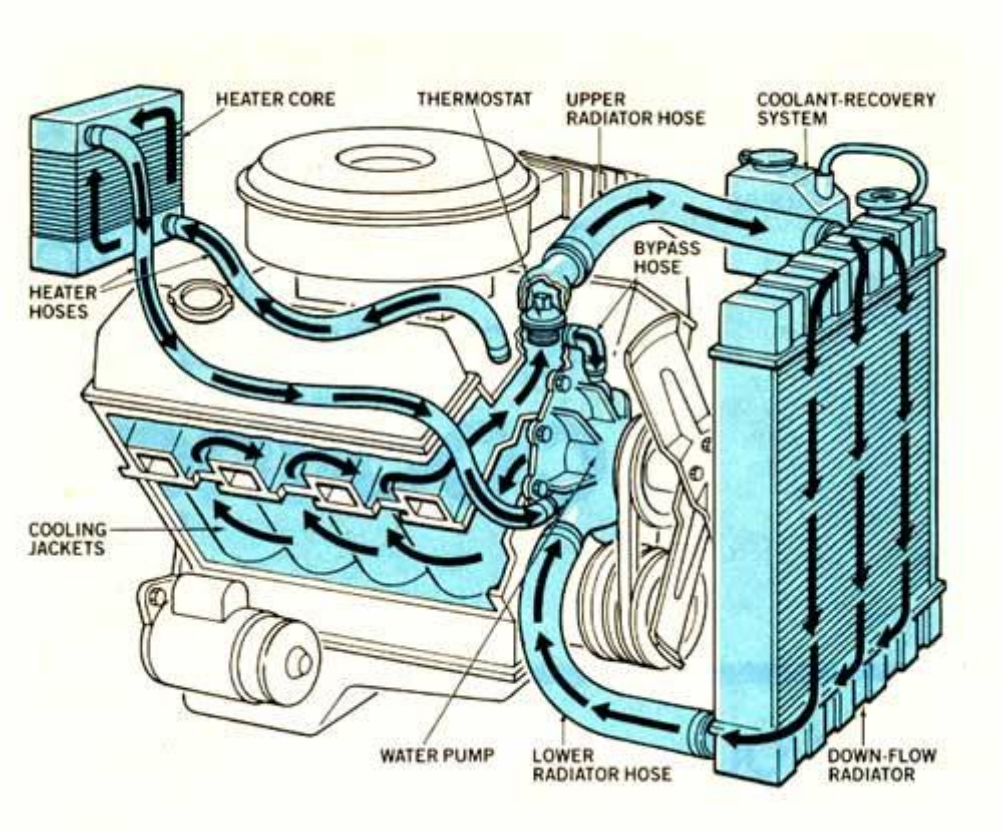
Engine Cooling Systems



Chapter 39 – Modern Automotive Technology

Engine Cooling Systems

Purpose of the Cooling system:

A cooling system must:

- Remove excess heat from the engine compartment
- Maintain a constant engine operating temperature
- Increase the temperature of a cold engine quickly
- Provide a means for warming the passenger compartment

Engine Cooling Systems

Engine temperatures can reach up to 2500°C

- **This heat needs to be controlled so the engine is not damaged!**

- **If excess heat is not removed from the engine serious damage can be caused to the engine in a matter of minutes.**

Engine Cooling Systems

Maintaining Operating Temperature:

The temperature the engine coolant reaches under normal operating temperatures (180°F – 210°F or 80°C – 100°C)

At proper operating temperature parts expand to ensure:

- **All part clearances are correct**
- **Proper combustion occurs**
- **Emission output is reduced**
- **Proper engine performance is achieved**

Engine Cooling Systems

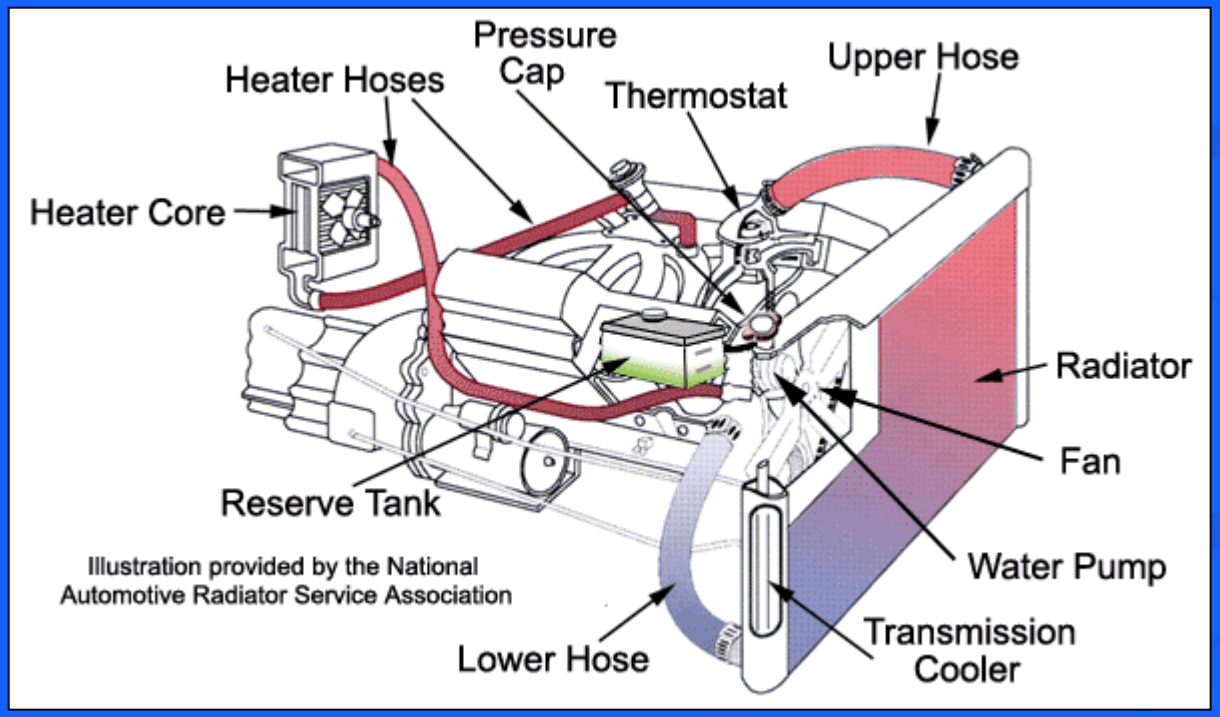
Reaching Operating Temperature Quickly:

Warm up must happen rapidly to prevent:

- Poor Combustion
- Part wear
- Oil contamination
- Reduced fuel economy
- Increased emissions
- Etc.

Heating the inside of the car…

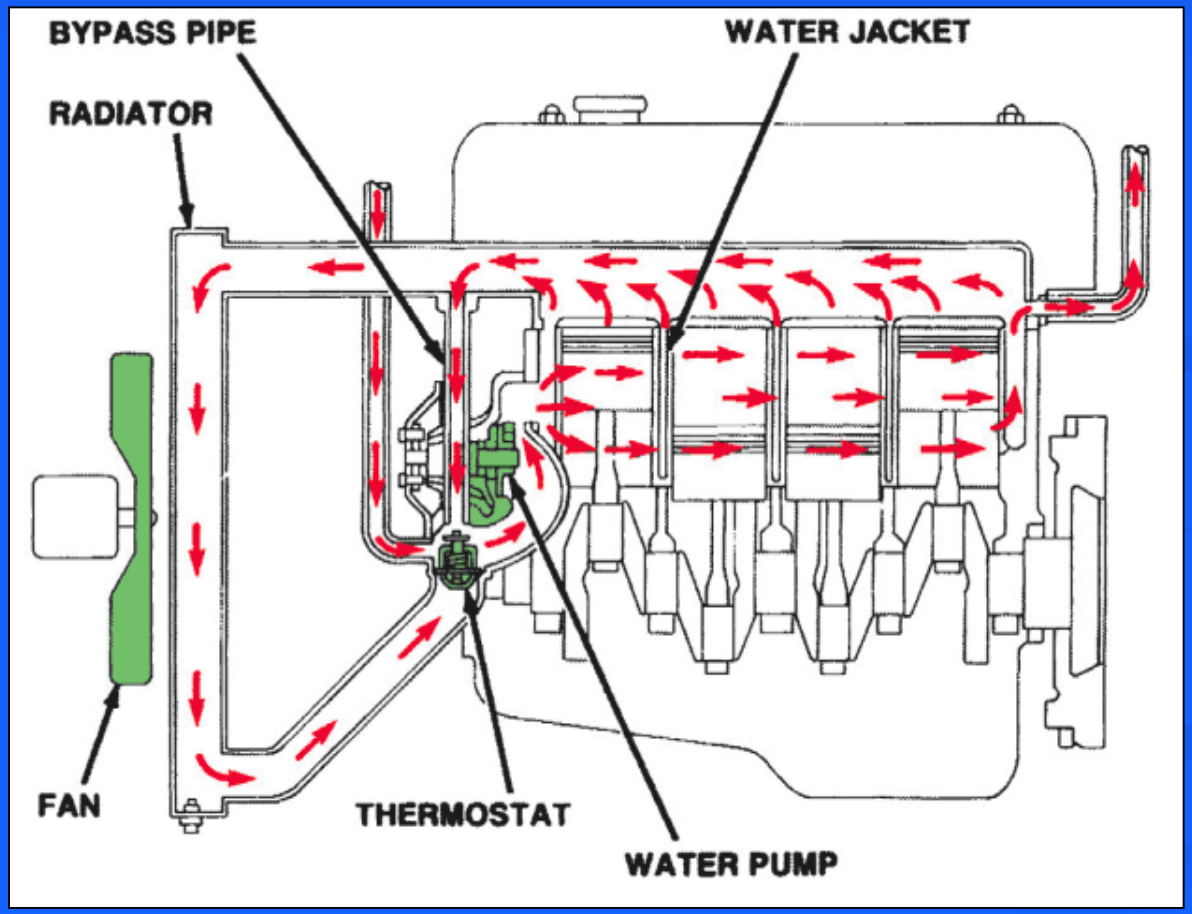
- Hot engine coolant is sent to a heater core through the heater hoses
- The heater fan blows air through the heater core to warm the interior of the car
- The flow of coolant through the heater core is controlled by the passengers in the vehicle



