MAINTENANCE OF AUTOMOTIVE ENGINE COOLING SYSTEMS

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1. GENERAL

1.01 This section covers in general the description, function, and maintenance of automotive engine cooling systems. For detailed information concerning the repair or replacement of specific cooling system components, refer to the appropriate manufacturer's maintenance manual.

1.02 This section is reissued to replace the handbook supplement, Maintenance of Automotive Engine Cooling Systems—HS40, that was prepared by the Society of Automotive Engineers and was formerly a part of this section. Since this reissue covers a general revision, arrows ordinarily used to indicate changes have been omitted.

1.03 The cooling system as referred to in this section includes the radiator, engine water jacket, water pump, thermostat, and associated items such as hoses, belts, fan, radiator cap, etc, that are normally used with a water-cooled automobile or truck engine.

1.04 The purpose of a cooling system is to control the temperature of the operating parts of an internal combustion engine and also to partially control the operating temperature of the engine lubricant by removing excess heat produced by the engine. The cooling system removes heat from the engine by the circulation of liquid coolant through the water jacket, where the excess heat is absorbed, and through the radiator, where the heat is dissipated into the outside air.

1.05 Engine overheating or overcooling are most frequently a result of a malfunction of some component in the cooling system. However, due to the interrelation of the other engine systems such as the lubrication, fuel, ignition, or exhaust systems, a failure of any one of these engine systems to perform satisfactorily could cause overheating.

2. COOLING SYSTEM DESCRIPTION

WATER JACKET

2.01 In a typical water-cooled internal combustion engine approximately half of the waste heat is dissipated through the cooling system, and the other half is removed with the exhaust gas through the exhaust system. The cooling system conducts heat away from the engine by circulating coolant through passages in the cylinder block and cylinder head. These passages form the water jacket.

2.02 The water jacket provides passages for coolant flow around the cylinders and through the head to aid in cooling the valves and combustion chamber area (Fig. 1). These passages are designed to equally divide coolant flow for efficient heat transfer. The coolant flows from the water jacket through the thermostat housing to the radiator or to the water pump inlet for recirculation (Fig. 2).

