HOW CAR COOLING SYSTEMS WORK

Although gasoline engines have improved a lot, they are still not very efficient at turning chemical energy into mechanical power. Most of the energy in the gasoline (perhaps 7-0%) 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! 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.

The engine in your car runs best at a fairly high temperature. When the engine is cold, components wear out faster, and the engine is less efficient and emits more pollution. 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.

In this article, we'll learn about the parts of a car cooling system and how they work. First, let's look at some basics.

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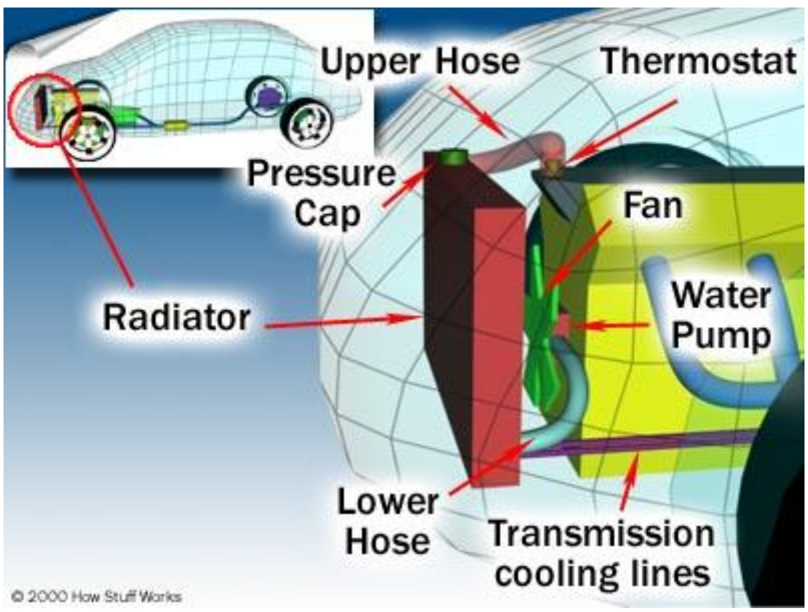


The Basics

Inside your car's engine, fuel is constantly burning. A lot of the heat from this combustion goes right out the exhaust system, but some of it soaks into the engine, heating it up. The engine runs best when its coolant is about 200 degrees Fahrenheit (93 degrees Celsius). At this temperature:

- The combustion chamber is hot enough to completely vaporize the fuel, providing better combustion and reducing emissions.
- The oil used to lubricate the engine has a lower viscosity (it is thinner), so the engine parts move more freely and the engine wastes less power moving its own components around.

- Metal parts wear less.

There are two types of cooling systems found on cars: liquid-cooled and air-cooled.

Liquid Cooling

The cooling system on liquid-cooled cars circulates a fluid through pipes and passageways in the engine. As this liquid passes through the hot engine it absorbs heat, cooling the engine. After the fluid leaves the engine, it passes through a heat exchanger, or radiator, which transfers the heat from the fluid to the air blowing through the exchanger.

Air Cooling

Some older cars, and very few modern cars, are air-cooled. Instead of circulating fluid through the engine, the engine block is covered in aluminum 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.

Plumbing

The cooling system in your car has a lot of plumbing. We'll start at the pump and work our way through the system, and in the next sections we'll talk about each part of the system in more detail.

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.

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.

	Pure Water	**50/50 $C_2H_6O_2$/Water**	**70/30 $C_2H_6O_2$/Water**
Freezing Point	0 C / 32 F	-37 C / -35 F	-55 C / -67 F
Boiling Point	100 C / 212 F	106 C / 223 F	113 C / 235 F

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.

Antifreeze also contains additives to resist corrosion.

Water Pump

Centrifugal pump like the one used in your car

The water 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 center continuously. The inlet to the pump is located near the center 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.

Engine

The engine block and cylinder head have many passageways cast or machined in them to allow for fluid flow. These passageways direct the coolant to the most critical areas of the engine.

Note that the walls of the cylinder are quite thin, and

that the engine block is mostly hollow.

Temperatures in the combustion chamber of the engine can reach 4,500 F (2,500 C), so cooling the area around the cylinders is critical. Areas around the exhaust valves are especially crucial, and almost all of the space inside the cylinder head around the valves that is not needed for structure is filled with coolant. If the engine goes without cooling for very long, it can seize. When this happens, the metal has actually gotten hot enough for the piston to weld itself to the cylinder. This usually means the complete destruction of the engine.

The head of the engine also has large coolant passageways.

One interesting way to reduce the demands on the cooling system is to reduce the amount of heat that is transferred from the combustion chamber to the metal parts of the engine. Some engines do this by coating the inside of the top of the cylinder head with a thin layer of **ceramic**. Ceramic is a poor conductor of heat, so less heat is conducted through to the metal and more passes out of the exhaust.