Cooling the Coolant

- Once the engine coolant reaches ≈100°C or more, it must be re-cooled so that it can continue to remove excess heat from the engine.

- The radiator, water pump and thermostat work together to lower coolant temperature



Cooling the Coolant

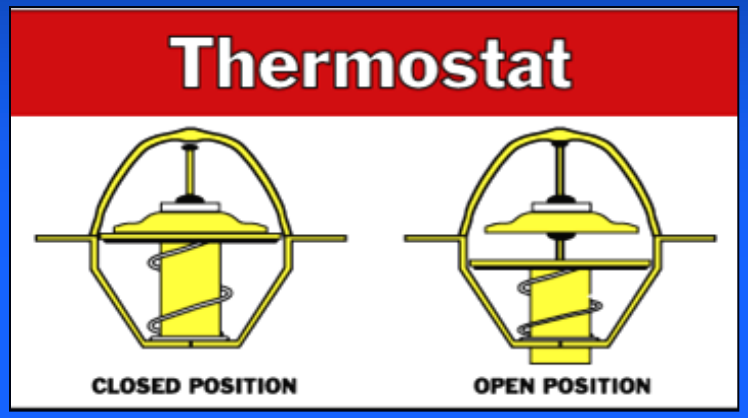
The *radiator* removes excess heat from the engine coolant using cold air that passes through its fins.

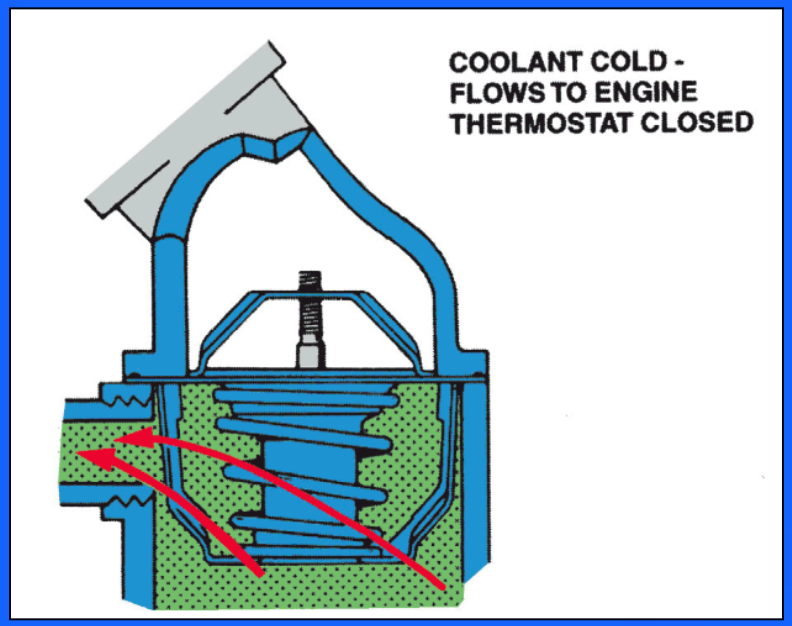
Coolant Circulation

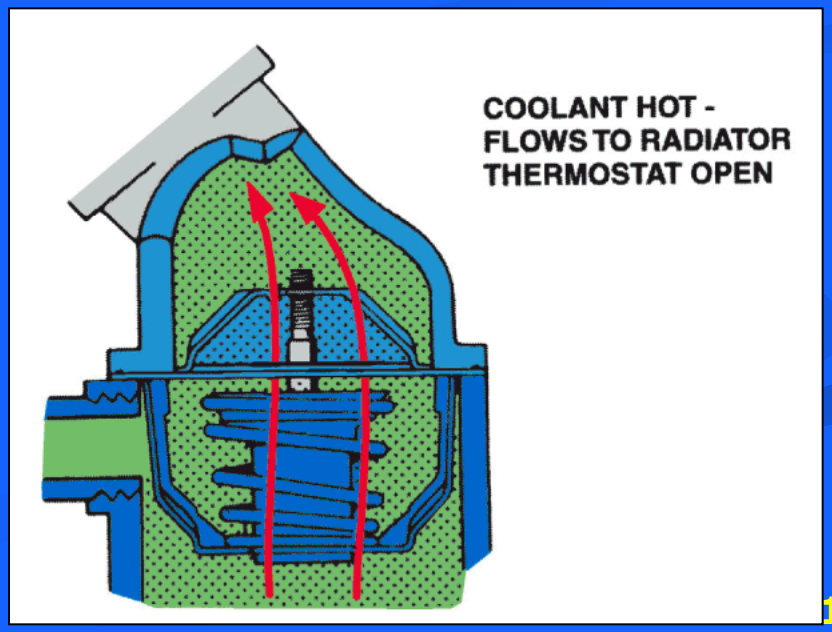
- The *water pump* pushes engine coolant out of the water jackets and into the radiator so that excess heat from the coolant can be removed.

Coolant Circulation

- The *thermostat* opens when the coolant is hot to allow coolant to flow to the radiator and closes when the coolant is cold to allow the engine to maintain its proper operating temperature.







Types of Cooling Systems

- **Air Cooled** - Not commonly found in passenger vehicles
  - Mostly found on small engines / motorcycles
- **Liquid Cooled** - Most common type found in Passenger vehicles
- Both air & liquid cooling systems have 4 main jobs…

1) To remove excess heat from engine parts
2) To maintain a consistent operating temperature
3) To allow the engine to reach normal operating temperature as quickly as possible
4) Provide a means of warming the passenger compartment

Types of Cooling Systems

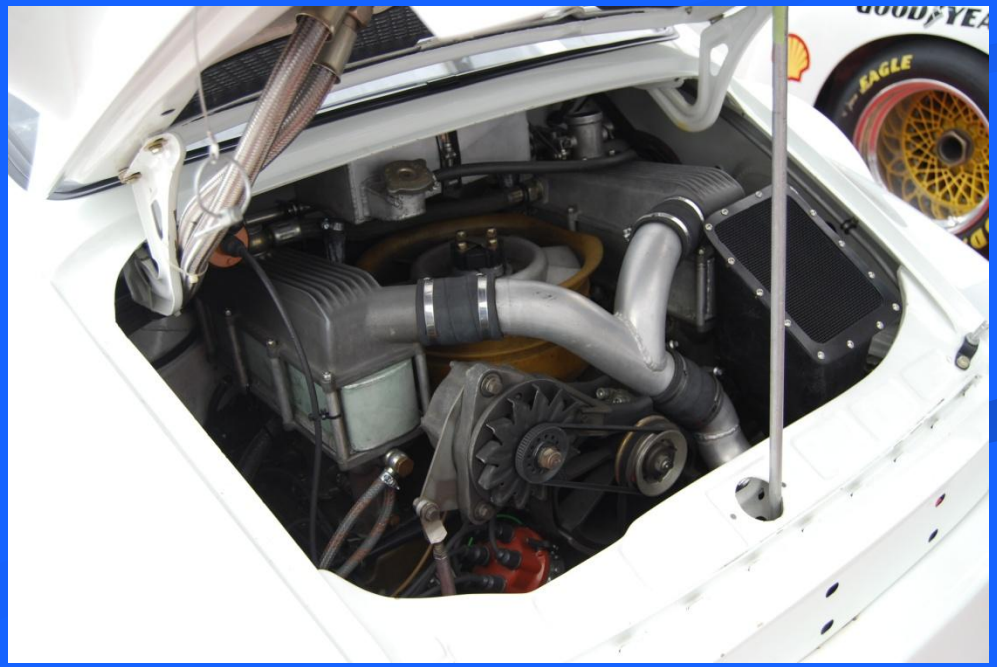
- **Air Cooled**
  - Not commonly found in passenger vehicles
  - Mostly found on small engines / motorcycles

-Uses large fins and outside air to remove excess heat from the engine

-The fins increase the surface area of the metal around the cylinder allowing enough heat to be transferred from the engine to the outside air

-Commonly uses plastic or metal ducts or shrouds to route air over the cylinder fins.

