Phase
2

Trade of Motor Mechanic

Module 3

Unit 3

Cooling System

Produced by

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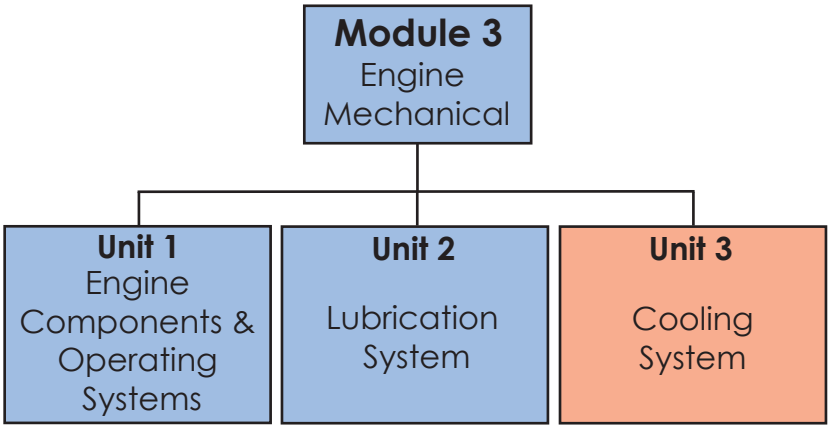
Introduction

This unit covers the basic function and operation of the cooling and system of the automotive internal combustion engine.



Combustion of the air-fuel mixture in the cylinders generates heat which produces high pressure, to force the piston down in the power stroke. Not all of this heat can be converted into useful work on the piston and it must be removed to prevent seizure of moving parts. This is the role of the cooling system. There are two types of cooling systems, liquid-cooled and air cooled. Liquid cooled being the most common.

In modern cars the engines that are liquid cooled a water pump forces the liquid through passages called water jackets in the engine block. It collects heat by conduction and becomes hot itself. Heated coolant then returns to the radiator for cooling and the cycle is repeated. Heat is removed from the engine and dispersed thus preventing overheating. These components along with the air cooled components and it's related health and safety issues will be covered in detail within this unit.

Unit Objective

By the end of this unit each apprentice will be able to:

- Describe the function and operating principle of a sealed, liquid cooling system for a multicylinder automobile engine
- Describe the basic operation of a mechanically driven fan-forced air, engine cooling system
- Define the following terms; heat transfer; conduction, convection and radiation
- Define the following terms; temperature, Celsius scale, Kelvin scale
- Test the operation of the principal cooling system components
- Describe the effects of ambient pressure levels on the boiling point of water
- Describe the hazards involved and Health and Safety precautions applicable when working on cooling systems
- Describe the advantage and disadvantage features of liquid and air cooling systems
- Use an antifreeze hydrometer to test the strength of antifreeze solution in a cooling system
- Describe the 'end of useful life' procedures to be used with engine coolant
- Drain a cooling system, fit antifreeze, bleed and top up the system
- Check the operation of the viscous coupling and bi-metal switch type automatic cooling fans
- Change cooling system components and pressure test the system for leaks
- Describe the main causes and resultant effects on engine components and performance by overheating or overcooling

1.0 Hazards and Safety Precautions

Key Learning Points

- Hazards; boiling liquid, pressure cap removal-scalding, rotating fans/pulleys, automatic cut in fans. Minor leaks e.g. loose hose going unnoticed - engine overheat/damage

1.1 Health and Safety

If the proper safety procedures are not adhered to when working on the *Cooling System* this could lead to burns, scalding, injuries from moving parts and slips & falls from coolant leaking onto floor

Instruction is given in the proper safety procedures applicable to working on cooling systems which include the following key points:

- Boiling liquid
- Pressure cap removal
- Rotating fans/pulleys
- Automatic fan cut in
- Engine overheating – damage
- Water leaks

Refer to motor risk assessments, Environmental policy and Material Safety Data Sheets (MSDS)

2.0 'End of Useful Life' Procedures

Key Learning Points

- 'Used' coolant disposal procedures, appropriate storage/ collection for industry approved recycling company use

2.1 Environmental Aspects - Coolant

When disposing of used coolant care must be taken not to cause pollution. Storage of used coolant must comply with the currant law regarding environment protection. Coolant must be disposed of by an authorised waste disposal company.

3.0 The Sealed, Liquid Cooling System

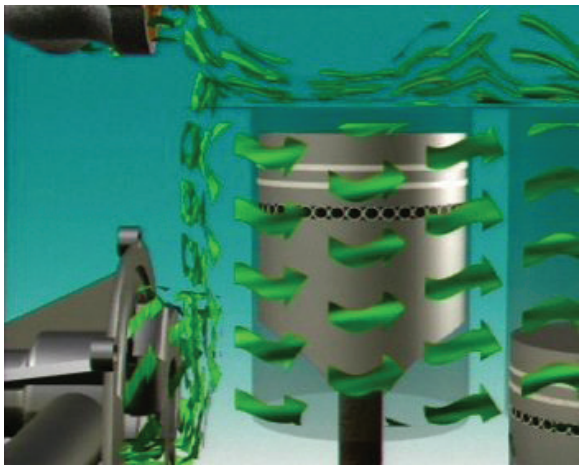
Key Learning Points

- Removal and dissipation of unusable, excess heat from the internal combustion engine (heat engine) by liquid or air flow
- Types of cooling systems; liquid; thermo siphon, pressurised and sealed, air (fan driven) flow
- Function and principle of operation of; wax thermostat, pressure cap, water pump, radiator etc

3.1 Cooling Systems

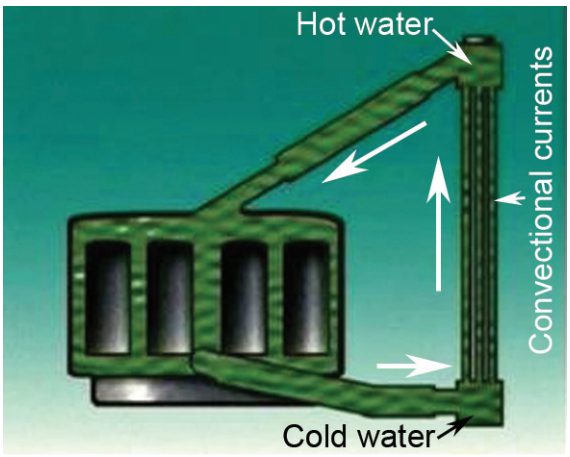
Combustion of the air-fuel mixture in the cylinders generates heat which produces high pressure, to force the piston down in the power stroke. Not all of this heat can be converted into useful work on the piston and it must be removed to prevent seizure of moving parts. This is the role of the cooling system. Most engines are liquid-cooled.

A *liquid-cooled* system uses coolant - a fluid that contains special chemicals mixed with water. Coolant flows through passages in the engine and through a radiator. The radiator accepts hot coolant from the engine and lowers its temperature. Air flowing around and through the radiator takes heat from the coolant. The lower-temperature coolant is returned to the engine through a pump.



Air cooling is common on smaller internal combustion engines. Some engines use cooling fins. Their design makes the exposed surface area as large as possible which allows more heat energy to radiate away and be carried off in convection currents in the air. Some engines also use a fan to direct air over the fins.

3.2 Liquid Cooling



Thermo Siphon System

In the very basic liquid-cooling system a coolant is stored in a radiator and in the engine. As the engine heats up a natural circulation starts as coolant rises through the engine block by convection. It passes through the top hose and into the radiator. Inside the radiator heat is removed from the coolant as it falls from the top to the bottom. When it reaches the bottom it returns to the engine through the lower radiator hose. Water has a high specific heat capacity which means that it has a good ability to absorb heat. It is this ability to absorb large quantities of unusable heat from around the engine cylinders retain the heat and carry it to the radiator where the high temperature coolant is exposed to air at a lower temperature and as heat always flows from a high temperature to lower temperature the heat energy is dissipated and the temperature of the water is reduced. This system is known as thermo siphon.

In modern cars the engines are more powerful therefore radiators are low and wide and a thermo-siphon process couldn't move the coolant quickly enough.

Instead, a water pump forces it through passages called water jackets in the engine block. It collects heat by conduction and becomes hot itself. Heated coolant then returns to the radiator for cooling and the cycle is repeated. Heat is removed from the engine and dispersed. Preventing overheating is one function of the cooling system.

It also helps the engine reach its best operating temperature as soon as possible. Every engine has a temperature at which it operates best. Below this temperature, ignition and combustion can be difficult.

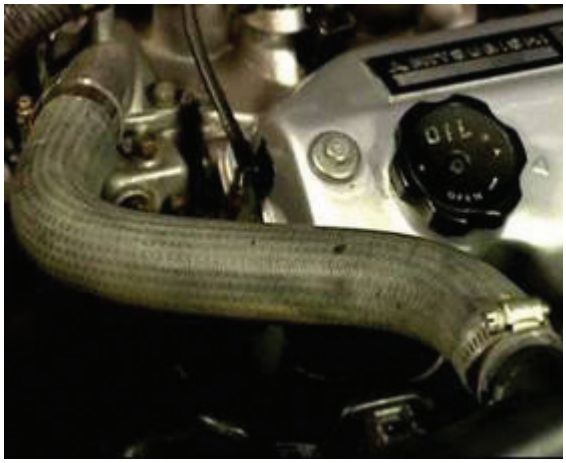
Most engine wear occurs during this warm-up period and most pollution too.

3.3 Cooling System Hoses

Coolant is transferred throughout the cooling system by hoses.

Most vehicles have the engine mounted on flexible mountings to reduce noise and vibration. Since the radiator is mounted to the vehicle body flexible hoses are needed.

Coolant is also carried to the heating system which is usually inside the cabin of the vehicle. Coolant hoses vary in diameter depending on the volume of coolant that passes through them. Heater hoses carry a smaller volume.



All hoses are subject to hot coolant and high under-bonnet temperatures and they can deteriorate and fail.

