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Cooling Systems

Student Guide

Caterpillar Service Technician Module
APLTCL030
Cooling Systems

Published by Asia Pacific Learning
1 Caterpillar Drive
Tullamarine Victoria Australia 3043

Version 3.2, 2003

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Acknowledgements

A special thanks to the Caterpillar Family for their contribution in reviewing the curricula for this program, in particular:

- Caterpillar engineers and instructors
- Dealer engineers and instructors
- Caterpillar Institutes.

MODULE INTRODUCTION

Module Title

Cooling Systems.

Module Description

This module covers the knowledge and skills of Cooling Systems. Upon satisfactory completion of this module students will be able to competently service and repair Cooling Systems.

Pre-Requisites

The following module(s) must be completed prior to delivery of this module:

- Occupational Health and Safety
- Workshop Tools
- Mechanical Principles
- Hydraulic Fundamentals
- Diesel Engine Fundamentals.

Learning & Development

Delivery of this facilitated module requires access to the Cooling Systems Activity Workbook.

The successful completion of the curriculum provides the knowledge for competency assessment, on further learning outcomes, by an Accredited Workplace Assessor.

Suggested References

- None.

Assessment Methods

Classroom and Workshop

To satisfactorily complete this module, students must demonstrate competence in all learning outcomes. Consequently, activities and assessments will measure all the necessary module requirements.

For this module, students are required to participate in classroom and practical workshop activities and satisfactorily complete the following:

- Activity Workbook
- Knowledge Assessments
- Practical Activities.

Workplace

To demonstrate competence in this module students are required to satisfactorily complete the Workplace Assessment(s).

KNOWLEDGE AND SKILLS ASSESSMENT

Learning Outcome 1: Describe the general safety precautions when working on engine cooling systems

Assessment Criteria

1.1 Describe and apply the general safety precautions to protect personnel form injury and protect the vehicle from damage

1.2 Explain and apply the specific safety precautions when working on hot engine cooling systems

  1.2.1 Effects of temperature and pressure

  1.2.2 Temperature controlled fans

  1.2.3 Removing a radiator cap

1.3 Explain and apply the precautions to be taken when working close to rotating components

1.4 Describe and apply the safety precautions required when handling chemical mixtures used in engine coolant

  1.4.1 Procedures for safe use

  1.4.2 Procedures for disposal

  1.4.3 Protection of the vehicle

Learning Outcome 2: Describe the requirements for cooling internal combustion engines and describe the physical properties of coolants

Assessment Criteria

2.1 Describe the requirements for water cooling internal combustion engines and describe the physical properties of coolants

Learning Outcome 3: Describe the requirements for water cooling internal combustion engines and describe the physical properties of coolants

Assessment Criteria

3.1 Purpose of the cooling system

3.2 Heat and temperature

  3.2.1 Effects of heat

    3.2.1.1 Change of temperature

    3.2.1.2 Change of colour

    3.2.1.3 Change of state

    3.2.1.4 Change of volume

  3.2.2 Physical properties of water

3.3 Heat transfer

  3.3.1 Conduction

  3.3.2 Convection

  3.3.3 Radiation

3.4 Electrolysis

- 3.5 Cavitation erosion
- 3.6 Engine coolant
  - 3.6.1 Ingredients
    - 3.6.1.1 Water
    - 3.6.1.2 Antifreeze
    - 3.6.1.3 Conditioners or corrosion inhibitors
- 3.7 Operating range
- 3.8 Extended life coolant

Learning Outcome 4: Describe the purpose and operation of the basic components in the cooling systems

Assessment Criteria

- 4.1 Describe the function and operation of components used in a water cooling system
  - 4.1.1 Overview
  - 4.1.2 Water pump
  - 4.1.3 Radiator
    - 4.1.3.1 Conventional
      - – Tubes
      - – Centre fins
      - – Horizontal fins
      - – Coolant flow
    - 4.1.3.2 Folded core
    - 4.1.3.3 Improved Multiple Row Module (IMRM)
    - 4.1.3.4 Advanced Modular Cooling System (AMOCS)
  - 4.1.4 Cooling fan
    - 4.1.4.1 Viscous drive
    - 4.1.4.2 Electric fan
    - 4.1.4.3 Hydraulic motor
    - 4.1.4.4 Multi-plate fan drive
  - 4.1.5 Radiator shroud
  - 4.1.6 Thermostat (regulator)
    - 4.1.6.1 Purpose
    - 4.1.6.2 Operation
  - 4.1.7 Radiator pressure cap
    - 4.1.7.1 Purpose
    - 4.1.7.2 Operation
  - 4.1.8 Expansion plugs
  - 4.1.9 Coolant conditioner element
  - 4.1.10 After coolers
  - 4.1.11 Engine oil coolers
  - 4.1.12 Water cooled exhaust
- 4.2 Describe the flow path of coolant through an engine
  - 4.2.1 From pump and return to pump

- 4.2.2 Pump
- 4.2.3 Shunt line
- 4.2.4 Oil cooler
- 4.2.5 Aftercooler (Intercooler)
- 4.2.6 Block and cylinder head passages
- 4.2.7 Air compressor
- 4.2.8 Thermostat housing
- 4.2.9 By-pass
- 4.2.10 Radiator
- 4.2.11 Pressure cap
- 4.2.12 Conditioner element

4.3 Describe the principles of air cooling for engines

- 4.3.1 Heat dissipation
- 4.3.2 Principles of operation

Learning Outcome 5: Describe the general service procedures for cooling systems

Assessment Criteria

5.1 Describe the procedures for visual inspection, testing and cleaning of the cooling system

- 5.1.1 Visual inspection of the cooling system
- 5.1.2 Visual inspection for air flow
- 5.1.3 Coolant circulation
  - 5.1.3.1 Water pump
  - 5.1.3.2 Radiator core flow
- 5.1.4 Air in coolant
- 5.1.5 Inspecting water pump
- 5.1.6 Pressure testing
  - 5.1.6.1 Testing cooling system for external and internal leaks
  - 5.1.6.2 Checking pressure cap
- 5.1.7 Water temperature indicator test
- 5.1.8 Thermostat (temperature regulator) testing
- 5.1.9 Caterpillar thermostat testing
- 5.1.10 Cleaning radiator cores
  - 5.1.10.1 Conventional radiators - suction and blower fans
  - 5.1.10.2 Folded core radiators
  - 5.1.10.3 Multiple row module radiator
- 5.1.11 Cleaning inside of the cooling system
  - 5.1.11.1 Contamination
  - 5.1.11.2 Scale or rust
- 5.1.12 Reverse flush

Learning Outcome 6:

Identify and state the purpose of cooling system test equipment

Assessment Criteria

6.1 Explain the purpose for testing the chemistry of a coolant

- 6.1.1 Coolant inspection and concentration testing

6.2 Describe the procedures for conducting service checks of a cooling system using test equipment

- 6.2.1 Test equipment
  - 6.2.1.1 Blowby/Air Flow Indicator
  - 6.2.1.2 Digital Thermometer
  - 6.2.1.3 Coolant and Battery Tester
  - 6.2.1.4 Supplemental Coolant Additive Test Kit
  - 6.2.1.5 Thermocouple Temperature Adaptor
  - 6.2.1.6 Multitach
  - 6.2.1.7 System Pressurising Pump
  - 6.2.1.8 Pressure Probe

Learning Outcome 7:

Describe systematic diagnostic procedures for vehicle cooling systems and identify correct action for repair

Assessment Criteria

7.1 Identify types of cooling system problems

- 7.1.1 Overheating
- 7.1.2 Loss of coolant
- 7.1.3 Overcooling

7.2 Describe visual checks

- 7.2.1 Coolant level
- 7.2.2 Coolant leaks
- 7.2.3 Radiator inspection
- 7.2.4 Fan shrouds
- 7.2.5 Fan
- 7.2.6 Fan clutch
- 7.2.7 Shutters
- 7.2.8 Hoses
- 7.2.9 Water pump
- 7.2.10 Cylinder head gasket
- 7.2.11 Radiator cap
  - 7.2.11.1 Gasket
  - 7.2.11.2 Sealing surfaces
  - 7.2.11.3 Contact
- 7.2.12 Relief valve
- 7.2.13 Fuel governor seat
- 7.2.14 Transmission and steering clutch slippage
- 7.2.15 Brake drag
- 7.2.16 Retarding device

- 7.2.17 Glycol concentration in coolant
- 7.3 Describe checks for system overheating
  - 7.3.1 Relief valve pressure check
  - 7.3.2 Air/gases in cooling system
  - 7.3.3 Temperature gauge
  - 7.3.4 Radiator/ambient air temperature differential
  - 7.3.5 Torque converter temperature
  - 7.3.6 Retarder
  - 7.3.7 Radiator coolant flow resistance
    - 7.3.7.1 Thermostat (temperature regulator)
    - 7.3.7.2 Water pump
  - 7.3.8 Radiator air flow resistance
  - 7.3.9 Fan speed
  - 7.3.10 Manifold and Aftercooler temperatures
- 7.4 Describe checks for coolant loss
  - 7.4.1 Coolant level
  - 7.4.2 Leakage
  - 7.4.3 Relief valve
  - 7.4.4 Air/gases in cooling system
  - 7.4.5 Water in engine oil
  - 7.4.6 Oil in coolant
  - 7.4.7 Water in torque converter oil circuit
- 7.5 Describe checks for overcooling
  - 7.5.1 Temperature gauge
  - 7.5.2 Shutter system
  - 7.5.3 Fan clutches
  - 7.5.4 Thermostat
  - 7.5.5 Vent line
- 7.6 Identify components that affect the cooling system
  - 7.6.1 Battery ground connections
  - 7.6.2 Oil cooler cores

Learning Outcome 8: Perform service tasks on a vehicle fluid cooling system

Assessment Criteria

- 8.1 State and follow the safety precautions that must be observed to prevent personal injury or damage to equipment
- 8.2 Tasks are identified according to manufacturer's specification
- 8.3 Tasks to include:
  - 8.3.1 Checks prior to starting
    - 8.3.1.1 Coolant level
    - 8.3.1.2 Coolant condition
    - 8.3.1.3 Relief valve
    - 8.3.1.4 Radiator core

- 8.3.1.5 Radiator fins
- 8.3.1.6 Pressure cap
- 8.3.1.7 Hoses
- 8.3.1.8 Fan drive belts
- 8.3.1.9 Fan blades
- 8.3.1.10 Cowling
- 8.3.1.11 Shrouds
- 8.3.1.12 Shutters or blinds
- 8.3.1.13 Water pump
- 8.3.1.14 System parts
- 8.3.1.15 Coolant leaks

8.3.2 Checks after starting

- 8.3.2.1 Coolant leaks
- 8.3.2.2 Fan operation
- 8.3.2.3 Shutters or blinds
- 8.3.2.4 Air or combustion gases in the cooling system
- 8.3.2.5 Air flow
- 8.3.2.6 Engine overheating or overcooling
- 8.3.2.7 Fan speed
- 8.3.2.8 Radiator coolant flow resistance

8.3.3 Thermostat

8.3.4 Reverse flush

8.3.5 Replace coolant

8.3.6 Bleed system

8.3.7 Function test

8.4 Appropriate workshop documentation is completed

8.5 Tasks are completed:

- 8.5.1 Without causing damage to components or equipment
- 8.5.2 Using appropriate tooling, techniques and materials
- 8.5.3 According to industry/enterprise guidelines, procedures and policies
- 8.5.4 Using and interpreting correct information from the manufacturer's specifications

Learning Outcome 9:

Perform repair tasks on a vehicle fluid cooling system

Assessment Criteria

9.1 State and follow the safety precautions that must be observed to prevent personal injury or damage to equipment

9.2 Tasks are identified according to manufacturer's specification

9.3 Tasks to include:

- 9.3.1 Visual checks
- 9.3.2 Remove coolant
- 9.3.3 Removal of a water pump

    - 9.3.3.1 Water pump inspection
      - – Viability of repairing or replacing pump
  - 9.3.4 Replace water pump
  - 9.3.5 Remove radiator
    - 9.3.5.1 Radiator inspection
  - 9.3.6 Refit radiator
  - 9.3.7 Remove expansion plug
  - 9.3.8 Replace expansion plug
  - 9.3.9 Remove oil cooler
    - 9.3.9.1 Oil cooler inspection
  - 9.3.10 Refit oil cooler
  - 9.3.11 Replace coolant
  - 9.3.12 Function test
- 9.4 Appropriate workshop documentation is completed
- 9.5 Tasks are completed:
  - 9.5.1 Without causing damage to components or equipment
  - 9.5.2 Using appropriate tooling, techniques and materials
  - 9.5.3 According to industry/enterprise guidelines, procedures and policies
  - 9.5.4 Using and interpreting correct information from the manufacturer's specifications
- 9.6

TABLE OF CONTENTS

TOPIC 1: Cooling System Safety

TOPIC 2: Cooling System Fundamentals

TOPIC 3: Cooling System Components

TABLE OF CONTENTS

TOPIC 4: Cooling System Service

TOPIC 5: Test Equipment

TOPIC 6: Cooling System Evaluation

TOPIC 1

Cooling System Safety

MATERIAL SAFETY INFORMATION

Material Safety Data Sheets (MSDS) on various materials used in cooling systems should be available at the workplace. Employees need to read these and adhere to their recommendations before using any materials for this unit.

