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Cooling Systems in Automobiles & Cars

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Abstract: Most internal combustion engines are fluid cooled using either air (a gaseous fluid) or a liquid coolant run through a heat exchanger (radiator) cooled by air.

In air cooling system, heat is carried away by the air flowing over and around the cylinder. Here fins are cast on the cylinder head and cylinder barrel which provide additional conductive and radiating surface. In water-cooling system of cooling engines, the cylinder walls and heads are provided with jacket through which the cooling liquid can circulate.

An internal combustion engine produces power byburning fuel within the cylinders; therefore, it is oftenreferred to as a "heat engine." However, only about25% of the heat is converted to useful power. Whathappens to the remaining 75 percent? Thirty to thirtyfive percent of the heat produced in the combustionchambers by the burning fuel are dissipated by thecooling system along with the lubrication and fuelsystems. Forty to forty- five percent of the heatproduced passes out with the exhaust gases. If this heatwere not removed quickly, overheating and extensive damage would result. Valves would burn and warp,lubricating oil would break down, pistons and bearingwould overheat and seize, and the engine would soonstop.The necessity for cooling may be emphasized byconsidering the total heat developed by an ordinary six-cylinder engine.

I. INTRODUCTION

We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300-2500°C. This is a very high temperature and may result into burning of oil film between the moving parts and may result into seizing or welding of the same.

So, this temperature must be reduced to about 150-200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most efficient operating temperature.

It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling.

It is also to be noted that :

(a) About 20-25% of total heat generated is used for producing brake power (useful work).

(b) Cooling system is designed to remove 30-35% of total heat.

(c) Remaining heat is lost in friction and carried away by exhaust gases.

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What the cooling system does for an engine.

1. Although gasoline engines have improved a lot, they are still not very efficient at turning chemical energy into mechanical power.
2. Most of the energy in the gasoline (perhaps 70%) is converted into heat, and it is the job of the cooling system to take care of that heat. In fact, the cooling system on a car driving down the freeway dissipates enough heat to heat two average-sized houses!
3. The primary job of the cooling system is to keep the engine from overheating by transferring this heat to the air, but the cooling system also has several other important jobs.
4. The engine in your car runs best at a fairly high temperature.
5. When the engine is cold, components wear out faster, and the engine is less efficient and emits more pollution.
6. So another important job of the cooling system is to allow the engine to heat up as quickly as possible, and then to keep the engine at a constant temperature.

What is a Cooling System?

A typical 4 cylinder vehicle cruising along the highway at around 50 miles per hour, will produce 4000 controlled explosions per minute inside the engine as the spark plugs ignite the fuel in each cylinder to propel the vehicle down the road. Obviously, these explosions produce an enormous amount of heat and, if not controlled, will destroy an engine in a matter of minutes. Controlling these high temperatures is the job of the cooling system.

The modern cooling system has not changed much from the cooling systems in the model T back in the '20s. Oh sure, it has become infinitely more reliable and efficient at doing it's job, but the basic cooling system still consists of liquid coolant being circulated through the engine, then out to the radiator to be cooled by the air stream coming through the front grill of the vehicle.

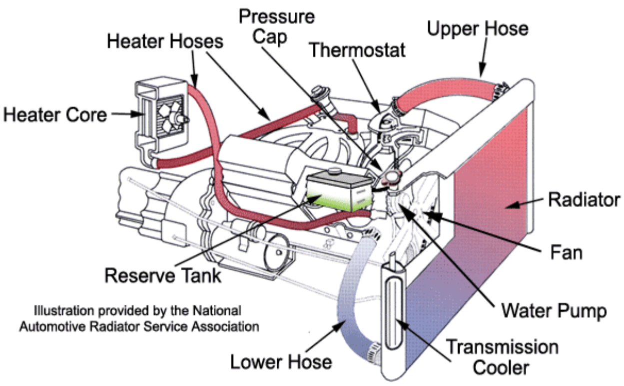
Today's cooling system must maintain the engine at a constant temperature whether the outside air temperature is 110 degrees Fahrenheit or 10 below zero. If the engine temperature is too low, fuel economy will suffer and emissions will rise. If the temperature is allowed to get too hot for too long, the engine will self destruct.

How Does a Cooling System Work?

Actually, there are two types of cooling systems found on motor vehicles: Liquid cooled and Air cooled. Air cooled engines are found on a few older cars, like the original Volkswagen Beetle, the Chevrolet Corvair and a few others. Many modern motorcycles still use air cooling, but for the most part, automobiles and trucks use liquid cooled systems and that is what this article will concentrate on.