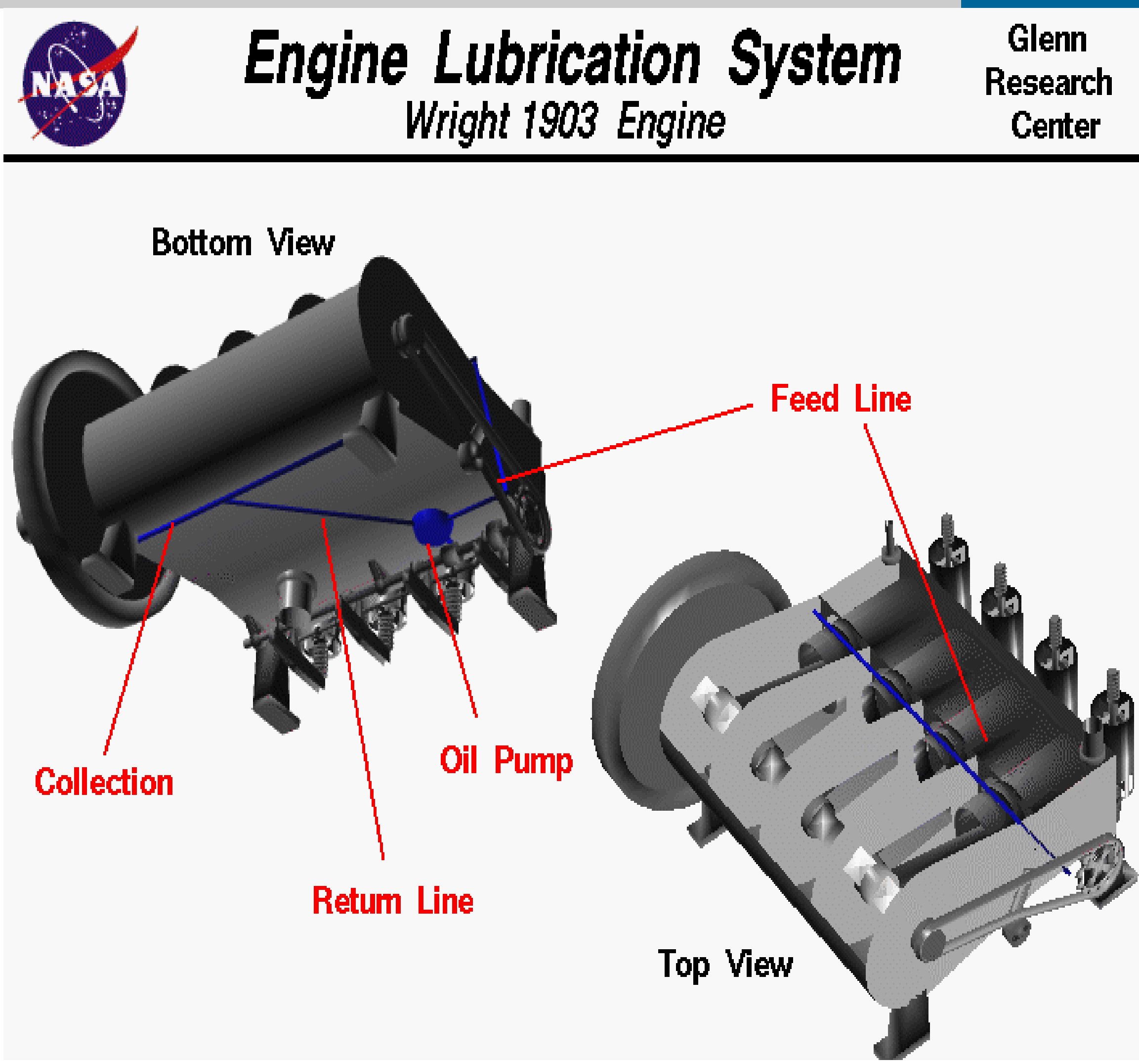
Radiator

A radiator is a type of **heat exchanger**. It is designed to transfer heat from the hot coolant that flows through it to the air blown through it by the fan.

Most modern cars use aluminum radiators. These radiators are made by brazing thin aluminum fins to flattened aluminum tubes. The coolant flows from the inlet to the outlet 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.

The tubes sometimes have a type of fin inserted into them called a **turbulator**, which increases the turbulence of the fluid flowing through the tubes. If the fluid flowed very smoothly through the tubes, only the fluid actually touching the tubes would be cooled directly. The amount of heat transferred to the tubes from the fluid running through them depends on the difference in temperature between the tube and the fluid touching it. So if the fluid that is in contact with the tube cools down quickly, less heat will be transferred. By creating turbulence inside the tube, all of the fluid mixes together, keeping the temperature of the fluid touching the tubes up so that more heat can be extracted, and all of the fluid inside the tube is used effectively.