GENERAL SAFETY GUIDELINES

- Wear protective footwear and clothing;
- Follow general safe workshop practices;
- Wear safety glasses and other personal safety equipment and adhere to safe practices;
- Use guard and seat covers to protect the vehicle;
- Beware of hot or moving components.

SPECIFIC SAFETY REQUIREMENTS

WARNING

Cooling systems operate at pressures of up to 150 kPa (22 psi) and temperatures approaching 110°C (230°F). Extreme care is required when working on cooling systems to prevent serious burns or scolding.

It is common for engines to be fitted with temperature controlled fans which may commence to rotate without any warning. Care must be taken to prevent personal injury.

When inspecting the coolant level in a hot engine, special precautions are required to remove the radiator cap.

Sudden release of the pressure from an engine near operating temperature causes the coolant to immediately boil, resulting in spraying of steam and boiling coolant. This could cause severe scalding.

Before removing the radiator cap or disconnecting any part of a hot cooling system:

- Allow the system to cool for at least two hours, or use precautions to prevent being scalded.
- Protect hands with mittens or a thick rag.
- Stand to one side and do not bend over the radiator.
- Twist and open the cap to its first notch (safety stop).
- Wait for the pressure to subside.
- Press the cap down and twist to remove it completely.
- Some caps may be fitted with a pressure release button or lever. Operate these as described by the manufacturer.
- Before disconnecting a hose, especially the lower hose, ensure the coolant is below scalding or burning temperature. The temperature of the hose will be lower than that of the water and a careful approach to feeling the hose will give a reasonable indication of whether the water is still too hot.

Rotating Components

Use care when working near rotating components. BE ALERT. Ensure there is no loose clothing, dangling chains or long hair that may cause hands and or other body parts to be dragged into the engine rotating components.

Safe Use Of Coolant

- Corrosion inhibitors and antifreeze solutions contain ethylene glycol and constituents that are toxic.
- To promote safe handling of these solutions, it is necessary to follow proper precautions:
    - Maintain adequate ventilation and do not inhale vapours.
    - Inhibitors must not be taken internally. Do not put a hose in your mouth when decanting and start siphoning or decanting cooling using your fingers and water filled hose instead.
    - If accidentally splashed or split on your skin, wash it off immediately.
    - If clothing is splashed, it should be changed and laundered before being worn again.
    - Do not spill it on vehicle paint work - wash it off immediately with water if it does.
    - Prevent loss of inhibitor or antifreeze solution when servicing the cooling system by draining it into a clean container.

Disposal of Coolant

Coolant must not be drained into the storm water or sewerage systems, because it is toxic to marine and plant life. It must be collected for disposal by a licensed waste disposal operator. Refer to company policies and procedures for correct disposal of coolants.

TOPIC 2

Cooling System Fundamentals

PURPOSE OF A COOLING SYSTEM

Engines burn fuel in order to produce power and this process creates very high temperatures in the combustion chambers. The engine temperature needs to be controlled within a desired operating range to maximise fuel combustion efficiency and to ensure that heat related damage does not occur. When the engine is cold, components also wear out faster.

A diesel engine depends on a well maintained cooling system to allow the engine to heat up as quickly as possible, and then keep the engine at a constant temperature, regardless of loads applied.

Need for a Cooling System

Combustion of the air-fuel mixture of the cylinders of the engine produces a considerable amount of heat and high temperatures. Heat is absorbed by the cylinder walls, the cylinder head and the pistons. In turn, they must be protected by the cooling system so that they do not become overheated.

Cooling not only protects engine parts, but also prevents the oil in the engine from breaking down and losing its lubricating properties. While the engine must be cooled, it still needs to operate at temperatures as high as the lubrication will allow. Removing too much heat would lower the engine's thermal efficiency, and useful energy would be lost.

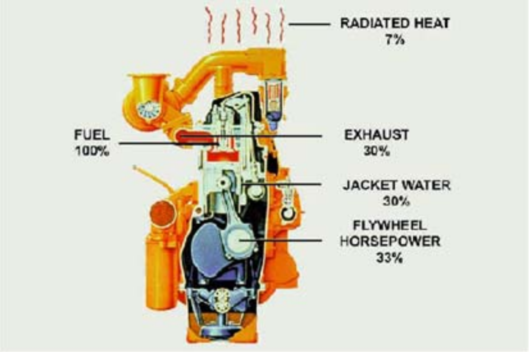


Figure 1 - Cooling System and Energy Distribution

In a diesel engine (Figure 1), approximately 33% of the total fuel consumed is converted to useful energy, the rest is wasted as heat. Approximately 30% of this heat goes out the exhaust, a further 30% is absorbed by the cooling system and 7% is radiated from the engine.

Some are air cooled, however most diesel engines are liquid cooled.

Advantages of liquid cooling include good temperature control, relative silence and ease of manufacture.

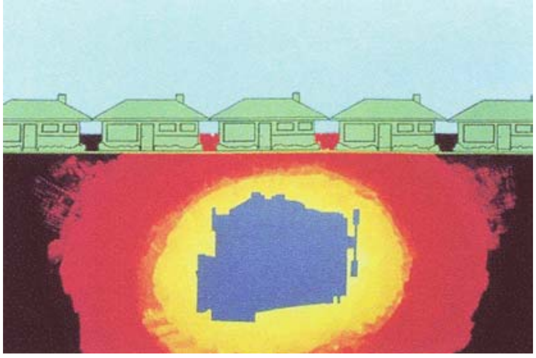


Figure 2

To emphasize in everyday terms, it has been calculated that a 200 HP diesel engine, operating at 70% of full load, produces enough heat to supply warmth to five 5-room houses with the outside temperature below freezing.

HEAT AND TEMPERATURE

Heat is a form of energy, and it is the heat from the burning fuel in the combustion chamber that causes the engine to function.

Heat and temperature are not the same. Heat is energy, while temperature is the degree of hotness (or coldness). Hot is referred to as something being above normal atmospheric temperature, and cold is when it is below atmospheric temperature.

To understand the difference between heat and temperature, heat is the molecule activity within an object and temperature is a measure of the molecule activity. Heat will flow from the more active molecules to the less active molecules, or from the hotter to the cooler parts of a body.

Effects of Heat

When heat is applied or removed from any substance, it can be effected in the following ways:

1. Change of temperature. Heat applied causes the temperature to rise, and heat removed causes the temperature to fall.

2. Change of colour. Heat applied to metals, particularly steel, causes a change in colour. If a bright steel surface is heated, it will gradually change colour, and, depending on the temperature, different colours will be obtained. An engine part that has been overheated can usually be identified because it will be discoloured.

3. Change of state. Heat can cause a change of state from a solid to a liquid, and a liquid to a gas (ice can change to water and water to steam). Metal heated during welding will change from a solid to a liquid.

4. Change of volume. Heat applied causes expansion, and heat removed causes contraction. Molecules of a substance that is heated will move further apart and so increase the volume, while molecules of a substance that is cooled will move closer together and so decrease the volume.

All substances expand when heated and contract when cooled. Gas expands easily to many times its size, but liquids and solids expand only a small amount. Their molecules are fixed and are not free to move like those of a gas.

Physical Properties of Water

The behaviour of water is different to all other liquids. It contracts when cooled until it reaches 4°C, and from this temperature until it freezes to become ice, it expands. When cooled below 0°C, ice contracts like any other solid.

Because of this property, special precautions must be taken when servicing a vehicle that operates in freezing winter conditions. An antifreeze solution is added to the coolant in the cooling system to prevent it from freezing. Without this protection, the water or coolant could freeze, and expansion could damage the engine.

HEAT TRANSFER

Heat can be transferred in three ways:

- conduction
- convection
- radiation.

All of these are used, in some way, to get rid of heat from the engine. Heat always moves from a hotter place to a colder one.

Conduction

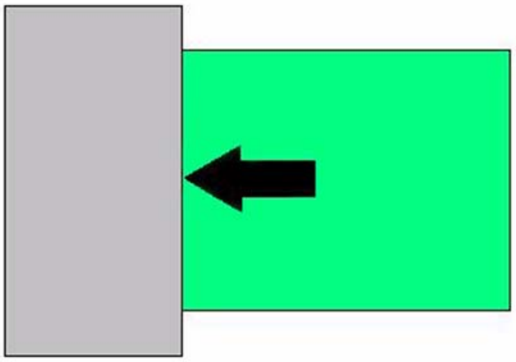


Figure 3

In the engine, heat is conducted from the combustion chamber through the metal parts of the engine to the cooling system (Figure 3).

In an air-cooled engine, the heat is conducted to the cooling fins of the cylinder and then dissipated into the surrounding air.

There are good conductors and bad conductors of heat; metals are good conductors, but asbestos, wood, paper and most non-metal materials are bad conductors and so can be classed as heat insulators.

Convection

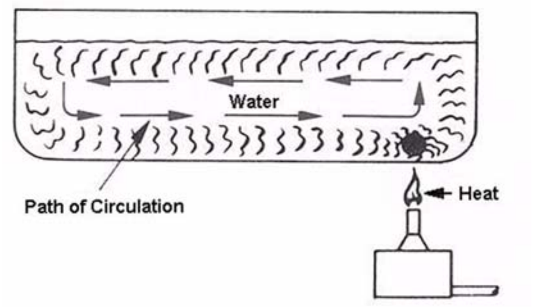


Figure 4 - Heat applied to the edge of the container produces convection currents in the water; a spot of dye in a transparent container allows this effect to be easily seen.

Convection is the method of heat transfer by the actual movement of the molecules of the substance. It relates to gases and liquids, but not to solids. When a portion of a liquid or a gas in a container is heated, it expands and therefore its volume increases, but the density is reduced.

This makes the heated particles less dense and so they float upwards, allowing the colder, denser particles to sink towards the bottom of the container. This sets up convection currents. This principle is illustrated in Figure 4.

Radiation

With radiation, heat is transferred across space. Heat energy felt from a fire is radiated heat. The energy is transformed into heat when the rays strike a colder object, so that the temperature of the receiving body is then increased.

Dark-coloured materials radiate heat better than light-coloured ones. For this reason, cooling fins on cylinders and radiators are usually painted mat black so that the heat will be more effectively radiated into the surrounding air. Dark substances are also good absorbers of heat by radiation.