The cooling system is made up of the passages inside the engine block and heads, a water pump to circulate the coolant, a thermostat to control the temperature of the

coolant, a radiator to cool the coolant, a radiator cap to control the pressure in the system, and some plumbing consisting of interconnecting hoses to transfer the coolant from the engine to radiator and
also to the car's heater system where hot coolant is used to warm up the vehicle's interior on a cold day.
A cooling system works by sending a liquid coolant through passages in the engine block and heads. As the coolant flows through these passages, it picks up heat from the engine. The heated fluid then makes its way through a rubber hose to the radiator in the front of the car. As it flows through the thin tubes in the radiator, the hot liquid is cooled by the air stream entering the engine compartment from the grill in front of the car. Once the fluid is cooled, it returns to the engine to absorb more heat. The water pump has the job of keeping the fluid moving through this system of plumbing and hidden passages.



A thermostat is placed between the engine and the radiator to make sure that the coolant stays above a certain preset temperature. If the coolant temperature falls below this temperature, the thermostat blocks the coolant flow to the radiator, forcing the fluid instead through a bypass directly back to the engine. The coolant will continue to circulate like this until it reaches the design temperature, at which point, the thermostat will open a valve and allow the coolant back through the radiator.

Circulation

The coolant follows a path that takes it from the water pump, through passages inside the engine block where it collects the heat produced by the cylinders. It then flows up to the cylinder head (or heads in a V type engine) where it collects more heat from the combustion chambers. It then flows out past the thermostat (if the thermostat is opened to allow the fluid to pass), through the upper radiator hose and into the radiator. The coolant flows through the thin flattened tubes that make up the core of the radiator and is cooled by the air flow through the radiator. From there, it flows out of the radiator, through the lower radiator hose and back to the water pump. By this time, the coolant is cooled off and ready to collect more heat from the engine.
The capacity of the system is engineered for the type and size of the engine and the work load that it is expected to undergo. Obviously, the cooling system for a larger, more powerful V8 engine in a heavy vehicle will need considerably more capacity then a compact car with a small 4 cylinder engine. On a large vehicle, the radiator is larger with many more tubes for the coolant to flow through. The radiator is also wider and taller to capture more air flow entering the vehicle from the grill in front.

Antifreeze

The coolant that courses through the engine and associated plumbing must be able to withstand temperatures well below zero without freezing. It must also be able to handle engine temperatures in excess of 250 degrees without boiling. A tall order for any fluid, but that is not all. The fluid must also contain rust inhibiters and a lubricant.
The coolant in today's vehicles is a mixture of ethylene glycol (antifreeze) and water. The recommended ratio is fifty-fifty. In other words, one part antifreeze and one part water. This is the minimum recommended for use in automobile engines. Less antifreeze and the boiling point would be too low. In certain climates where the temperatures can go well below zero, it is permissible to have as much as 75% antifreeze and 25% water, but no more than that. Pure antifreeze will not work properly and can cause a boil over.

II. TYPES OF COOLING SYSTEMS

There are mainly two types of cooling systems :
(a) Air cooled system, and
(b) Water cooled system.

Introduction to air cooling:

Turbo cooling have been adopted for IC-engines at least since 1975 by I Kalmar and J Antal for Nox reduction in CI-engines. Engineers from SWRI contributed in the same subject between 1990-1991 with adress to M Shahed and RH Thring in the "Clean Diesel Project" Volvo Truck also performed a MSc thesis work carried out by Jan Wiman in 1991.

III. AIR COOLING SYSTEM

Air cooled system is generally used in small engines say up to 15-20 kW and in aero plane engines. In this system fins or extended surfaces are provided on the cylinder walls, cylinder head, etc. Heat generated due to combustion in the engine cylinder will be conducted to the fins and when the air flows over the fins, heat will be dissipated to air.

The amount of heat dissipated to air depends upon :

(a) Amount of air flowing through the fins.b) Fin surface area.
(c) Thermal conductivity of metal used for fins.

Advantages of Air Cooled System

Following are the advantages of air cooled system :
(a) Radiator/pump is absent hence the system is light.
(b) In case of water cooling system there are leakages, but in this case there are no leakages.
(c) Coolant and antifreeze solutions are not required.
(d) This system can be used in cold climates, where if water is used it may freeze.

Disadvantages of Air Cooled System

(a) Comparatively it is less efficient.
(b) It is used in aero planes and motorcycle engines where the engines are exposed to air directly.

Air cooling

Cars and trucks using direct air cooling (without an intermediate liquid) were built over a long period from the very beginning and ending with a small and generally unrecognized technical change.