-Thermostatically controlled flaps regulate airflow and engine operating temperature



Types of Cooling Systems

- **Liquid Cooled** - Most common type found in Passenger vehicles

Circulates coolant through the water jackets

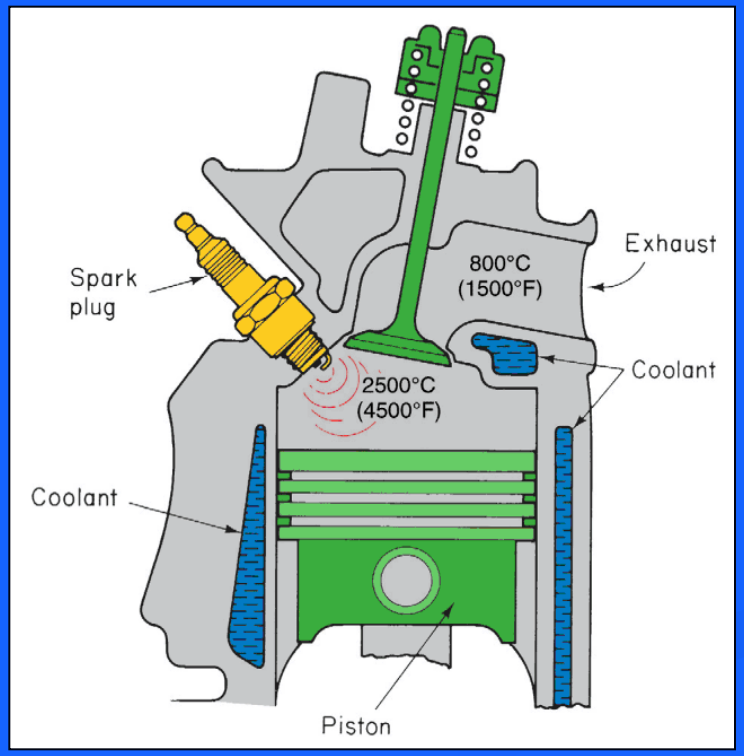
Coolant collects excess heat and carries it out of the engine.

Advantages over air cooled:

- More precise control of engine operating temperature
- Less temperature variation inside engine
- Reduced exhaust emission because of better temperature control
- Improved heater operation to warm passengers

Controlling the Heat

- Hollow passages called water jackets surround the cylinders and valve chambers.
- The water jackets are filled with a 50/50 mixture of water and antifreeze (coolant).
- The engine coolant absorbs the excess heat from the cylinders, valves & combustion chamber area.



Types of Cooling Systems

Conventional and Reverse Flow Cooling:

Conventional Flow – hot coolant flows from the cylinder head to the radiator and back to the engine block (most common)

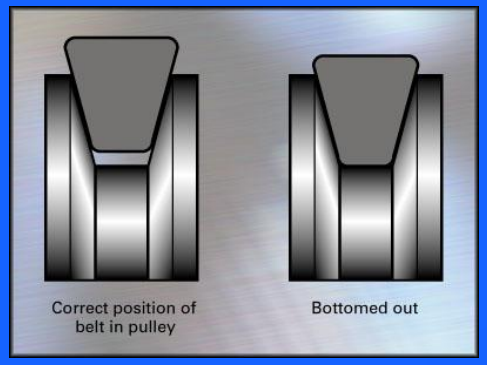
Reverse Flow – Cool coolant enters the head and hot coolant exits the block to return to the radiator.

- Helps keep a more uniform temperature throughout the engine especially around the hot exhaust valves.

- Is mostly found in HIGH PERFORMANCE ENGINES.

Components of Cooling Systems

- Coolant
- Water pump
- Radiator
- Radiator Cap
- Radiator Hoses
- Overflow (Reserve) Tank
- Thermostat



- Coolant Temperature Sensor
- Engine Cooling Fan
- Interior Heater Fan
- Heater Core
- Heater hoses
- Frost plugs
- Drive belt

Water Pump

Water Pump: Impeller or centrifugal pump that forces coolant through the engine block, cylinder head, intake manifold, hoses and radiator.

- Usually belt driven off of the crankshaft pulley

- Can be made of steel or plastic.

- Blades can be curved or straight (straight blades, like paddle wheels, are sometimes used to reduce engine power consumptions.

Water Pump

Water Pump parts:

Impeller: Disk with fan like blades; spins to produce pressure and flow

Shaft: Steel shaft that transfers turning force from the hub to the impeller

Seal: Prevents coolant leakage between pump shaft and pump housing

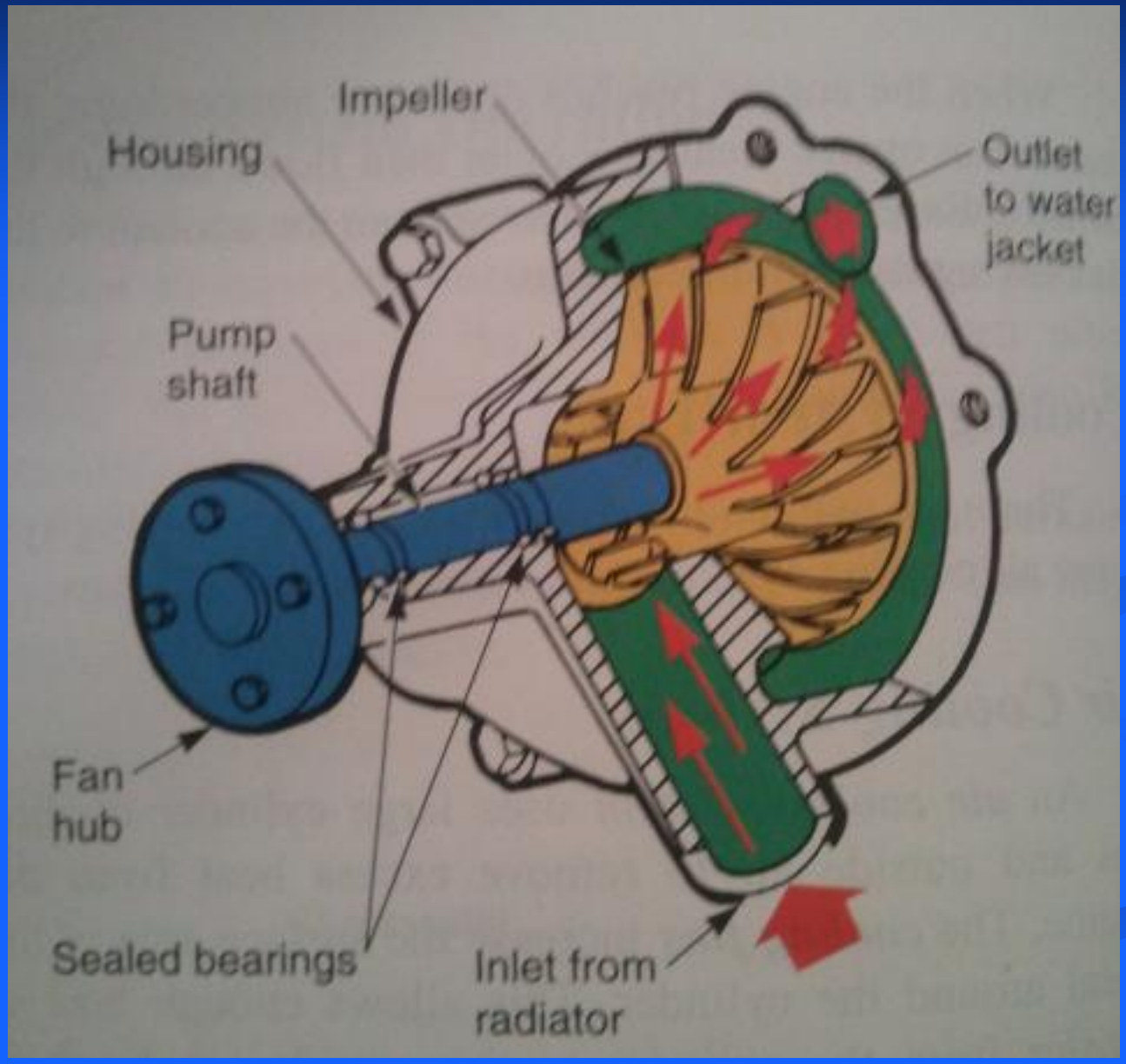
Bearings: plain or ball bearings that allow the pump shaft to spin freely in housing

Hub: Provides mounting place for belt pulley and fan

Housing: iron or aluminum casting that forms the main body of pump

Gasket: Fits between the engine and pump housing to prevent coolant leakage

Water Pump Parts



Water Pump

Water Pump Operation:

The spinning engine crankshaft pulley causes the drive belt to turn the water pump pulley, pump shaft and impeller. The coolant trapped between the impeller blades is thrown outwards by centrifugal force. Coolant is pulled out of the radiator into the engine, circulates through the block, around the cylinders, up through the cylinder head(s), through the thermostat and back to the radiator.