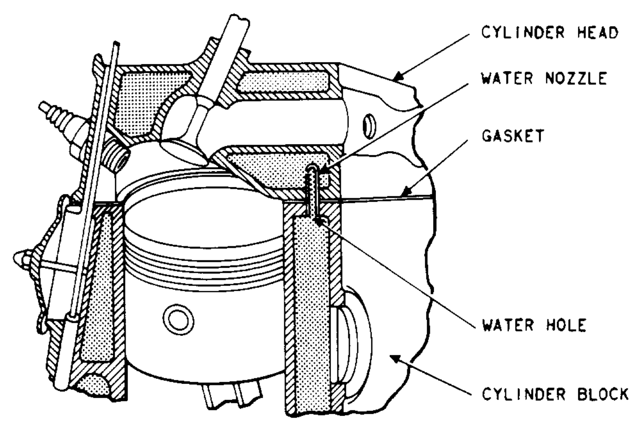

Fig. 1—Coolant Passages in Water Jacket

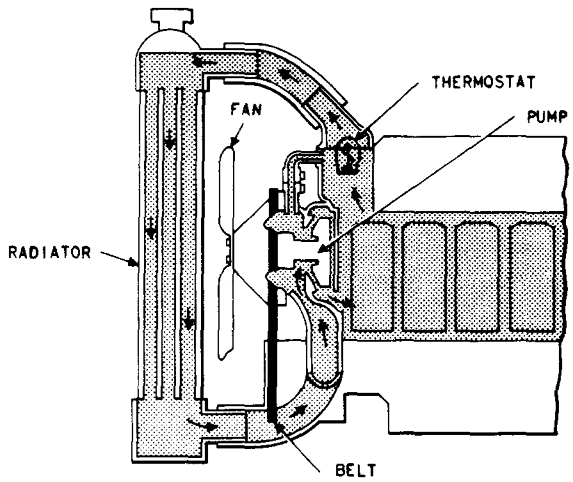

Fig. 2—Coolant Circulation Path

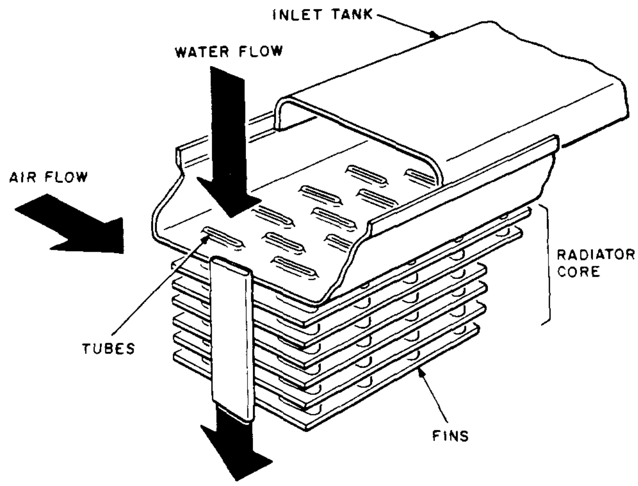

Fig. 3—Typical Radiator Construction

RADIATOR

2.03 The radiator consists of the core, which is a series of tubes surrounded by fins and air passages, and inlet and outlet tanks (Fig. 3). In most radiators the hot coolant enters the inlet tank at the top of the radiator and is cooled as it flows downward through the radiator core. The coolant is drawn from the outlet tank by the water pump for recirculation. On some radiators the inlet and outlet tanks are at the sides of the core, and the coolant is circulated across the core. These crossflow radiators are equipped with an expansion tank, which is usually located above or adjacent to the radiator, to allow for coolant expansion during warm-up and to assure that the radiator tubes are always full of liquid. It is important that the coolant level in crossflow radiators be maintained according to manufacturer's recommendations to avoid air entrapment in the radiator tubes.

2.04 Most radiators on vehicles equipped with automatic transmissions are also used to cool the transmission oil. When provided, the transmission oil cooler unit is located in the outlet tank of the radiator. The transmission oil is cooled by circulating through the cooler by means of oil lines connected to the transmission.

THERMOSTAT

2.05 The thermostat is a heat-operated valve that controls the flow of coolant to the radiator. At certain times, such as during initial warm-up or during cold weather operation, maximum cooling is not required. During these times the thermostat is closed or partially closed to limit the coolant flow through the radiator. However, continuous high-volume flow through the passages in the cylinder head is always necessary. This continuous flow is made possible by a recirculation by-pass in the water pump that permits high-volume flow through the water jacket regardless of whether the thermostat is opened or closed.

WATER PUMP

2.06 The typical water pump is a centrifugal-type which is driven by a V-belt connected to a pulley on the engine crankshaft. The pump basically consists of a housing and the rotating assembly or impeller. Oil and water seals, bearings, etc, mounted on the shaft and in the housing complete the assembly. In most cases the fan is mounted on the water pump shaft.

2.07 The water pump draws coolant from the radiator outlet tank or from the radiator by-pass, depending on whether the thermostat is open or closed. The water pump impeller forces the coolant into the engine water jacket at a high velocity where the coolant is circulated back to the radiator or through the by-pass.

RADIATOR CAP

2.08 The type of radiator cap most commonly used is the vented pressure cap. This type of cap is designed to allow the cooling system to operate under pressure and, therefore, at higher temperâtures without loss of coolant.