Before World War II, water-cooled cars and trucks routinely overheated while climbing mountain roads, creating geysers of boiling cooling water. This was considered normal, and at the time, most noted mountain roads had auto repair shops to minister to overheating engines.
ACS (Auto Club Suisse) maintains historical monuments to that era on the **Susten Pass** where two radiator refill stations remain (See a picture here). These have instructions on a cast metal plaque and a spherical bottom watering can hanging next to a water spigot. The spherical bottom was intended to keep it from being set down and, therefore, be useless around the house, in spite of which it was stolen, as the picture shows.
During that period, European firms such as Magirus-Deutz built air-cooled diesel trucks, Porsche built air-cooled farm tractors, and Volkswagen became famous with air-cooled passenger cars. In the USA, Franklin built air-cooled engines. The Czechoslovakia based company Tatra is known for their big size air-cooled V8 car engines, Tatra engineer Julius Mackerle published a book on it. Air-cooled engines are better adapted to extremely cold and hot environmental weather temperatures, you can see air-cooled engines starting and running in freezing conditions that stuck water-cooled engines and continue working when water-cooled ones start producing steam jets.

IV. WATER COOLING SYSTEM

In this method, cooling water jackets are provided around the cylinder, cylinder head, valve seats etc. Thewater when circulated through the jackets, it absorbs heat of combustion. This hot water will then be cooling in the radiator partially by a fan and partially by the flow developed by the forward motion of the vehicle. The cooled water is again recirculated through the water jackets.

There are two types of water cooling system :
Thermo Siphon System
In this system the circulation of water is due to difference in temperature (i.e. difference in densities) of water. So in this system pump is not required but water is circulated because of density difference only.

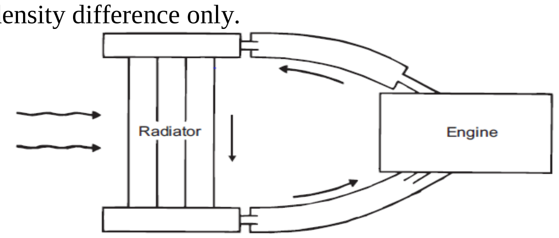


Figure 5.2 : Thermo Siphon System of Cooling

Pump Circulation System
In this system circulation of water is obtained by a pump. This pump is driven by means of engine output shaft through V-belts

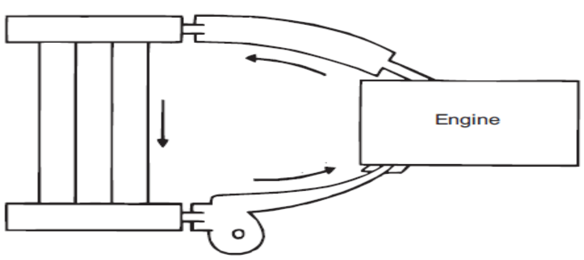


Figure 5.3 : Pump Circulation System

Components of Water Cooling System:

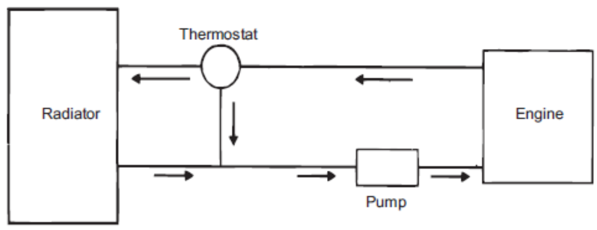


Figure 5.4 : Water Cooling System using Thermostat Valve

Water cooling system mainly consists of :
(a) Radiator,
(b) Thermostat valve,
(c) Water pump,
(d) Fan,
(e) Water Jackets, and
(f) Antifreeze mixtures.

Radiator

It mainly consists of an upper tank and lower tank and between them is a core. The upper tank is connected to the water outlets from the engines jackets by a hose pipe and the lover tank is connect to the jacket inlet through water pump by means of hose pipes.
There are 2-types of cores :
(a) Tubular
(b) Cellular as shown.
When the water is flowing down through the radiator core, it is cooled partially by the fan which blows air and partially by the air flow developed by the forward motion of the vehicle. As shown through water passages and air passages, wafer and air will be flowing for cooling purpose. It is to be noted that radiators are generally made out of copper and brass and their joints are made by soldering.

Thermostat Valve

It is a valve which prevents flow of water from the engine to radiator, so that engine readily reaches to its maximum efficient operating temperature. After
attaining maximum efficient operating temperature, it automatically begins functioning. Generally, it prevents the water below 70°C. Bellow type thermostat valve which is generally used. It contains a bronze bellow containing liquid alcohol. Bellow is connected to the butterfly valve disc through the link. When the temperature of water increases, the liquid alcohol evaporates and the bellow expands and in turn opens the butterfly valve, and allows hot water to the radiator, where it is cooled.