3.4 Cooling Fans-Electric/ Viscous Hub

In a vehicle moving at high speed airflow through the radiator cools the coolant but at low speed or when the engine is idling extra airflow comes from a fan.

Fans can be driven in different ways. More and more modern vehicles now use an electric fan. Air-conditioned cars often have extra fans.

Electric fans can be behind the radiator, in front, or both. This arrangement would be difficult with a belt-driven fan. Some fans can be driven from the crankshaft.

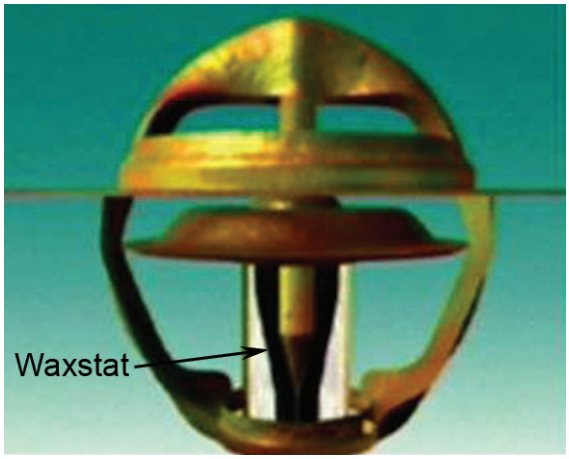
When an engine is mounted longitudinally, its fan is usually mounted on the water pump shaft. The drive belt then turns the water pump and fan. Some use a hydraulic link from the power steering system. Fan blades can be rigid or flexible. Rigid blades tend to be noisy and use more energy. This noise can be reduced by using irregular spacing of the fan blades. Some vehicles use a shroud to direct all of the air that the fan moves through the radiator core.

At high speeds, plenty of air is already flowing through the radiator. If the fan is always working at full speed, it's a waste of energy and since the engine drives the fan, it's a waste of fuel too. What's needed is some way to control the fan. A heat-sensitive switch in contact with the coolant can work like a thermostat and turn the fan on and off according to coolant temperature.

Another way to alter the speed of the fan is with a *viscous hub*. This type of fan slips when it is cold but as the engine heats up it grips more and more. Testing of this hub can only be done following manufacturers instructions. The drive has a disc shaped clutch plate that is placed in a container of silicone fluid. The viscous drag of the fluid caused by its resistance to shear provides a non-positive drive that is designed to slip at an increasing rate as the engine speed rises. Viscous fans are made in two forms: torque-Limiting and air temperature sensitive.

3.5 Cooling System Thermostat

The thermostat helps an engine to warm up. It's found in different positions on different engines.



It is a valve that operates according to coolant temperature. When coolant is cold a spring holds the valve closed.

When a cold engine starts coolant circulates within the engine block and cylinder head and through a coolant bypass to the water pump inlet. It can't get to the radiator. As the engine warms up the coolant in the engine gets hotter and hotter.

Thermostats have a small hole or valve to let out air that was trapped in the engine block. Heated coolant is pumped from an outlet in the cylinder head. It goes into the upper radiator hose then to the radiator.

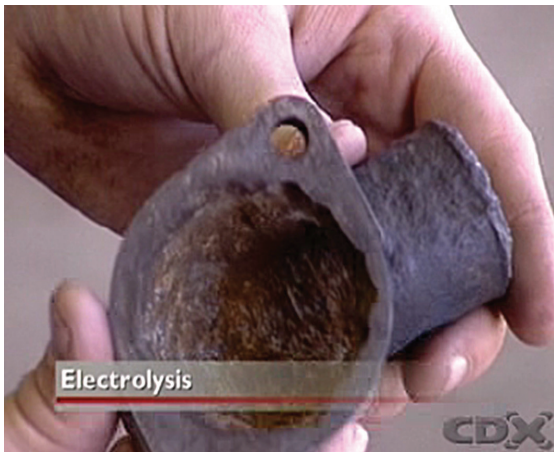
3.6 Electrolysis

In chemistry and manufacturing electrolysis is a method of separating bonded elements and compounds by passing an electric current through them.

Electrolysis is a chemical and electrical process. It occurs when two different metals are in contact in the presence of a moist agent such as water. One of the metals is corroded away.

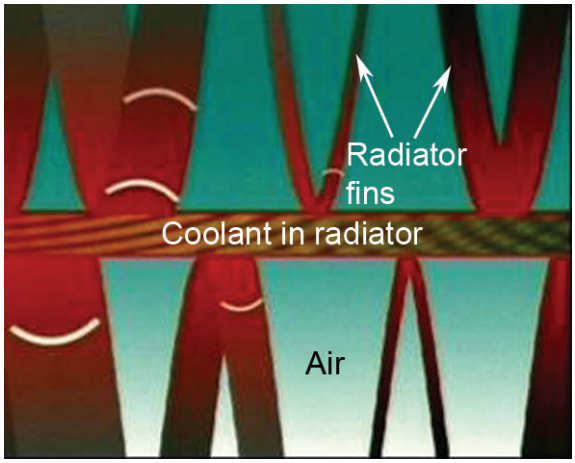
This can occur even in pure water. Immersed in this water are 2 plates, one of aluminium alloy the other of cast iron. The atomic structure of aluminium means it loses electrons easily leaving behind aluminium ions which are positively charged. Negative oxygen ions in the water are then attracted to the aluminium ions and they join

to form deposits of aluminium oxide. As a result the aluminium alloy is eaten away or corroded.



3.7 Radiator

Many radiators are mounted at the front of the vehicle in the path of greatest airflow. The air carries heat away cooling the liquid before it returns to absorb more heat from the engine.



It can be made of sheet metal or hardened plastic. The radiator has 2 tanks and a core. The materials used in the radiator must be good heat conductors like brass or copper. Brass and copper are often used for tanks combined with a copper core.

Modern vehicles often use plastic tanks combined with an aluminium core. This saves weight but still provides good heat transfer. The core consists of a number of tubes that carry coolant between the 2 tanks. The tubes can be in a vertical down flow pattern, or a horizontal cross flow pattern.

A cross flow radiator fits more easily under a steeply sloped bonnet. In the core small thin cooling fins are in contact with the tubes. The shape of the fins increases the surface area exposed to the air.

Where coolant touches tube walls and where the tubes touch the fins heat is removed from the coolant by conduction then by radiation and convection at the surface of the fins. Air rushing by carries the heat away. Liquid emerges cooler at the bottom of the radiator. It travels through the lower radiator hose to the water pump inlet then through the engine again.

3.8 Radiator Pressure Cap

If a coolant boils it can be as serious for an engine as having it freeze.

Boiling coolant in the water-jacket becomes a vapour. No liquid is left in contact with the cylinder walls or head. Heat transfer by conduction stops. Heat builds up and that can cause serious damage.

One way to prevent this is with a radiator-pressure cap that uses pressure to change the temperature at which water boils. As coolant temperature rises the coolant expands and pressure in the radiator rises and that lifts the boiling point of the water. Engine temperature keeps rising and the coolant expands further. Pressure builds against a spring-loaded valve in the radiator cap until at a preset pressure the valve opens.

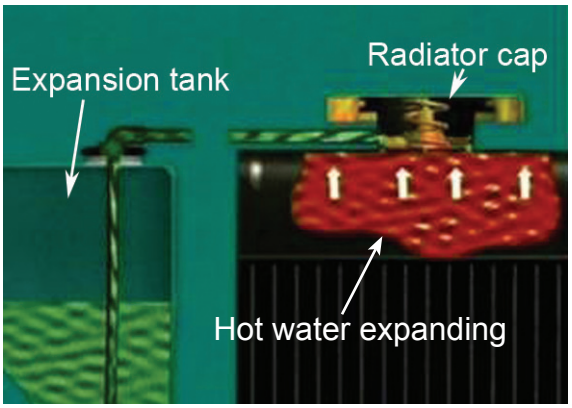
In a recovery system the hot coolant flows out into an overflow container. As the engine cools, coolant contracts and pressure in the radiator drops. Atmospheric pressure in the overflow container then opens a second valve, a vacuum vent valve and overflow coolant flows back into the radiator.

This system stops low pressure developing in the radiator and that stops atmospheric pressure collapsing the radiator hoses.

3.9 Recovery System

A recovery system maintains coolant in the system at all times.

As engine temperature rises coolant expands. Pressure builds against a valve in the radiator cap until at a preset pressure the valve opens. Hot coolant flows out into an overflow container.

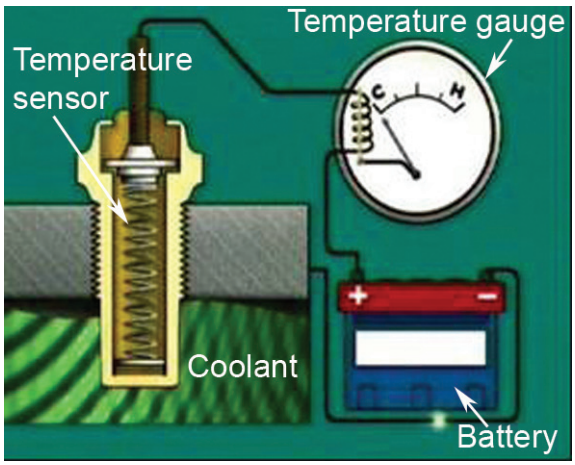


As the engine cools coolant contracts and pressure in the radiator drops. Atmospheric pressure in the overflow container opens a second valve and overflow coolant flows back into the radiator.

3.10 Temperature Indicators

Overheating can seriously damage an engine so having warning of trouble is obviously useful.

A device that's sensitive to engine temperature sends readings to a temperature gauge or a warning lamp. To give an accurate reading this sensor must always be immersed in liquid.