> ***Caution: If it is necessary to remove the radiator cap when the radiator is hot, place a thick cloth over the cap and loosen the cap slowly to the first notch to gradually release pressure in the radiator. Suddenly releasing the pressure can cause the hot liquid to erupt from the radiator.***

2.09 The primary function of any radiator cap is to act as a closure for the radiator filler neck. However, the vented pressure cap acts as a pressure control valve as well as a closure. This type of cap incorporates a vacuum valve, which when open allows passage of air, and a spring loaded valve that limits cooling system pressure (Fig. 4). The vacuum valve remains open until the coolant temperature approaches the boiling point. At this point the valve closes putting the cooling system under pressure. The increased pressure allows the coolant to operate at temperatures above the boiling point of water without boiling away, up to approximately 245 degrees depending on the preset pressure rating of the cap. Any excess pressure in the system above the rated pressure of the cap is released automatically by the spring loaded pressure valve being unseated from the filler neck seat.

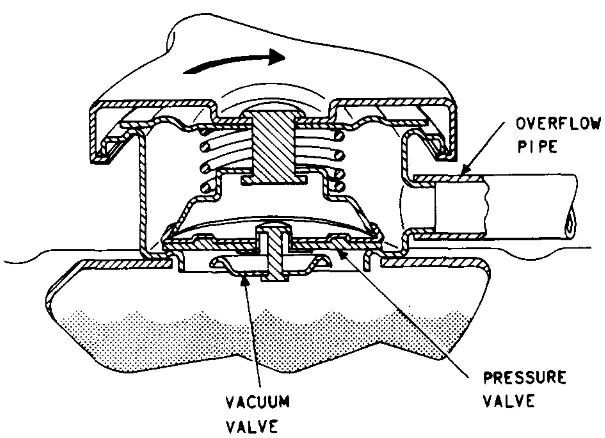

Fig. 4—Vented Pressure Cap

2.10 After the engine is shut down and begins to cool, atmospheric pressure opens the vacuum valve to prevent a vacuum from being created in the cooling system.

ENGINE COOLING FAN

2.11 The engine cooling fan can be a fixed-blade, direct drive; a variable-pitch, direct drive; or a fixed-blade, variable speed type of fan. The fixed-blade, direct drive fan has no provision for changing blade pitch and its speed is directly controlled by the engine speed. The variable-pitch, direct drive fan is equipped with a heat controlled device that changes the blade pitch angle to increase or decrease air flow in proportion to coolant temperature. Its speed is also directly controlled by engine speed. The fixed-blade, variable speed fan has no provision for changing blade pitch, but the fan speed may be regulated by either a fluid drive or a viscous clutch which is controlled by a thermal unit that detects either coolant or air temperature.

2.12 The engine cooling fan moves a large volume of air through the air passages and around the fins of the radiator. The circulation of air removes heat from the liquid coolant as it flows through the radiator core and into the outlet tank where the cooled liquid is picked up by the water pump.

HOSES

2.13 Flexible hoses provide the necessary passages for coolant flow between the radiator and engine block. The flexibility of the radiator hoses serves to protect the radiator from damage due to engine vibration or relative movement. Flexible hoses are also used to connect the hot water type of passenger compartment heaters to the engine cooling system.

COMPARTMENT HEATER

2.14 The hot water type of passenger compartment heater is essentially a second fan and radiator combination. The construction of the heater radiator is, on a smaller scale, practically identical to that of the engine radiator and they function in the same manner. As coolant is circulated through the heater radiator core, air flow is established by an electrically powered fan (in some cases ram air is induced by forward vehicle motion) to distribute the heat for windshield defrosting and passenger compartment heating.

2.15 The heater hoses, which connect to the engine block and water pump, circulate the coolant from the engine block to the heater core and from the heater core to the water pump. Heater output, which can be as high as 30,000 Btu/hr, is regulated by controlling either coolant flow or air flow.

BELTS

2.16 The fan belt, which is made of a rubber compound and textiles to form a continuous flexible band, has two primary functions. The fan belt must drive the fan, which pulls air through the air passages in the radiator core, and drive the water pump, which circulates the coolant through the cooling system, in order for the engine to operate without overheating. In addition, the belt or additional belts may be used to drive accessories such as the generator or alternator, power steering pump, and air conditioning compressor.