Radiator & Heater Hoses

Radiator hoses carry coolant between the engine water jackets and the radiator.

Being Flexible, hoses can withstand the vibrating and rocking of the engine on its motor mounts without breakage

The upper radiator hose normally connects to the thermostat housing on the intake manifold or cylinder head. Its other end fits on the radiator.

The lower hose connects the water pump inlet to the radiator

Types of Hoses

Molded hoses – manufactured in a special shape to clear the cooling fan and other parts.

Types of Hoses

Flexible hose – Accordion shape and can be bent to different angles. Also called a universal-type hose

Types of Hoses

Hose spring – Frequently used in the lower radiator hose to prevent its collapse (lower hose is exposed to suction from the water pump)

Types of Hoses

Heater hoses – Small diameter hoses that carry coolant to the heater core

Types of Hoses

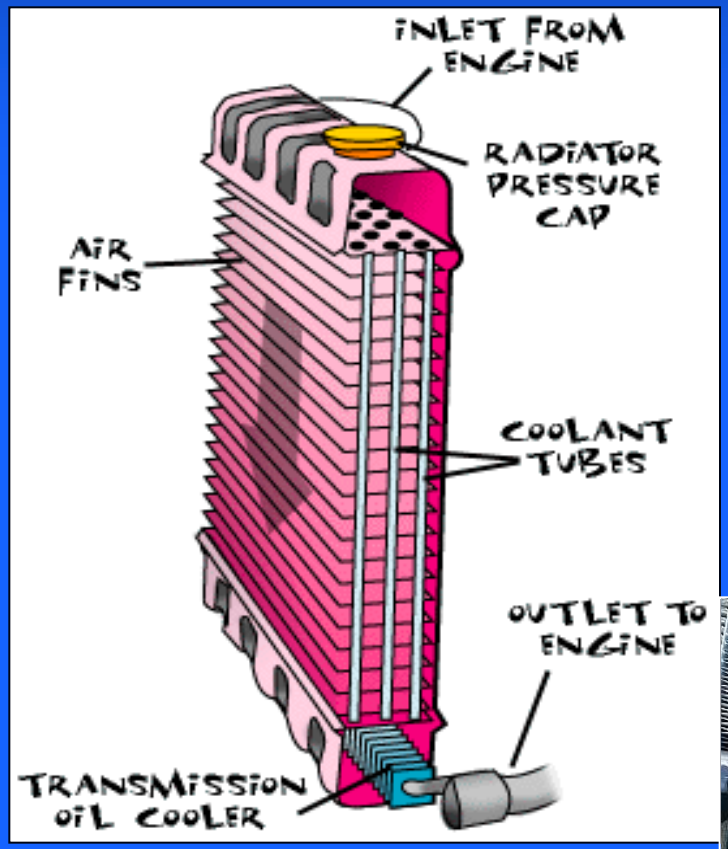
Hose clamps – Hold the radiator hoses and heater hoses on their fittings

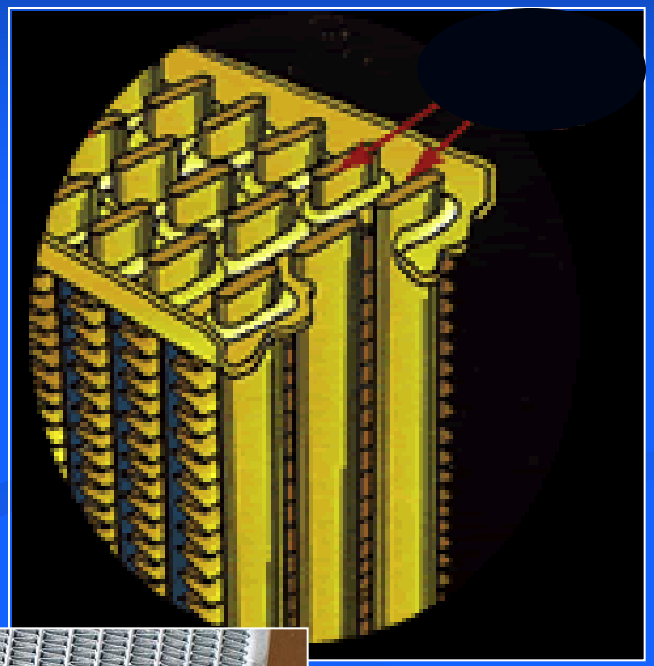
Worm-drive hose clamp – uses a worm gear that engages slots in the clamp strap to allow tightening around the hose (most common for replacement clamps)

Radiator

Radiator – Transfers coolant heat to the outside air.

Normally mounted in the front of the engine.





Radiator

Radiator Components:

Radiator Core – Center section of the radiator made up of tubes and cooling fins.

Radiator tanks – metal or plastic ends that fit over the core tube ends to provide storage for coolant and fittings fro hoses.

Radiator filler neck – Opening for adding coolant. Also holds the radiator cap and overflow tube.

Transmission oil cooler - Inner tank for cooling automatic transmission or transaxle fluid.

Radiator petcock - Fitting on the bottom of the tank for draining coolant.

Radiator

Radiator Action:

Under normal operation, hot engine coolant circulates through the radiator tanks and core tubes. Heat transfers into the core's tubes and fins. Cooler air flows over and through the radiator fins, so heat is removed from the radiator. This reduced the temperature of the coolant before it flows back into the engine.

Radiator

Radiator Types:

Downflow radiator – Tanks are on top and bottom of the core and core tubes run vertically between tanks.

Hot coolant enters the top tank and flows downward through to core tubes

After cooling, the coolant flows out of the bottom tank and back into the engine.

Radiator

Radiator Types:

Crossflow radiator – Tanks are on sides of the core and core tubes run horizontally between tanks.

Radiator cap is normally on outlet tank

Can be shorter than a downflow radiator allowing for a lower hood line

Radiator

Radiator Tubes:

Can be made of metal or plastic

With metal tanks, the core and tanks are soldered together.

With plastic tanks, rubber seals fit between the tanks and core to prevent leakage

Transmission Oil Cooler

Transmission Oil Cooler:

Often placed in radiator on cars with automatic transmissions or transaxles to prevent the transmission fluid from overheating.

A small tank enclosed in one of the main radiator tanks

Since transmission fluid is hotter than engine coolant, heat is removed as it passes through the radiator

In downflow radiators, the transmission oil cooler is located in the lower tank, in crossflow radiators, the oil cooler is in the tank having the radiator cap.

Radiator Cap

Radiator Cap:

Performs several functions:

1. Seals the top of the radiator filler neck to prevent leakage
2. Pressurizes the system to raise the boiling point of coolant. This keeps coolant from boiling and turning to steam
3. Relieves excess pressure to protect against system damage
4. In modern closed systems, it allows coolant flow between the radiator and the coolant reservoir.

Radiator Cap

Radiator Cap Pressure Valve:

Spring-loaded disc that contacts the filler neck

Spring pushes the valve into the neck to form a seal

Under pressure, water's boiling point increases, normally water boils at 212°F (100°C), however for every pound of pressure increase, water's boiling point goes up about 3°F

Radiator Cap

Radiator Cap Pressure:

Typically is between 12 & 16 psi

This raises the engine coolant boiling point to 250-260°F (121-127°C)

If the engine overheats and pressure exceeds the cap rating, the pressure valve opens. Excess pressure and steam force the coolant out of the overflow tube and into the reservoir or onto the ground. This prevents high pressure from rupturing the radiator, gaskets, seals, or hoses.

Radiator Cap

Radiator Cap Vacuum Valve:

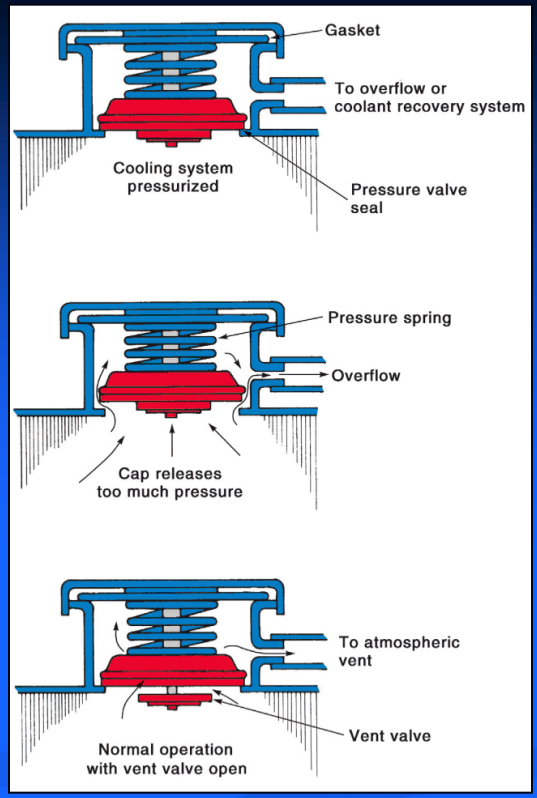
Opens to allow flow back into the radiator when the coolant temperature drops after engine operation.

