ASTM

Manual on Selection and Use of Engine Coolants and Cooling System Chemicals

Fourth Edition

Joseph A. Lima and
George R. Otterman
editors

Manual on Selection and Use of Engine Coolants and Cooling System Chemicals: 4th Edition

Joseph A. Lima and George R. Otterman, editors

ASTM Manual Series: MNL 6
Revision of STP 120B

ASTM
1916 Race Street
Phildelphia, PA 19103

Library of Congress Cataloging-in-Publication Data

Manual on selection and use of engine coolants and cooling system chemicals/Joseph A. Lima and George R. Otterman, editors.—4th ed.
(ASTM manual series ; MNL 6) (Special technical publication ; STP 120)
ISBN 0-8031-1265-3
1. Anti-freeze solutions. I. Lima, Joseph A. II. Otterman, George R. III. Series. IV. Series: ASTM special technical publication ; 120.
TP362.M36 1988
629.2′56—dc19 89-342
CIP

© 1989 by American Society for Testing and Materials
ASTM Publication Code Number (PCN) 28-006089-15

NOTE: The Society is not responsible, as a body, for the statements and opinions advanced in this publication.

Printed in Baltimore, MD
May 1989

Contents

Introduction

This ASTM manual has been developed by Committee D-15 on Engine Coolants and is a revision to ASTM Special Technical Publication (STP) 120B. This publication provides consumers with practical information and advice on engine coolants as well as cooling system chemicals, such as cleaning compounds and practices, antirusts, and stop-leaks. This fourth edition presents new information on coolants containing silicates for the protection of aluminum components in today's engines.

More detailed information on engine components, antifreeze, coolants, and cooling system maintenance was presented at two Committee D-15 symposia and published in STP 705 and STP 887 on Engine Coolant Testing. Good cooling system maintenance is an important factor in maintaining the efficient operation of a liquid cooled engine. Any operation of engines using water alone, as the coolant, will cause some degree of corrosion. Selection and use of proper coolant or coolant treatment for your engine cannot be overemphasized. This manual will assist the consumer in selecting quality engine coolants and proper maintenance procedures to ensure efficient and trouble free operation of today's engine cooling systems.

The procedures and practices described herein have no official status as ASTM standards. However, Committee D-15 has developed full consensus standards, and some of these standards are specifically cited in this manual. The full set of the Committee D-15 standards on engine coolants are published in Volume 15.05 of the Annual Book of ASTM Standards.

This manual may involve hazardous materials, operations, and equipment, and does not purport to address all of the safety problems associated with their use. It is the responsibility of the user of this manual to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

The revisions of this manual were prepared by a D-15 task group consisting of the following members: N. R. Cooper, Union Carbide Corp., R. H. Faye, Dow Chemical Corp., J. A. Lima, Houghton Chemical Corp., and G. R. Otterman, General Motors Corp. Union Carbide Corp. is acknowledged for contributing photographs for this publication.

The Engine Cooling System

Purpose

The purpose of an engine cooling system is to remove excess heat produced by engine operation and control metal temperatures within safe limits. High speed driving with today's engines can produce enough heat energy to melt a 200 lb (91 kg) cast iron engine block in 20 minutes [*1*]! Even operating at moderate speeds, the temperatures inside the engine are extremely high. Combustion gas temperatures may be as high as 4500°F (2482°C). The heads of the exhaust valves may be red hot, and the temperature of lubricated parts, such as pistons, may run 200°F (93°C) or more above the boiling point of water. When metal temperatures are not controlled by adequate cooling, the consequences are lubrication failure and serious engine damage. This is especially true with engines having aluminum heads.

Need for Antifreeze Coolant

Liquid cooled internal combustion engines require a circulating coolant to remove excess heat. While water is an effective heat transfer fluid, it has serious shortcomings as an engine

Copyright© 1989 by ASTM International www.astm.org

coolant. It freezes at too high a temperature, 32°F (0°C), boils at too low a temperature, 212°F (100°C), and causes corrosion of cooling system metals.

Various alcohols and glycols can be used as "antifreezes" and are effective freeze point depressants for water. However, because glycols raise the boiling point of water while alcohols lower it, only glycol bases are recommended for use by engine manufacturers.

Corrosion is effectively controlled by using chemical inhibitor systems which are added to the glycol to make a complete coolant concentrate formulation commonly referred to as permanent engine coolant.