COOLANT

2.17 Engine cooling systems are designed to operate satisfactorily with water when both engine output and air temperatures are high. However, water tends to corrode cooling system metals. Deposits caused by corrosion can affect the heat transfer properties of the metal at the walls of the engine water jacket and in the radiator tubes. If corrosion continues unchecked, failure of parts or clogging that can lead to serious overheating problems will result. If cooling system efficiency is to be maintained, rust and corrosion must be prevented. This can be accomplished by adding rust and corrosion inhibitors to the water for summer driving, and by using an antifreeze product that contains inhibitor for winter driving. If antifreeze is used in the cooling system on a year-around basis, periodic tests of the coolant must be made to determine that the inhibitors have not been depleted.

> ***Note:*** Avoid overfilling the radiator. When the radiator is hot, the coolant should just be visible, not up into the filler neck. Attempting to maintain a higher level will only result in a coolant loss through overflow. Continued replacement of this loss with water will reduce freeze protection and, what is just as important, will neutralize the rust and corrosion inhibitors allowing deposits to build up in the cooling system.

2.18 Any antifreeze solution or inhibitor added to water must have performance characteristics such that the coolant will not foam and cause overflow loss of solution and will not contribute to leakage tendencies.

2.19 Of the various types of antifreeze solutions available, methyl alcohol gives the best protection per gallon against freezing, with ethylene glycol rated second. However, protection against freezing is not the only performance factor to be considered, and when other factors such as boiling point, evaporation rate, and expansion rate are considered it will be found that ethylene glycol will generally provide better service. Maximum freeze protection with ethylene glycol antifreeze is obtained with a mixture of approximately 68% antifreeze and 32% water. This solution will protect to -90°F. A solution containing more than 68% ethylene glycol will actually give less protection. Undiluted ethylene glycol protects to only 0°F.

3. OVERHEATING AND OVERCOOLING

3.01 An automotive engine cooling system is designed to prevent engine overheating and overcooling, and in order for the cooling system to operate efficiently, proper coolant level must be maintained. Engine overheating will occur if the coolant level gets too low or if circulation is poor, and conversely engine overheating can cause coolant loss. Coolant loss, which is usually a result of leaks but can also result from other causes, can often be detected early enough to avoid serious overheating damage by periodically checking the coolant level.

RADIATOR LEAKS

3.02 Leaks in a radiator are usually a result of either failure of a soldered joint or corrosion that eats through the thin metal of the radiator core. Vibration of the radiator from such causes as loose mounting attachments, excessive engine or front end vibration, or driving on rough roads can cause solder joints to fail.

3.03 When water or water with an alcohol base product is used as the coolant, the only evidence of a leak may be the presence of white, rusty, or colored stains on the radiator since water and alcohol evaporate rapidly. However, when a permanent-type antifreeze solution is used, a leak will normally appear as a damp spot since the permanent-type antifreeze will not evaporate as rapidly.

WATER JACKET LEAKS

3.04 Leaks in the engine water jacket at core plugs, gaskets, hose connections, etc, that allow coolant to escape to the outside of the engine can usually be detected by the presence of stains in the area of the leak. Leakage of coolant into the crankcase or of oil into the cooling system through the head gasket, casting cracks, etc, may be detected by the presence of oil in the radiator or coolant in the motor oil. Since expansion and contraction of the engine due to extremes of temperature can often cause a water jacket leak to rapidly increase in size, early detection and repair can prevent serious engine damage.