ELECTROLYSIS

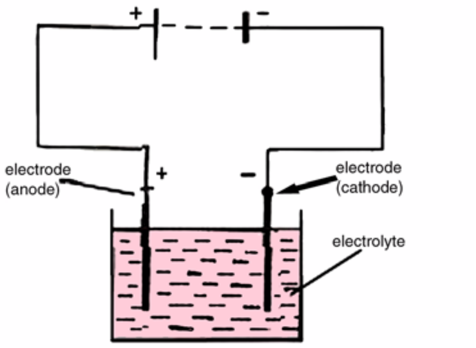


Figure 5 - Electrolysis - a chemical effect of an electric current

Some liquids, such as water containing small quantities of impurities, will conduct an electric current, and this will produce a chemical action. The conductors that are in contact with the liquid are known as electrodes, the liquid is known as an electrolyte and the chemical action which occurs is called electrolysis (Figure 5).

In electrolysis, conduction in the electrolyte is by movement of ions, which are atoms carrying positive or negative charges. When a current flows though the electrolyte, it does this by the movement of ions. The positive ions move through the electrolyte to the cathode, which is the negative electrode, and the negative ions move to the anode, which is the positive electrode.

The action of electrolysis not only enables current to flow in a liquid, but it can also deposit material from the anode onto the cathode. The extent to which this occurs will depend on the material of the electrodes and the type of electrolyte. The process of electroplating uses this principle to deposit plating material from the anode onto the article being plated, which is arranged as the cathode. In this process, the material of the anode gradually erodes away as it is deposited on the cathode.

Electroplating is a controlled process, but electrolysis can exist where it is not wanted, taking place wherever there are two dissimilar metals and moisture or impure water. The dissimilar metals have different electrical potential, so one becomes the anode and the other the cathode. The moisture acts as an electrolyte, and over a period of time, material is gradually removed from the anode.

The conditions outlined above exist in an engine’s cooling system, where cast iron of the cylinder block, aluminium alloy of the cylinder head, and water are present. Electrolysis can occur in the cooling system and cause corrosion of the water-jackets and passages. For this reason, distilled or deionised water, which is practically free of chemicals, is used in cooling systems together with chemical additives.

The greatest cause of electrolysis in cooling systems is improper grounding of electrical equipment.

CAVITATION EROSION

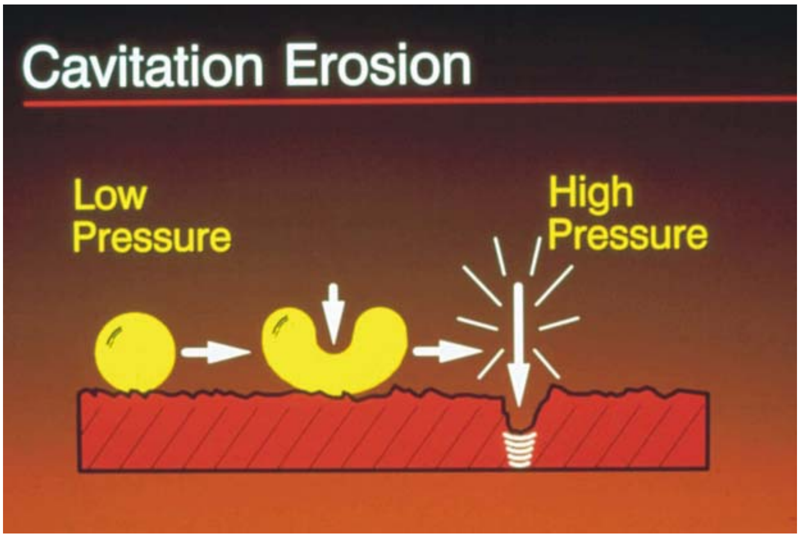


Figure 6

Cavitation erosion occurs when vapour bubbles collapse against metal surfaces.

All liquids contain dissolved gases which form bubbles in low pressure areas, and abnormal system conditions can introduce additional vapour bubbles.

When these bubbles enter high pressure areas, they implode (burst inward) sending a fluid “jet” against the metal surface at supersonic speeds.

Fine cracks sometimes form and join until small metal particles are removed leaving pits.

Bubbles can form under the following conditions:

- When liquids reach their boiling point.
- When fluids move rapidly across cavities (Bernoulli's principle).
- When parts move within a fluid creating low pressure areas (such as liner vibration).
- When static system pressures are low (bad radiator cap, high altitude operation).
- When inlet restrictions cause fluid pump cavitation.
- When leaks in suction lines introduce air bubbles.
- When low fluid levels cause fluid aeration.

Some of these conditions are normal in diesel engines and frequently occur together.

During the combustion cycle, the cylinder liner is constantly expanding and contracting. Upon contraction, the void that the liner tries to leave causes the pressure of the coolant next to the liner to decrease. This lower pressure causes the coolant to boil, forming bubbles.

In cooling systems, conditioners are used to form a protective layer that keeps bubbles away from the metals.

Figure 7

This rough pitted liner surface (Figure 7) is the result of cavitation erosion. The damage is confined to one area of the liner. Disassembly facts reveal the damaged area was located between liners.

Figure 8

Aluminium housings in cooling systems (Figure 8) can be damaged by cavitation erosion, especially if there are suction restrictions that create lower pressures and subsequently cause fluid cavitation at the pump impeller.

Bubbles form on the low pressure (suction) side and collapse violently on the high pressure (discharge) side.

ENGINE COOLANT

Engine coolant is a mixture of water, conditioner and antifreeze which circulates through passages or jackets within the engine to remove the heat. The coolant absorbs heat from internal engine surfaces and carries it away to be released in a heat exchanger or radiator.

Most engine cooling systems use water as a base with additives included to reduce:

- Corrosion of the engine water jackets and other parts of the system.
- Freezing of the water in very cold climatic conditions when the engine is stationary.

Ingredients of Coolants

Figure 9

There are three main ingredients that make up engine coolant (Figure 9):

- Water, to protect against overheating.
- Antifreeze, to protect against freezing.
- Coolant conditioner, to protect against corrosion.

Coolant in the correct concentration must be capable of providing the following basic requirements:

- Provide an adequate heat transfer medium.
- Protect against cavitation damage.
- Provide a corrosion/erosion resistant environment.
- Prevent the formation of scale or sludge deposits.
- Be compatible with cooling system hose and seal materials.
- Provide adequate freeze protection.

Water

Water has the best heat transfer properties than any other substance but also has severe drawbacks:

- It boils easily.
- It freezes.
- It is extremely corrosive to metal.

Antifreeze and conditioner are added to correct these deficiencies.

Antifreeze

Antifreeze, or ethylene glycol, raises the boiling point and lowers the freezing point of water. The amount of antifreeze determines by how much these temperatures change. Frozen coolant cannot flow and therefore not cool, and it expands and can crack castings.

Conditioners or Corrosion Inhibitors

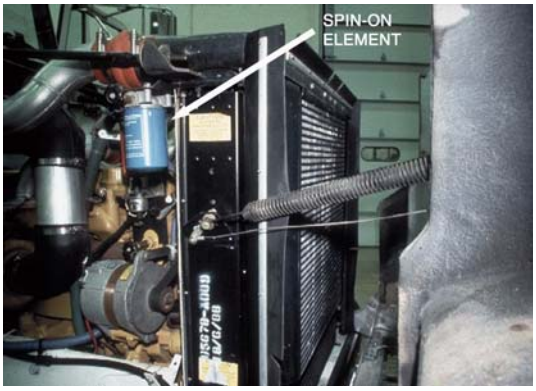


Figure 10

Conditioners may be added to the coolant by use of spin on elements, or direct addition to the system (Figure 10).

Figure 11

Conditioners (Figure 11) coat all engine components and protect against corrosion and scaling (adherence of water based minerals to hot metal surfaces).

Operating Range

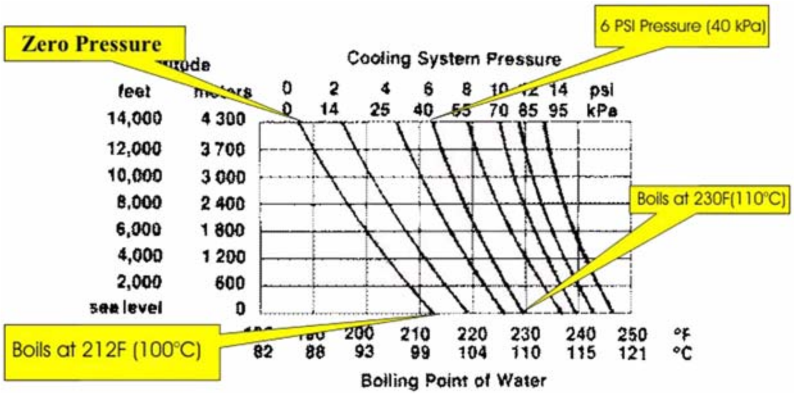


Figure 12

The operating range is influenced by operating altitude and system pressure, as well as concentration of the antifreeze.

Increasing altitude lowers the boiling point of water.

Increasing system pressure raises the boiling point of water. This is why most engines have a pressurised cooling system.

Water will boil at a temperature of 100°C (212°F) at normal atmospheric pressure. The chart in Figure 12 shows that if the pressure in the cooling system is increased by 40 kPa (6 psi), the boiling point of the coolant is increased to 110°C (230°F).

If coolant boils, it creates bubbles that do not transfer heat well, reducing cooling effectiveness, and the bubbles affect the pumping capacity of the pump. When the steam bubbles break they can remove small particles from the metal components (cavitation erosion).

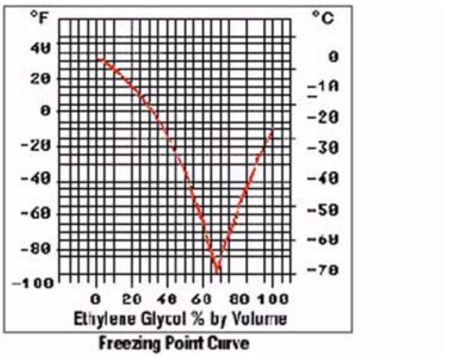


Figure 13 - Freezing Point Curve

To provide adequate protection to the engine the concentrations of antifreeze and conditioner must be in the correct proportion.

When antifreeze is added, the concentration should be between 30% and 60%. Below 30% there is not enough protection, whilst above 60% the heat removal properties are affected (Figure 13). Also, at high antifreeze concentrations, silica drop-out can occur resulting in partial clogging of the system and seal life is reduced.

Corrosion Inhibitors are additives dissolved in the cooling water, to protect the various metals used in engine cooling systems against corrosion. The correct concentration of the compounds must be maintained to achieve the correct PH level and provide satisfactory protection.

Coolant conditioner concentration should be kept between 3 and 6%. If the concentration is lower the components will corrode. With too high concentration, heat transfer properties of the coolant are reduced and there is possibility of silica-dropout occurring which results in thickening of the coolant.

Some of the additives used are chromates, borates and nitrates. Most diesel engine manufacturers recommend specific products for corrosion protection. Caterpillar currently recommends pre-mixed extended life coolant (ELC).

Extended Life Coolant

Figure 14

Extended Life Coolant (ELC) provides:

- Coolant life of 6000 hours or four years
- Corrosion protection
- Good water pump seal life
- Protection against freezing to low temperatures
- Good anti-boil properties.

The only maintenance required is the addition of ELC Extender after 3000 hours or two years of use.

ELC contains organic acid inhibitors and antifoam agents with fewer nitrates than other ethylene glycol based coolants. It comes pre-mixed with distilled water in a 50/50 concentration. This provides freezing protection to -37°C (-35°F). Boiling protection with a 90 kPa (13 psi) radiator cap is to 129°C or 265°F.

TOPIC 3

Cooling System Components

OVERVIEW

The basic components of every water cooled cooling system include:

- The water jacket surrounding the upper engine
- The water temperature thermostat/s (regulator/s)
- The radiator (or heat exchanger between liquid and air)
- The pressure cap
- The water or coolant circulation pump
- Hoses.

Stationary and larger engines may also have some type of coolant cooled after-cooler, oil cooler, hydraulic cooler, or transmission cooler.

Some marine or stationary systems circulate fresh water through a heat exchanger in place of the radiator.