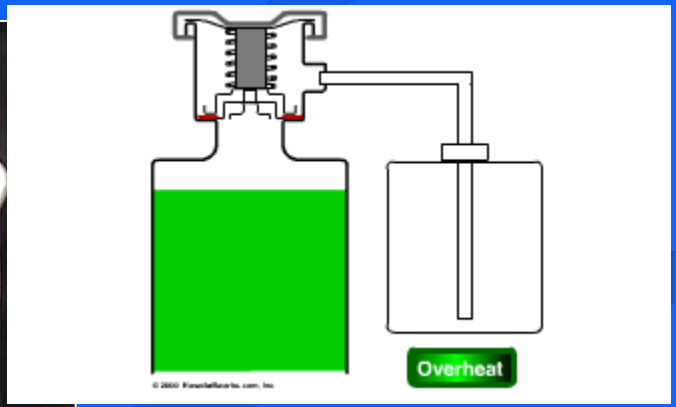
Is often a small valve located in the center of the bottom of the cap.

The cooling and contraction of the coolant and air in the system decrease the coolant volume and pressure. Without a cap vacuum valve, the radiator hoses and radiator tanks could collapse from outside pressure.

Radiator Cap Operation

- as the coolant heats up and expands, a pressure valve opens & excess pressure is sent to the expansion bottle
- when the engine is turned off and the coolant begins to cool, a vacuum valve opens & allows coolant to return back to the radiator
- this is called a closed cooling system
- The pressure inside the cooling systems allows the boiling point to rise keeping the system safe
  - 14-15 psi = 25°C





Closed & Open Cooling Systems

Closed Cooling System:

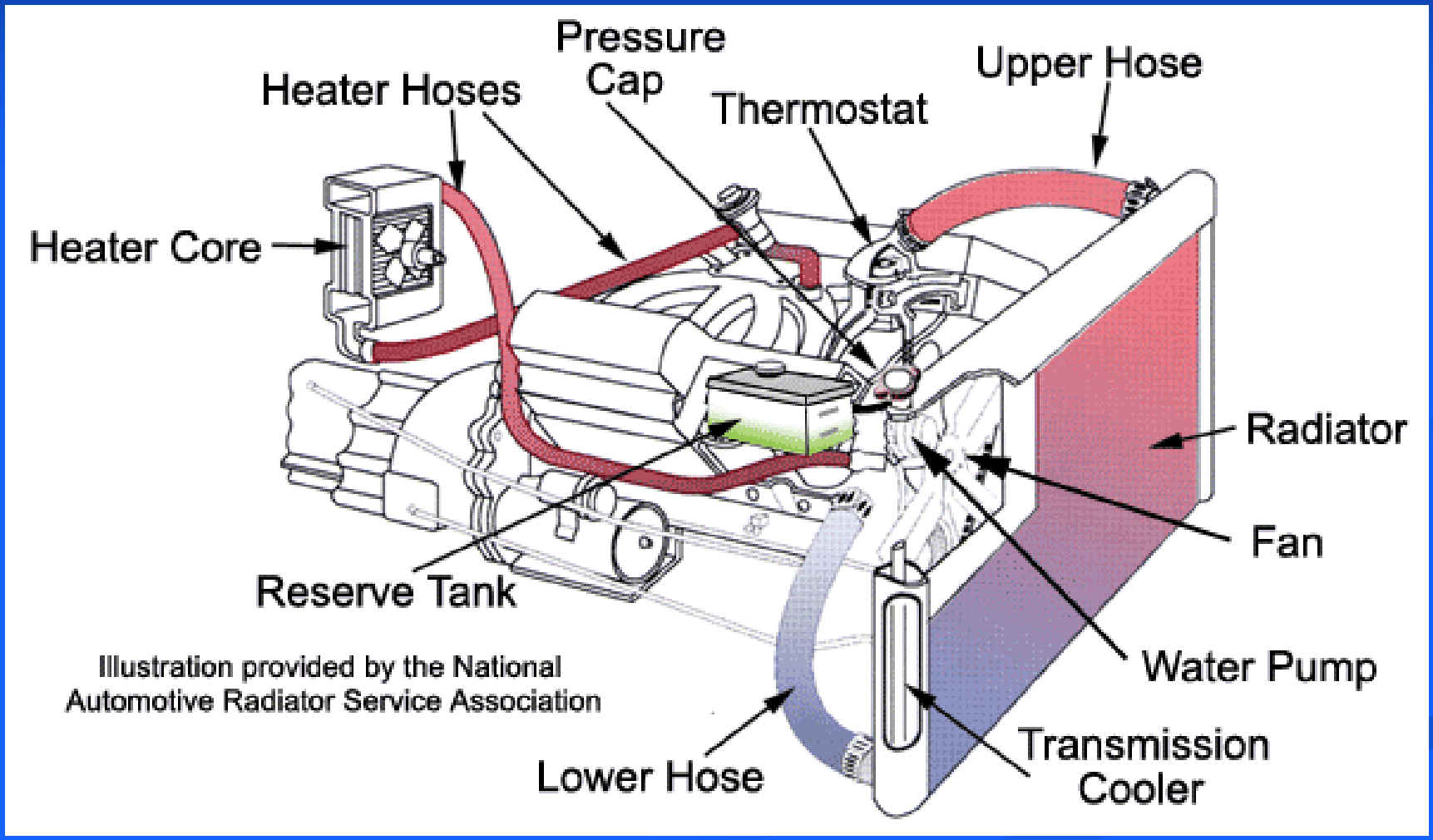
Uses an expansion tank, or reservoir and a radiator cap with pressure and vacuum valves.

The overflow tube is routed into the bottom of the reservoir tank.

Pressure & vacuum valve action pull coolant in and out of the reservoir tank as needed. This keeps the cooling system correctly filled at all times.

Closed & Open Cooling Systems

Closed Cooling System:



Closed & Open Cooling Systems

Closed Cooling System Operation:

When the engine heats up, the coolant expands and opens the cap pressure valve. Instead of leaking onto the ground, the coolant flows into the reservoir.

After the engine has been shut off, the coolant temperature drops and its volume decreases. This causes the vacuum valve to open. Atmospheric pressure (system suction) then forces coolant back into the radiator.

This compensates for any small system leak, keeping the system properly filled.

Closed & Open Cooling Systems

Open Cooling System:

Does not use a coolant reservoir

The overflow tube allows excess coolant to leak onto the ground

Does not provide a means of adding fluid automatically

No longer used on automobiles, it has been replaced by the closed system which requires less maintenance

Cooling System Fans

Cooling System Fan:

Pulls air through the core of the radiator and over the engine to help remove heat.

Increases the volume of air flowing through the radiator, especially when the car is standing still.

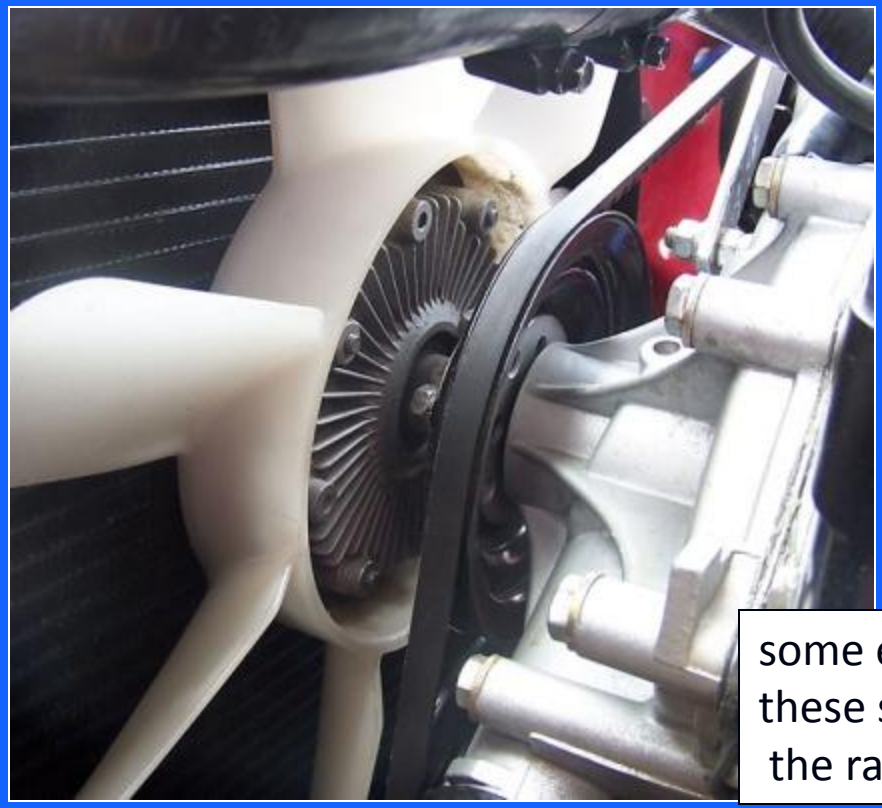
Driven by a belt or an electric motor.