OVERFLOW LOSS OF COOLANT

3.05 Coolant loss through the overflow pipe due to coolant expansion or excessive cooling system pressure is often caused by cooling system or engine irregularities that cause overheating. Overheating caused by generally poor circulation due to a faulty fan belt, corroded or loose water pump impeller, rust or corrosion clogged radiator or water jacket, faulty thermostat, defective radiator hose, etc, is readily detected by observing the temperature gauge. However, poor coolant circulation in one specific area of the water jacket, such as around one combustion chamber, can cause the coolant in that area to be heated to the point of being converted to steam without necessarily causing the remainder of the coolant in the system to be heated to the point that the temperature gauge will indicate an overheated condition. The presence of steam in the cooling system can create pressures that force coolant out through the overflow pipe.

3.06 A faulty head gasket or a cracked cylinder head can permit exhaust gas under compression pressure to escape from the compression chamber into the water jacket. Exhaust gases in the cooling system not only deplete the inhibitors in the coolant and form acids which cause rust and corrosion but also cause an increase in cooling system pressure that can force coolant out of the overflow pipe, which in turn causes overheating.

3.07 While the engine is running, the water pump draws coolant through the radiator core and out of the outlet tank of the radiator. If there is a leak either in the water pump or at a point between the pump and the radiator, it is possible for air to be drawn in through the leak and into the coolant, due to the suction created by the water pump. Also, low coolant level or turbulance in the inlet tank can create a situation where air can be drawn into the radiator core creating air bubbles in the coolant. The presence of air bubbles in the coolant can cause foaming, overheating, and overflow loss. In addition, aeration of the coolant promotes the formation of rust and corrosion even though inhibitors are used.

EFFECTS OF OVERHEATING

3.08 In most engines at normal operating temperatures, engine components such as valves, pistons, and rings operate near their critical temperature limits. Therefore, operating an engine for any length of time at abnormally high temperatures can raise the temperature of the components enough to cause lubrication failure, excessive wear, scoring, burning of valves, possible seizure of moving parts, and warped or cracked cylinder heads or engine block.

EFFECTS OF OVERCOOLING

3.09 Engine overcooling, which can result from a faulty thermostat, or a lack of a thermostat, can cause improper ignition and contamination of the engine lubricant. If an engine runs too cool, unburned fuel and water vapor may blow past the piston rings into the crankcase, dilute the motor oil, and cause sludge and acids to form resulting in improper lubrication and excessive wear of moving parts.

4. MAINTENANCE

4.01 Proper maintenance of the cooling system includes regular checks by the vehicle operator for any indication of overheating, overcooling, low coolant level, or the existence of leaks in the cooling system. Early detection of the signs of a cooling system defect will make it possible to correct the defect before serious engine damage results. It is recommended that each time the vehicle is used, the operator observe the following and report any indication of trouble.

(a) Before entering the vehicle, look at the ground under the vehicle for the presence of coolant that may have leaked from the radiator or engine. If any leakage is detected, attempt to determine its source.

(b) After starting the engine, observe the temperature indicator to see that the engine reaches operating temperature during the normal warm-up period. Failure to do so is an indication of trouble.

(c) During the warm-up period, watch the indicator for any sudden rise in temperature. This indicates a defect and should be reported.

(d) During operation if the engine overheats, it should be shut down and not operated until the cause of the trouble has been corrected. If the engine temperature should drop below normal, the trouble should be reported and corrected before the vehicle is driven again.

4.02 Each time the vehicle is serviced it is advisable to check the coolant level and oil level. In addition to service checks, regular intervals for inspection and maintenance of the cooling system components should be established. The frequency of inspection for a particular vehicle or for vehicles used in specific areas may vary, but in most cases, maintenance procedures recommended by the vehicle manufacturer will be adequate. Where local conditions are such that it is deemed necessary to perform maintenance at more frequent intervals than those recommended by the manufacturer, local procedures shall take precedence.

4.03 As a part of the regular inspection and maintenance procedure, perform the following:

(a) ***Radiator:*** Inspect the core for bent fins or other damage and remove any foreign matter. Inspect the core, tanks, and joints for the presence of leaks. Tighten or replace loose or worn radiator mounting insulators and mounting bolts.