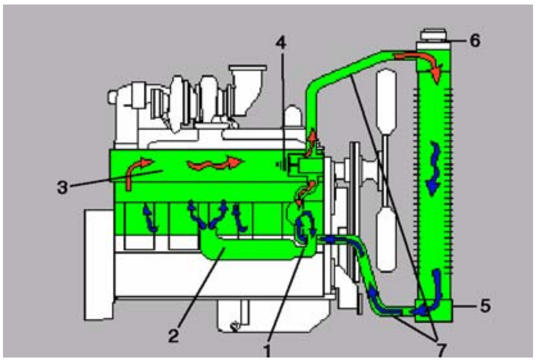


Figure 15

Figure 15 shows the components of the cooling system and the flow of coolant through the system.

The water pump (1) provides flow in the cooling system. It takes cooler liquid from the bottom of the radiator (5) and “pushes“ it through the system.

Most high performance diesel engines are fitted with an engine oil cooler (2) and the coolant is forced through the oil cooler and then into the cylinder block (3).

A thermostat (regulator) (4) controls temperature of the coolant by causing a restriction to coolant flow when the coolant is too cold. The coolant then returns to the radiator (5) which is fitted with a pressure cap (6) to control the pressure in the cooling system.

Hoses (7) are used to provide a flexible connection to the engine.

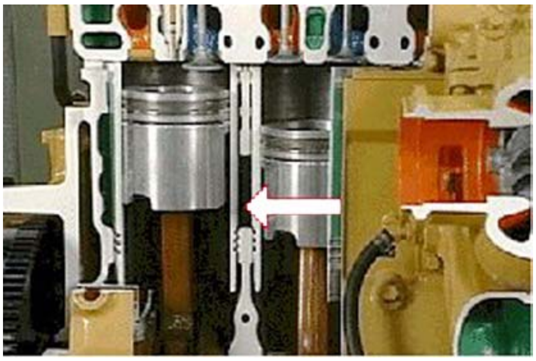


Figure 16

The cutaway of the engine block (Figure 16) shows the internal cooling passages that are provided to cool the cylinder liners.

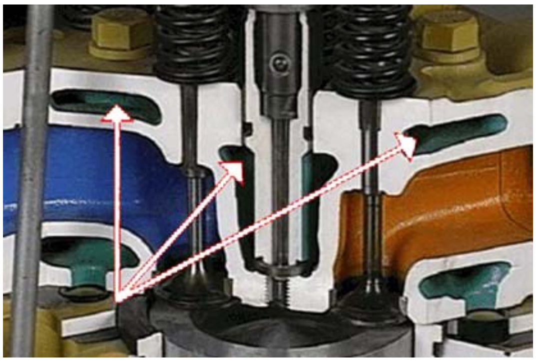


Figure 17

Figure 17 shows passages in the cylinder head that are provided to cool the injectors and the valves.

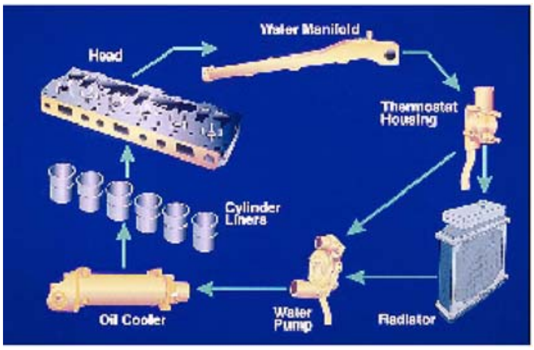


Figure 18

Figure 18 is indicating how coolant is pumped via the oil cooler into the cylinder block. It passes around the cylinder liners and through water directors, which send the flow of coolant to the valve and exhaust passages in the cylinder head to the water outlet housing of the cylinder head.

The temperature of the coolant is controlled by the thermostat, which is a water temperature regulator. If the coolant within the engine is cold, the thermostat closes slightly and directs some of the coolant straight back to the inlet side of the water pump.

The engine block temperature will then rise quickly because the portion of redirected water is not cooled. When the desired temperature is reached depending on the setting of the thermostat, the thermostat opens more and directs coolant to the radiator, which removes the heat. This is a continuous process and aids in maintaining the engine temperature to a pre-determined level.

WATER PUMP

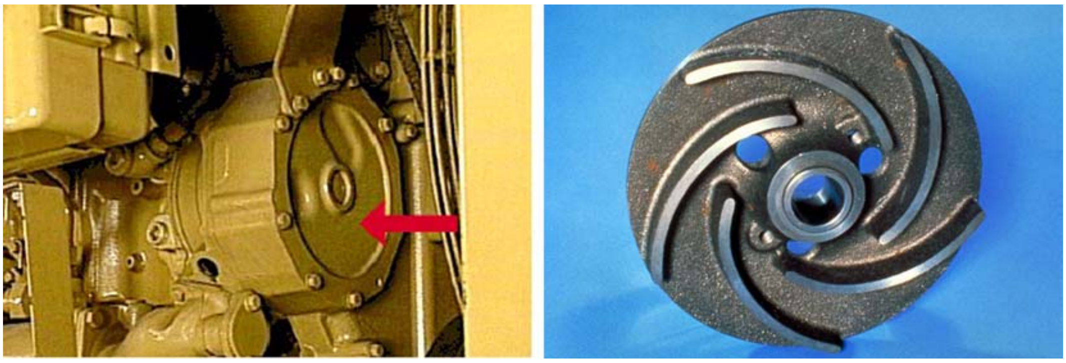


Figure 19

Water pumps fitted to diesel engines are of the centrifugal design (Figure 19 left). The impeller incorporates vanes which create a low pressure area in the centre of the hub when it rotates (Figure 19 right).

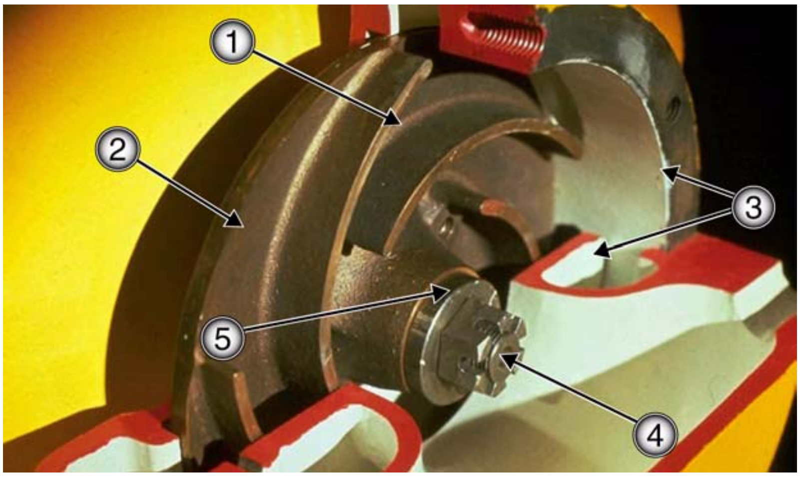


Figure 20

1. Curved Blades
2. Impeller
3. Housing and Outlet
4. Input Shaft
5. Centre of Housing

Water pumps (Figure 20) are usually mounted at the front end of the cylinder block. The pump consists of a housing with a water inlet and outlet (shown in Figure 20).

When the impeller rotates, coolant is drawn into the inlet side of the pump (around the centre shaft (4) of the pump), onto the blades (1) and thrown outward by centrifugal force (3) and is forced through the pump outlet (3) and into the cylinder block.

The pump inlet is connected by a hose to the bottom of the radiator, and coolant from the radiator is drawn into the pump to replace coolant forced through the outlet.

The shaft supporting the impeller is usually mounted in bearings. These are either pre-lubricated or lubricated by engine oil. The drive shaft may be driven by Vee belts or directly driven by the timing gears.

A special spring loaded, carbon faced seal (located between the impeller and the housing) is used to seal the coolant to prevent external leaks. Water pumps contain a weep or witness hole on the shaft housing (normally at the back of the pump) that allows leaking coolant to escape to the outside if the carbon faced seal fails.

RADIATOR

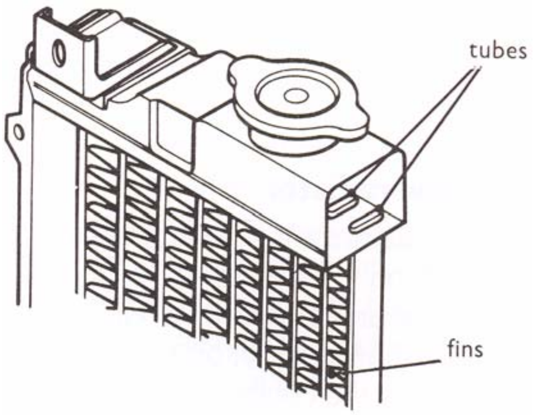


Figure 21

The radiator consists of two tanks connected by a core. The core (Figure 21) is made up of the number of tubes that carries the coolant between the tanks.

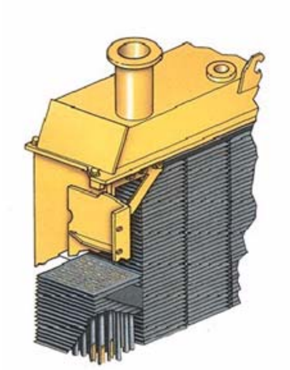


Figure 22

The core tubes of a radiator are fitted with fins. There are two designs of cores - a core with centre fins as shown in Figure 21 and a core with horizontal fins is shown in Figure 22. In most heavy vehicle applications the radiator with the horizontal fins is used. The fins increase the surface area of the core and improves heat transfer. Air flowing over the core, either by vehicle movement or by assistance of the fan, moves over the tubes and fins and removes the heat of the coolant in the radiator. The major design factors of a radiator that influences heat transfer to the atmosphere are the speed of the coolant flow through the radiator, the quantity of fins and cores and consequently the overall surface area.

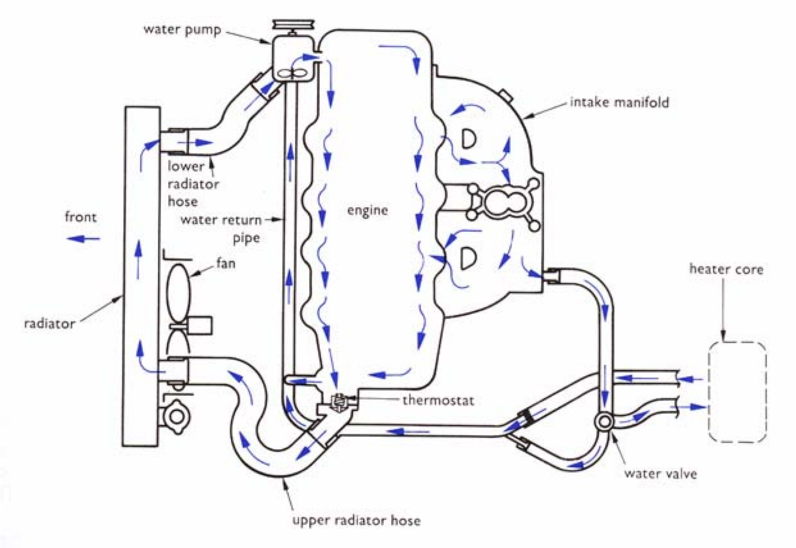


Figure 23

Coolant Flow

A simplified cooling system arrangement is shown in Figure 23. Arrows show the flow of the coolant. In this instance, the thermostat, which controls the flow of coolant through the radiator, is at the side of the engine.

When the engine is cold, the thermostat is closed and blocks off the flow of coolant to the radiator. At this stage the coolant is flowing through the engine only. When the operating temperature is reached, the thermostat opens and allows coolant to circulate through the radiator as well as the engine. This allows hot engine coolant to be passed through the radiator, allowing it to cool before entering the engine again. This continuous circulation removes any excess heat from the engine and with the assistance of the thermostat, maintains the engine temperature at the pre-determined set level.

