AUTOMOTIVE COOLING SYSTEMS FOR INTERNAL COMBUSTION ENGINES – An Introduction

Almost all cars currently use what is called a four-stroke combustion cycle to convert gasoline into motion. Modern automotive internal combustion engines generate a huge amount of heat. It has been stated that a typical average-sized vehicle can generate enough heat to keep a 5-room house comfortably warm during zero degree weather.

The Necessity of having a good Engine Cooling System

- An Engine Cooling System is a system that controls the engine temperature, is known as a cooling system. The cooling system is provided in the IC engine for the following reasons:
- The temperature of the burning gases in the engine cylinder reaches up to 1500 to 2000°C, which is above the melting point of the material of the cylinder body and head of the engine. (Platinum, a metal which has one of the highest melting points, melts at 1750 °C, iron at 1530°C and aluminium at 657°C.) Therefore, if the heat is not dissipated, it would result in the failure of the cylinder material.
- Due to very high temperatures, the film of the lubricating oil will get oxidized, thus producing carbon deposits on the surface. This will result in piston seizure.
- Due to overheating, large temperature differences may lead to a distortion of the engine components due to the thermal stresses set up. This makes it necessary for, the temperature variation to be kept to a minimum.
- Higher temperatures also lower the volumetric efficiency of the engine.

The two main requirements of an efficient cooling system are:

1. It must be capable of removing only about 30% of the heat generated in the combustion chamber. Too much removal of heat lowers the thermal efficiency of the engine.
2. It should remove heat at a fast rate when the engine is hot. During the starting of the engine, the cooling should be very slow so that the different working parts reach their operating temperatures in a short time.

There are two Types of Engine Cooling System; there are two types of cooling systems:

- Air Cooling System
- Liquid - Cooling system

The Air Cooling System
Found mostly in older cars and motorcycles, an air-cooled system is where the engine block is covered in aluminium fins that conduct the heat away from the cylinder. A powerful fan forces air over these fins, which cools the engine by transferring the heat to the air.

The amount of heat reduced by the air-cooling depends upon factors such as factors; the total area of the fin surfaces, the velocity / amount of the cooling air and also the temperature of the fins as well as the cooling air.

Air-cooling is mostly used in less horsepower engines like, motorcycles, scooters, small cars and small aircraft engines where the forward motion of the machine gives good velocity to cool the engine. Air-cooling is also provided in some small industrial engines.

The Advantages of an Air Cooled System:

They are cheaper to manufacture. They need less care and maintenance.

The design of air-cooled engine is simple. They are lighter in weight than liquid - cooled engines due to the absence of water jackets, radiator, circulating pump and the weight of the cooling water.

This system of cooling is particularly advantageous where there are extreme climatic conditions in the arctic or where the evaporation factor of liquids is higher- deserts. There is no risk of damage from frost, such as cracking of cylinder jackets or radiator water tubes.

Liquid Cooling System:
The liquid cooled systems are the ones that are used the most these days. In an automotive with Liquid Cooling System, the heat is carried away by the use of a heat absorbing coolant that circulates through the engine, especially around the combustion chamber in the cylinder head area of the engine block.

The coolant is pumped through the engine, then after absorbing the heat of combustion is circulated to the radiator where the heat is transferred to the atmosphere. The cooled liquid is then transferred back into the engine to repeat the process.

This Cooling system has four types of systems:

- Direct Or Non-Return System
- Thermo - Syphone System
- Hopper System
- Pump / Forced Circulation System

Direct or Non-Return Water Cooling System: This is suitable for large installations and where plenty of water is available. The water from a storage tank is directly supplied to the engine cylinder. The hot water is not cooled for reuse but simply discharges. The low H.P. engine, coupled with the irrigation pump is an example.

Thermo-Syphone Water Cooling System: This system works on the principle that hot water being lighter rises up and the cold water being heavier goes down. In this system the radiator is placed at a higher level than the engine for the easy flow of water towards the engine.

Heat is conducted to the water jackets from where it is taken away due to convection by the circulating water. As the water jacket becomes hot, it rises to the top of the radiator.

Cold water from the radiator takes the place of the rising hot water and in this way a circulation of water is set up m the system. This helps in keeping the engine at working temperature.