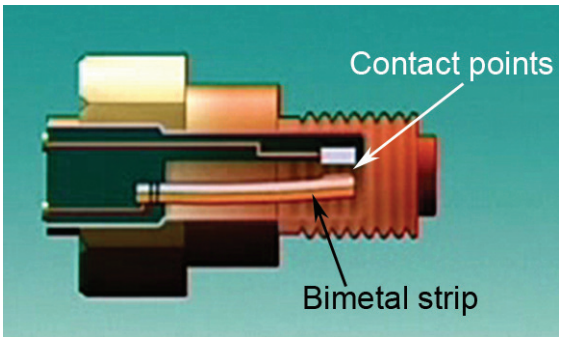


Indicators that measure coolant levels can give warning if the level falls too low.

3.11 Thermo-Switch/Bi-Metal Switch

A thermo-switch opens and closes according to pre-set temperature levels. Some are mechanical others are electrical. It may be designed to switch off when temperature rises above a certain level or it can be made to switch on when the temperature reaches a certain level.

Heat switches can operate on the bimetallic strip principle. It consists of two different metals or alloys attached back-to-back. As different metals and alloys heat and cool they expand and contract differently. That means that if they are joined and then heated the faster expansion of one will force the whole strip into a curved shape.



As the strip changes shape it can be designed to complete a circuit and a resulting electrical signal can then do a range of tasks or it might have a mechanical effect simply opening a passageway.

Cooling then produces the opposite effect. Breaking the circuit and closing the passage. Testing of this type of switch can only dome using manufactures specifications.

3.12 Water Pump

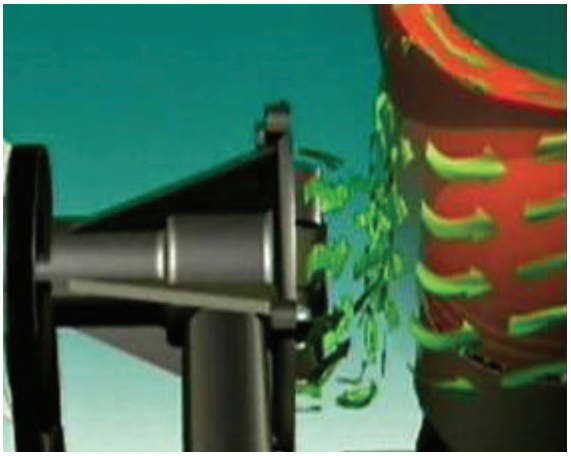
The water pump is usually in front of the cylinder block belt-driven from a pulley on the front of the crankshaft. A hose connects it to the bottom of the radiator where the cooler liquid emerges.

It has fan-like blades on a rotor or impeller. Coolant enters the centre of the pump. The rotor spins and centrifugal force moves the liquid outward. It is driven through the outlet into the cooling passages called waterjackets.

3.13 Centrifugal Force

Centrifugal force is a force pulling outward on a rotating body.

A vehicle turning a curve is a similar system to this rotating body so it is subject to centrifugal force too. Centrifugal force resists turning and tries to keep the vehicle moving in a straight line. Centrifugal force is also the force that causes an out-of-balance wheel to vibrate. Centrifugal force can also be useful. When coolant enters the centre of this pump and the rotor spins centrifugal force moves the liquid outward.



4.0 Mechanically Driven Fan-Forced Air, Engine Cooling System

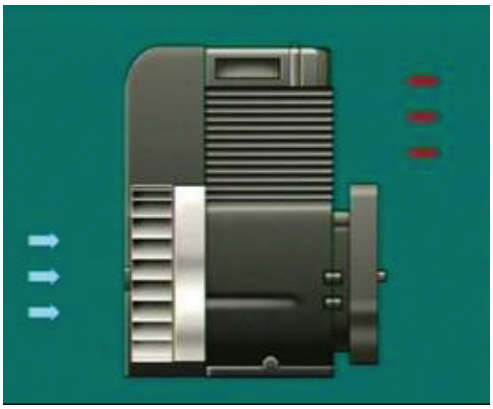
4.1 Air Cooling

Air-cooling is common on smaller internal combustion engines. They may be small but they still generate a lot of heat.

It's the air that does the work of keeping them cool, so an air-cooling system is usually simple. That's useful on an engine where weight is important and it works best on the engine that's exposed to a high airflow.

Some engines use what are called cooling fins. Their design makes the exposed surface area as large as possible which allows more heat energy to radiate away and be carried off in convection currents in the air.

More air flows over the fins and more heat is carried away. For a vehicle moving at speed airflow over the engine is high. At low speeds or during idling heat builds up. Then the engine can use some help.



Air should always be able to flow over the engine effectively.

One way to remove heat is to use a fan with shrouds and ducts to direct air to the cylinders.

There are many places to mount a fan and many ways to drive it. For instance in some engines it's on the flywheel driven by fan-belts off the crankshaft.

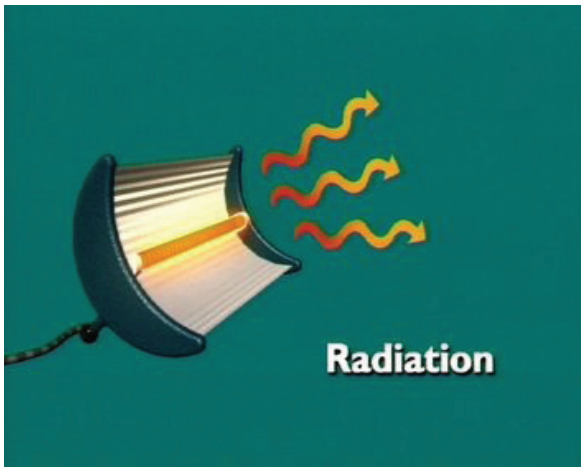
5.0 Heat Transfer Conduction, Convection and Radiation

Key Learning Points

- Definition of heat movement; conduction, convection and radiation, temperature and temperature scales, Celsius, Kelvin

5.1 Heat transfer

The internal combustion engine works by changing heat energy into kinetic energy. There are many ways to do this some better than others. But no matter how efficiently it is done and no matter the size of the engine the heat energy generated never completely changes into kinetic energy. Some energy is always lost.



This is certainly true in internal combustion engines where only about a third of the heat generated is transformed into the mechanical energy that moves the piston and turns the crankshaft. Another third goes out the exhaust wasted. The rest tries to spread round the engine.

Heat always moves from areas of higher temperature to areas of lower temperature which can be a problem. To control this movement it is necessary to understand how heat is transferred.

Heat travels in just 3 ways:

- The way it moves through solids is called *conduction*.
- Through liquids and gases it is called *convection*. It follows paths called convection currents.
- Through space it moves by *radiation*.

5.2 Temperature and Temperature Scales

Temperature definition: *The degree of hotness or coldness of a body or environment.*

The *degree Celsius (°C)* scale was devised by dividing the range of temperature between the freezing and boiling temperatures of pure water at standard atmospheric conditions (sea level pressure) into 100 equal parts. Temperatures on this scale were at one time known as degrees centigrade.

The *kelvin (K)* temperature scale is an extension of the degree Celsius scale down to absolute zero a theoretical temperature characterized by a complete absence of heat energy. Temperatures on this scale are called kelvins, NOT degrees kelvin. Kelvin is not capitalized and the symbol (capital K) stands alone with no degree symbol.

Temperature	*kelvin-K*	*Degree Celsius-°C*
Boiling point of water	373.15	100
Melting point of ice	273.15	0
Absolute zero	0	-273.15

Temperature Conversions Between the Three Temperature Scales

Kelvin/degree Celsius Conversions (exact)

- kelvin = degree Celsius + 273.15
- degree Celsius = kelvin - 273.15

6.0 Testing Cooling System Components

Key Learning Points

- Use of a thermometer to evaluate wax type thermostat performance with manufacturer's specifications

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

6.1 Removing & Replacing a Thermostat

Preparation and Safety

Objective

Safely remove and replace a cooling system thermostat.

Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

Safety Check

- Coolant in the cooling system could be above its boiling point. Never open a radiator cap fully until ALL pressure has been

released.

- Before removing the pressure cap, check the temperature of the cooling system with an infrared temperature gun if you have one available.
- When removing a radiator cap, use appropriate gloves, clothes, full face shield, etc.
- Before commencing a repair or service task on the cooling system and allow approximately 30 minutes for the system to cool sufficiently before opening the pressurised system.
- When removing a radiator cap, use appropriate gloves, clothes, full face shield, etc.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

- Drain the at least 50% of the coolant in the system to avoid spills.
- Position the thermostat air bleed valve (if fitted) in the proper position.
- Make sure the thermostat is fully seated in the groove and stays there before fitting the housing. Failure to do so will damage the new thermostat and possibly break the housing as it is tightened up.
- Tighten the housing bolts to the correct torque.
- Make sure to use the manufacturer's procedure to properly bleed all air from the cooling system.

Step-by-step Instruction

1. *Remove the thermostat:* Unbolt the thermostat housing from the engine block. Be very careful not to damage the housing as it is generally made from aluminium or a similar fragile material. Remove the thermostat.

2. *Inspect the mating surfaces:* Inspect the thermostat housing and remove any gasket material from the mating surface of the housing. Inspect the engine block and remove any gasket material from its mating surface.

3. *Install the new thermostat:* Inspect the new thermostat to ensure that the identification number is the same as the one you have removed. Fit the new thermostat, ensuring the air bleed hole is in the correct position. Check the thermostat is fully seated in its groove. Fit the correct type of gasket for the vehicle you are working on. Carefully refit the thermostat housing to the engine block and bolt it into place.

4. *Refill the cooling system:* Refill the system with coolant. Run the engine to circulate the coolant and remove any air trapped in the system. Check that the temperature indicator gauge shows the coolant temperature is in the normal operational range. Top up the radiator or reservoir with coolant if necessary.