During engine operation, aeration of the coolant may occur if the coolant level is low or if coolant flow turbulence occurs due to a worn water pump seal, loose hose clamps on the low pressure side of the system or incorrect coolant filling procedure. Entrapped air leads to localised overheating of the combustion chamber, which may result in the cylinder head cracking.

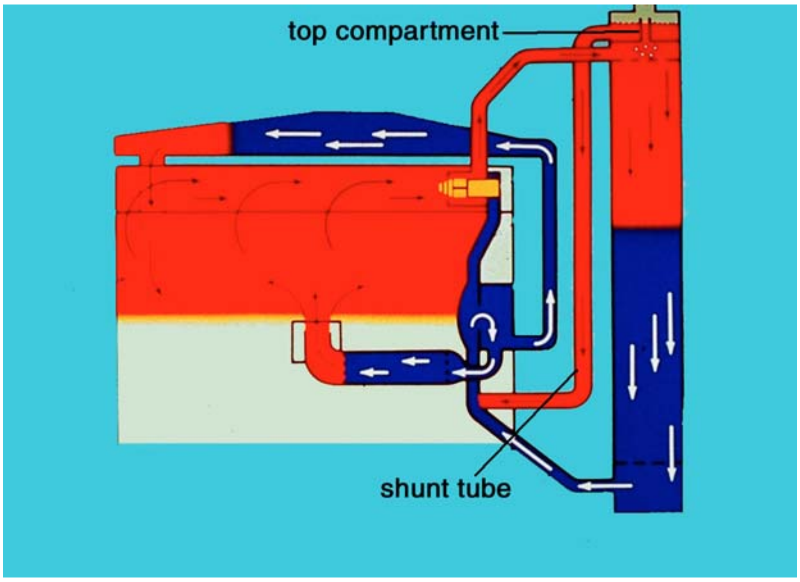


Figure 24

Engines fitted to heavy road transport vehicles normally use a “shunt” type cooling system (Figure 24). It operates the same as a typical radiator system, except the radiator has an additional top compartment and a shunt tube is installed between this top compartment and the inlet of the pump. This is done to provide a constant head for the pump during radical rpm changes of the engine at truck gear changes (downshifts). Without this additional line, the pump could pull negative pressure during downshifts and cavitate.

Radiators fitted to heavy mobile vehicles are designed to provide optimum heat transfer at specified maximum ambient temperatures and to be as durable as possible.

Some key design factors for heavy vehicle radiators are:

- Angled and staggered tubes to maximise heat transfer for the lowest air restriction.
- Proper fin-to-tube bonding forms a complete joint between the fins and tubes-to ensure maximum heat transfer to the fins.
- Durable construction of the tube-header solder joints to protect against the considerable loading and stresses that occur in this area, preventing cracks and leaks for longer radiator life.

Apart from conventional radiators there are three different Caterpillar designed radiators for use on Caterpillar Earthmoving Machines.

Folded Core

Figure 25

The folded core radiators (Figure 25) are of a modular design to enable replacement of the individual cores. This is useful when the cores are damaged by external impacts and allows the radiator to be repaired in a non specialised area, (i.e. no soldering is required.) The core assemblies are sealed between the top and bottom tanks.

The cores are angled to increase the surface area and reduce the potential to block.

A feature of the folded core radiator is the exceptionally high fin density of 35 fins per 25 mm compared with a standard of approximately 9 fins per 25 mm.

In some earthmoving applications, this tight fin spacing results in severe blocking problems and difficulty with cleaning.

Improved Multiple Row Module (IMRM)

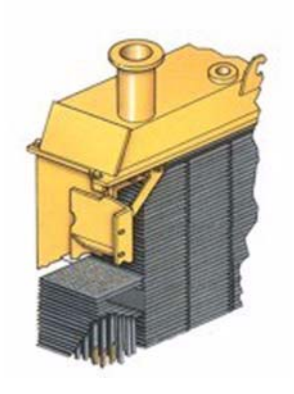


Figure 26

The Improved Multiple Row Module (IMRM) radiator (Figure 26) was designed to overcome situations where the application of the machine resulted in blockage problems with the folded core radiator.

The (IMRM) has a lower fin density than the folded core radiator, so its modules are more open to air flow through the core. This design makes the IMRM radiator more resistant to plugging by fine, fibrous, or fluffy debris. This results in extended cleaning intervals.

The IMRM radiator features the same easy-to-service design as the folded core radiator. Individual core assemblies require replacement of damaged modules only, eliminating the time and cost associated with removing entire cores.

Advanced Modular Cooling System (AMOCS)

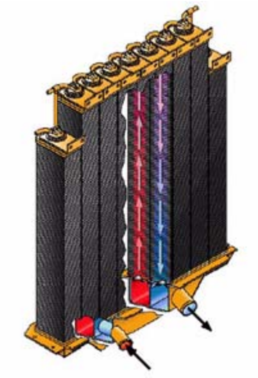


Figure 27 - Caterpillar AMOCS Radiator and Coolant Flow

The AMOCS radiator (Figure 27) is a unique design which is found on many current machines. AMOCS stands for Advanced Modular Cooling System. It utilises a two-pass cooling system and increases cooling surface area to provide significantly more cooling capacity than conventional radiators. This system allows for working in higher air ambient conditions with a smaller surface area.

The two pass cooling system circulates coolant from the sectioned bottom tank, up through the front side of the radiator cooling element. The coolant then flows down through the rear side cooling element, returning the coolant to the bottom tank and then on to the water pump. Like the folded core and IMRM designs, the construction is modular.

Hoses

Radiator hoses connect the radiator to the water pump and the engine block (normally at the thermostat housing). Their purpose is to allow the flow of coolant to and from the radiator and susceptible to the temperature variations in the cooling system.

The appearance of the hose and connections usually indicate their condition. If a hose is soft and spongy and collapses easily when squeezed, it indicates the hose has deteriorated internally and should be replaced. If a hose is hard and no longer flexible as a result of heat, it should be replaced. Some hoses have an internal reinforcement (similar to a spring) to prevent the hose from collapsing when temperatures in the cooling system drop.

Hose clamps should be checked regularly for tightness and connections checked for leaks.

COOLING FAN

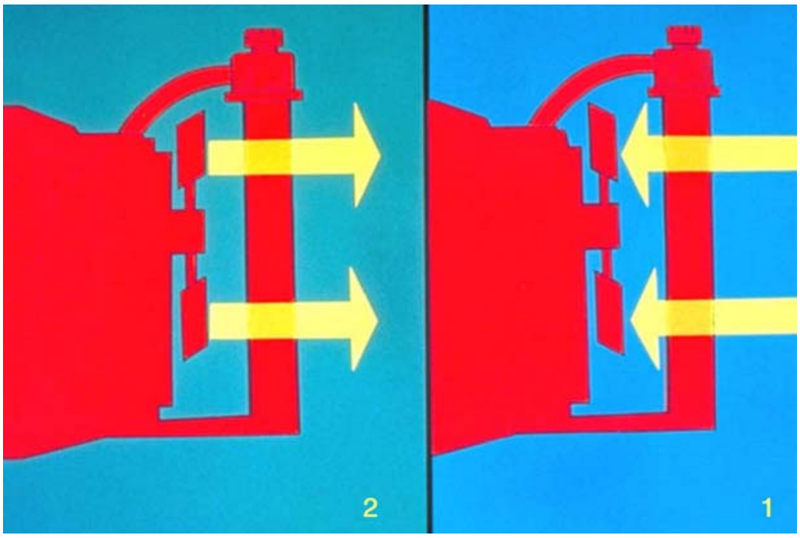


Figure 28

Fans fitted to machines can be either a conventional suction fan or blower type fan.(Figure 28) Suction fans (1) draw outside air through the radiator, across the engine and exhaust through spaces at the rear or underneath the machine.

Blower type fans (2) operate in the opposite manner, where air is drawn from the rear, underneath or side covers, passed across the engine and lastly through the radiator. The blower type fan is used on machines operating in extremely dusty conditions, e.g. track type tractors, specialised refuse disposal tip sites and help reduce radiator blockage and core erosion damage.

Road transport vehicles normally use conventional suction type fans to take advantage of the forward motion of the vehicle and the consequent ram effect.

It is not possible to simply turn a fan around to change a pusher fan into a suction fan as the pitch of the blade becomes incorrect. A reduced air flow will result from this practice.

Most heavy vehicle fans are manufactured from steel, although in some applications the fan may be manufactured from plastic. The plastic design has a weight advantage and it allows the blades to flex under high speed. This reduces the power requirements to drive the fan. Therefore drive belt life, bearing life and reduced noise are acclaimed advantages of this design.

Most fans are fixed drive, that is they operate continuously. However some current designs in heavy vehicles use variable speed fan drives or fans which are not driven under certain circumstances. These fans are controlled by the temperature of the coolant and can be energy saving devices when compared with a fixed fan.

VISCOUS DRIVE

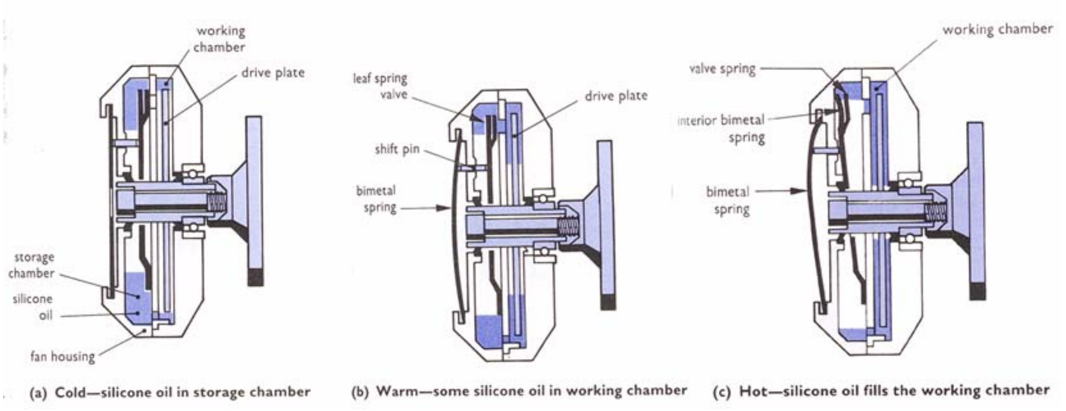


Figure 29

One form of variable drive uses a viscous, temperature sensitive coupling filled with silicon oil (Figure 29). As the heat load of the radiator increases, the air flow temperature through the radiator and over the fan hub also increase. This then causes a temperature sensitive valve (Bi-metallic strip) to open (distort) and allow a metered amount of silicon oil to enter the drive hub.

This creates resistance to the hub and causes driving of the fan drive disc. Fan speed increases in direct proportion to the amount of oil allowed into the hub.

As fan speed increases the heat transferred into the air stream from the radiator will gradually reduce, causing the temperature sensitive valve to move towards the closed position. This causes the fan speed to modulate and reduce.

During engine warm up or cooler weather the fan speed will reduce, thus conserving engine horse-power.

ELECTRIC FAN

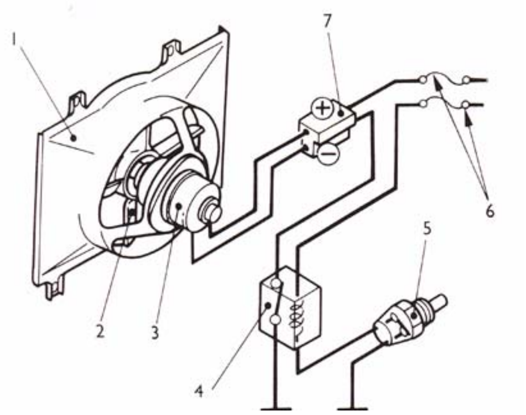


Figure 30

The arrangement of an electric fan and its controls is shown in Figure 30. In some installations, a single fan is used behind the radiator; in other cases, a fan is fitted at both the front and rear of the radiator.