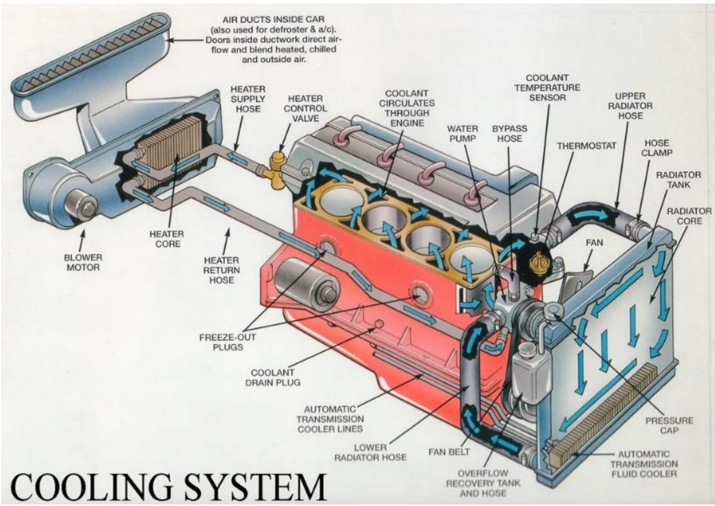
Hopper Water Cooling System: This also works on the same principle as the thermo-syphone system. In this there is a hopper on a jacket containing water, which surrounds the engine cylinder. In this system, as soon as water starts boiling, it is replaced by cold water. An engine fitted with this system cannot run for several hours without it being refilled with water.

Pump / Force Circulation Water Cooling System: This system is similar in construction to the thermo-syphone system except that it makes use of a centrifugal pump to circulate the water throughout the water jackets and radiator

The water flows from the lower portion of the radiator to the water jacket of the engine through the centrifugal pump. After the circulation water comes back to the radiator, it loses its heat by the process of radiation. This system is employed in cars, trucks, tractors, etc

The main parts in the Liquid - Cooling System are:

- Radiator and Pressure Cap
- Pump
- Radiator Fan
- Plumbing
- Fluids
- Thermostat Valve
- Temperature Gauge
- Hose pipes.



Radiator

A radiator is a type of heat exchanger. It is designed to transfer heat from the hot flows through it to the air blown through it by the fan. Most modern cars use aluminium radiators. The radiators are made by brazing thin aluminium fins to flattened aluminium tubes. The coolant flows from the inlet to the outlet through many through many tubes mounted in a parallel arrangement. The fins conduct the heat from the tubes and transfer it to the air flowing through the radiator.

There are normally three types of Radiators:

- Gilled Tube Radiator
- Tubular Radiator
- Honey Comb or Cellular Radiator

Gilled Tube Radiator: This is perhaps the oldest type of radiator, although it is still in use. In this, water flows inside the tubes. Each tube has a large number of annular rings or fins pressed firmly over its outside surface.

Tubular Radiator: The only difference between a gilled tubes radiator and a tubular one is that in this case there are no separate fins for individual tubes. The radiator vertical tubes pass through thin fine copper sheets which run horizontally.

Honey Comb or Cellular Radiator: The cellular radiator consists of a large number of individual air cells which are surrounded by water. In this, the clogging of any passage affects only a small parts of the cooling surface. However, in the tubular radiator, if one tube becomes clogged, the cooling effect of the entire tube is lost.

Pressure cap:

The radiator cap actually increases the boiling point of your coolant by about 45 F (25 C). How does this simple cap do this? The same way a pressure cooker increases the boiling temperature of water. The cap is actually a pressure release valve, and on car is usually set at 15 psi. The boiling point of water increases when the water is placed under pressure. When the fluid in the cooling system heats up, it expands, causing the pressure to build up. The cap is the only place where this pressure can escape so the setting of the spring defines the pressure in the cooling system.

When the pressure reaches 15 psi, the pressure pushes the valve open, allowing coolant to escape from the cooling system. This coolant flows through the overflow tube into the bottom of the overflow tank. This arrangement keeps air out of the system.

When the radiator cools back down, a vacuum is created in the cooling system that pulls open another spring loaded valve, sucking water back in from the bottom of the overflow tank to replace the water that was expelled.

The Pump

The pump is a simple centrifugal pump driven by a belt connected to the crankshaft of the engine. The pump circulates fluid whenever the engine is running. The water pump uses centrifugal force to send fluid to the outside while it spins, causing fluid to be drawn from the centre continuously. The inlet to the pump is located near the centre so that fluid returning from the radiator hits the pump vanes. The pump vanes fling the fluid to the outside of the pump, where it can enter the engine. The fluid leaving the pump flows first through the engine block and cylinder head, then into the radiator and finally back to the pump.

Radiator Fan
A radiator fan is used to draw the air towards the radiator and help in the cooling process.
The radiator fan has four or more blades that spin rapidly to provide sufficient air that would cool the engine. It is usually mounted between the radiator and the engine so that the air can easily get to the radiator. Some cars have an additional fans in front of the radiator in order to draw more cool air into the engine. Especially when it is so hot and the vehicle isn't moving fast enough, very little cool air reaches the radiator, and thus, the engine is not cooled properly.