Water Pump

It is used to pump the circulating water. Impeller type pump will be mounted at the front end. Pump consists of an impeller mounted on a shaft and enclosed in the pump casing. The pump casing has inlet and outlet openings. The pump is driven by means of engine output shaft only through belts. When it is
driven water will be pumped.

Fan

It is driven by the engine output shaft through same belt that drives the pump. It is provided behind the radiator and it blows air over the radiator for cooling purpose.

Water Jackets
Cooling water jackets are provided around the cylinder, cylinder head, valve seats and any hot parts which are to be cooled. Heat generated in the engine cylinder, conducted through the cylinder walls to the jackets. The water flowing through the jackets absorbs this heat and gets hot. This hot water will then be cooled in the radiator.

Antifreeze Mixture
In western countries if the water used in the radiator freezes because of cold climates, then ice formed has more volume and produces cracks in the cylinder blocks, pipes, and radiator. So, to prevent freezing antifreeze mixtures or solutions are added in the cooling water.
The ideal antifreeze solutions should have the following properties :
(a) It should dissolve in water easily.
(b) It should not evaporate.
(c) It should not deposit any foreign matter in cooling system.
(d) It should not have any harmful effect on any part of cooling system.
(e) It should be cheap and easily available.
(f) It should not corrode the system.
No single antifreeze satisfies all the requirements. Normally following are used as antifreeze solutions :
(a) Methyl, ethyl and isopropyl alcohols.
(b) A solution of alcohol and water.
(c) Ethylene Glycol.
(d) A solution of water and Ethylene Glycol.
(e) Glycerin along with water, etc.

Advantages of Water Cooling System
(a) Uniform cooling of cylinder, cylinder head and valves.
(b) Specific fuel consumption of engine improves by using water cooling system.
(c) If we employ water cooling system, then engine need not be provided at the front end of moving vehicle.
(d) Engine is less noisy as compared with air cooled engines, as it has water for damping noise.

Disadvantages of Water Cooling System
(a) It depends upon the supply of water.
(b) The water pump which circulates water absorbs considerable power.
(c) If the water cooling system fails then it will result in severe damage of engine.
(d) The water cooling system is costlier as it has more number of parts. Also it requires more maintenance and care for its parts.

Engine cooling system
The cooling system is a key to efficient engine operation. An internal combustion engine only uses one-third of the power produced. One-third heats oil or goes out the exhaust and one-third must be controlled by the water cooling system.
1. An engine wears out four times faster if it continually operates at a low temperature.
2. A tractor doing the same work will use 3.8 gallons of fuel per hour at 400 and only 2.8 gallons of fuel per hour at 1800. Warm up your engine before putting under load.
3. Too much heat can damage an engine, increase oxidation to the oil, and reduce the effectiveness of the additives in the oil.
4. Excessive heat may attack seals, liners, gaskets, and sealants.
5. A thin (1/16") layer of calcium carbonate build-up on an engine is equal to 4" of solid cast iron in heat transfer.

Antifreeze
1. Antifreeze should be changed every year unless you add chemical inhibitors to reinforce the rust inhibiting ability.
2. Diluting antifreeze one-third to one-half with water is usually recommended. More than two-thirds antifreeze is too much. It offers less freezing protection rather than more.
3. Distilled or rain water is better than plain water because of the corrosion deposits.
4. Ethylene-Glycol antifreeze in the cooling system raises the boiling temperature substantially. This makes for greater heat dissipation.
5. Antifreeze is not a waste of money if you consider risk factor alone. It is insurance that makes sense.

Internal combustion engine cooling over view:
Heat engines generate mechanical power by extracting energy from heat flows, much as a water wheel extracts mechanical power from a flow of mass falling through a distance. Engines are inefficient, so more heat energy enters the engine than comes out as mechanical power; the difference is waste heat which must be removed. Internal combustion engines remove waste heat through cool intake air, hot exhaust gases, and explicit engine cooling.
Engines with higher efficiency have more energy leave as mechanical motion and less as waste heat. Some waste heat is essential: it guides heat through the engine, much as a water wheel works only if there is some exit velocity (energy) in the waste water to carry it away and make room for more water. Thus, all heat engines need cooling to operate.
Cooling is also needed because high temperatures damage engine materials and lubricants. Internal-combustion engines burn fuel hotter than the melting temperature of engine materials, and hot enough to set fire to lubricants. Engine cooling removes energy fast enough to keep temperatures low so the engine can survive.
Some high-efficiency engines run without explicit cooling and with only accidental heat loss, a design called adiabatic. For example, 10,000 mile-per-gallon "cars" for the Shell economy challenge are insulated, both to transfer as much energy as possible from hot gases to mechanical motion, and to reduce reheat losses when restarting. Such engines can achieve high efficiency but compromise power output, duty cycle, engine weight, durability, and emissions.