(b) ***Pipes, Hoses, and Connections:*** Inspect hoses and connections for damage, leaks, and deterioration. If a hose feels soft or if there is any doubt as to the internal condition, remove one end of the hose and examine its interior. If there is any sign of deterioration of the interior surface, replace the hose. Inspect the overflow pipe to be sure it is not dented or clogged.

(c) ***Thermostats:*** Normal operation of a thermostat can usually be determined by observing that the engine reaches operating temperature during the normal warm-up period with no sudden rise, and that the engine does not run too cool. If it is suspected that the thermostat is not operating properly, it may be removed and tested either with a commerical tester or by suspending the thermostat in a container of water, heating the water, and observing a thermometer also suspended in the water. Note the exact temperature at which the thermostat operates. If the thermostat does not operate at a temperature within 5 degrees of its specified rating, replace the thermostat.

(d) ***Compartment Heater:*** The heater radiator should be inspected in the same manner as the engine radiator and cleaned or repaired as necessary. Heater switches and controls should be checked for proper operation.

(e) ***Fans and Shrouds:*** Inspect fans for bent, cracked, or otherwise damaged blades. Replace fans that have damaged blades. Variable pitch and variable speed fans require periodic lubrication and inspection of moving parts. Inspect shrouds for damage and tightness. There should be no air leaks between the shroud and the radiator core.

(f) ***Water Pump:*** Inspect for leaks. Follow manufacturer's recommendation for those pumps requiring lubrication. Overheating can be caused by restricted passages in the pump or a worn or eroded impeller. If it is suspected that the pump is not operating properly, remove the pump and replace parts or pump as required.

(g) ***Belts:*** Inspect belts for evidence of wear and deterioration. Replace if frayed, glazed, or cracked on the inner surface. Check for proper belt tension. Too little tension causes belt slippage which can cause overheating. Too much tension shortens bearing life in water pump, generator, etc.

(h) ***Radiator Cap:*** Remove the radiator cap and inspect the seat in the radiator filler neck for dents or nicks and make any necessary repairs. Examine the cap for damage. Commercial testers are available for testing the opening pressure of the cap valve. Replace the cap if it is damaged or defective. Be sure the replacement cap has the same pressure rating and is of the same type as the original.

(i) ***Coolant:*** Check the coolant appearance, level, solution strength, and alkalinity. If the coolant appears rusty or dirty, follow procedures covered in Section 720-210-300. Adding coolant and testing for strength and alkalinity should be done in accordance with procedures covered in Section 720-205-012. The presence of oil in the coolant can indicate serious trouble. Its source should be determined and the trouble corrected.

(j) ***Miscellaneous:*** See that all drain cocks, expansion plugs, and block drain plugs are tight and do not leak. Replace those that are defective. Check for the presence of rust or watermarks on the underside of the hood, the engine block, or firewall. Their presence usually indicates a defective radiator cap. Check the oil level. A low oil level can cause overheating. An oil level above normal indicates that coolant is leaking into the crankcase.

5. TROUBLESHOOTING

5.01 It is normal for a certain amount of coolant to be lost through evaporation. However, any coolant loss that seems to be excessive should be investigated and the cause determined and corrected. Usually, coolant leaks can be located by making a visual inspection of the cooling system components, but internal leaks or pressure leaks that cause loss of coolant may not be visible and are difficult to locate unless special tests are used.

PRESSURE TEST FOR EXTERNAL LEAKS

5.02 A leak may exist in the cooling system that will not be visible unless the system is pressurized. To assist in locating such leaks one of two methods may be used. In each case the test is most effective when performed with the coolant at operating temperature and the engine operating at idling speed.

(a) One method of pressure testing is to use a commercial pressure cap tester with appropriate adapters to apply pressure to the system through the filler neck. Pump air into the system and observe the radiator, hose connections, etc, for any indication of leakage. ***Do not exceed the operating pressure for which the system was designed.*** Apply a soap solution to the top or expansion tank in the areas above the coolant level and check for air leaks.