Plumbing
The cooling system has a lot of plumbing. We'll start at the pump and work our way through the system. The pump sends the fluid into the engine block, where it makes its way through passages in the engine around the cylinders. Then it returns through the cylinder head of the engine. The thermostat is located where the fluid leaves the engine. The plumbing around the thermostat sends the fluid back to the pump directly if the thermostat is closed. If it is open, the fluid goes through the radiator first and then back to the pump. There is also a separate circuit for the heating system. This circuit takes fluid from the cylinder head and passes it through a heater core and then back to the pump.

Fluid
Cars operate in a wide variety of temperatures, from well below freezing to well over 100 F (38 C).So whatever fluid is used to cool the engine has to have a very low freezing point, a high boiling point, and it has to have the capacity to hold a lot of heat. Water is one of the most effective fluids for holding heat, but water freezes at too high a temperature to be used in car engines.

The fluid that most cars use is a mixture of water and ethylene glycol ($C_2H_6O_2$), also known as antifreeze. By adding ethylene glycol to water, the boiling and freezing points are improved significantly. The temperature of the coolant can sometimes reach 250 to 275 F (121 to 135 C). Even with ethylene glycol added, these temperatures would boil the coolant, so something additional must be done to raise its boiling point.

The cooling system uses pressure to further raise the boiling point of the coolant. Just as the boiling temperature of water is higher in a pressure cooker, the boiling temperature of coolant is higher if you pressurize the system. Most cars have a pressure limit of 14 to 15 pounds per square inch (psi), which raises the boiling point another 45 F (25 C) so the coolant can withstand the high temperatures.

Thermostat
A thermostat allows the engine to heat up quickly, and then to keeps the engine at a constant temperature. It does this by regulating the amount of water that goes through the radiator. At low temperatures, the outlet to the radiator is completely blocked -- all of the coolant is recirculated back through the engine. Once the temperature of the coolant rises to 180 and 195 F (82 - 91 C), the thermostat starts to open, allowing fluid to flow through the radiator. By the time the coolant reaches 200 to 218 F (93 - 103 C), the thermostat is open all the way.

Other types of additional Engine Cooling System: Charge Air Coolers / Intercooler / After Coolers

A charge air cooler is simply an all-encompassing term, meaning that it cools the turbo's air charge, before it is routed into the engine. Usually a charge air cooler means an air-to-air cooler, where the heat is rejected using ambient air flowing through the heat exchanger, much like the engine's coolant radiator.

These heat exchangers are also referred to as a Charge Air Cooler (CAC), Intercooler or Aftercooler. These terms are commonly used interchangeably. The term intercooler refers to the fact that this heat exchanger performs its task in between two stages of compression, i.e., between compression in the compressor and compression in the cylinder of the engine.

The term aftercooler refers to the charge air being cooled after being compressed in the compressor. Increasing demand for improvements in fuel economy and exhaust emissions that has made the charge air cooler an important component of most modern turbocharged engines.

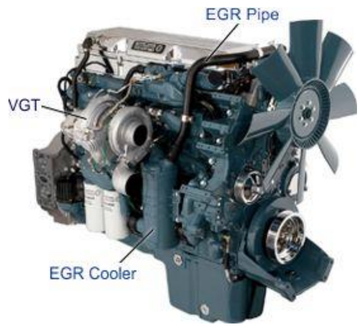
Oil Coolers

Oil in an automobile lubricates and helps regulate temperatures of moving metallic components of an engine or transmission. The surfaces of these components cause friction, which generates heat; without an oil cooler, oil can prematurely break down, eventually resulting in engine wear and failure.

There are two types of oil coolers, the tube and fin system, and the shell and tube system. The tube and fin system is normally located in front of the radiator, and oil passing through copper tubes is cooled by air through the system's fins. The shell and tube system circulates water or liquid coolant around a series of tubes to cool heated oil.

Standard vehicles generally have no need for oil coolers because their radiators are adequate to provide the cooling requirements of engines. Oil coolers are typically installed on specialized vehicles, such as high-performance cars, racing cars, towing trucks and oversized vehicles that haul heavy loads.

Exhaust Gas Recirculation (EGR) Coolers



Found in most types of diesel engines: from light-duty engines through medium- and heavy-duty engine applications the application of EGR is mainly for reduction of NOx.

The EGR system is a high pressure loop, cooled EGR configuration. A portion of the exhaust is channelled through an EGR control valve to the EGR cooler. From the cooler, EGR flows to a throttle valve assembly where it is mixed with filtered, high-pressure, fresh combustion air that has been cooled by an intercooler to recover some of its density.