There are two parts to the electrical circuit; the fan switch circuit and the fan circuit that included the fan motor and the fan relay.

Operation

The fan motor is operated by the fan relay (4). The relay is controlled by the fan switch (5), which is located in the thermostat housing. This is a heat-sensitive switch that is normally closed but which opens at approximately 100°C.

When the coolant temperature is less than 100°C, the fan switch is closed. With the ignition switch turned on, current flows through the fuse, through the relay windings and through the fan switch to earth. This energises the windings in the fan relay and holds the relay points open, so that the fan does not operate.

When the coolant reaches 100°, the fan switch opens, the relay windings are demagnetised and the relay points close. This completes the fan circuit to earth and the fan operates. The fan will continue to operate until the coolant temperature drops and the fan switch again closes, the fan will cut in and out as determined by the changes in the temperature of the coolant at the fan switch.

HYDRAULIC MOTOR

Figure 31

Another type is a hydraulic motor with a thermostatic valve. The fan is driven when the coolant reaches a predetermined temperature. The thermostatic value is activated and allows oil flow to the fan hydraulic motor.

MULTIPLATE FAN DRIVE

A different form of fan drive is a multi plate fan clutch, which is engaged by spring pressure to cause the fan to rotate. Disengagement of the fan is by compressed air that forces the engagement spring away from the clutch plates. This type of drive method is either on or off.

NOTE:
Some manufacturers reverse this operating procedure.

RADIATOR SHROUD

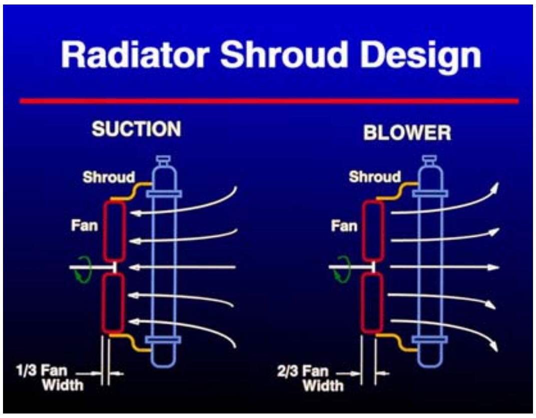


Figure 32

Fan and radiator design on high output engines usually incorporate a fan shroud. The fan shroud is a shaped metal or plastic cover that prevents the escape of fan air and directs air flow into the fan. Use of the shroud ensures that the maximum amount of air that the fan moves, actually passes through the radiator. Without a shroud, air may just circulate at the tip of the fan blades. The position of the fan within its shroud is important to the shroud's effectiveness.

WATER TEMPERATURE REGULATOR /THERMOSTAT

Purpose

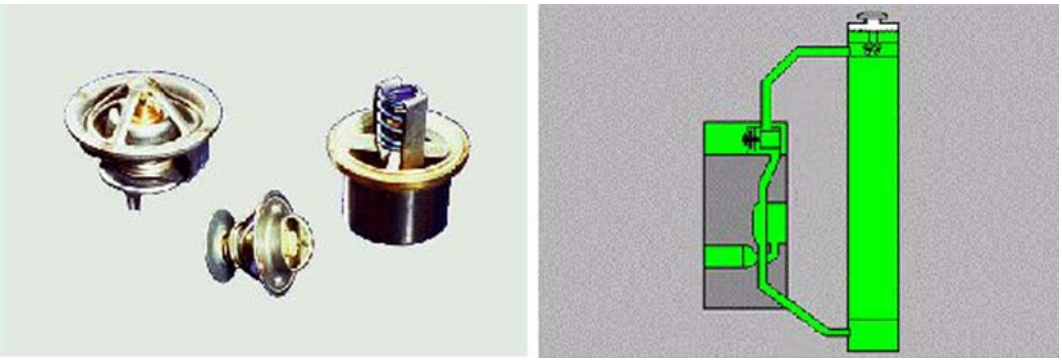
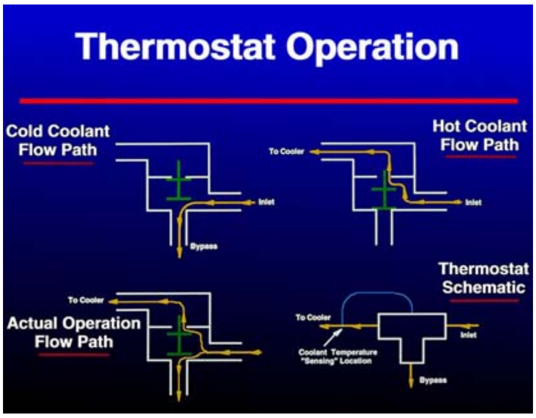


Figure 33 - Water Temperature Regulators or Thermostats

The water temperature thermostat(s) or regulator(s) regulate the flow of coolant to the radiator.

Different engine manufacturers used different designs of thermostats, however operating principles are similar.



Thermostat Operation

Cold Coolant Flow Path

Hot Coolant Flow Path

Actual Operation Flow Path

Thermostat Schematic

Figure 34

When the engine is cold, the thermostat is closed and stops the flow to the radiator. Water is then re-circulated through a by-pass, back into the engine. This assists the engine to achieve operating temperature quickly.

When the engine is warm, the thermostat allows the coolant to flow to the radiator, to be cooled, before re-entering the engine. The thermostat is not strictly fully open or fully closed. It modulates between open and closed in order to keep a constant temperature in the engine.

Proper engine temperature is very important. An engine that runs too cold will not have efficient combustion and will have sludge build up in the lubrication system, or carbon or lacquer deposits on the pistons and increased chances of blow by. With cooler temperatures, there is also a possibility that products of combustion will condense and form acid in the piston ring area.

An engine that runs too hot will overheat and may lead to damage to other components in the engine or piston grabbing.

Figure 35

Thermostats only control the minimum coolant temperature. The maximum temperature depends on coolant capacity and engine heat load. Normal coolant temperature falls between 71°C (160°F) and 107°C (225°F).

Opening temperatures are stamped on the thermostat as shown in Figure 35.

It is important that the thermostat is in an operable condition. An engine should never be operated with the thermostat removed. This will allow a continuous flow of coolant and the engine will tend to run below its designated operating temperature.

OPERATION

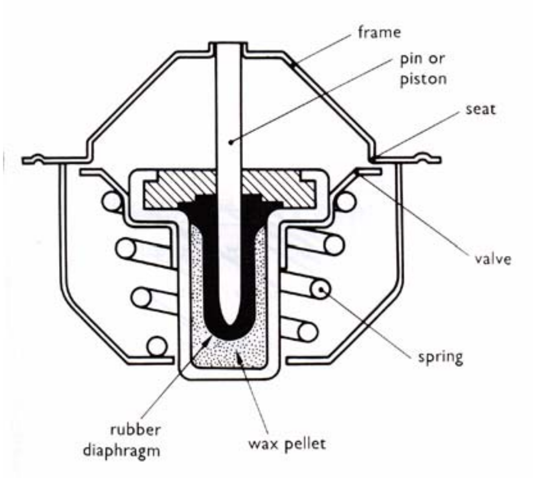


Figure 36

The thermostat in Figure 36 above is in the closed position. As the temperature of the coolant increases, the wax in the pellet expands and applies pressure to the rubber diaphragm. This tries to force the pin out, but the pin is fixed and cannot move, so the pellet container moves downwards. This moves the valve off its seat, opening the valve and allowing coolant to flow to the radiator.

When the engine temperature drops, the wax in the pellet contracts and allows the spring to close the valve, blocking the flow of coolant to the radiator.

Thermostats are designed to open at specific temperatures. For example, a thermostat designated as an 85°C unit will start to open between 84°C (184°F) and 86°C (187°F) and will be fully open at 100°C (212°F).

The design of the wax pellet type thermostat means that if it fails it will normally remain in the open position. The wax-pellets will tend to remain in the expanded position; thereby keeping the valve open.

Temperature Indicators

The cooling system has a temperature gauge and sometimes a warning light. Any unusual rise in temperature is a warning to the operator. The engine should be stopped and checked before serious damage occurs.

A thermo sensor in the radiator or cooling system is used to operate the gauge or warning light on the instrument panel.

Radiator Pressure Cap

Purpose

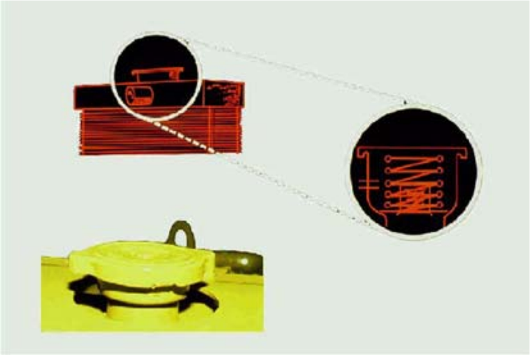


Figure 37 - Pressure Cap

Perhaps the most overlooked component of the cooling system is the pressure cap (Figure 37).

The radiator cap contains a relief valve which limits the amount of pressure developed in the system.

It is important to maintain the correct pressure in the cooling system because the boiling point of the coolant is increased as the pressure increases. By increasing the pressure of the cooling system by 7 kPa (1 psi) the boiling point of the coolant is raised by 1.8°C (3.25°F).

A typical cooling system will have a specified operating pressure which could be from a 48 to 165 kPa (7 to 24 psi).

Operation

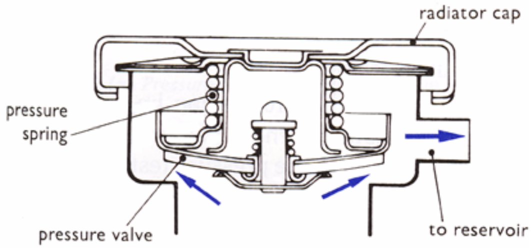


Figure 38 - Coolant expanding

The pressure cap contains a large spring and a pressure valve (Figure 38).

When pressure in the cooling system is low, there is not enough force to lift the valve off its seat. Pressure will build up in the cooling system until it is high enough to overcome spring force. The valve will then lift off its seat and prevent excessive pressure build up in the system.

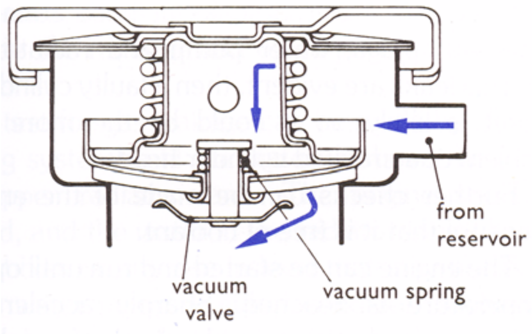


Figure 39 - Coolant contracting

When the engine is shut down, the coolant contracts. If air in the top tank was vented during operation, this must now be made up to prevent a pressure less than atmospheric in the cooling system. This is achieved by the small vacuum valve in the centre of the large disc valve (Figure 39). The small valve opens when the atmospheric pressure is greater than the light spring pressure plus radiator pressure.

Many highway vehicles use an expansion tank (or reservoir) which is piped to the vent tube on the right side of Figure 39. In this situation, the cooling system is replenished with coolant from the expansion tank when the system cools down.

The pressure cap also allows for coolant level inspection and replenishment.

Figure 40

In general the coolant should always come up to the bottom of the filler pipe (Figure 40).

When the system is fitted with a coolant recovery system (expansion tank or reservoir), the level is normally checked in the recovery container.