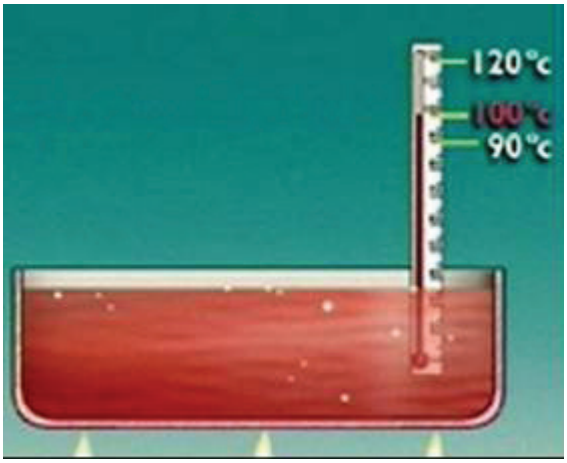
7.0 The Boiling Point of Water

Key Learning Points

- Ambient pressure - pressure caps - boiling point of water

7.1 Boiling Point and Pressure

Water at atmospheric pressure at sea level boils at 100 degrees Celsius. That is it's 'boiling point'.



Atmospheric Pressure

If the water is put under pressure higher than atmospheric pressure it boils at a higher temperature.

If the pressure is decreased below sea level atmospheric pressure it boils at a lower temperature. Therefore raising pressure above atmospheric pressure increases the boiling point. Lowering it below atmospheric pressure lowers the boiling point.

Changing water pressure changes the temperature at which it boils.

8.0 Comparison of Liquid and Air Cooling Systems

8.1 Air Cooled Engines

Listed here are some advantages and disadvantages.

Advantages

- An air-cooled engine should generally be lighter than the equivalent water-cooled engine.
- The engine warms up to its normal running temperature very quickly.
- The engine can operate at a higher temperature than a water-cooled engine.
- The system is free from leakage problems and requires no maintenance.
- There is no risk of damage due to freezing of the coolant in cold weather.

Disadvantages

- A fan and suitable cowls are necessary to provide and direct the airflow. The fan is noisy and absorbs a fairly large amount of engine power. The cowling makes it difficult to get at certain parts of the engine.
- The engine is more liable to overheating under arduous conditions than a water-cooled engine.
- Mechanical engine noises tend to be amplified by the fins.
- The cylinders usually have to be made separately to ensure proper formation of the fins. This makes the engine more costly to manufacture.
- Cylinders must be spaced well apart to allow sufficient depth of fin.
- It is more difficult to arrange a satisfactory passenger compartment heating system.

8.2 Liquid Cooled Engines

Listed here are some advantages and disadvantages.

Advantages

- Temperatures throughout the engine are more uniform thus distortion is minimized.
- Cylinders can be placed close together and the engine made more compact.
- Although a fan is usually fitted to force air through the radiator, it is smaller than that required in an air-cooled system and is thus quieter and absorbs less engine power.
- There is no cowling to obstruct access to the engine.
- The water and jackets deaden mechanical noise.
- The engine is better able to operate under arduous conditions without overheating.

Disadvantages

- Weight, not only of the radiator and connections but also of the water. The whole engine installation is likely to be heavier than an equivalent air-cooled engine.
- Because the water has to be heated, the engine takes longer to warm up after starting from cold.
- If water is used, the maximum temperature is limited to about 85 to 90° to avoid the risk of boiling away the water.
- If the engine is left standing in very cold weather, precautions must be taken to prevent the water freezing in the cylinder jackets and cracking them.
- There is a constant risk of leaks developing.
- A certain amount of maintenance is needed, e.g. checking water level, anti-frost precautions, cleaning out deposits, etc.

9.0 Testing Antifreeze Solution in a Cooling System

Key Learning Points

- Correct use of the antifreeze hydrometer to test the specific gravity of the coolant

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

9.1 Checking & Adjusting Coolant

Preparation and Safety

Objective

Check and adjust coolant levels and test coolant quality in a vehicle with a recovery reservoir.

Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

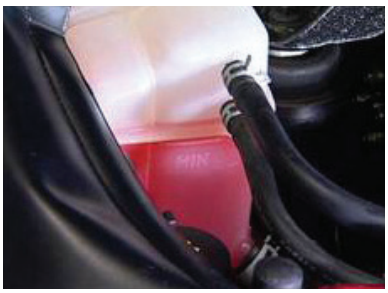
Safety Check

- Always be very careful when opening a radiator cap because the cap keeps the coolant under pressure to raise its boiling point. Sometimes even the pressure in a warm engine can force the coolant to spurt out when the cap is released.
- Always cover the radiator cap with a rag to catch any hot spray.
- Always wear eye protection.
- *Never* open a radiator cap on an overheated engine; wait for it to cool down first.
- Always make sure that you wear the appropriate personal protection equipment before starting the job. It is very easy to hurt yourself even when the most exhaustive protection measures are taken.
- Always make sure that your work area/environment is as safe as you can make it. Do not use damaged, broken or worn out workshop equipment.
- Always follow any manufacturer's personal safety instructions to prevent damage to the vehicle you are servicing.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

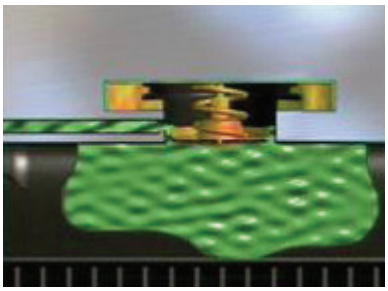
Points to Note

- There are two correct level marks on the reservoir because the coolant in the system expands and contracts in volume depending on how hot it is. The coolant level should be at the lower mark when the vehicle is cold. The coolant level should be at the upper mark when the coolant is hot.

- If the reservoir is completely empty, add coolant until the level is up to the appropriate mark for the engine temperature. Then run the engine until it is at its normal operating temperature and check the level again. You will probably need to adjust the level again.



- For each 10 kPa increase in the radiator cap operating pressure, it will increase the boiling point of the coolant by 2°C.



Step-by-Step Instruction

1. *Check fluid level*: Most modern vehicles have a coolant system that uses a transparent recovery tank as a coolant reservoir. Check the level of coolant in this reservoir; if the engine is hot the level should be visible at the upper mark. If the engine is cold it should be at the lower mark.

2. *Check protection level with a hydrometer*: Before adding new coolant; check the specific gravity of the coolant in the system with a coolant hydrometer. Draw some coolant up into the hydrometer and read the mark on the float at the level of the fluid in the chamber. This will indicate the freezing point of the coolant mixture in the system, so you can tell if it has the right proportions of antifreeze and water.

3. *Adjust fluid level*: Check the service manual for the recommended type and mixture of coolant that will produce an appropriate level of protection for the conditions where the vehicle will be used. Use a funnel to add enough coolant to bring the level up to the appropriate mark. Replace the coolant reservoir cap.

10.0 Servicing the Cooling System

Key Learning Points

- Antifreeze fitted to correct specific gravity; system bled and topped up fully

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

10.1 Draining & Refilling Coolant

Preparation and Safety

Objective

Drain cooling system and refill with correct mixture of engine coolant.

Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items, this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

Safety Check

- Never drain and refill the cooling system of a hot engine. Wait for it to cool down first.
- Always make sure that you wear the appropriate personal protection equipment before starting the job. It is very easy to hurt yourself even when the most exhaustive protection measures are taken.

- Always make sure that your work area/environment is as safe as you can make it. Do not use damaged, broken or worn out workshop equipment.
- Always follow any manufacturer's personal safety instructions to prevent damage to the vehicle you are servicing.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

Some vehicles have drain plugs on the side of the engine block. The shop service manual will tell you if these need to be opened when draining the coolant.

Step-by-step Instruction

1. *Locate drain plug:* Locate the cooling system drain plug or valve on the bottom tank of the radiator. Place a clean drain pan large enough to contain all the coolant underneath the drain valve.
2. *Drain radiator*: Carefully remove the radiator pressure cap. This will allow air into the cooling system so that it can drain quickly and completely. Open the drain valve so that the coolant can drain into the pan below. When all the coolant has drained out, close the drain valve.
3. *Refill coolant system*: Check the shop service manual for the capacity of the system and the recommended type and mixture of coolant for the operating conditions of the vehicle. Measure the recommended amount of coolant and using a funnel pour it in through the top of the radiator.
4. *Start engine and verify*: Air can be trapped in the cooling system, so leave the radiator cap off to allow it to escape and run the engine for a few minutes to allow the coolant to circulate and get rid of trapped air. Then replace the radiator cap and bring the engine up to operating temperature. Check the coolant level in the reservoir and top it up to the high or hot engine mark.
5. *Dispose of waste*: Antifreeze is toxic, so dispose of the waste coolant carefully and in an environmentally recommended way.

11.0 Testing Viscous Coupling and a Bi-Metal Switch

Key Learning Points

- Test procedure for automatic cut in fan/thermo switch/ circuit

Practical Task

The testing of the radiator fan thermo switch circuit has to be done according to manufactures specification. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

12.0 Cooling System Components and Pressure Test

Key Learning Points

- Use of pressure tester, maximum pressure not exceeded, engine compartment and vehicle interior checked for leaks

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

12.1 Testing Cooling System Pressure

Preparation and Safety

Objective

Test a cooling system to confirm that it is without leaks and has the ability to hold the pressure specified by the manufacturer.

Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items this may include:

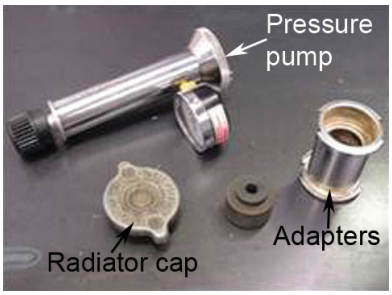
- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream

Safety Check

- Respiratory equipment – such as face masks etc.
- When working around the cooling system, care must be taken particularly if the engine is at operating temperature, as the coolant may be hot enough to scald.
- Always allow the system to cool before removing the radiator cap.
- Do not remove a radiator cap from a hot cooling system.
- Always use extreme caution when removing the radiator cap. Releasing the pressure cap, on an engine at operating temperature, may cause the hot coolant to superheat.
- If you must remove the radiator cap from a hot system, wear protective gloves and eyewear and remove it slowly, to the first (safety) point, to prevent the pressure inside from erupting. If you don't this could cause the scalding hot coolant to spill hot fluid over you or someone standing nearby.
- Make sure the engine is off when carrying out any visual inspection of the system or when you connect the tester. You may be required to run the engine after the tester has been installed and pressurized.
- When the engine is running, make sure that you keep any loose clothing away from rotating parts.
- When pressure testing a system, make sure you do not exceed the manufacturer's maximum pressure.
- Have a qualified instructor show you the correct operation of the tester.
- Make sure that you understand and comply with all environmental and occupational health and safety standards for your workplace at all times. If you are unsure of what these are, ask your instructor.

