ASE 1 - Engines

Module 2
Engine Cooling Systems
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Introduction

After completing this unit, the technician will demonstrate an understanding of automotive coolant systems. The technician will also demonstrate the skills required to troubleshoot and replace automotive coolant system components.

Objectives

• Understand the theory and operation of typical cooling systems
• Understand the construction and components of a typical cooling system
• Demonstrate successful troubleshooting skills on cooling systems

NATEF Area I. A.

1. Perform cooling system, cap, and recovery system tests (pressure, combustion leakage, and temperature); determine necessary action.
2. Inspect, replace, and adjust drive belts, tensioners, and pulleys; check pulley and belt alignment.
3. Inspect and replace engine cooling and heater system hoses.
4. Inspect, test, and replace thermostat and housing.
5. Test coolant; drain and recover coolant; flush and refill cooling system with recommended coolant; bleed air as required.
6. Inspect, test, remove, and replace water pump.
7. Remove and replace radiator.
8. Inspect, and test fans(s) (electrical or mechanical), fan clutch, fan shroud, and air dams.

STC Tasks:

• Describe cooling system components
• Describe cooling system functions
Lesson 1. Theory and Operation

Cooling System Overview

The cooling system's function is to maintain an efficient engine operating temperature during all engine speeds and operating conditions. The cooling system is designed to remove approximately one-third of the heat produced by the burning of the air-fuel mixture. When the engine is cold, the coolant does not flow to the radiator until the thermostat opens. This allows the engine to warm quickly.

Coolant is drawn from the radiator outlet and into the water pump inlet by the water pump. Some coolant will then be pumped from the water pump, to the heater core, then back to the water pump. This provides the passenger compartment with heat and defrost.

Coolant is also pumped through the water pump outlet and into the engine block. In the engine block, the coolant circulates through the water jackets surrounding the cylinders where it absorbs heat.

The coolant is then forced through the cylinder head gasket openings and into the cylinder heads. In the cylinder heads, the coolant flows through the water jackets surrounding the combustion chambers and valve seats, where it absorbs additional heat.

Coolant is also directed to the throttle body. There it circulates through passages in the casting. During initial start up, the coolant assists in warming the throttle body. During normal operating temperatures, the coolant assists in keeping the throttle body cool.
From the cylinder heads, the coolant is then forced to the thermostat. The flow of coolant will either be stopped at the thermostat until the engine is warmed, or it will flow through the thermostat and into the radiator where it is cooled and the coolant cycle is completed.

Operation of the cooling system requires proper functioning of all cooling system components. The cooling system consists of the following components:

**Air Intake**
- Ambient air flows across the condenser/radiator
- Pushed by forward vehicle movement and pulled by cooling fans
- Fan shrouds and seals maximize the amount of air intake for cooling

**Condenser/Radiator**
- Each transfers absorbed heat to the incoming ambient air by radiation from finned surfaces
- The condenser releases heat absorbed in the refrigerant
- The radiator releases heat absorbed in the coolant

**Fan(s)**
- GM vehicles use a belt driven or electric cooling fan(s)

**Coolant**
- Coolant flows through engine passages to absorb combustion heat

**Heater Core**
- Hot coolant flows through this heat exchanger
- Located in the HVAC module
- To heat the vehicle's interior during cold weather
- Or to blend with conditioned air for a desired temperature during moderate weather

**Other Components:** Thermostat, Radiator Cap, Overflow Tank, Surge Tank, Coolant Pump and Hoses/Clamps
- Thermostat
  - Insures proper engine warm-up by staying closed until the coolant reaches temperature
- Reservoir or Overflow bottle
  - Allows coolant expansion during operation
• Surge Tank and Cap
  – Allows coolant expansion during operation.
  – Pressure cap seals the system.
• Water (Coolant) Pump
  – A belt-driven pump circulates coolant.
• Hoses and clamps
  – Proper operation of the cooling system depends on the hoses and clamps being in good condition.

Air Intake
• Air intake system directs air flow from outside the vehicle through the fins of the condenser and the radiator.
• Includes specific grille design, air dams, shrouds and seals to insure maximum airflow to the condenser and radiator.
• Any structural damage to the front-end of a vehicle will compromise the effectiveness of the air intake system.
• Any obstructions or blockages in this path can cause insufficient heat transfer at both the condenser and the radiator.
• Hidden blockage between the condenser and radiator is a problem.
• A damaged or missing fan shroud, or loose or missing air intake seals, can decrease the amount of cooling air by allowing some of the incoming air to pass around, not through, the condenser and radiator.
Radiator

• The radiator is mounted behind the condenser.

• As a result, the radiator must transfer heat from the coolant into already pre-heated air.

As a note, if the cooling system is not operating properly, excess heat may build up in the radiator and adversely affect the heat-transfer capability of the condenser.