Basic principle
Most internal combustion engines are fluid cooled using either air (a gaseous fluid) or a liquid coolant run through a heat exchanger (radiator) cooled by air. Marine engines and some stationary engines have ready access to a large volume of water at a suitable temperature. The water may be used directly to cool the engine, but often has sediment, which can clog coolant passages, or chemicals, such as salt, that can chemically damage the engine. Thus, engine coolant

may be run through a heat exchanger that is cooled by the body of water.

Most liquid-cooled engines use a mixture of water and chemicals such as antifreeze and rust inhibitors. The industry term for the antifreeze mixture is *engine coolant*. Some antifreezes use no water at all, instead using a liquid with different properties, such as propylene glycol or a combination of propylene glycol and ethylene glycol. Most "air-cooled" engines use some liquid oil cooling, to maintain acceptable temperatures for both critical engine parts and the oil itself. Most "liquid-cooled" engines use some air cooling, with the intake stroke of air cooling the combustion chamber. An exception isWankel engines, where some parts of the combustion chamber are never cooled by intake, requiring extra effort for successful operation.

However, properties of the coolant (water, oil, or air) also affect cooling. As example, comparing water and oil as coolants, one gram of oil can absorb about 55% of the heat for the same rise in temperature (called the specific heat capacity). Oil has about 90% the density of water, so a given volume of oil can absorb only about 50% of the energy of the same volume of water. The thermal conductivity of water is about 4 times that of oil, which can aid heat transfer. The viscosity of oil can be ten times greater than water, increasing the energy required to pump oil for cooling, and reducing the net power output of the engine.

Comparing air and water, air has vastly lower heat capacity per gram and per volume (4000) and less than a tenth the conductivity, but also much lower viscosity (about 200 times lower: 17.4×10^{-6} Pa·s for air vs 8.94×10^{-4} Pa·s for water). Continuing the calculation from two paragraphs above, air cooling needs ten times of the surface area, therefore the fins, and air needs 2000 times the flow velocity and thus a recirculating air fan needs ten times the power of a recirculating water pump. Moving heat from the cylinder to a large surface area for air cooling can present problems such as difficulties manufacturing the shapes needed for good heat transfer and the space needed for free flow of a large volume of air.

The Components of a Cooling System

- The Radiator
- Radiator Cooling Fans
- Pressure Cap & Reserve Tank
- Water Pump
- Thermostat
- Bypass System
- Freeze Plugs
- Head Gaskets & Intake Manifold Gaskets
- Heater Core
- Hoses

The Radiator

The radiator core is usually made of flattened aluminum tubes with aluminum strips that zigzag between the tubes. These fins transfer the heat in the tubes into the air stream to be carried away from the vehicle. On each end of the radiator core is a tank, usually made of plastic tha covers the ends of the radiator,

On most modern radiators, the tubes run horizontally wit the plastic tank on either side. On other cars, the tubes ru vertically with the tank on the top and bottom. On olde vehicles, the core was made of copper and the tanks wer brass. The new aluminum-plastic system is much mor efficient, not to mention cheaper to produce. On radiators with plastic end caps, there are gaskets between the aluminum core and the plastic tanks to seal the system and keep the fluid from leaking out. On older copper and brass radiators, the tanks were brazed (a form of welding) in order to seal the radiator.

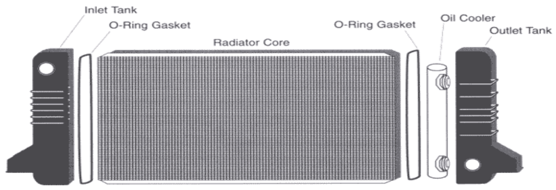


Illustration provided by the National Automotive Radiator Service Association.

Radiator Fans

Mounted on the back of the radiator on the side closest to the engine is one or two electric fans inside a housing that is designed to protect fingers and to direct the air flow. These fans are there to keep the air flow going through the radiator while the vehicle is going slow or is stopped with the engine running. If these fans stopped working, every time you came to a stop, the engine temperature would begin rising. On older systems, the fan was connected to the front of the water pump and would spin whenever the engine was running because it was driven by a fan belt instead of an electric motor.