Points to Note

- To test the cooling system for both internal and external leaks, a pressure tester is normally used. These are often referred to as cooling system testers or analyzers. There are a number of different analyzers used today. Make sure you are familiar with the system used in your workshop.



- If you need to replace a pressure cap, use only a cap with the correct recommended pressure. If a cap with a lower pressure rating is fitted, it will lower the boiling point of the coolant. Alternatively a higher rated cap will increase the boiling point.

- Each 10 kPa (1.45 PSI) of cap-rated pressure changes the boiling point by 2°C. For example: A 90 kPa (13 PSI) radiator cap will increase the boiling point from 100°C to 118°C. Similarly, a 100 kPa (14.5 PSI) radiator cap will raise the boiling point from 100°C to 120°C.
- Pressure testing kits come with a number of adapters for various cooling systems. These adapters can be used to connect the tester to the radiator or to the radiator cap.

Step-by-step Instruction

1. *Inspect cooling system visually:* Before pressure testing the system, visually inspect the system for any obvious signs of leaks or wear in the radiator core, radiator tanks, coolant and heater hoses, water pump, all accessible engine core plugs, cooling fan, drive belt and radiator cap and seals.

2. *Check the operating instructions of the tester:* Refer to the pressure tester's manual for correct operation. The outside of the radiator cap should be marked with its operating pressure. When this pressure is reached, the pressure relief valve in the cap will allow a discharge into the overflow system.

3. *Test the radiator cap:* Refer to the workshop manual or vehicle owner's manual to check that the pressure cap fitted has the correct pressure rating for that cooling system. Attach the radiator cap to the tester with an adaptor and pump up the pressure on the radiator cap spring. The pressure should hold just below the relief pressure setting. If the pressure will not hold or it cannot reach this pressure, then replace it with a new cap of the correct type and recommendation.

4. *Test the cooling system:* Before testing the integrity of the cooling system, top up the coolant level. Attach the cooling system tester to the radiator cap locator. Pump up the system pressure to slightly above the pressure recommended by the rating specified on the pressure relief cap. Observe the pressure reading. If it remains steady and does not drop then the system is not leaking. However, if the pressure drops, look for the leak. If there is no visible external leak, then the leak is most probably internal. If there are any visible leaks, or the pressure drops, refer you test results to your instructor.

13.0 Overheating or Overcooling

Key Learning Points

- Causes of main mechanical failure: engine overheating/ overcooling
- Main effects of engine overheat/overcooling e.g. head gasket/head distortion, engine seizure and excessive fuel consumption – emission levels

13.1 Causes of Engine Overheating

There are a number of reasons why an engine is running hot (overheating) and showing an indication much higher that the normal range on the temperature gauge. Listed here are a few reasons.

- *Low coolant levels:* The quantity of coolant present in the system is the first possible cause of overheating. How or why the level of coolant dropped is next. Is it simply leaking or is it being boiled off due to faulty thermostat, head gasket or other fault? Check all possible external and internal hoses and clips etc.
- *Faulty thermostat:* As you have seen ('Testing of the thermostat), the thermostat can fail in the open or shut positions more usually in the open position. If the thermostat is a combined wax and electrically operated a malfunction will trigger an EOBD fault code, e.g. PO116, 7, 8 and 9.
- *Stresses on the cylinder head gasket:* The head gasket, fitted between the block and cylinder head, seals in combustion gases/ pressures, coolant and oil. However the cylinder head and engine block can be affected by differing rates of thermal expansion ('superficial expansion'). The manufacturer will do the best to neutralize this movement by good design but the head gasket may still subjected to movement, especially if the temperatures become excessive*.

** Excessive temperatures can occur even after the engine has been switched off due to 'heat soak' i.e. lack of movement of the coolant and the soaking of combustion chamber temperatures outward to the cylinder head.*

Manufacturer's remedies to avoid temperature rise due to 'heat soak':

A small electric water pump may be fitted that will switch on automatically should the temperature rise excessively due to 'heat soak' after the engine has been switched off. This pump will then circulate the coolant through the system which will distribute the unwanted heat away.

- *Faulty cylinder head gasket:* As the head gasket gradually becomes faulty the initial movement will consist of only molecules of combustion gas that creep unnoticed into the coolant. Eventually the amount of hot gases entering, affect the operation of the cooling system creating bubbles of hot gas that raise both the temperature and pressure inside the system. The engine eventually begins to boil/overheat and lose coolant. The more coolant is lost the faster the temperature will rise.
- *'Hydraulic lock':* Hydraulic lock is the term used to describe the locking solid of the engine due to its inability to compress a liquid inside the combustion chamber. This problem particularly affects diesel engines with their high compression ratios and therefore very small combustion chamber volumes. The effect of water intake into the combustion chamber is often seen in times of severe road flooding as drivers of diesel powered vehicles drive too quickly through high levels of surface water and some of the splashing water is drawn into the air intake. A very serious problem for conrods and pistons!
- *Hydraulic lock of the engine during starting:* Engines with faulty cylinder head gaskets allow combustion gases into the coolant but the reverse will also happen, As a faulty head gasket problem persists and the system is being continually topped up with coolant over the longer time period, coolant may begin to enter the cylinder when the engine is switched off and eventually if enough gets inside the combustion chamber a 'hydraulic lock' may occur during starting.
- *Electrolysis damage:* A problem that is more often associated with large diesel engines that use 'wet' cylinder liners, but the problem of electrolysis attacking and eventually making holes through from the outside to the inside of the wet liner does affect petrol engines that use these wet liners/sleeves. Holes from electrolysis may be invisible from the cylinder interior and therefore the cause of the overheating may be difficult to diagnose fully.

Effects of Serious Overheating on Engine Components

- *Cylinder head damage due to overheating:* The cylinder head will usually suffer distortion damage, i.e. 'warp' should head gasket faults and over heating occur. 'Warp' is the term used to describe distortion of the surface of the cylinder head and this distortion can also occur to aluminium engine blocks!
- *Testing the distortion of aluminium cylinder head and of aluminium block:* Both should be checked using a straight edge longitudinally, laterally and diagonally to highlight discrepancies outside of the recommended tolerances. Cracking can also occur that may necessitate replacement of the head. Always check the manufacturer's recommendations on cylinder head cracks, their location and size. Sometimes some cracking in certain locations may be acceptable.
- *Reducing possibility of cylinder head warping:* To help avoid 'warp' of aluminium heads, the manufacturers recommendations should be followed carefully during dismantling and reassembly e.g. the engine should be allowed to cool down fully before attempting removal of the head, all bolts should be removed in the correct sequence etc.
- *Care of the cylinder head surface:* The surface must not be scratched or sanded, always turn the surface up when the head is left on a bench, cleaning may only be done with gasket remover and wooden/plastic spatula. Only use gasket remover in open spaces, do not inhale fumes! Follow manufacturer's recommendations.
- *Cylinder head re-surfacing:* Manufacturers may supply tolerances for the re-surfacing of the cylinder head but great care and attention must be given to any re-working of a cylinder head that has camshaft/s running/fitted in it.
- *Damage to the 'short block' due to overheating:* 'Short block' is the term used to describe the engine block and all its internal components e.g. crankshaft, pistons etc. The most serious result that overheating can have on this is over- expansion of the pistons. Severe overheating inevitably means that the rear pistons, which have the least supply of low temperature coolant, expand until they no longer can fit comfortably inside the cylinder.

- *Why the pistons at the rear are first to 'melt':* Remember, the water pump is always in the front of the engine, with its impeller driving the cool water that is returning from the radiator from the front cylinders to the further cylinders at the rear. As the coolant travels back through the engine it is gaining heat all the time. Should the coolant level get low, bubbles and air pockets form around the cylinders, these reduce the effectiveness of the coolant, the temperatures rise abnormally. Eventually the pistons get tight in the cylinder bore, friction increases and the pistons begin to melt!
- *Crankshaft damage:* At the same time as some pistons are getting tight in the cylinders, others are working away pushing and dragging the tight pistons up and down the bores, this causes excessive pressures on the crankshaft bearings where friction now increases and the shell bearings overheat and begin to melt. The engine is now about to 'seize' up. A total rebuild is now required.