• The radiator is a large heat exchanger with two sets of passages.
  – One set is for coolant flow
  – The other is for air flow

• As coolant is pumped through the radiator, the air passing through its fins removes heat.

• Heat dissipation at the radiator is affected by:
  – Vehicle speed
  – Cooling fan operation
  – Air intake system
  – Condenser heat load

• Most GM radiators are a cross-flow design.
  – Takes up less space than down-flow designs
  – Allows lower hood lines
  – Inlet and outlet tanks are on the ends
Engine Oil Cooler

- The engine oil cooler is a heat exchanger. It is located inside the left side end tank of the radiator. The engine oil temperature is controlled by the temperature of the engine coolant that surrounds the oil cooler in the radiator.
- The engine oil pump pumps the oil through the engine oil cooler line to the oil cooler. The oil then flows through the cooler where the engine coolant absorbs heat from the oil. The oil is then pumped through the oil cooler return line, to the oil filter, to the engine block oil system.

Pressure Cap

- The pressure cap is a cap that seals and pressurizes the cooling system. It contains a blow off or pressure valve and a vacuum or atmospheric valve. The pressure valve is held against the seat by a spring of predetermined strength, which protects the radiator by relieving pressure if it exceeds 15 psi. The vacuum valve is held against the seat by a spring, which permits opening of the valve to relieve vacuum created in the cooling system as the radiator cools off. The vacuum, if not relieved, might cause the radiator to collapse.
- The pressure cap allows pressure in the cooling system to build up. As the pressure builds, the boiling point of the coolant goes up as well. Therefore, the coolant can be safely run at a temperature much higher than the boiling point of the coolant at atmospheric pressure. The hotter the coolant is, the faster the heat moves from the radiator to the cooler, passing air. The pressure in the cooling system can get too high, however. When the pressure exceeds the strength of the spring, the pressure valve rises so that the excess pressure can escape. As the engine cools down, the temperature of the coolant drops and a vacuum is created in the cooling system. This vacuum causes the vacuum valve to open, allowing outside air into the cooling system. This equalizes the pressure in the cooling system with atmospheric pressure, preventing the radiator from collapsing.
Belt Driven Cooling Fan and Clutch

The engine cooling fan and clutch are driven by the crankshaft via the drive belt. The cooling fan draws air through the radiator to improve the transfer of heat from the coolant to the atmosphere. As the fan blades spin, they pull cool, outside air past the radiator core. The fan clutch drives the cooling fan. The fan clutch controls the amount of torque that is transmitted from the crankshaft to the fan blades. The clutch allows more torque to engage on the fan when the engine operating temperature increases and/or the vehicle speed is low. As the torque increases, the fan turns more quickly. The fan clutch decreases the torque applied to the cooling fan when the engine temperature decreases and/or the vehicle speed is high. As the torque decreases, the fan speed decreases.

Figure 2-6,

Electric Coolant Fan

- Coolant Fan operation generally occurs when:
  - Coolant temperature exceeds a certain temperature.
  - A/C system operation is requested.
  - The A/C coolant fan pressure switch closes at a certain compressor head pressure.

Pusher Fan

- Fan mounted on the outboard side of the condenser.

Puller Fan

- Fan mounted on the inboard side of the radiator.
**Coolant/Antifreeze**

The coolant in the engine cooling system remains a liquid as it:

- Soaks up combustion heat.
- Circulates through the system to the radiator and heater core.
- Releases its heat to the ambient air flowing across the radiator.

*Figure 2-8,*

Antifreeze can be added to raise the boiling point of the coolant, but too much will affect the freezing point. Do not use a solution stronger than 70 percent antifreeze, as the freeze level rises rapidly after this point. Pure antifreeze will freeze at -22°C (-8°F).

Coolant is a mixture of water and "antifreeze".

- **Conventional Coolant**
  - Green in color
  - 2 years/30,000 miles
  - Ethylene glycol-based antifreeze
  - The mix is 50-50 water and antifreeze

- **Dex-Cool® Coolant**
  - Orange in color
  - 5 years/150,000 miles
  - Use in all GM vehicles since 1997
  - Non-phosphate
  - Silicate free
  - Ethylene glycol-based antifreeze
  - Recommended for aluminum engine protection and increased water pump seal life
  - The mix is 50-50 water and antifreeze
  - Mixtures with less than 30% antifreeze provide inadequate corrosion protection
  - Mixtures with more than 67% antifreeze freeze quicker and have less heat-transfer ability
GM Goodwrench DEX-COOL® was developed in order to last for 240,000 km (150,000 miles) or 5 years, whichever occurs first. Use only GM Goodwrench DEX-COOL® or HAVOLINE® DEX-COOL® when adding or changing the coolant.