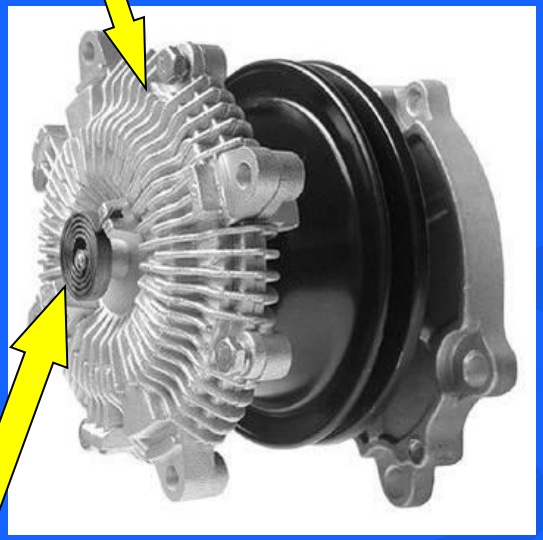
Cooling System Fans

3 types of fans include:

- Electric fan
- Engine powered flex fan)
- Engine powered fluid coupling fan clutch

Shrouded fans are used to direct air flow





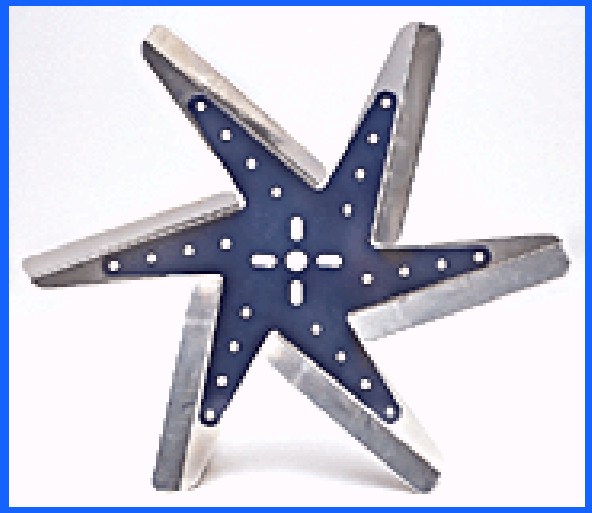
some engine powered fans have thermostatic clutches – these spin the fan only when the air temperature thru the radiator reaches a predetermined level

Cooling System Fans

Engine Powered Fans:

Bolt to the water pump hub and pulley, sometimes a fan spacer fits between the fan and pulley to move the fan closer to the radiator.

Flex Fan



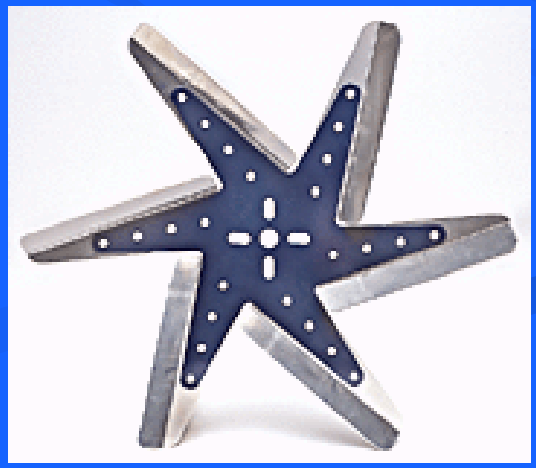
Thermostatic fan Clutch

Cooling System Fans

Engine Powered Fans:

Flex Fan – Has thin, flexible blades that alter airflow with engine speed.

At low speeds, the fan blades remain curved and pull air through the radiator. At higher speeds, the blades flex until they are almost straight reducing the fan action and saving engine power.



Cooling System Fans

Engine Powered Fans:

Fluid Coupling fan Clutch – designed to slip at higher engine speeds.

It performs the same function as a flexible fan.

The clutch is filled with silicone-based oil.

At a specific fan speed, there is enough load to make the clutch slip.

Cooling System Fans

Engine Powered Fans:

Thermostatic Fan Clutch – has a temperature sensitive, bimetal spring that controls fan action

The spring controls oil flow in the fan clutch.

When cold, the spring causes the clutch to slip, speeding engine warm-up. After reaching operating temperature, it locks the clutch, providing forced-air circulation.

Cooling System Fans

Electric Cooling Fans:

Use an electric motor and a thermostatic switch (coolant temperature sensor) to provide cooling action.

Needed on Transversally mounted engine vehicles where the water pump is located away from the radiator

Can be used on any engine/transmission layout.

Cooling System Fans

Electric Cooling Fan Motor:

Small DC (Direct Current) motor.

Mounts on a bracket secured to the radiator.

Metal or plastic fan blades mount on the end of the motor shaft to cause airflow.

Saves energy and increases cooling system efficiency.

Only functions when needed speeding up engine warm-up, reducing emissions and fuel consumption.

May shut off at high speeds due to cool air flowing through grill

Cooling System Fans

Electric Engine Fan Circuits:

The fan switch is a temperature sensitive switch that controls fan motor operation.

The coolant temperature sensor , relays, and engine control module (ECM) operate the engine cooling fan motors.

When the engine is cold the coolant sensor signals the ECM it is cold and the ECM does not energize the fan relays, keeping the fan off and warming up the engine faster.

When the engine warms up the coolant sensor signals the ECM to send power to the cooling fan.

Cooling System Fans

Radiator Shroud:

Helps ensure that the fan pulls air through the radiator.

Fastens to the rear of the radiator and surrounds the area around the fan.

When the fan is spinning, the shroud keeps air from circulating between the back of the radiator and the front of the fan resulting in a huge amount of air flowing through the radiator core.

Without the shroud the engine could overheat.

Thermostats

Thermostat:

Senses engine temperature and controls coolant flow through the radiator.

Reduces coolant flow when the engine is cold and increases coolant flow when the engine is hot.

Usually located under a thermostat housing between the engine and the end of the upper radiator hose.

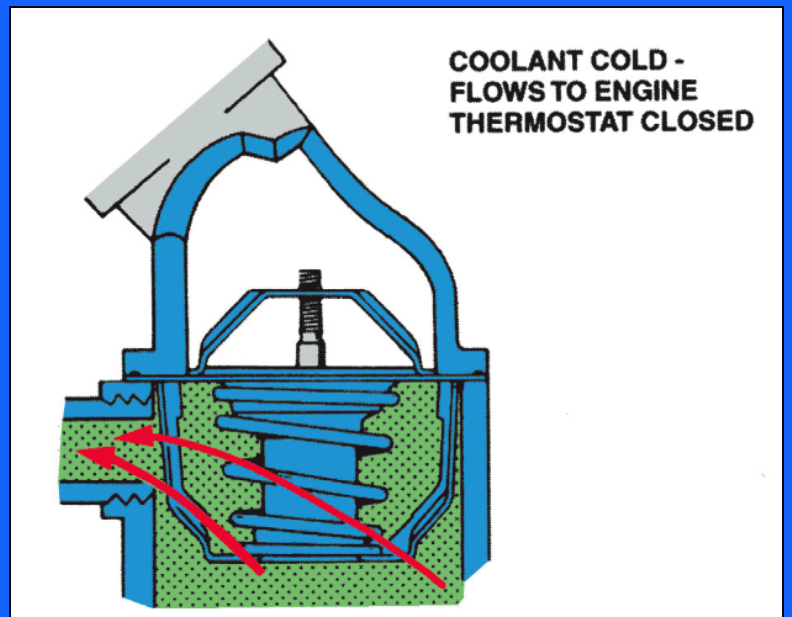
Can be located at the inlet or the outlet of the engine

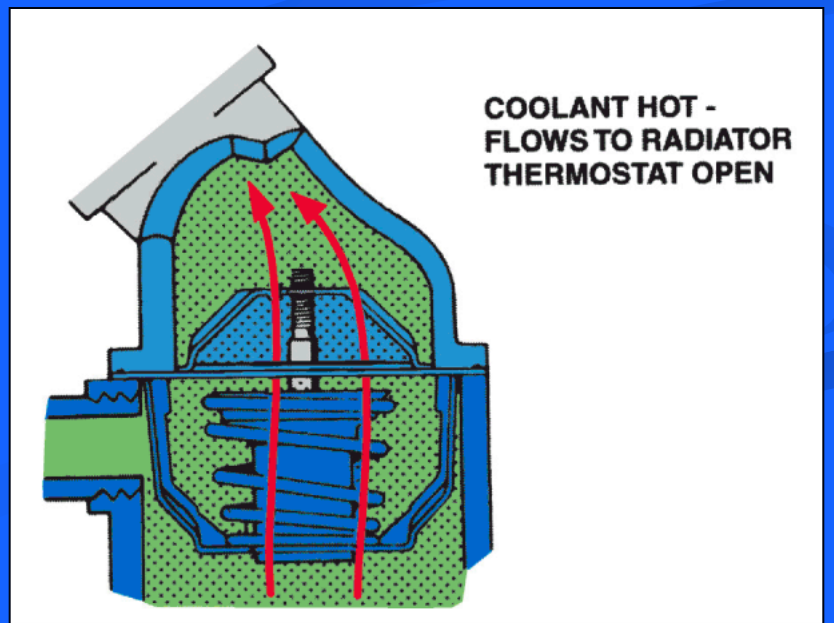
Thermostats

Thermostat Construction:

Thermostats contain a wax filled pellet inside a contained cylinder and piston assembly

When the thermostat heats up the pellet expands pushing the valve open, as it cools spring tension overcomes pellet expansion and the valve closes.