Pressure cap and reserve tank:

As coolant gets hot, it expands. Since the cooling system is sealed, this expansion causes an increase in pressure in the cooling system, which is normal and part of the design. When coolant is under pressure, the temperature where the liquid begins to boil is considerably higher. This pressure, coupled with the higher boiling point of ethylene glycol, allows the coolant to safely reach temperatures in excess of 250 degrees.

The radiator pressure cap is a simple device that will maintain pressure in the cooling system up to a certain point. If the pressure builds up higher than the set pressure point, there is a spring loaded valve, calibrated to the correct Pounds per Square Inch (psi), to release the pressure.

Water Pump

A water pump is a simple device that will keep the coolant moving as long as the engine is running. It is usually mounted on the front of the engine and turns whenever the engine is running. The water pump is driven by the engine through one of the following:

- A fan belt that will also be responsible for driving an additional component like an alternator or power steering pump A serpentine belt, which also drives the alternator, power steering pump and AC compressor among other things.
- The timing belt that is also responsible for driving one or more camshafts.

Thermostat

The thermostat is simply a valve that measures the temperature of the coolant and, if it is hot enough, opens to allow the coolant to flow through the radiator. If the coolant is not hot enough, the flow to the radiator is blocked and fluid is directed to a bypass system that allows the coolant to return directly back to the engine. The bypass system allows the coolant to keep moving through the engine to balance the temperature and avoid hot spots. Because flow to the radiator is blocked, the engine will reach operating temperature sooner and, on a cold day, will allow the heater to begin supplying hot air to the interior more quickly.

Since the 1970s, thermostats have been calibrated to keep the temperature of the coolant above 192 to 195 degrees. Prior to that, 180 degree thermostats were the norm. It was found that if the engine is allowed to run at these hotter temperatures, emissions are reduced, moisture condensation inside the engine is quickly burned off extending engine life, and combustion is more complete which improves fuel economy.

The heart of a thermostat is a sealed copper cup that contains wax and a metal pellet. As the thermostat heats up, the hot wax expands, pushing a piston against spring pressure to open the valve and allow coolant to circulate.

The thermostat is usually located in the front, top part of the engine in a water outlet housing that also serves as the connection point for the upper radiator hose. The thermostat housing attaches to the engine, usually with two bolts and a gasket to seal it against leaks.

Bypass System

This is a passage that allows the coolant to bypass the radiator and return directly back to the engine. Some engines use a rubber hose, or a fixed steel tube. In other engines, there is a cast in passage built into the water pump or front housing. In any case, when the thermostat is closed, coolant is directed to this bypass and channeled back to the water pump, which sends the coolant back into the engine without being cooled by the radiator.

Freeze Plugs

When an engine block is manufactured, a special sand is molded to the shape of the coolant passages in the engine block. This sand sculpture is positioned inside a mold and molten iron or aluminum is poured to form the engine block. When the casting is cooled, the sand is loosened and removed through holes in the engine block casting leaving the passages that the coolant flows through. Obviously, if we don't plug up these holes, the coolant will pour right out.

Head Gaskets and Intake Manifold Gaskets

All internal combustion engines have an engine block and one or two cylinder heads. The mating surfaces where the block and head meet are machined flat for a close, precision fit, but no amount of careful machining will allow them to be completely water tight or be able to hold back combustion gases from escaping past the mating surfaces. In order to seal the block to the heads, we use a head gasket. The head gasket has several things it needs to seal against. The main thing is the combustion pressure on each cylinder

Heater Core

The hot coolant is also used to provide heat to the interior of the vehicle when needed. This is a simple and straight forward system that includes a heater core, which looks like a small version of a radiator, connected to the cooling system with a pair of rubber hoses. One hose brings hot coolant from the water pump to the heater core and the other hose returns the coolant to the top of the engine.

Hoses

There are several rubber hoses that make up the plumbing to connect the components of the cooling system. The main hoses are called the upper and lower radiator hoses. These two hoses are approximately 2 inches in diameter and direct coolant between the engine and the radiator.

Radiators

Radiators are used for cooling internal combustion engines, mainly in automobiles but also in piston-engined aircraft, railway locomotives, motorcycles, stationary generating plant or any similar use of such an engine.

Internal combustion engines are often cooled by passing a liquid called *engine coolant* through the engine block, where it is heated, then through the radiator itself where it loses heat to the atmosphere, and then back to the engine in a closed loop. Engine coolant is usually water-based, but may also be oil. It is common to employ a water pump to force the engine coolant to circulate, and also for an axial fan to force air through the radiator.

In automobiles and motorcycles with a liquid cooled internal combustion engine, a radiator is connected to channels running through the engine and cylinder head, through which a liquid (coolant) ispumped. This liquid may be water (in climates where water is unlikely to freeze), but is more commonly a mixture of water and antifreeze in proportions appropriate to the climate.