(b) An alternate method of pressure testing utilizes an air line with pressure regulator and gauge to apply low pressure to the system through a drain cock in either the radiator or engine block. ***Do not exceed the operating pressure for which the system was designed.*** Observe the radiator, hose connections, etc, for any indication of leakage. Apply a soap solution to the top or expansion tank above the coolant level and check for air leaks. The pressure at which the pressure valve in the radiator cap operates may be checked by observing the pressure gauge reading at the moment air escapes through the relief valve.

COMBUSTION LEAKAGE TEST

5.03 The test must be started with the engine cold in order to obtain satisfactory results. To set-up for the test, remove the fan belt or disconnect the water pump coupling so the pump will not operate. Remove the upper radiator hose, thermostat housing, and thermostat. Fill the block completely by pouring water into the radiator to remove any air trapped in the block.

5.04 To perform the test the engine must be operated under load. To load the engine:

(a) On vehicles with manual shift, place wheel chocks against the front wheels and jack up the rear wheels so that when the engine is started, throttle and brake can be applied while operating in high gear.

(b) On vehicles with automatic transmission, place wheel chocks and set the parking brake. When the engine is started, apply foot brake and set the selector lever in the drive position. Depress accelerator to load the engine.

> ***Caution: When performing this test take all necessary precautions to prevent any movement of the vehicle. Do not allow anyone to be in front of the vehicle while the test is being performed.***

5.05 Start the engine and operate it under load while a second person closely observes the coolant at the block outlet. The appearance of bubbles or a sudden rise of the coolant indicates exhaust gas leakage into the cooling system.

Note: The test must be performed quickly before the coolant starts to boil since steam bubbles will give a false indication of leakage.

5.06 An alternate method of testing for combustion leakage may be used if an adapter is available that can be threaded into a spark plug or injector hole and used for injecting compressed air into the combustion chamber.

(a) Start the test by performing the steps covered in 5.03.

(b) Manually bring piston to top dead center on compression stroke and thread adapter into spark plug or injector hole.

(c) Apply controlled air pressure through the adapter. Leakage between the water jacket and combustion chamber is indicated by the presence of air bubbles or a rise of coolant in the cylinder head outlet opening. Repeat the test for each cylinder.

AIR SUCTION TEST

5.07 To perform the test replace the pressure cap with a plain, ***air-tight*** cap. Attach a length of rubber tube to the overflow pipe making sure the connection is air tight. Operate the engine at a fast idle until the engine reaches normal operating temperature. Without changing engine speed, insert the free end of the rubber tube into a bottle of clear water and watch for the presence of air bubbles. A continuous stream of bubbles indicates that air is being drawn into the cooling system.

OVERFLOW LOSS TEST

5.08 The obvious result of coolant loss is overheating. However, there are other causes of overheating, and overheating can cause coolant loss through overflow. The fact that the coolant level is low following an overheated condition does not necessarily mean that low coolant level was the original cause of overheating. To determine whether or not coolant loss is the cause of overheating:

(a) Install a container, which has a capacity of one gallon or more, in the engine compartment. The container should be at a level below the bottom of the radiator, if possible. Attach one end of a rubber tube to the overflow pipe, and attach the other end of the tube so it extends into the container (catchpot) about one inch.

(b) Operate the engine with no load until normal operating temperature is reached. Check the coolant level to be sure the radiator is full.

(c) Operate the engine under load (see 5.04). Vary the load while gradually increasing its severity and occasionally stopping the engine until an overheated condition exists. By observing the temperature indicator, the coolant level in the radiator, and the level in the catchpot, it can be determined whether overflow occurs before overheating or as a result of overheating.