There are many corrosion mechanisms which can take place in today's engines. The complexity has increased with the use of aluminum alloys in the head and block. Aluminum used in areas such as the head, where large quantities of heat are liberated to the coolant, is subject to a unique heat rejection corrosion. To protect against the heat rejection corrosion of aluminum, a coolant having special corrosion inhibitor systems must be used.

Follow the recommendations of your vehicle manufacturer concerning engine coolants and be certain the product you select conforms to standard specifications for engine coolant such as ASTM Specification for Ethylene Glycol Base Engine Coolant (D 3306). Any high quality engine coolant must pass the requirements of this specification.

The New Role of the Coolant

Years ago water was considered to be the best choice for engine cooling and engine designers used water as the baseline fluid in developing cooling system parameters. Beginning in the early 1960s, and continuing today, engines are designed to operate throughout the year on ethylene glycol engine coolant. Today, 44 to 55% concentrations of inhibited ethylene glycol engine coolant are installed in new cars on the production line. Most major engine coolant marketers recommend a 50% concentration for year-round use.

An important property of today's engine coolant, that is now being more fully utilized, is its higher boiling point. A 50% concentration of ethylene glycol coolant raises the boiling point of water 15°F (9°C). See Table 1 for details. The higher boiling point of glycol engine coolant makes possible the higher engine operating temperatures of today's automotive engine.

The maximum possible heat transfer capacity of a given cooling system is reached when the coolant entering the radiator is at boiling temperature and at the design pressure of the cooling system. Axiomatically, it is then evident that raising the boiling point temperature of the coolant will increase the heat transfer capability of the cooling system. This is achieved by the increase in coolant temperature at the radiator inlet. The resulting increase in radiator core average temperature generates a greater temperature differential between the core and the cooling air. This markedly increases the radiator cooling capacity [*2*].

Most vehicle and engine coolant manufacturers recommend a 50% (vol) concentration be used year round. This concentration is needed to achieve the engine design cooling capacity, to

TABLE 1—*Boiling Points of Various Concentrations of Ethylene Glycol.*

Ethylene Glycol Concentration by Volume	Boiling Point	
	Atmospheric Pressure	15 psig/(103 kPa) System Pressure
44	224°F (107°C)	262°F (128°C)
50	227°F (108°C)	265°F (129°C)
60	232°F (111°C)	270°F (132°C)
70*	238°F (114°C)	276°F (136°C)

*Concentrations higher than 68% are not recommended; 68% provides maximum freezing protection to approximately −92°F (−69°C).

provide a margin of safety against boilover, to insure an adequate level of inhibitor concentration (Fig. 1) and to provide freeze protection to −34°F (−37°C). If greater freeze protection is needed, more engine coolant concentrate may be used, however, the concentration should never exceed 68%. Concentrations greater than 68% actually raise the freeze point. Undiluted ethylene glycol engine coolant freezes at approximately 9°F (−13°C).

In addition to reduced freeze protection, over concentrated engine coolant adversely affects cooling capability and corrosion inhibitor stability. Heat from engine operation causes corrosion inhibitors to precipitate from the coolant making it unable to protect engine components from corrosion and possibly plugging small cooling passages in the engine and radiator.

Antifreeze Coolants

Although the long standing function of engine coolants is to prevent freezing in the engine cooling system, it also must meet other requirements to be satisfactory [*3,4*]. It should: 1) have a high boiling point; 2) prevent corrosion of cooling system metals; 3) effectively transfer heat; 4) be chemically stable; 5) be miscible with water; and 6) be relatively nonflammable. It should not adversely affect other materials in the system, not foam, evaporate, or expand excessively. A number of materials have been used as freezing point depressants, but none satisfy all these requirements. However, usage and extensive testing have established certain coolant base materials as preferable to others.

Types of Antifreeze Coolant

Glycols. A properly formulated ethylene glycol coolant can satisfy the requirements of the modern engine cooling system. When ethylene glycol coolant is sufficiently diluted with water of good quality, it provides good chemical stability and adequately satisfies the requirements outlined earlier. Evaporation of glycol is practically nil, and loss of engine coolant can only occur from boilover, leaking, expansion, overfilling, or evaporation of water.

Diethylene glycol or propylene glycol alone can also be used as antifreeze coolants, but they are more likely to be mixed with ethylene glycol. Their addition is usually restricted to a small percentage of the total glycol content.