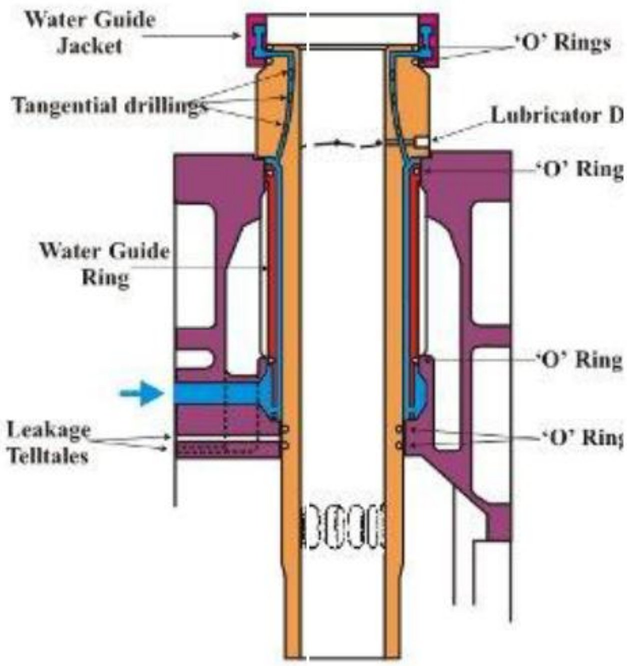
Antifreeze itself is usually ethylene glycol or propylene glycol (with a small amount of corrosion inhibitor).
The radiator transfers the heat from the fluid inside to the air outside, thereby cooling the fluid, which in turn cools the engine. Radiators are also often used to cool automatic transmission fluids, air conditioner refrigerant, intake air, and sometimes to cool motor oil or power steering fluid. Radiators are typically mounted in a position where they receive airflow from the forward movement of the vehicle, such as behind a front grill. Where engines are mid- or rear-mounted, it is common to mount the radiator behind a front grill to achieve sufficient airflow, even though this requires long coolant pipes. Alternatively, the radiator may draw air from the flow over the top of the vehicle or from a side-mounted grill. For long vehicles, such as buses, side airflow is most common for engine and transmission cooling and top airflow most common for air conditioner cooling.

Radiator construction

Automobile radiators are constructed of a pair of header tanks, linked by a core with many narrow passageways, thus a high surface area relative to its volume. This core is usually made of stacked layers of metal sheet, pressed to form channels and soldered or brazed together. For many years radiators were made from brass or copper cores soldered to brass headers. Modern radiators save money and weight by using plastic headers and may use aluminium cores. This construction is less easily repaired than traditional materials.

The Cylinder Liner

The cylinder liner forms the cylindrical space in which the piston reciprocates. The reasons for manufacturing the liner separately from the cylinder block (jacket) in which it is located.The Liner will get tend to get very hot during engine operation as the heat energy from the burning fuel is transferred to the cylinder wall. So that the temperature can be kept within acceptable limits the liner is cooled.
Cylinder liners from older lower powered engines had a uniform wall thickness and the cooling was achieved by circulating cooling water through a space formed between liner and jacket. The cooling water space was sealed from the scavenge space using 'O' rings and a telltale passage between the 'O' rings led to the outside of the cylinder block to show a leakage.To increase the power of the engine for a given number of cylinders, either the efficiency of the engine must be increased or more fuel must be burnt per cycle. To burn more fuel, the volume of the combustion space must be increased, and the mass of air for combustion must be increased. Because of the resulting higher pressures in the cylinder from the combustion of this greater mass of fuel, and the larger diameters, the liner must be made thicker at the top to accommodate the higher hoop stresses, and prevent cracking of the material. If the thickness of the material is increased, then it stands to reason that the working surface of the liner is going to increase in temperature because the cooling water is now further away. Increased surface temperature means that the material strength is reduced, and the oil film burnt away, resulting in excessive wear and increased thermal stressing.
The solution is to bring the cooling water closer to the liner wall, and one method of doing this without compromising the strength of the liner is to use tangential bore cooling.



V. ANALYSIS OF THE CYLINDER LINER USING ANSYS

The analysis of the cylinder liner is done with two different materials. And the type of the analysis is Thermal Analysis.

FINITE ELEMENT MODEL OF THE CYLINDER

Convection **Convection**

1 **2** **3** **4** **5**

(Liner) **(CYLINDER)**

The numbers 1,2,3,4,5 are the nodes of the element.