Self Assessment

Q1: Which method of heat transfer is prevented by heat shields fitted to the exhaust on some vehicles? (Tick one box only)

- ❑ 1. Conduction
- ❑ 2. Convection
- ❑ 3. Induction
- ❑ 4. Radiation

Q2: Cross-flow radiators are fitted to many modern vehicles because they: (Tick one box only)

- ❑ 1. Allow a low bonnet line to be achieved
- ❑ 2. Are cheaper to manufacture
- ❑ 3. Are more efficient than vertical-flow types
- ❑ 4. Are more efficient on transverse engine vehicles

Q3: Natural circulation of coolant in a cooling system is called: (Tick one box only)

- ❑ 1. Induction thermo-flow
- ❑ 2. Convention-circulation
- ❑ 3. Thermo-flow
- ❑ 4. Thermo-siphon

Q4: Adequate air circulation over the fins of an air-cooled stationary engine is provided by: (Tick one box only)

- ❑ 1. Convection currents as the fins heat up
- ❑ 2. An engine-driven fan
- ❑ 3. Natural air movement
- ❑ 4. Heat radiating to the lubricating oil

Q5: The thermostat in an engine cooling system: (Tick one box only)

- ❑ 1. Assists the engine to warm up quickly
- ❑ 2. Prevents coolant loss
- ❑ 3. Switches on the electric cooling fan
- ❑ 4. Prevents the coolant freezing

Q6: The thermostat in an engine cooling system controls: (Tick one box only)

- ❑ 1. Pressurization of the system
- ❑ 2. Operation of the electric fan
- ❑ 3. Circulation of coolant to the heater
- ❑ 4. Circulation of coolant to the radiator

Q7: A by-pass is incorporated in a cooling system to: (Tick one box only)

- ❑ 1. Raise the boiling point of the water
- ❑ 2. Prevent the radiator hoses from collapsing on engine cooling
- ❑ 3. Allow the coolant to by-pass to the radiator when the pressure becomes excessive
- ❑ 4. Allow the coolant to circulate through the engine when the thermostat is closed

Q8: Some modern coolants are developed from organic materials. (Tick one box only)

- ❑ 1. True
- ❑ 2. False

Q9: Cooling fins on the cylinders of an air cooled engine: (Tick one box only)

- ❑ 1. Reduce engine noise
- ❑ 2. Reduce the severity of burns
- ❑ 3. Provide increased surface area
- ❑ 4. Improve engine strength

Q10: All coolants are designed to change colour as they get older as an indication of loss of effectiveness. (Tick one box only)

- ❑ 1. True
- ❑ 2. False

Q11: The purpose of the viscous clutch on the fan hub is to: (Tick one box only)

- ❑ 1. Improve cooling at high road speeds
- ❑ 2. Extend engine warm-up time
- ❑ 3. Reduce engine power loss and noise
- ❑ 4. Reduce under-bonnet temperatures

Q12: The 2 valves incorporated in the radiator cap are: (Tick one box only)

- ❑ 1. The pressure and regulator valves
- ❑ 2. The vacuum and pressure valves
- ❑ 3. The regulator and vacuum valves
- ❑ 4. The temperature and pressure valves

Q13: Cooling systems are pressurized to: (Tick one box only)

- ❑ 1. Improve coolant circulation
- ❑ 2. Prevent internal coolant leaks
- ❑ 3. Raise the boiling point of the coolant
- ❑ 4. Increase the warm-up period

Q14: The vacuum valve in the radiator cap: (Tick one box only)

- ❑ 1. Maintains a vacuum in the system at all times
- ❑ 2. Prevents a vacuum occurring as the engine cools
- ❑ 3. Prevents air entering the system
- ❑ 4. Allows thermo-siphon circulation of the coolant

Q15: Special chemicals are added to the water in an engine cooling system to: (Tick one box only)

- ❑ 1. Lower its boiling point
- ❑ 2. Prevent foaming and evaporation
- ❑ 3. Prevent corrosion and freezing
- ❑ 4. Prevent cavitation and lubricate the pump seal

Q16: A cooling system thermostat that is seized in the "open" position will cause: (Tick one box only)

- ❑ 1. The viscous coupling on the clutch to lock up
- ❑ 2. The engine to overheat
- ❑ 3. Excessive water pump speeds
- ❑ 4. Excessive fuel consumption and exhaust emissions

Q17: Conduction is the transfer of heat: (Tick one box only)

- ❑ 1. Through a solid
- ❑ 2. Through a liquid or gas
- ❑ 3. By invisible rays
- ❑ 4. From the fins of an air cooled engine to the atmosphere

Q18: With a downflow radiator the coolant flow is from: (Tick one box only)

- ❑ 1. Side to side
- ❑ 2. Top to bottom
- ❑ 3. End to end
- ❑ 4. Bottom to top

Q19: What is the main function of a separate recovery tank? (Tick one box only)

- ❑ 1. To stabilize the coolant temperature
- ❑ 2. To maintain coolant in the system at all times
- ❑ 3. To increase the system's operating pressure
- ❑ 4. A more convenient location for adding coolant to the system

Q20: One of the functions of a radiator cap is to: (Tick one box only)

- ❑ 1. Increase the boiling point of the coolant in proportion to the spring tension
- ❑ 2. Protect the chemical additives of some coolants from breaking down
- ❑ 3. To control the temperature of the heater core
- ❑ 4. To prevent the engine coolant from boiling

Q21: With a crossflow radiator, the coolant flow is from: (Tick one box only)

- ❑ 1. Side to side
- ❑ 2. Top to bottom
- ❑ 3. End to top
- ❑ 4. Bottom to end

Q22: The primary function for the engine water pump is to: (Tick one box only)

- ❑ 1. Pressurize the cooling system
- ❑ 2. Circulate the coolant through the engine
- ❑ 3. Circulate the coolant when the thermostat is closed
- ❑ 4. Pump the heated coolant into the heater core

Q23: A vehicle coolant inhibitor needs to prevent 3 conditions. These conditions are: (Tick one box only)

- ❑ 1. Over heating, corrosion and staining
- ❑ 2. Freezing, corrosion and staining
- ❑ 3. Freezing, over heating and corrosion
- ❑ 4. None of these

Q24: When overhauling an air cooled engine it is necessary to ensure that all fins are clean and intact to: (Tick one box only)

- ❑ 1. Stop dilution of the engine
- ❑ 2. Assist the engine in warming up
- ❑ 3. Prevent oil leaks
- ❑ 4. Maintain correct heat transfer

Q25: An engine operating at well below the designed operating temperature will: (Tick one box only)

- ❑ 1. Produce the same power as an engine operating at the correct temperature
- ❑ 2. Increase cylinder, piston and piston ring wear
- ❑ 3. Have no detrimental effect on engine life
- ❑ 4. Enable a longer useful life for engine lubricating oil

Q26: Removing the radiator cap of a hot engine may cause: (Tick one box only)

- ❑ 1. The bottom hose to collapse
- ❑ 2. The engine to seize due to a sudden rise in temperature
- ❑ 3. Immediate boiling of the coolant
- ❑ 4. Damage to the radiator core

Suggested Exercises

1. Use an electronic data facility to procure manufacturer's appropriate data for use with practical exercises
2. Remove/refit/replace cooling system components
3. Test operation of the thermostat, refill, bleed system and check for leaks
4. Test the specific gravity of antifreeze
5. Test the operation of the cooling fan and thermo switch

Training Resources

- Technical information in book/electronic form on heat and temperature, changes of state of engine coolant; i.e. boiling and freezing temperatures, internal combustion engine, air and liquid cooling systems
- Training vehicles/units for practical exercises
- Cooling system test kits
- Antifreeze hydrometer
- Used coolant collection/recycling/disposal facility
- Manufacturer's data

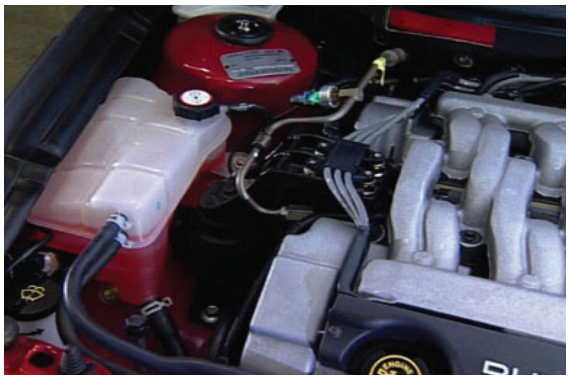
Task Sheets

Checking & Adjusting Coolant

Preparation and Safety

Objective

Check and adjust coolant levels and test coolant quality in a vehicle with a recovery reservoir.



Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items, this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

Safety Check

- Always be very careful when opening a radiator cap because the cap keeps the coolant under pressure to raise its boiling point. Sometimes even the pressure in a warm engine can force the coolant to spurt out when the cap is released.
- Always cover the radiator cap with a rag to catch any hot spray.
- Always wear eye protection.
- *Never* open a radiator cap on an overheated engine; wait for it to cool down first.

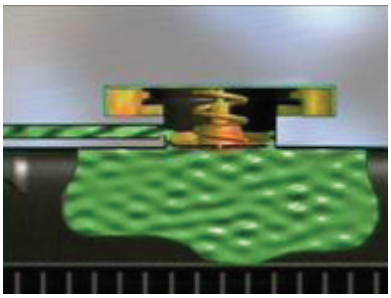
- Always make sure that you wear the appropriate personal protection equipment before starting the job. It is very easy to hurt yourself even when the most exhaustive protection measures are taken.
- Always make sure that your work area/environment is as safe as you can make it. Do not use damaged, broken or worn out workshop equipment.
- Always follow any manufacturer's personal safety instructions to prevent damage to the vehicle you are servicing.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

- There are two correct level marks on the reservoir because the coolant in the system expands and contracts in volume depending on how hot it is. The coolant level should be at the lower mark when the vehicle is cold. The coolant level should be at the upper mark when the coolant is hot.

- If the reservoir is completely empty, add coolant until the level is up to the appropriate mark for the engine temperature. Then run the engine until it is at its normal operating temperature and check the level again. You will probably need to adjust the level again.

- For each 10 kPa increase in the radiator cap operating pressure, it will increase the boiling point of the coolant by 2°C (1 PSI for each 3°F).



Step-by-step Instruction

1. *Check fluid level*: Most modern vehicles have a coolant system that uses a transparent recovery tank as a coolant reservoir. Check the level of coolant in this reservoir; if the engine is hot the level should be visible at the upper mark. If the engine is cold it should be at the lower mark.

2. *Check protection level with a hydrometer*: Before adding new coolant; check the specific gravity of the coolant in the system with a coolant hydrometer. Draw some coolant up into the hydrometer and read the mark on the float at the level of the fluid in the chamber. This will indicate the freezing point of the coolant mixture in the system, so you can tell if it has the right proportions of antifreeze and water.

3. *Adjust fluid level*: Check the service manual for the recommended type and mixture of coolant that will produce an appropriate level of protection for the conditions where the vehicle will be used. Use a funnel to add enough coolant to bring the level up to the appropriate mark. Replace the coolant reservoir cap.

Draining & Refilling Coolant

Preparation and Safety

Objective

Drain cooling system and refill with correct mixture of engine coolant.

Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items, this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

Safety Check

- Never drain and refill the cooling system of a hot engine. Wait for it to cool down first.
- Always make sure that you wear the appropriate personal protection equipment before starting the job. It is very easy to hurt yourself even when the most exhaustive protection measures are taken.
- Always make sure that your work area/environment is as safe as you can make it. Do not use damaged, broken or worn out workshop equipment.
- Always follow any manufacturer's personal safety instructions to prevent damage to the vehicle you are servicing.

- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

Some vehicles have drain plugs on the side of the engine block. The shop service manual will tell you if these need to be opened when draining the coolant.

Step-by-Step Instruction

1. *Locate drain plug:* Locate the cooling system drain plug or valve on the bottom tank of the radiator. Place a clean drain pan large enough to contain all the coolant underneath the drain valve.

2. *Drain radiator*: Carefully remove the radiator pressure cap. This will allow air into the cooling system so that it can drain quickly and completely. Open the drain valve so that the coolant can drain into the pan below. When all the coolant has drained out, close the drain valve.

3. *Refill coolant system:* Check the shop service manual for the capacity of the system and the recommended type and mixture of coolant for the operating conditions of the vehicle. Measure the recommended amount of coolant and using a funnel pour it in through the top of the radiator.

4. *Start engine and verify*: Air can be trapped in the cooling system, so leave the radiator cap off to allow it to escape and run the engine for a few minutes to allow the coolant to circulate and get rid of trapped air. Then replace the radiator cap and bring the engine up to operating temperature. Check the coolant level in the reservoir and top it up to the high or hot engine mark.

5. *Dispose of waste*: Antifreeze is toxic, so dispose of the waste coolant carefully and in an environmentally recommended way.

Checking & Replacing a Coolant Hose

Preparation and Safety

Objective

Check, remove and replace coolant hoses.

Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items, this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

Safety Check

- Never try to assess the serviceability of a coolant hose while the engine is hot. Let it cool down so that you can handle the hoses comfortably and safely.
- Always ensure the engine is turned 'off' before attempting to check the radiator hoses.
- Always make sure that you wear the appropriate personal protection equipment before starting the job. It is very easy to hurt yourself even when the most exhaustive protection measures are taken.
- Always make sure that your work area/environment is as safe as you can make it. Do not use damaged, broken or worn out workshop equipment.
- Always follow any manufacturer's personal safety instructions to prevent damage to the vehicle you are servicing.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.
-

Points to Note

- If you find one defective hose, the chances are that the other hose(s) may be deteriorating in the same way and will soon need to be replaced. For this reason, most technicians will generally replace both hoses at once as a sensible precaution.
- You may need to use a torch to inspect the coolant hoses so that you can clearly see if the surface is starting to crack.

Radiator Hose Problems

Swollen hose. This hose has lost its elasticity and is swelling under pressure. It may soon rupture

Hardened hose. This hose has become brittle and will break and leak.

Cracked hose. This hose has cracked and will soon start to leak.

Soft hose. This hose has become very weak and may collapse and close up completely.

Clamp Types

Gear or worm-type clamp. Adjust with a screwdriver.

Banded or screw-type clamp. Also adjusted with a screwdriver.

Wire clamp. This spring clamp is not adjustable and is fitted and removed with special hose clamp pliers, which have grooved jaws.

Clamps are not expensive, so it is good practice to fit new ones at the same time as new hoses. Even if not corroded, the old clamps may have become distorted when being removed from an unserviceable hose.

Step-by-Step Instruction

1. *Inspect hoses and clamps:* Locate both the hoses that carry coolant between the radiator and the engine. One is at the top and the other is at the bottom of the radiator. Squeeze each hose. It should feel pliable and springy. If it feels very soft and weak, or very hard and brittle, it will need to be replaced. Look for signs of swelling or cracking, particularly on the vulnerable underside of the lower hose. Check that the clamps are holding the hoses firmly in position and are not corroded.

2. *Remove hose*: Drain the coolant from the system before removing either of the hoses. Remove the clamp using the appropriate tool. If the hose is stuck and won't pull off easily, be careful you do not damage the radiator fitting by using too much force. It is better to cut the hose in several places so that you can remove it easily. Clean the hose fittings thoroughly on both the engine and the radiator with fine sandpaper or emery cloth, so that it will make a good seal with the new hose.

3. *Verify replacement:* Obtain new hoses and compare them with the removed hoses to make sure they are the same length and diameter. If the hose is a moulded type, the new one must also have the same pre-formed curve.

4. *Refit hose:* Apply some sealing compound to the hose fittings and place the loosened clamps over the hose ends before sliding the hose into position on the block and radiator fittings. Tighten the clamps securely about a quarter of an inch or 6mm from the end of the hose. Be careful not to over tighten and damage the hoses, but it is important they do not fall off once the pressure in the cooling system increases.

5. *Refill cooling system and check:* Refill the cooling system and then run the engine for a few minutes. Check the hose connections to make sure that there are no leaks. When the engine is at its normal operating temperature, check the tightness of the clamps again, as the clamps and hoses will both expand at different rates as they heat up.

Testing Cooling System Pressure

Preparation and Safety

Objective

Test a cooling system to confirm that it is without leaks and has the ability to hold the pressure specified by the manufacturer.

Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items, this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

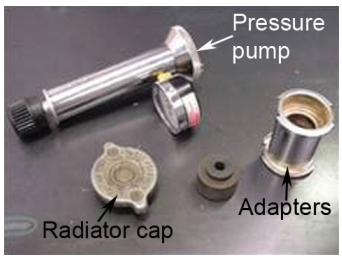
Safety Check

- When working around the cooling system, care must be taken particularly if the engine is at operating temperature, as the coolant may be hot enough to scald.
- Always allow the system to cool before removing the radiator cap.
- Do not remove a radiator cap from a hot cooling system.

- Always use extreme caution when removing the radiator cap. Releasing the pressure cap, on an engine at operating temperature, may cause the hot coolant to superheat.
- If you must remove the radiator cap from a hot system, wear protective gloves and eyewear and remove it slowly, to the first (safety) point, to prevent the pressure inside from erupting. If you don't this could cause the scalding hot coolant to spill hot fluid over you or someone standing nearby.
- Make sure the engine is off when carrying out any visual inspection of the system or when you connect the tester. You may be required to run the engine after the tester has been installed and pressurized.
- When the engine is running, make sure that you keep any loose clothing away from rotating parts.
- When pressure testing a system, make sure you do not exceed the manufacturer's maximum pressure.
- Have a qualified instructor show you the correct operation of the tester.
- Make sure that you understand and comply with all environmental and occupational health and safety standards for your workplace at all times. If you are unsure of what these are, ask your instructor.

Points to Note

- To test the cooling system for both internal and external leaks, a pressure tester is normally used. These are often referred to as cooling system testers or analyzers. There are a number of different analyzers used today. Make sure you are familiar with the system used in your workshop.



- If you need to replace a pressure cap, use only a cap with the correct recommended pressure. If a cap with a lower pressure rating is fitted, it will lower the boiling point of the coolant. Alternatively, a higher rated cap will increase the boiling point.

- Each 10 kPa (1.45 PSI) of cap-rated pressure changes the boiling point by 2°C. For example: A 90 kPa (13 PSI) radiator cap will increase the boiling point from 100°C to 118°C. Similarly, a 100 kPa (14.5 PSI) radiator cap will raise the boiling point from 100°C to 120°C.
- Pressure testing kits come with a number of adapters for various cooling systems. These adapters can be used to connect the tester to the radiator or to the radiator cap.

Step-by-Step Instruction

1. *Inspect cooling system visually:* Before pressure testing the system, visually inspect the system for any obvious signs of leaks or wear in the radiator core, radiator tanks, coolant and heater hoses, water pump, all accessible engine core plugs, cooling fan, drive belt and radiator cap and seals.
2. *Check the operating instructions of the tester:* Refer to the pressure tester's manual for correct operation. The outside of the radiator cap should be marked with its operating pressure. When this pressure is reached, the pressure relief valve in the cap will allow a discharge into the overflow system.
3. *Test the radiator cap:* Refer to the workshop manual or vehicle owner's manual to check that the pressure cap fitted has the correct pressure rating for that cooling system. Attach the radiator cap to the tester with an adaptor and pump up the pressure on the radiator cap spring. The pressure should hold just below the relief pressure setting. If the pressure will not hold or it cannot reach this pressure, then replace it with a new cap of the correct type and recommendation.

4. *Test the cooling system:* Before testing the integrity of the cooling system, top up the coolant level. Attach the cooling system tester to the radiator cap locator. Pump up the system pressure to slightly above the pressure recommended by the rating specified on the pressure relief cap. Observe the pressure reading. If it remains steady and does not drop then the system is not leaking. However, if the pressure drops, look for the leak. If there is no visible external leak, then the leak is most probably internal. If there are any visible leaks, or the pressure drops, refer you test results to your instructor.

Removing & Replacing a Radiator

Preparation and Safety

Objective

Safely remove and replace a radiator.

Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items, this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

Safety Check

- Coolant in the cooling system could be above its boiling point. Never open a radiator cap fully until ALL pressure has been released.
- When removing a radiator cap, use appropriate gloves, clothes, full face shield, etc.

- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

- Make sure the coolant catch tray is large enough to catch any spills and has the capacity to hold all the system coolant.
- If changing coolant, dispose of the old coolant properly in accordance with environmental and legislative requirements.
- If reusing the old fluid, keep it stored in a covered and uncontaminated container.
- Inspect the cooling system hoses and clamps. Replace them if worn or damaged.
- When removing the hoses from the radiator fittings do NOT twist them as this can cause internal damage to the hose and the fitting. If they do not easily release, carefully work a tool between the hose and fitting breaking it loose all the way around. If the hoses are to be replaced, you can slit them with a knife and peel them off the fitting.
- When refitting or replacing hoses, reinstall them all the way on the fittings. Make sure the clamps are installed at the proper place on the fitting, beyond the flared segment, not on top of it.
- Some vehicles have transmission cooler lines attached to the radiator. Remember to disconnect these lines when removing the radiator and always refit before refilling the system with coolant.
- Refill the system with the correct coolant at the proper anti-freeze/water ratio.
- There are a number of different types of coolant, often recognized by colour, as they have different chemical additives that can affect the materials that the engine and system components are made from.
- It is advisable to pressure test the system to check for leaks on completion of the job.
- Start the engine, warm it up until the thermostat has opened and check for proper operation of the cabin heater.
- Check for proper coolant level after it cools sufficiently.