Ethylene glycol base coolants meeting specification requirements of ASTM D 3306, used at 50% concentration, offer freezing protection to −34°F (−37°C), provide a sufficiently high

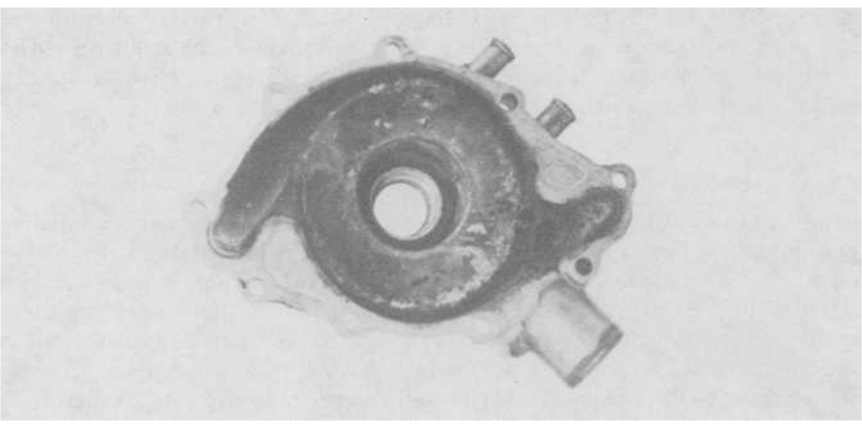

FIG. 1—*Coolant pump damaged by cavitation-erosion-corrosion. Pitting can be controlled by a properly inhibited antifreeze coolant that is used as directed by the manufacturer.*

Copyright© 1989 by ASTM International www.astm.org

boiling point, and effectively inhibit corrosion. At a concentration of 68% by volume, an ethylene glycol base coolant has a freezing point of approximately −92°F (−69°C). Ethylene glycol is modified sometimes by the addition of glycol ethers, such as 2-methoxy-ethanol, to lower the viscosity at very low temperatures and to prevent freezing of the undiluted engine coolant concentrate.

Alcohols. Methyl alcohol, and to a lesser extent ethyl alcohol, were used as freezing point depressants for many years. Their use now is minimal. When properly inhibited, alcohol-water solutions can be satisfactory coolants only under restricted conditions. Alcohol antifreezes fell into disuse because of their low boiling point (lower than that of water) and the danger of loss from boiling or evaporation. Alcohol volatilizes from hot surfaces much more readily than glycol coolant and can be a potential fire hazard. Methyl alcohol liquids are both flammable and poisonous. Methyl alcohol vapors are toxic when inhaled at high concentrations.

Others. Methoxy propanol, a glycol ether, has had limited use in recent years as an engine coolant principally in heavy-duty vehicles. Its advantage is said to be better compatibility with engine oil should internal leakage occur. It has a lower flash point and boiling point than ethylene glycol. It has not been extensively used in automotive cooling systems because of its higher cost and the present satisfaction with glycol products.

Several attempts have been made to use other materials as antifreezes. Salts, such as calcium chloride or sodium acetate, depress freezing points, but are corrosive. They can cause severe corrosive damage to the engine. Leakage of these salt solutions can cause short circuiting of the electrical system.

Petroleum base coolants have been considered for use because of their low freezing point and negligible corrosive effect on cooling system metals. Since they are not miscible with water, a larger volume of coolant material is required, and their use is more costly than other engine coolants. They are not recommended because of their adverse effect on hose materials, their potential fire hazard at engine operating temperatures, and their inferiority to water-glycol coolants as heat transfer agents. Furthermore, if the engine temperature warning device should malfunction during a cooling system failure, these materials will not give the secondary warning of boiling-over because of their high boiling points. These excessive engine temperatures may burn out engine bearings, cause piston seizure, warp heads, or melt the solder in the radiator.

Solutions of sugar or honey have also been tried. These are unsatisfactory because high concentrations are required to provide adequate freezing protection. These solutions are unstable as well as too viscous.

Laws have been enacted in many states in an attempt to prevent the sale and distribution of deleterious antifreeze products, such as salt solutions or petroleum coolants. Even ethylene glycol engine coolants must be evaluated by testing and comparison of test results with specifications for engine coolant concentrate, such as ASTM D 3306. These tests ensure desired levels of antifreeze coolant concentrate and inhibitor are available to adequately protect cooling systems against freezing, boilover and corrosion (Fig. 2).

Antifreeze Coolant Composition

A properly formulated engine coolant concentrate is composed of several essential ingredients, including base fluid, corrosion inhibitors, foam suppressor, dye, and water.