Thermostats

Thermostat Ratings:

Stamped on the thermostat to indicate the operating (opening) temperature of the thermostat.

Normal ratings are between 180°F & 195°F (82°C & 91°C)

High thermostats heat ranges are used in modern automobiles to reduce exhaust emissions and increase combustion efficiency.

Thermostats

Thermostat Operation:

When the engine is cold the , the thermostat will be closed and coolant cannot circulate through the radiator.

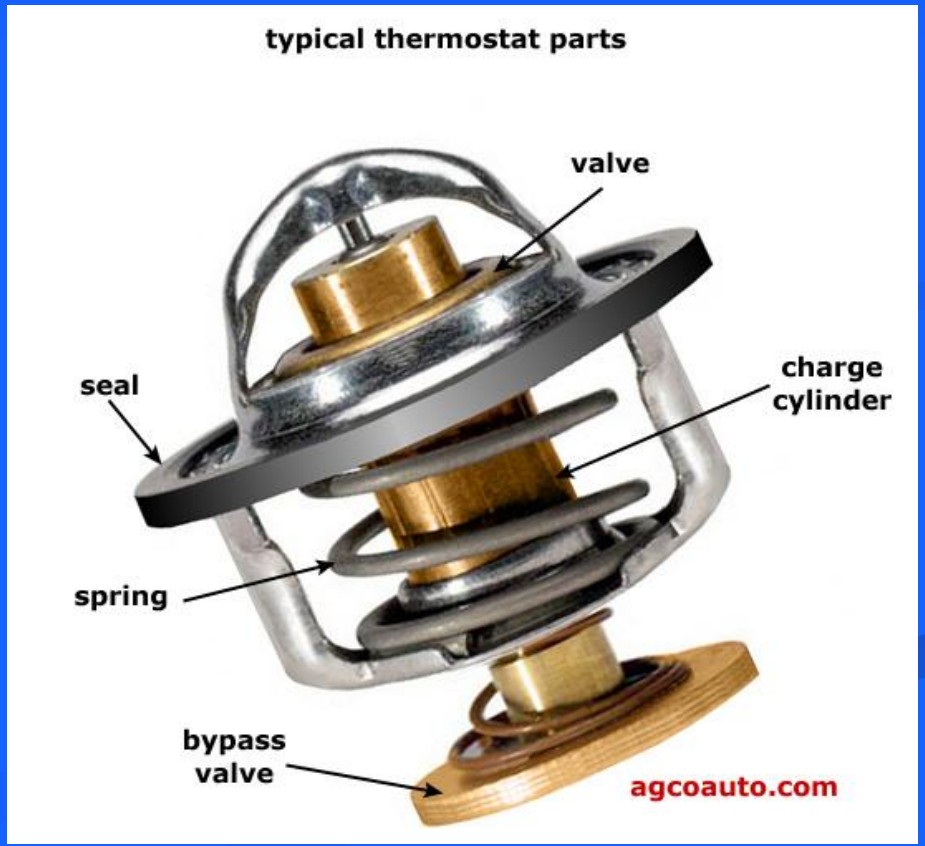
A bypass valve and bypass hose or passage permit coolant circulation through the engine when the thermostat is closed. If the coolant cannot circulate, hot spots could develop inside the engine.

Thermostats

Bypass Thermostat:

A bypass thermostat has a second valve for routing all the hot coolant through the radiator, not just most of the hot coolant.

The main thermostat valve regulates flow through the engine and radiator like a conventional thermostat. The added valve blocks off the bypass once the engine has reached operating temperature.



Thermostats

Thermostat Jiggle Valve:

A small valve fit into a hole formed in the thermostat. It helps prevent air pockets from forming in the housing.

Consistent Operating Temperature

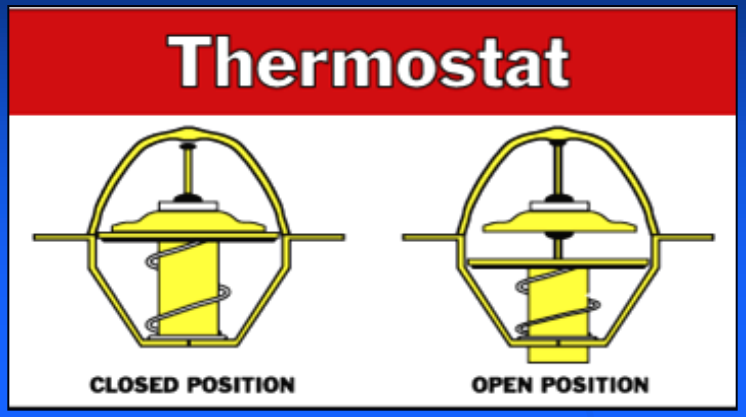
Engine too Cold

Inefficient – Combustion in incomplete

May run rough

Have excessive emissions

Excessive blow-by



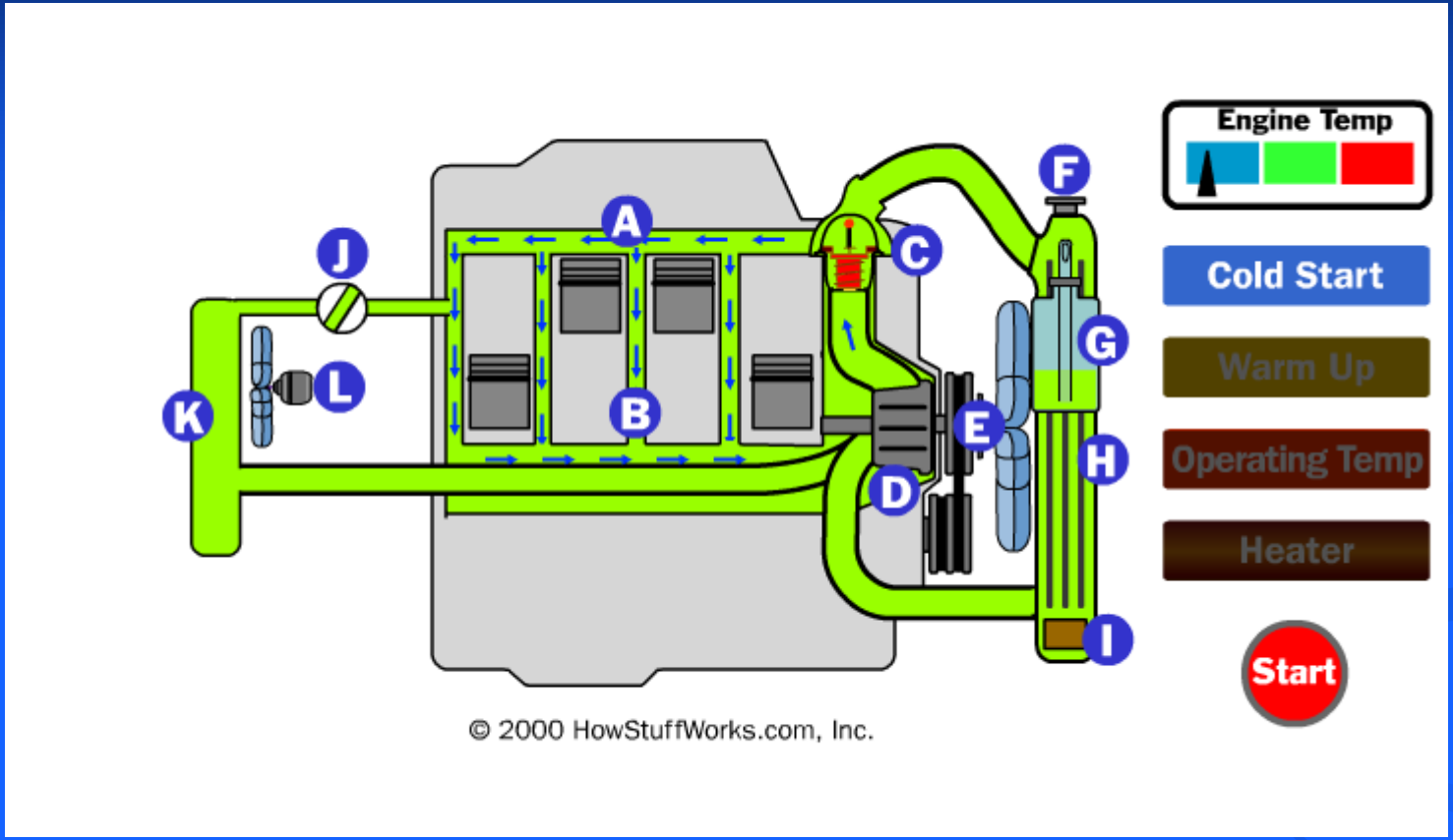
Engine too Hot

Oil lubricating film breaks down

Internal engine parts can warp, bend or melt

Pre-ignition can occur

Coolant Circulation



A Head cooling	E Cooling fan	I Transmission cooler
B Block cooling	F Radiator cap	J Heater valve
C Thermostat	G Overflow tank	K Heater core
D Water pump	H Radiator	L Heater fan

Cooling System Instrumentation

Most vehicles are equipped with a temperature warning light. Some vehicles also have an engine temperature gauge. It is important that you understand the operation of both.