A 50/50 mixture of ethylene glycol DEX-COOL® and water will provide the following protection:

- Give freezing protection down to -37°C (-34°F)
- Give boiling protection up to 129°C (265°F)
- Protect against rust and corrosion
- Help keep the proper engine temperature
- Let the warning lights and gauges work as they should

**Check when system is cool and not under pressure.**

- Engine coolant level can be checked at radiator or surge tank.
- There should be no rust, deposits, scale or oil in surge tank, overflow bottle or on coolant cap.
- If coolant is excessively dirty, cooling system should be flushed and cap replaced

*Figure 2-9,*

**Heater Core**

- Hot coolant flows through this heat exchanger
- Located in the HVAC module
- To heat the vehicle's interior during cold weather.
- Or to blend with conditioned air for a desired temperature during moderate weather
- The heater core is a heat exchanger with two sets of passages. One set is for coolant flow the other is for air flow. As coolant is pumped through the heater core, the air passing through its fins removes heat into the vehicle's interior.

Heat dissipation at the heater core is affected by:

- Blower fan operation
**Thermostat**

The thermostat is a coolant flow control component that utilizes a temperature sensitive wax-pellet element.

The lower end of the thermostat, containing the element, is installed in the engine water jacket.

The thermostat performs the following functions:

- Controls the flow of coolant through the radiator
- Enables controlled engine warm-up
- Assists in coolant temperature control

The wax pellet element in the thermostat expands when heated, and contracts when cooled.

The element connects through a piston to a thermostat valve.

When the element is heated, pressure is exerted against a rubber diaphragm which forces the thermostat valve to open. As the element is cooled, the contraction allows a spring to close the thermostat valve.

While the coolant is cold, the thermostat valve remains closed. This prevents circulation of coolant through the radiator. At this point, coolant is only allowed to circulate throughout the engine block and heater core in order to allow the engine to warm quickly.

As the engine warms, the element expands and the thermostat valve opens. This permits coolant to flow through the radiator, where the heat dissipates to the atmosphere.

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![Figure 2-10, Typical Pellet-Type Thermostat](image)
Surge Tank and Cap
- Mounted near the radiator.
- Uses a pressurized coolant surge tank.

Reservoir or Overflow Bottle
- Uses a plastic coolant overflow bottle.
- Mounted near the radiator.

Water (Coolant) Pump
- The water pump is a centrifugal-type pump that consists of the following components:
  - An impeller
  - An impeller driveshaft
  - A pulley flange
  - A cast housing

- The drive belt drives the pulley. The pulley attaches to the pump.
- The water pump is a centrifugal vane impeller type pump. The pump consists of a housing with coolant inlet and outlet passages and an impeller. The impeller is a flat plate mounted on the pump shaft with a series of flat or curved blades or vanes. When the impeller rotates, the coolant between the vanes is thrown outward by centrifugal force. The impeller shaft is supported by one or more sealed bearings. These sealed bearings never need to be lubricated. With a sealed bearing, grease cannot leak out, and dirt and water cannot get in.
- The purpose of the water pump is to circulate coolant throughout the cooling system. The water pump is driven by the crankshaft via the drive belt.
Lesson 2. Procedures

Hose and Clamp Inspection

- The proper operation of the cooling system depends on the hoses and clamps being in good condition.
- Yet, these items are often taken for granted and overlooked.
- When these oversights occur, roadside emergencies will follow, which will lead to low customer satisfaction.
- Proper physical and visual inspection of hoses and clamps can avoid these problems.

Figure 2-14,
• Hoses should not only be checked by means of a thorough visual inspection, but also by squeezing each hose along its entire length. Look for these problems:
  – Sponginess: If the hose collapses too easily as you feel along its length, replace it. It’s deteriorating.
  – Bulging or Swelling: This means there has been weakening under pressure.; Replace the hose.
  – Brittleness: As you feel and wiggle the hose and it has a feeling of brittleness, replace the hose.
  – Cracking at the point of Attachment: Replace the hose anytime you see this condition.

Figure 2-15,

Hose Replacement
• When replacing hoses, reference the appropriate service manual for procedures.
• General tips on hose replacement
  – When removing a hose for replacement, slit the hose end, twist left and right, then pull straight off.
  – Dip ends of new hose into coolant for easier installation.
Draining and Filling Cooling System

Caution:
Under some conditions, the ethyleneglycol engine coolant is combustible. In order to help avoid being burned, do not spill the antifreeze or the coolant on the exhaust system or the hot engine parts.

Caution:
Do not remove the radiator cap when the radiator is warm. Removing the cap immediately lowers the boiling point of the coolant, and could cause a violent overflow, resulting in a large coolant loss and personal injury

Notice:
Alcohol, methanol-based coolants or plain water alone should not be used in the cooling system at any time. Damage to the cooling system could result from their use.