EXPANSION PLUGS (FROST PLUGS)

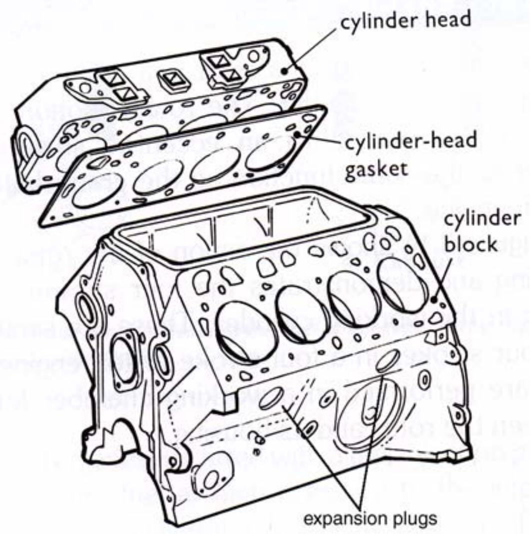


Figure 41 - Expansion Plugs

Expansion plugs (Figure 41) are used to plug casting holes in the engine block and normally come into contact with the coolant. Expansion plugs are normally made of an alloy and are a thinner material than the block. Expansion plugs provide some relief if the coolant becomes frozen. Coolant expansion tends to crack the cylinder block and expansion plugs flex to assist in eliminating the damage that may occur. They are susceptible to corrosion. Replacement of expansion plugs should be conducted as per manufacturer's specifications, ensuring the correct bonding compound is used and the plug is inserted to the correct depth.

COOLANT CONDITIONER ELEMENT

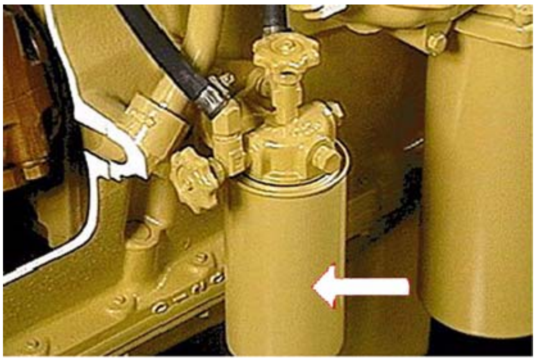


Figure 42

Some vehicles are fitted with replaceable coolant conditioner elements (Figure 42). The conditioner element contains corrosion inhibitors to protect the cooling system.

Systems that use the conditioner element require a initial fill element to be used when the cooling system is first filled. During normal service intervals, a maintenance element is used.

The coolant filter consists of a filter element and a block of chemical that dissolves into the coolant over a period of time, thus ensuring that the correct concentration level of chemicals are maintained over a period of time.

The filter also serves to maintain an acid-free condition of the coolant as the chemicals slowly dissolve. As the filter is of the bypass design, only a small flow of coolant circulates through the filter, but over a period of time all the coolant has been through the filter. One filter hose is usually on the pressure side of the pump e.g. block and thermostat housing, whilst the other is on the low pressure side e.g. inlet to the water pump.

Coolant, depending on the manufacturer, usually adopts an identifying colour such as pink, green, or yellow - this however must not be used as a measure of the level of coolant concentration.

Coolant may possess a distinct colour but the level of protection may be insufficient.

AFTER-COOLERS

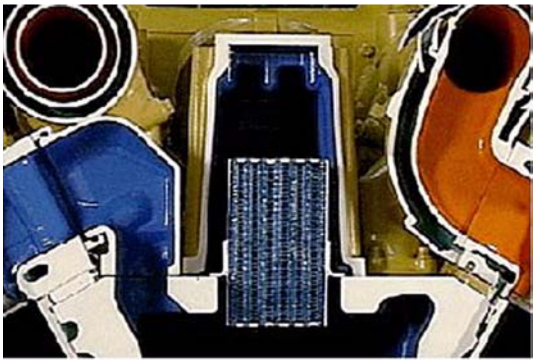


Figure 43

Aftercoolers (Figure 43) are fitted to high performance diesel engines and are in effect a heat exchanger.

After-coolers are used to cool the engine incoming air so that the volume of air available is increased.

After coolers are fitted after the turbocharger as the compression of air by the turbocharger causes the air temperature to increase.

Some engine manufacturers refer to the aftercooler as an intercooler.

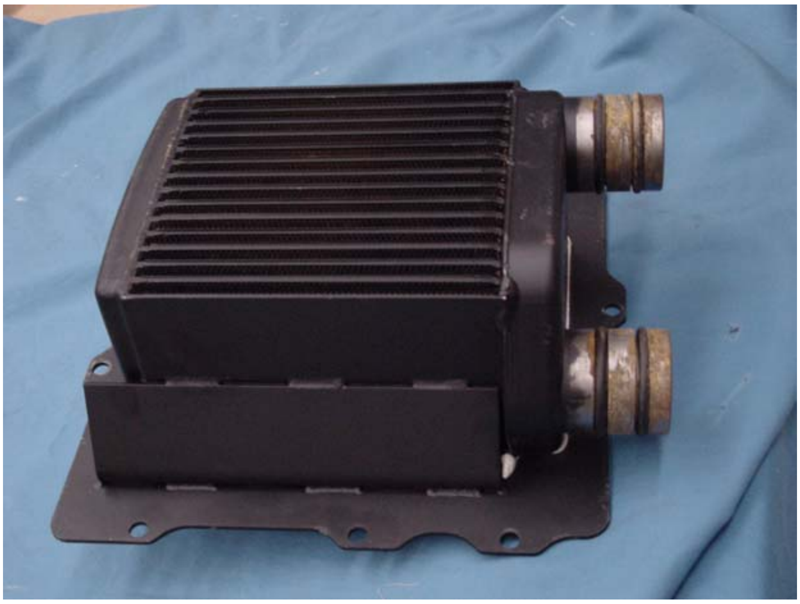


Figure 44

There are two basic designs of after-cooler: one uses engine coolant for cooling of the intake air, (Figure 44) and the other uses the air flow by vehicle movement and cooling fan to create an air draft.

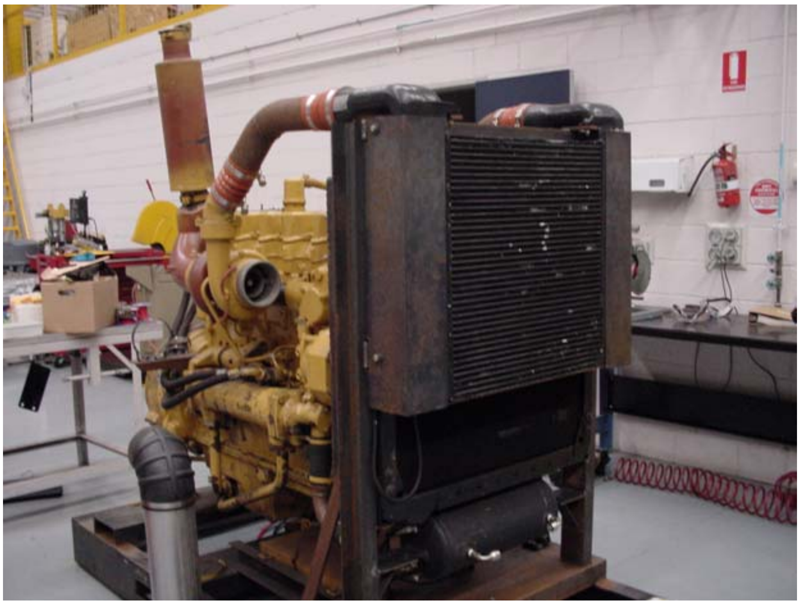


Figure 45

In the latter case, the after-cooler is positioned in front of the engine coolant radiator (Figure 45).

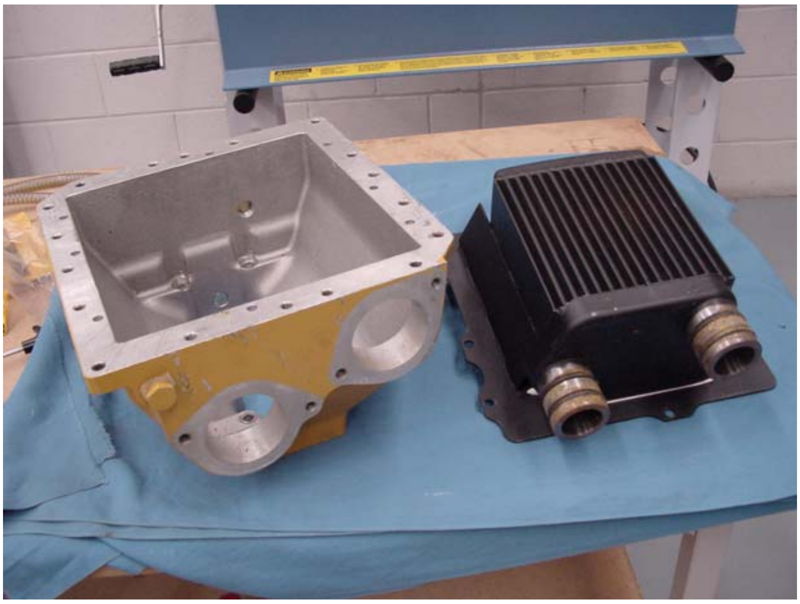


Figure 46

The core of the after-cooler, which uses engine coolant, appears similar to a compressed radiator core, with coolant flowing through the core and the intake air being blown across the fins, releasing heat to the coolant. Coolant taken from the bottom of the block enters the cooler core and then exits to the thermostat housing where it will pass through the engine radiator. The core is a neat fit into the specially designed intake manifold.

Some machines use a separate aftercooler circuit where a portion of the radiator is used only for aftercooler water. In this system, cooler water is normally available to cool the engine intake air.

ENGINE OIL COOLER

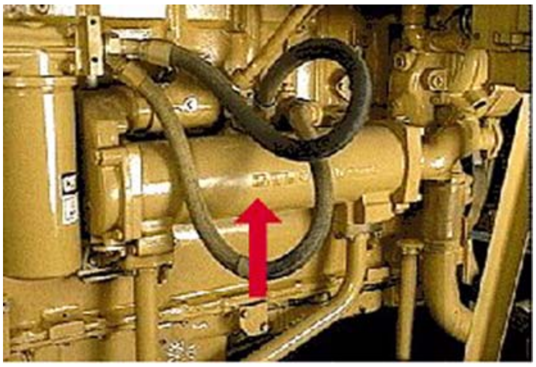


Figure 47

For efficient lubrication, the engine oil needs to be maintained at a desirable level. Engine oil temperature should never exceed 120°C. Due to the friction and heat loads placed on the oil in a high performance, heavy duty diesel engine, the oil temperature would be higher than desirable and therefore needs to be continuously cooled.

Figure 48

The engine oil cooler consists of a metal housing which contains a packed bunch of copper tubes which are separated by a series of baffles. (Figure 48)

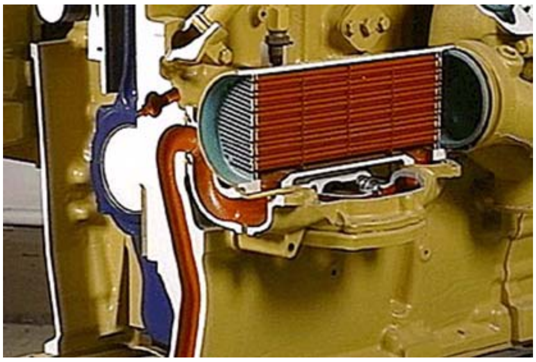


Figure 49

Engine cooling water flows inside the tube bundle and hot engine oil flows around the outside of the tubes. (Figure 49)

The oil cooler reduces the maximum temperature of the engine oil and also reduces the amount of time for the engine to reach operating temperature, by heating up the circulating oil until maximum operating temperature is reached.

WATER COOLED EXHAUSTS

The exhaust manifold used on mobile vehicles are normally open and cooled by air. Occasionally, there are shielded manifolds to prevent heat damage by radiation.