Base Fluid. This material constitutes the bulk of the concentrate. In most cases ethylene glycol is the major component. When mixed with water it depresses the freezing point and raises the boiling point. When glycol base coolant is used at the proper concentration it will provide excellent cooling performance over a wide temperature range. Only antifreeze grade ethylene glycol conforming to ASTM Specification for Anti-Freeze Grade Ethylene Glycol (E 1177) shall be used to formulate antifreeze coolant concentrates.

Corrosion Inhibitors. Unless properly inhibited, ethylene glycol-water solutions are corrosive

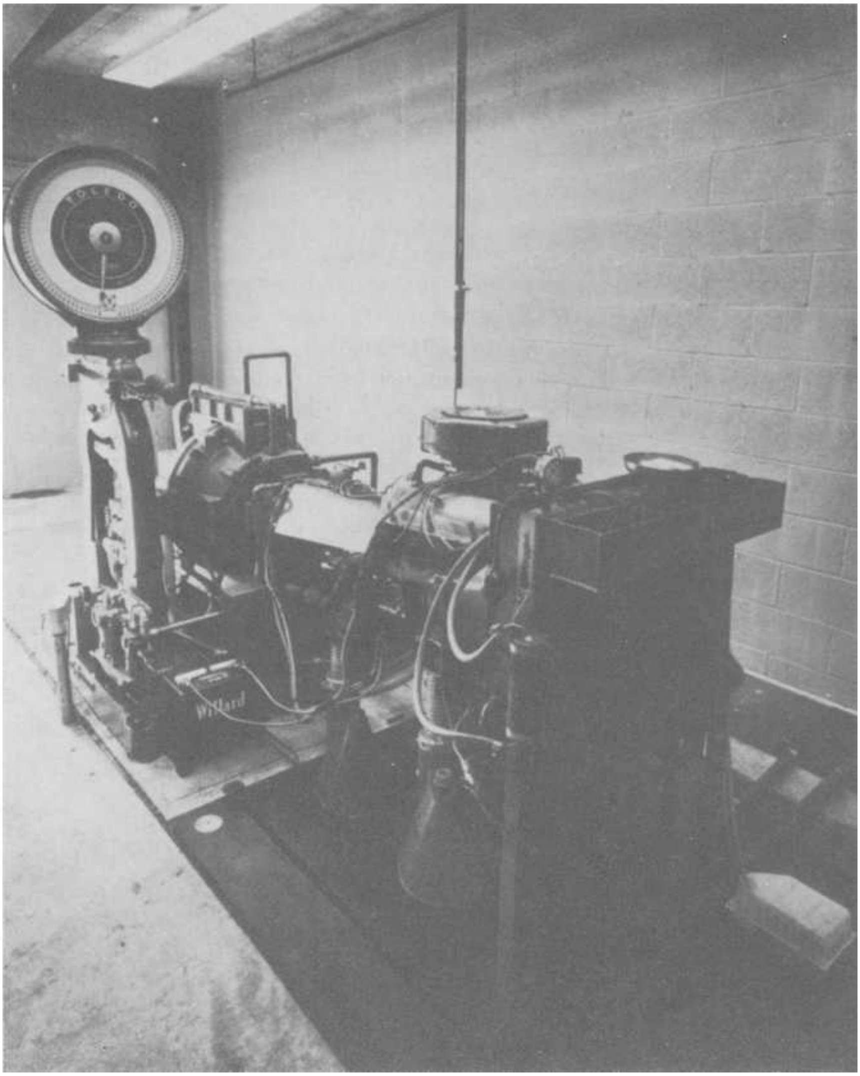

FIG. 2—*Engine Dynamometer Test Equipment. This is the third step in a comprehensive four-step evaluation program, consisting of glassware, simulated service, engine dynamometer, and vehicle testing.*

to metals in the cooling system. Inhibitors are chemical compounds that protect metals from corrosion. A balanced formulation is composed of many inhibitors all required to protect the various metals present in the modern cooling system. Some typical inhibitors, that are used in engine coolants, are borates, phosphates, nitrites, nitrates, silicates, mercaptobenzothiazole, tolyltriazole, and benzotriazole. In addition to direct inhibition, these chemical additives provide a buffering action and alkaline reserve. Maintaining the coolant in an alkaline condition is necessary to neutralize acidic products that may be formed by heat induced deterioration of the coolant or by entry into the coolant of corrosive exhaust gases past leaking cylinder head gaskets (Fig. 3).