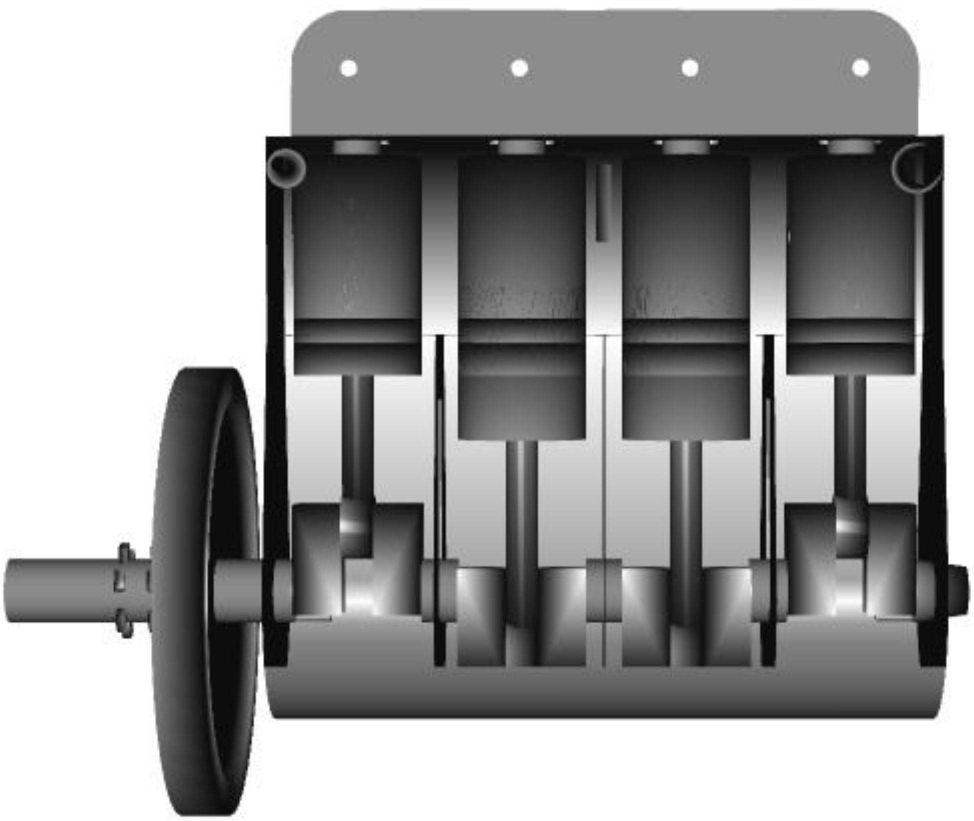
Radiators usually have a tank on each side, and inside the tank is a transmission cooler. In the picture above, you can see the inlet and outlet where the oil from the transmission enters the cooler. The transmission cooler is like a radiator within a radiator, except instead of exchanging heat with the air, the oil exchanges heat with the coolant in the radiator.



For the forty years following the first flight of the Wright brothers, airplanes used internal combustion engines to turn propellers to generate thrust. Today, most general aviation or private airplanes are still powered by propellers and internal combustion engines, much like your automobile engine. We will discuss the fundamentals of the internal combustion engine using the Wright brothers' 1903 engine, shown in the figure, as an example. The brothers' design is very simple by today's standards, so it is a good engine for students to study and learn the fundamentals of engines and their operation. On this page we present a computer drawing of the **lubrication system** of the Wright brothers' 1903 aircraft engine.

Mechanical Operation

The figure at the top shows the major components of the **lubrication system** on the Wright 1903 engine. In any internal combustion engine, fuel and oxygen are combined in a combustion process to produce the power to turn the crankshaft of the engine. The combustion generates high pressure exhaust gas which exerts a force on the face of a piston. The piston moves inside a cylinder and is connected to the crankshaft by a rod which transmits the power. There are many moving parts is this power train as shown in this computer animation:



The job of the lubrication system is to distribute oil to the moving parts to reduce friction between surfaces which rub against each other.

The lubrication system used by the Wright brothers is quite simple. An **oil pump** is located on the bottom of the engine, at the left of the figure. The pump is driven by a worm gear off the main exhaust valve cam shaft. The oil is pumped to the top of the engine, at the right, inside a **feed line**. Small holes in the feed line allow the oil to drip inside the crankcase. In the figure, we have removed the fuel system and peeled back the covering of the crankcase to see inside. The oil drips onto the pistons as they move in the cylinders, lubricating the surface between the piston and cylinder. The oil then runs down inside the crankcase to the main bearings holding the crankshaft. Oil is picked up and splashed onto the bearings to lubricate these surfaces. Along the outside of the bottom of the crankcase is a **collection tube** which gathers up the used oil and **returns** it to the oil pump to be circulated again. Notice that the brothers did not lubricate the valves and rocker assembly for the combustion chambers.

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