|
| 1. Fan belt may be fixed with heavy tight. | Has to be adjusted for exact tension. |
| 2. Fan belt may be worn out. | Has to be changed with a new one. |
| 3. Fan pulley may be loosened. | Has to be tightened. |
| 4. There may be high amount of ply in the water pump shaft. | Has to be adjusted for correct scale of ply. |
| 5. Fan blades may be expanded. | Have to be changed with a new fan. |
| 6. Water pump pulley may leave its position and hanged on the radiators body. | Has to be checked and repaired. |

**Student Activity**

**I. Students have to follow the following safety precautions:**

1. Students should visit the nearby workshops to study the process of engine cooling with external fins and should have a hands-on experience on engine dismantling and assembling.
2. Students should visit the nearby workshops to study the process of cooling engines with water and should a report with the sketch of radiator tank, water pump and thermostat valve.

## Glossary

| | | |
|---|---|---|
| Decarbonizing | - | கரி நீக்குதல் |
| Pressure Cap | - | அழுத்த நிறுத்தி மூடி |
| Centrifugal Pump | - | மையவிலக்கு தூக்கி |
| Thermostat | - | வெப்ப கட்டுப் படுத்தி |
| Water Pump | - | தண்ணீர் தூக்கி |
| Freezing | - | உறைதல் |
| Water Jacket | - | தண்ணீர் உரைகள் |
| Deposition | - | கசடு படிதல் |
| Blockages | - | அடைப்புகள் |
| Corrosion | - | அரிப்பு |

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## SAMPLE QUESTIONS

### Choose the correct answer

1. Which chemical is used to prevent freezing of cooling water?
   a) Ethyl glycol
   b) Acetone
   c) Methane
2. Which valve is located in radiator pressure cap?
   a) Pressure valve
   b) Thermostat valve
   c) Pressure and vacuum valve
3. How many types of radiators according to the flow of water and Air?
   a) Two
   b) Three
   c) Four
4. Which is used to prevent engine over cooling?
   a) Water pump
   b) Radiator
   c) Thermostat
5. What is the effect if low water level in radiator?
   a) Engine if over heated
   b) Fan belt wear quickly
   c) More noise in water pump

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### Answer the following questions

1. What are the disadvantages due to the over heat of the engine?
2. What are the disadvantages due to the over cool of the engine?
3. What are the advantages and disadvantages of the Air Cooling system?
4. What are the different types of Water Cooling system?
5. What are the important parts of the Pump circulation system?
6. What are the merits and demerits of the water cooling system?
7. What are the parts in the cooling system?
8. Name the types of the radiator.
9. What is meant by radiator pressure cap?
10. What is meant by Thermostat valve?
11. Tabulate the difference between Air cooling and water cooling system.
12. Explain the working principles of water pump.