Each inhibitor must be present at a sufficient concentration to provide adequate corrosion protection. The amount of inhibitor required is affected by a variety of factors including operating conditions, the corrosivity of the water used for dilution, operating temperatures, and the length of time at operating temperatures. Corrosion inhibition is one of the reasons for maintaining the engine coolant at a 50% concentration all year. Furthermore, inhibitors are depleted with time through interaction with metals and other substances in the system. They must be replenished or replaced. The preferred practice is to replace the antifreeze coolant at periodic intervals because of in-service inhibitor depletion or contamination that may have entered the system.

Select the engine coolant or antirust with care to ensure adequate corrosion protection. Use only those products conforming to recognized standards such as ASTM D 3306 for engine coolant. Additionally, if your vehicle engine contains major cast aluminum components, be certain the engine coolant meets the heat rejection corrosion limits in ASTM specification D 3306 as determined by ASTM Test Method for Corrosion of Cast Aluminum Alloys in Engine Coolants Under Heat-Transfer Conditions (D 4340).

Most engine coolants formulated to provide protection against the heat corrosion of aluminum contain elevated levels of silicate. Silicates are very sensitive to "gelling" or "dropping" out

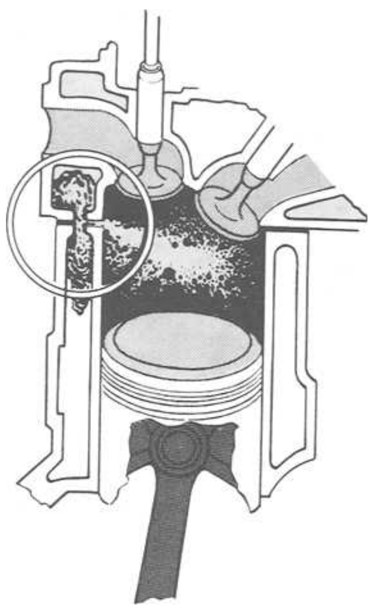

FIG. 3—*Exhaust gas leakage into the cooling system can cause foaming, overflow, loss of coolant, overheating, and shortened inhibitor life with subsequent corrosion and rust clogging.*

of solution if the engine coolant is over-concentrated or left in service too long. Never use more than a 68% concentration of engine coolant. Generally 50% is the recommended concentration. Changing your engine coolant annually will help ensure your coolant is maintained in optimal condition.

Foam Suppressor. Bubbles that accumulate in the system through the introduction of exhaust gases or air entrainment are detrimental to the function of the cooling system. Higher alcohols or other organic chemicals are added to engine coolant to suppress the formation of foam. These substances are surface active agents that affect the surface tension of the liquid, causing the bubbles to break.

Dye. A dye is added to the engine coolant to differentiate it from other functional fluids (such as automatic transmission fluid, brake fluid, etc.) and to signal its presence in the cooling system. The dye should remain stable during the period of use and should not affect the appearance of paint finishes in case of accidental spillage of coolant.

Water. All engine coolant concentrate contains a small amount of water, usually less than 5%. This includes water of hydration from some of the chemical additives, water of reaction produced during formulating, water originally present in the base material, and water deliberately added to help dissolve the inhibitors. Water must be held at a low level in order that the appropriate freezing protection will be obtained when the engine coolant concentrate is diluted for use with water on the basis of standard tables. It should be noted, however, that some highly watered antifreeze coolants are sold to the unsuspecting motorist. The consumer may identify such products by referring to the protection chart on the container. An inferior coolant concentrate will show less than the industry standard of −34°F (−37°C) for a 50% (volume) solution.

Properties of Antifreeze-Coolants

The physical properties of compounds used as engine coolants are quite different and have a determining effect on their suitability for use. Physical properties can be used to identify coolant compounds and to determine, in part, how well the compound will function as a coolant. Some typical values for coolant compounds are shown in Table 2.

The physical properties that are of most importance to the user of engine coolants are the freezing and boiling points. These can be measured accurately in a laboratory or determined indirectly in the field using readily available instruments that indicate the freeze point or boiling point based on specific gravity or refraction of light. These instruments give approximate

TABLE 2—*Typical Physical Properties of Coolant Compounds [4].*

Property	Water	Methyl Alcohol	Ethylene Glycol
Specific Gravity 68/68°F (20/20°C)	1.00	0.7924	1.1155
Specific Heat, 77°F (25°C)			
cal/(g) (°C)	0.99765	0.600	0.574
Freezing Point, °C			
Pure	32°F (0°C)	−144°F (−97°C)	9°F (−13.3°C)
50% water solution	...	−48°F (−44.5°C)	−34°F (−36.6°C)
Boiling Point,			
100%	212°F (100°C)	148°F (64.5°C)	387°F (197.3°C)
50% water solution	...	76°F (24.4°C)	225°F (107.2°C)
Vapor Pressure, 68°F (20°C) mm Hg	17.535	96.1	0.12
Flash Point, open-cup	...	60°F (15.6°C)	240°F (115.6°C)
Viscosity, 68°F (20°C), cP	1.01	0.59	20.9

results. Do not mix engine coolant of different bases. To do so would make it impossible to determine freeze/boilover protection using field instruments.