Important:
Maintain the cooling system protection at -36°C (-33°F). This temperature will prevent corrosion and loss of coolant from boiling. Maintain this level of protection even if extreme temperatures are not expected.

The cooling system is filled (by the manufacturer) using a coolant that is a 50/50 mixture of water and ethylene glycol antifreeze. This coolant solution provides freezing protection to -36°C (-33°F).

Add ethylene glycol-based coolant to the coolant reservoir when the coolant level is low. Refer to the antifreeze proportioning chart and the coolant capacity chart.

1. Remove the radiator cap.

Important:
Watch for a potential overheating condition while the engine is operating with the radiator cap off.

2. Start the engine. Run the engine for 15 minutes.
Important:
Dispose of used coolant in a coolant holding tank which is picked up along with used oil.
Do not pour used coolant down the drain. Ethylene glycol antifreeze is a toxic chemical. Do not dispose of ethylene glycol antifreeze into the sewer system or ground water.

3. Stop the engine.

4. Open the drain plug on the radiator. Drain the coolant into a container.
5. Close the drain plug.
6. Fill the cooling system with water.
7. Repeat the drain and fill procedure until the drained water is clean.

Notice:
Use the correct fastener in the correct location. Replacement fasteners must be the correct part number for that application. Fasteners requiring replacement or fasteners requiring the use of thread locking compound or sealant are identified in the service procedure. Do not use paints, lubricants, or corrosion inhibitors on fasteners or fastener joint surfaces unless specified. These coatings affect fastener torque and joint clamping force and may damage the fastener. Use the correct tightening sequence and specifications when installing fasteners in order to avoid damage to parts and systems.

8. Close the radiator drain plug. **Tighten**
   
   Tighten the drain plug to 13 N•m (9 lb ft).
9. Remove the hose from the reservoir cap.
10. Remove the coolant reservoir assembly.
11. Drain the coolant from the coolant reservoir into a container.
12. Use soap and water in order to clean the inside of the coolant reservoir.
13. Thoroughly rinse the coolant reservoir.
14. Install the coolant fan and coolant reservoir assembly.
15. Prepare a 50/50 mixture of ethylene glycol coolant GM P/N 1052753 (or equivalent) and water.
16. Fill the radiator to the base of the radiator filler neck.
17. Fill the coolant reservoir to the FULL mark on the reservoir.
18. Install the reservoir hose to the reservoir cap.

Important:
Watch for a potential overheating condition while the engine is operating with the radiator cap off.

19. Start and run the engine until the coolant is at operating temperature.
20. The coolant is at operating temperature when the following conditions exist:
   • The hoses feel warm.
   • The coolant is moving in the radiator.

21. Add coolant to the radiator until the coolant level reaches the radiator filler neck.
22. Install the radiator cap.
23. Inspect the following components for leaks:
   • The radiator
   • The coolant reservoir
   • The coolant pipe connections
   • The hose connections
24. Tighten any loose connections as necessary.
Pressure Cap Testing

Tools Required

- Cooling System Pressure Tester

Caution:

To avoid being burned, do not remove the radiator cap or surge tank cap while the engine is hot. The cooling system will release scalding fluid and steam under pressure if radiator cap or surge tank cap is removed while the engine and radiator are still hot.

1. Remove the pressure cap.
2. Wash the pressure cap sealing surface with water.
3. Use the Cooling System Tester in order to test the pressure cap.
4. Test the pressure cap for the following conditions:
   - Pressure release when the Cooling System Tester exceeds the pressure rating of the pressure cap.
   - Maintain the rated pressure for at least 10 seconds.
5. Replace the pressure cap under the following conditions:
   - The pressure cap does not release pressure which exceeds the rated pressure of the cap.
   - The pressure cap does not hold the rated pressure.
Cooling System - Worksheet 1

Objective: At the completion of this worksheet, the technician will be able to explain the functionality of various cooling system components.

Reference: Refer to Module 2 Engine Cooling participant guide.

Directions: Answer the following questions individually, then review in a class.

Questions for Review
1. What is the purpose of the air intake portion of the cooling system?
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________

2. What is the purpose of the condenser within the cooling system?
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________

3. What cooling system component, on the L81 engine, provides a quick warm-up of the heater core and cockpit area?
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________

4. How do the coolant fan(s) differ on the L-Series, when compared to the VUE and S-Series?
   ___________________________________________________________
   ___________________________________________________________
Exercise 2-1

Pick one of the following for standard text after each "exercise". Read each question carefully and choose the correct response. Read each question carefully and fill in the blank. Questions to be numbered sequentially and answers indented - for example.

1. In a series circuit, any open will
   a. cause current to stop flowing
   b. cause an increase in current flow
   c. cause an intermittent failure
   d. have no effect