The element between the nodes 2&3 is the cylinder liner and the element between the nodes 3&4 is the cylinder surface. The element between the nodes 1&2 is an imaginary surface drawn for the convection between the surface and the surroundings which acts as an ambient nature. Similarly with the nodes 4&5.

VI. THE PROCEDURAL STEPS FOR THE ANALYSIS OF THE LINER USING ANSYS

1. Starting the Ansys
2. File-Clear and Start New
3. File-Change the file name
4. File-Change the Directory
5. Preferences-Thermal-Ok
6. Pre-Processor-Element type-thermal-link-
   2D Conduction
   Convection 34
7. Pre-Processor-Real Constants-
   Area1=1mm² Area2=1mm²
8. Pre-Processor-Material Properties-Material Models-Material Model-1 Thermal-Convection-h=
9. Pre-Processor-Material Properties-Material Models-Material Model2-Thermal convection-h=
10. Pre-Processor-MaterialProperties-Material Models-Material Model3-Thermal-Conductivity-Isotropic-k=

11. Pre-Processor-Material Properties-Material Models-Material Model4-Thermal conductivity-Isotropic-K=
12. Modeling-Create-Nodes-In Active CS

NODE	X	Y	Z
1			
2			
3			
4			

13. Modeling-Elements-Auto numbered-Thru Nodes
14. Solution-Analysis Type-Thermal
15. Solution –Define Loads-apply-Thermal-Temperature on nodes
16. Solution-Define Loads-apply-Thermal-convection on nodes
17. Solution-Solve-Current LS-Ok
18. General Post Processor-List Results-Nodal Solution-Nodal Temperature
19. General Post Processor-Plot Results-Contour Plot

Various When Different Material are Used for a liner for Analysis:

The Required Values taken for the Analysis:

S.NO	COMPONENT	MATERIAL
1	LINER	GREY CAST IRON
2	CYLINDER	ALUMINIUM

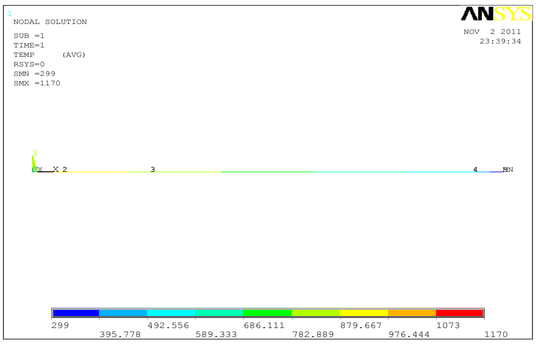
K (in BTU) = 118 at 68F
= 124 at 200F for Aluminium
= 144 at 400F
K(in Btu) = 36 at 70F (for Cast Iron)
(1BTU=1.731 w/mk)
H=20w/(m²k) for air

Temperatures
Inside liner=700ºc
Outside Cylinder=36ºc
When Cast Iron-Aluminium are used:

POST1 NODAL DEGREE OF FREEDOM LISTING
LOAD STEP= 0 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

NODE	TEMP
1	**1170.0**
2	**949.18**
3	**857.18**
4	**519.82**
5	**299.00**

MAXIMUM ABSOLUTE VALUES
NODE 1
VALUE 1170.0



When Both are Made with Aluminium:

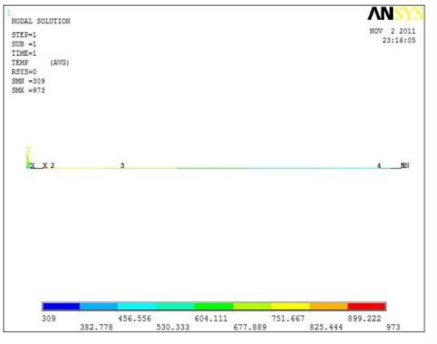
RINT TEMP NODAL SOLUTION PER NODE

POST1 NODAL DEGREE OF FREEDOM LISTING

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

NODE	TEMP
1	973.00
2	804.66
3	734.52
4	477.34
5	309.00

MAXIMUM ABSOLUTE VALUES
NODE 1
VALUE 973.00



PRINT TEMP NODAL SOLUTION PER NODE

POST1 NODAL DEGREE OF FREEDOM LISTING

LOAD STEP= 1 SUBSTEP= 1

TIME= 1.0000 LOAD CASE= 0

NODE	TEMP
1	**1170.0**
2	**949.18**
3	**857.18**
4	**519.82**
5	**299.00**

MAXIMUM ABSOLUTE VALUES

NODE 1
VALUE 1170.0
These Results show the Variations in the action of stresses at different points of the Cylinder Liner

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