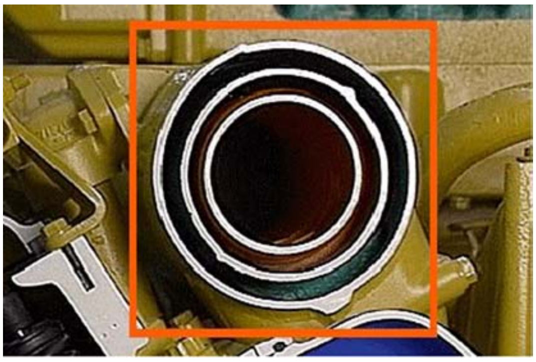


Figure 50

On marine engines, it is normal to use exhaust manifolds that have a water jacket around the exhaust to cool the exhaust gas (Figure 50).

This system eliminates radiated heat and will prevent overheating in the engine room.

COOLING SYSTEM REVIEW

Graphics from a Caterpillar 3406B engine are used to review the flow of coolant through the system.

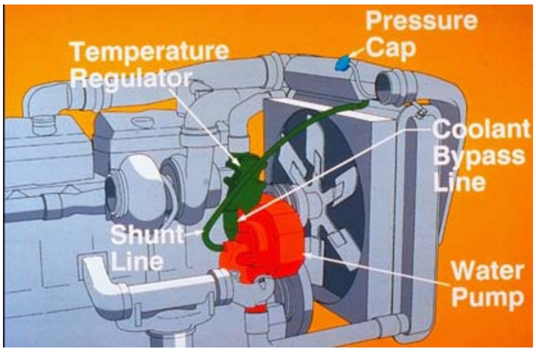


Figure 51

The cooling system on the Caterpillar 3406B engine (Figure 51) includes the following components:

- Water pump
- Block and cylinder head passages
- Thermostat housing and manifold
- Coolant bypass line
- Pressure cap
- Shunt line.

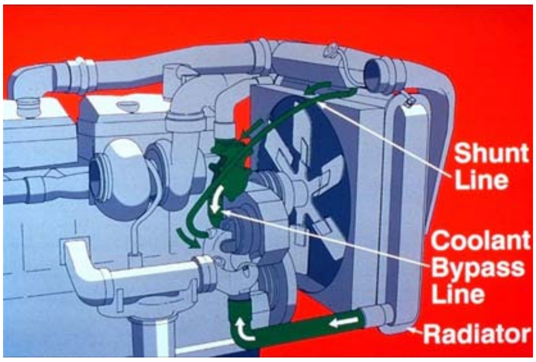


Figure 52

Starting at the inlet of the water pump. The water pump draws coolant from three sources: the bottom tank of the radiator, the bypass and the shunt line.

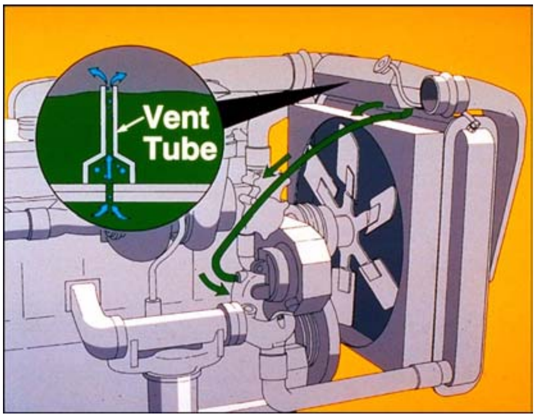


Figure 53

The shunt line (Figure 53) provides a positive coolant pressure at the water pump inlet to prevent pump cavitation. A small amount of coolant constantly goes through the shunt line to the inlet of the water pump. This causes a small amount of coolant to move constantly through the vent tube between the lower and upper compartment in the radiator top tank. This allows the air bubbles to separate from the coolant.

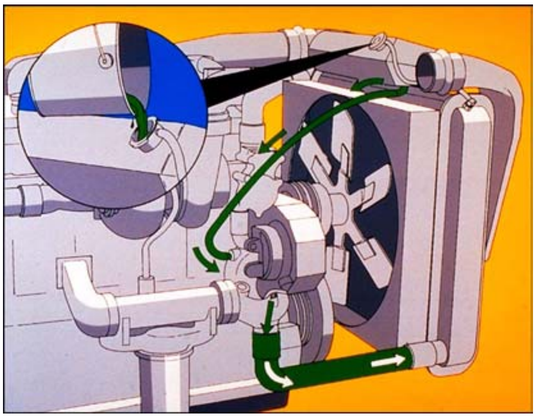


Figure 54

The shunt line also acts as the fill line when an empty cooling system is filled with the coolant (Figure 54). This allows the system to fill without creating air locks.

Figure 55

The water pump (Figure 55) is gear driven from the crankshaft.

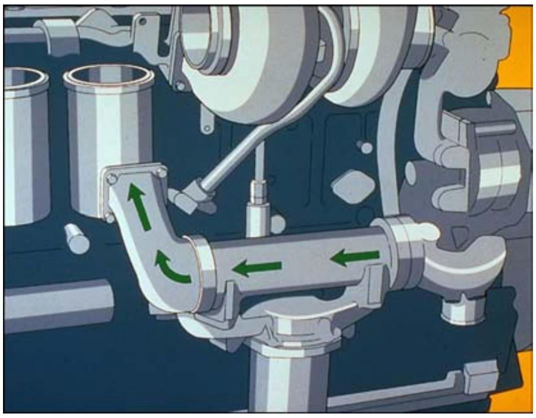


Figure 56

The pump draws coolant through the inlet and sends most of the coolant to the oil cooler (Figure 56).

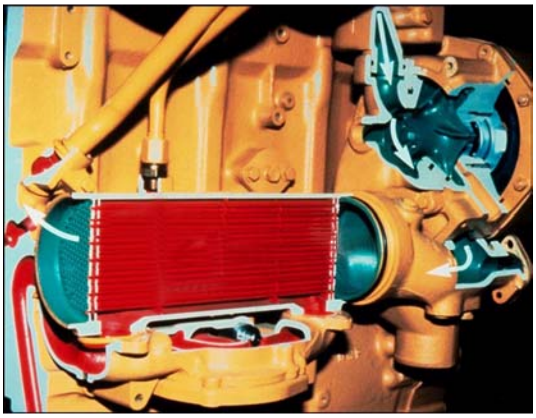


Figure 57

In the oil cooler (Figure 57), the heat from the oil is transferred to the coolant.

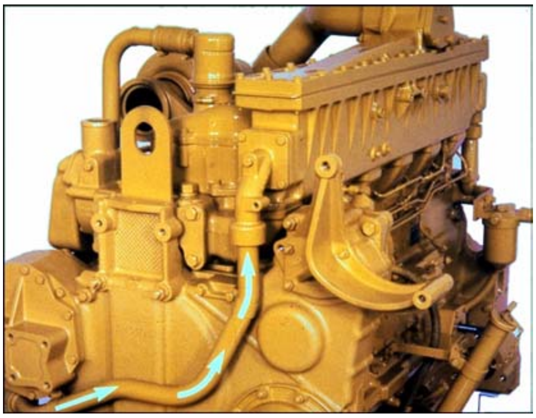


Figure 58

If the engine has a jacket water aftercooler, a small amount of the coolant goes to the aftercooler (Figure 58).

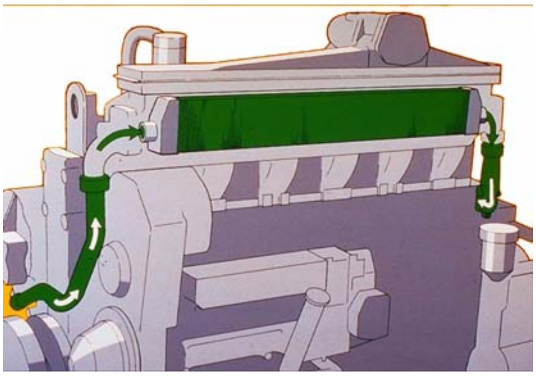


Figure 59

This coolant passes through the aftercooler core to cool the inlet air. Coolant return from the aftercooler enters the rear of the cylinder block (Figure 59).

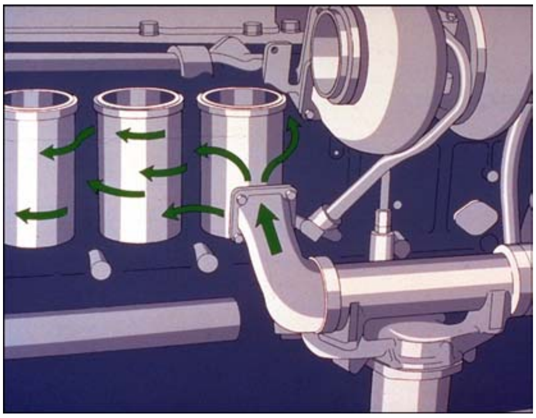


Figure 60

Inside the block, the coolant travels around the cylinder liners and up through the water directors into the cylinder head (Figure 60). The heat generated by combustion transfers through the liners into the circulating coolant.

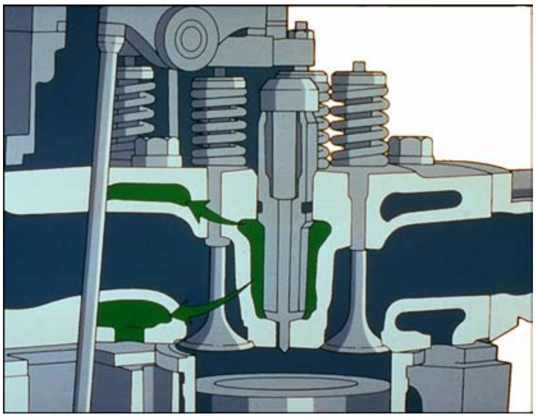


Figure 61

In the cylinder head (Figure 61), coolant flows around the valves and the exhaust ports.

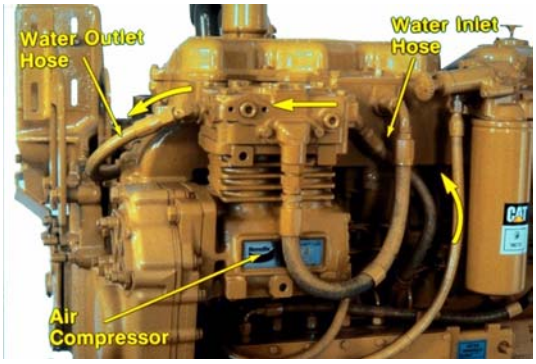


Figure 62

Coolant for the air compressor comes from the cylinder block through the compressor water inlet hose. From the compressor the coolant is routed back into the front of the cylinder head (Figure 62).

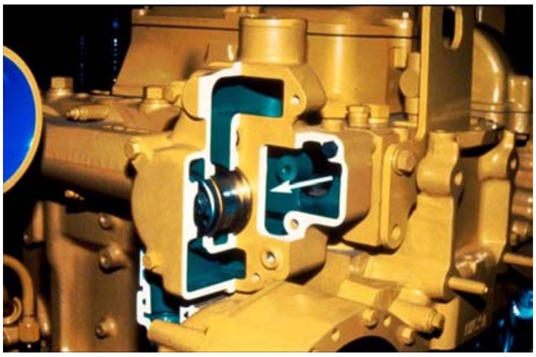


Figure 63

In the cylinder head coolant flows to the front of the head and enters the thermostat housing (Figure 63).

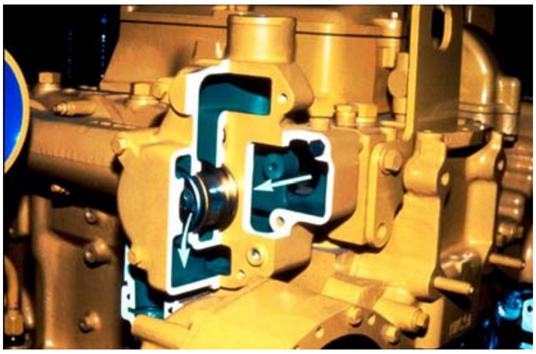


Figure 64

When the coolant is below operating temperature, the thermostat is closed. The coolant flows through the regulator housing and bypass line, back to the water pump (Figure 64). This allows a quicker warm-up time for the engine.