Step-by-Step Instruction

1. *Drain the coolant:* Place a drain pan below the radiator and remove the drain plug. Drain the coolant from the system. Replace the drain plug and dispose of the drained coolant in an environmentally approved manner.

2. *Remove the radiator:* Carefully remove any hoses that are attached to the radiator. Unscrew any cowlings or covers from the radiator. Remove the bolts or screws that hold the radiator in position in the engine bay and lift the radiator from its location.

3. *Inspect the radiator:* Carry out a visual inspection of the radiator to ensure that it is suitable for reinstallation in the vehicle. If the radiator fins are blocked by debris carefully clean the fins with a dry brush. If the radiator is damaged, advise your instructor so a decision can be made whether to repair it or replace it.

4. *Replace the radiator:* Place the radiator into position and replace the securing bolts or screws. Refit the cowlings or covers. Rotate the fan and belts by hand to check the covers do not restrict movement. Attach the coolant hoses to the radiator.

5. *Refill the system:* And refill the system with new coolant of the correct type. Run the engine to circulate the coolant and remove any air trapped in the system. Check that the temperature indicator gauge shows the coolant temperature is in the normal operational range. Top up the radiator or reservoir with coolant if necessary.

Removing & Replacing a Thermostat

Preparation and Safety

Objective

Safely remove and replace a cooling system thermostat.

Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items, this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

Safety Check

- Coolant in the cooling system could be above its boiling point. Never open a radiator cap fully until ALL pressure has been released.
- Before removing the pressure cap, check the temperature of the cooling system with an infrared temperature gun if you have one available.
- When removing a radiator cap, use appropriate gloves, clothes, full face shield, etc.
- Before commencing a repair or service task on the cooling system and allow approximately 30 minutes for the system to cool sufficiently before opening the pressurised system.
- When removing a radiator cap, use appropriate gloves, clothes, full face shield, etc.

Points to Note

- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.
- Drain the at least 50% of the coolant in the system to avoid spills.
- Position the thermostat air bleed valve (if fitted) in the proper position.
- Make sure the thermostat is fully seated in the groove and stays there before fitting the housing. Failure to do so will damage the new thermostat and possibly break the housing as it is tightened up.
- Tighten the housing bolts to the correct torque.
- Make sure to use the manufacturer's procedure to properly bleed all air from the cooling system.

Step-by-Step Instruction

1. *Remove the thermostat:* Unbolt the thermostat housing from the engine block. Be very careful not to damage the housing as it is generally made from aluminium or a similar fragile material. Remove the thermostat.
2. *Inspect the mating surfaces:* Inspect the thermostat housing and remove any gasket material from the mating surface of the housing. Inspect the engine block and remove any gasket material from its mating surface.
3. *Install the new thermostat:* Inspect the new thermostat to ensure that the identification number is the same as the one you have removed. Fit the new thermostat, ensuring the air bleed hole is in the correct position. Check the thermostat is fully seated in its groove. Fit the correct type of gasket for the vehicle you are working on. Carefully refit the thermostat housing to the engine block and bolt it into place.
4. *Refill the cooling system:* Refill the system with coolant. Run the engine to circulate the coolant and remove any air trapped in the system. Check that the temperature indicator gauge shows the coolant temperature is in the normal operational range. Top up the radiator or reservoir with coolant if necessary.

Inspecting & Adjusting an Engine Drive Belt

Preparation and Safety

Objective

Inspect and manually adjust engine accessory drive belts.

Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items, this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

Safety Check

- Never try to inspect belts with the engine running.
- Always make sure that you wear the appropriate personal protection equipment before starting the job. It is very easy to hurt yourself even when the most exhaustive protection measures are taken.
- Always make sure that your work area/environment is as safe as you can make it. Do not use damaged, broken or worn out workshop equipment.
- Always follow the manufacturer's personal safety instructions to prevent damage to the vehicle you are working on.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

There are two types of drive belts:

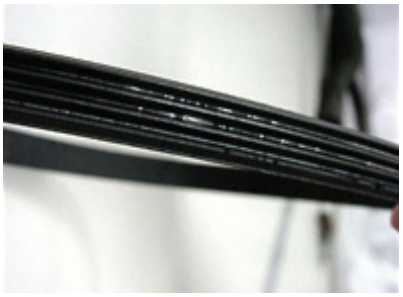
- *V-type*
  A V-type belt has a profile that looks like the photo below and sits inside a deep v-shaped groove in the pulley wheel. The sides of the V-belt contact the sides of the groove.

- *Serpentine*
  Serpentine-type belts have a flat profile with a number of grooves running lengthwise along the belt. These grooves are the exact reverse of the grooves in the outer edge of the pulley wheels; they increase the contact surface area, as well as prevent the belt from slipping off the wheel as it rotates.

Conditions to look for on a drive belt:

- *Cracked*
  Cracks in a belt indicate that it is getting ready to fail and should be replaced.

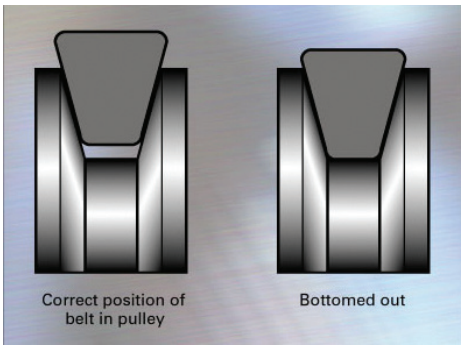
- *Oil-soaked*
  A belt that has been soaked in oil will not grip properly on the pulleys and will slip. If the oil contamination is severe enough for this to happen, replace the belt.



- *Glazed*
  Glazing is shininess on the surface of the belt, which comes in contact with the pulley. If the belt is worn, the glazing could be caused by the belt "bottoming-out" (see below) and it should be replaced. If it is not old and worn, glazing could simply indicate that the belt is not tight enough. Tightening the belt may be all that is necessary, depending on how bad the glazing is.

- *Torn*
  Torn or split belts are unserviceable and should be replaced immediately.

- *'Bottoming-out'*
  When a V-type belt becomes worn, the bottom of the V-shape may contact the bottom of the groove in the pulley, preventing the sides of the belt from making good contact with the sides of the pulley groove. This reduced friction causes slippage; a belt worn enough to bottom-out should be replaced.



Manual Belt Tension Versus Automatic Belt Tension.

Many vehicles require the technician to manually adjust the tension on the belt. Other vehicles have an automatic spring tensioning system. Depending on the system used on the particular vehicle, you should always follow the manufacturer's service instructions.

There are a number of different types of tension gauges. Follow the operating instructions on the tool. If you don't have a tension gauge, you can estimate the tension by pushing the belt inwards with your hand. If it's correctly tensioned, you should be able to deflect the belt about 1.25 centimetres for each 30cm of belt (half an inch for each foot).

Step-by-Step Instruction

1. *Inspect and check belt condition*: Twist the belt so that you can see the underside of the 'V' shape or the ribs on a Serpentine belt. Look for signs of wear and damage. You may need a flashlight to see these clearly. A cracked or glazed or torn belt will need to be replaced.

2. *Check tension*: Check the belt tension by attaching the tension gauge to the longest belt span and pulling it to measure the tension. Compare your reading to the specifications in the vehicle workshop manual.

3. *Choose the correct tools*: Select the correct wrench to loosen the tension adjustment fastener. This is usually on the Alternator mounting or on a separate idler pulley wheel. You will also need a pry bar, which is a metal bar you can use as a lever to apply tension on the belt.

4. *Adjust belt tension*: Loosen the adjustment fastener, then wedge the pry bar between the alternator and a strong part of the engine and pull in the direction that will apply tension to the belt. Tighten the adjustment fastener.

5. *Check tension again and readjust if necessary*: Check the tension again with the gauge and if necessary loosen the fastener and adjust the belt again until it is at the correct tension for the vehicle.

6. *Start the engine*: Start the engine and observe the belt to make sure it is properly seated and operating correctly. Stop the engine again and recheck the tension.

Suggested Further Reading

- Advanced Automotive Diagnosis. Tom Denton. ISBN 0340741236
- Automobile Electrical and Electronic Systems (3rd Edition). Tom Denton. ISBN 0750662190
- Automotive Mechanics (10th Edition). William H. Crouse and Donald L. Anglin. ISBN 0028009436
- Bosch Automotive Electrics Automotive Electronics: Systems and Components (4th Edition). Robert Bosch. ISBN 0837610508
- Bosch Automotive Handbook (6th Edition). Robert Bosch. ISBN 1860584748
- Bosch Automotive Technology Technical Instruction booklet series (numerous titles)
- Hillier's Fundamentals of Motor Vehicle Technology: Book One (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780823
- Hillier's Fundamentals of Motor Vehicle Technology: Book Two (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780998
- Modern Automotive Technology. James E. Duffy. ISBN 1566376106
- Motor Vehicle Craft Studies - Principles. F.K. Sully. ISBN 040800133X
- National Car Test (NCT) Manual (Department of Transport, Vehicle Testers Manual - DoT VTM). Department of Transport
- Transmission, Chassis and Related Systems (Vehicle Maintenance and Repair Series: Level 3) (3rd Edition) John Whipp and Roy Brooks. ISBN 186152806X
- Vehicle and Engine Technology (2nd Edition). Heinz Heisler. ISBN 0340691867
- http://www.cdxglobal.com/
- http://auto.howstuffworks.com/
- http://www.autoshop101.com/
- http://www.cdxetextbook.com/
- Automotive Encyclopedia and Text Book Resource (CD version of e-textbook), Available from your instructor.

Notes

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