Cooling System Instrumentation

Temperature Warning Light:

Informs the driver when the engine is overheating, when the coolant becomes too hot.

When coolant becomes too hot, a temperature sending unit in the engine block closes completing the circuit, making the indicator light on the dash glow.

When the coolant is at normal operating temperature, the sending unit circuit is open and the light remains off.

Cooling System Instrumentation

Temperature Warning Light:

With many late model vehicles, the engine temperature warning light is energized by the engine control module. If the sensor detects an overheating engine, the ECU sends current to the warning light.

Cooling System Instrumentation

Engine Temperature Gauge:

Shows the exact operating temperature of the engine coolant. A variable resistance sending unit and a gauge are used in the circuit.

A cold engine gives a high resistance (less current) and no needle deflection, a hot engine gives low resistance (more current) and lots of needle deflection

Antifreeze

Usually ethylene glycol, is mixed with water to produce engine coolant.

Antifreeze has several functions:

- Prevents from freeze up
- Prevents rust and corrosion
- Lubricates the water pump
- Cools the engine

Antifreeze

Prevents from freeze up:

Antifreeze keeps the coolant from freezing in very cold weather.

Coolant freezing can cause serious cooling system and engine damage.

As ice forms it expands. This expansion can produce great force, the water pump housing, cylinder head, engine block, radiator, or other parts could be cracked and ruined by this force.

Antifreeze

Prevents Rust and Corrosion:

Antifreeze prevents rust and corrosion inside the cooling system.

It provides a protective film on part surfaces.

Even in hot climates, antifreeze should be used to protect internal parts from corrosion.

Antifreeze

Lubricates the water pump:

Antifreeze acts as a lubricant for the water pump and thermostat.

Antifreeze increases the service life of the water pump bearings and seals.

Antifreeze prevents thermostat wear and corrosion.

Antifreeze

Cools the Engine:

Antifreeze conducts heat better than water and therefore, cools the engine better.

It is normally recommended in hot weather.

For example:

Using the air conditioning in your car increases the temperature of the air flowing through the radiator, antifreeze can prevent overheating when the air conditioning is on.

Antifreeze

Antifreeze : Water Mixture:

For ideal cooling and protection from freeze up, a 50/50 mixture of water and antifreeze is usually recommended.

It will provide protection from ice formation to about -34°F (-37°C)

Higher ratios of antifreeze may produce even lower freeing temperatures, but this is not normally needed.

Plain water should never be used in a cooling system

Block Heater

Block Heater:

May be used on an engine to aid engine starting in cold weather.

Block Heater

Block Heater:

It is simply a 120 volt heating element mounted in the block water jacket.

The heater power cord is plugged into a wall outlet.

This keeps the engine warm when the vehicle is not being used, then when the owner cranks the engine it will start more easily.

Most commonly used on diesel engines as they are harder to start in cold weather.

Ch. 39 Cooling System Fundamentals Review

For ideal cooling of an engine, what mixture of water to antifreeze do we use?

50/50

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The component in the cooling system that controls coolant flow is called the:

Thermostat

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A water pump is located on the _____ of an engine.

Front

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What can be used to prevent coolant leakage between the water pump housing and the engine block?

A Gasket

RTV Sealant

Or

An O-Ring

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Core, Petcock and Transmission Cooler are all components of what cooling system part?

Radiator

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The radiator cap provides functions, what are they?

Seals radiator filler neck

Allows excess pressure to escape

Pressurizes the cooling system

Allows coolant to flow from radiator to overflow and vise versa

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Why do we use a radiator shroud?

To direct (control) airflow

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Explain how a thermostat works

It is closed when the engine is cold, when the engine coolant is hot enough it makes the wax filled pellet in the thermostat expand pushing the piston open to allow coolant to flow to the radiator and cool down.

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Why is a block heater useful in diesel engines?

It keeps the coolant warm which allows the engine to start easier (compression ignition) in colder temperatures.

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What are the 4 functions of the cooling system?

Remove excess heat from the engine compartment

Maintain operating temperature

Allow engine to reach operating temperature quickly

Provide a means of heating the passenger compartment

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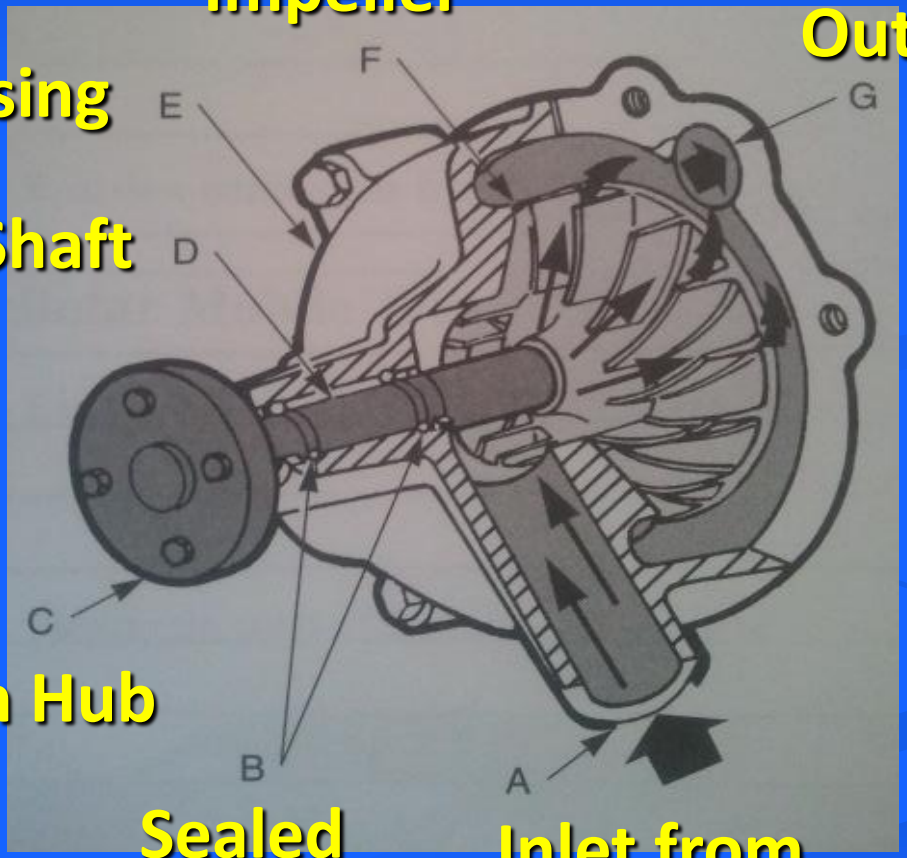
Name the parts of the Water pump below



Impeller

Housing

Outlet to Water Jacket

Pump Shaft

Fan Hub

Sealed Bearings

Inlet from Radiator

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What type of fan is used on front wheel drive vehicles with transverse engines?

Electric Fan

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What allows coolant flow through the engine when the thermostat is closed?

A bypass hose

and

a bypass valve in the thermostat

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What cooling system circulates coolant around the engine?

Water pump

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Antifreeze has 4 functions, what are they?

Prevents winter freeze up

Prevents rust and corrosion

Lubricates the water pump

Cools the engine

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By raising the pressure in the cooling system you also increase the _____ _____ of the coolant

Boiling point

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A temperature _____ on the engine is used to operate the temperature warning light.

Sensor

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It is ok to remove a thermostat in warm weather because the engine will run warmer.

True

False

The engine will take longer to warm up and will wear out faster.

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Liquid cooling systems have replaced air cooling systems in automobiles.

True

False

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Downflow radiators are used in small front wheel drive cars because they allow for a lower hood line.

True

False

Crossflow radiators are used in these vehciles

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Some transmission oil coolers are built into the radiator.

True

False

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An open cooling system uses an overflow tank to collect and return extra coolant to the system during warm up and cool down.

True

False

A closed cooling system does this. An open cooling system spills overflow onto the ground.

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A small diameter hose that carries coolant to the heater core is called a:

Heater hose

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A hose that is manufactured in a special shape, with bends to clear the cooling fan and other parts is called a:

Molded hose

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What is commonly used in a lower radiator hose to prevent its collapse?

A Spring

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What carries coolant from the water jackets in the engine to the radiator?

Radiator Hoses

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The part of the water pump that provides a mounting place for the belt pulley and the fan is called:

The Water Pump Hub

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What is the difference between a water pump seal and a water pump gasket?

The seal is internal to prevent leakage between the pump shaft and pump housing and the gasket is between the housing and the engine block

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Do you feel ready for the Test?

If YES ------- GREAT!

If NO ---------- Start studying!

Don’t forget to make notes if you haven’t already