(d) Each time the engine is stopped during the test, check the coolant level in the radiator and determine whether coolant has been discharged into the catchpot. Any coolant in the catchpot may be returned to the radiator. If the amount of coolant in the catchpot does not restore the original coolant level in the radiator, there has been a coolant loss resulting from leakage.

DETERMINING CAUSE OF COOLING SYSTEM TROUBLE

5.09 The most common cooling system trouble is loss of coolant, and any excessive coolant loss or leak that continues undetected will lead to engine overheating. In addition, overheating can be caused by cooling system malfunctions other than coolant loss and also by improper performance of the fuel system, the lubrication system, the exhaust system, or various accessories. When attempting to determine the cause of overheating, the possibility must be considered that the trouble will not be confined to the cooling system.

5.10 ***Determining Cause of Coolant Loss:*** Any significant loss of coolant will be through leaks, either external or internal, or overflow. To locate the cause of coolant loss:

(a) With the engine stopped and coolant at normal level, make a thorough inspection of the hoses, clamps, radiator, pump, drain cocks, gaskets, core plugs, etc, for wet spots, stains, rust, or other indications of leaks. Check radiator cap, filler neck seat, fan belt, oil level, and radiator air passages.

(b) Start engine and operate at fast idle until engine reaches normal operating temperature. During warm-up, feel radiator core for cold spots (indicates clogging). After warm-up, check coolant level, coolant foaming, coolant rise when engine is accelerated, and coolant drop after operation. While engine is operating check for external leaks, check hoses for swelling, check bottom hose for collapse during acceleration.

(c) If there is a coolant loss after operation and no external leaks are apparent, perform pressure test for external leaks, test for combustion leaks, and test for overflow loss.

5.11 ***Determining Cause of Overheating:*** If overheating has occurred, check coolant level. If coolant level is down, it can be determined whether coolant loss occurred before or after overheating by performing overflow loss test covered in 5.08. If overheating occurs prior to coolant loss, it may be caused by poor coolant flow, poor air flow, poor heat transfer, incorrect engine adjustments, or severe operating conditions. Check fan belt, fan, thermostat, and water pump. A clogged water jacket or radiator can restrict coolant flow, and corrosion deposits can retard heat transfer. If coolant loss occurs before overheating, check for leaks or overflow loss.

5.12 ***Determining Cause of Overcooling:*** Overcooling can occur in very cold weather due to excessive heat removal caused by air circulation around the engine or by an overexposed radiator. However, overcooling or slow warm-up when outside air temperatures are not extremely cold can usually be attributed to a faulty or missing thermostat.

THAWING FROZEN COOLANT

5.13 If overheating occurs shortly after starting an engine that has been exposed to below-freezing temperatures, a freeze-up of the coolant may be indicated. To check for the presence of frozen coolant, examine coolant in top tank, or if coolant level is down, attempt to draw some coolant into a hydrometer or open a drain cock.

5.14 If coolant has frozen solid, allow the vehicle to stand in a warm place until all ice has melted. Do not attempt to operate an engine if there is solid ice in the cooling system. If there is only slush ice in the cooling system, thawing may be accomplished by using the following procedure:

(a) Replace any coolant lost with antifreeze, and replace radiator cap in vent position.

(b) Start engine and operate at slow idle. Watch temperature gauge, and stop engine as soon as temperature approaches boiling point.

(c) Allow engine to cool to normal and restart. Repeat the process until all slush has melted and full circulation has been restored.

FINAL ROAD TEST

5.15 After any cooling system trouble has been repaired, a final road test should be made to determine that all cooling system components are performing satisfactorily. If the initial trouble caused overheating, the overheating in itself could create a condition that would cause further overheating. For example: A broken or loose fan belt can cause boiling to the extent that rust deposits in the water jacket could be loosened and carried into the radiator causing a clogging condition. In this case, replacing or adjusting the fan belt to correct the initial trouble would not prevent further overheating. Since severe overheating can damage the thermostat, the final road test should also include a check for overcooling.