The freezing point of an engine coolant is the temperature at which the first ice crystals form. A solution may be cooled a few degrees below this temperature before flow of coolant is impeded. To avoid engine damage from "freeze up" it is important that sufficient glycol engine coolant concentration be used to provide protection to the lowest expected temperature. Boiling point has taken on as much significance as freezing point because of the higher operating temperature in the modern engine. It is no longer safe to use low boiling point fluids. Thus, the concentration and type of coolant used should be based on both freezing and boiling points. The best recommendation for the continental United States is to use a 50% solution of ethylene glycol engine coolant year-round.

The chemical properties of an engine coolant are determined in part by the pH or reserve alkalinity of the coolant. The pH is indicative of the acidity or alkalinity. It is desirable that engine coolants have an alkaline pH (greater than 7.5). The degree of alkalinity is defined by *reserve alkalinity,* a number obtained by titration of a known volume of engine coolant with a standard acid solution; the higher the number, the greater the alkalinity. It is a measure of the concentration of inhibitors or other chemicals that have been added which contribute to the alkaline character of the coolant. However, *reserve alkalinity* alone does not completely indicate the quality of corrosion inhibition and should not be interpreted to be a complete indication of this quality. Corrosion inhibition can only be determined by actual corrosion testing.

Water Quality

Water used to dilute engine coolant concentrate for use must be of high quality. Clean, clear, potable water, low in chloride and hardness is generally acceptable. Avoid using any water that is brackish or that you couldn't drink. Deionized or distilled water is ideal to dilute engine coolant concentrate for use. With properly inhibited engine coolant, water meeting the requirements outlined in Table 3 is considered suitable for use. Water exceeding these levels can cause excessive scale, sludge deposits, and increased corrosion potential.

TABLE 3—*Water Quality.*

Property	Requirement
Total Solids, Maximum	340 ppm (20 grains/gal.)
Total Hardness, Maximum	170 ppm (10 grains/gal.)
Chloride (as Cl), Maximum	40 ppm (2.5 grains/gal.)
Sulfate (as SO_4), Maximum	100 ppm (5.8 grains/gal.)

Installation and Service

Preparing the Cooling System

Inspection and Test. Before installing any engine coolant, the cooling system should be inspected and necessary service work completed. The essential Spring and Fall cooling system service [5] is as follows:

(1) Check coolant concentration, 50% by volume optimum.
(2) Check coolant level and condition. Change if dirty, or over a year old.
(3) Before starting engine, check for signs of coolant leakage such as color stains near hose connections and coolant spots on floor or driveway, etc.

Copyright© 1989 by ASTM International www.astm.org

(4) Test pressure cap - inspect radiator filler neck for dirt.
(5) Inspect hoses. Tighten all hose connections, including those to the expansion tank, to protect against coolant loss.
(6) Test thermostat if engine is running too hot or too cold.

NOTE

Steps (3) through (6) should be performed by qualified automotive service personnel.

Water Flushing. Draining your cooling system through the radiator drain cock will remove only about half of the coolant from the cooling system. For this reason, repeated water flushings are necessary to flush all traces of old coolant. A special tee and fittings may be purchased to completely flush the cooling system (Fig. 4).

NOTE

Disposal of depleted engine coolant is under study by state and federal environmental authorities. While biodegradable, ethylene glycol can be toxic to man and animals when consumed in sufficient quantity. Do not leave engine coolant where accidental ingestion can occur. Consult with your local environmental agency for current disposal practices in your area.

Cleaning. If the drained coolant is rust-colored or the radiator, as viewed through the filler neck, is rusty, the system should be cleaned. A flush type product will facilitate removal of sludge and loosely adherent rust. However, if the system is badly rusted, a heavy-duty cooling system cleaner will be required. In either case, the manufacturer's directions should be carefully followed.

Mechanical Service. Repair all leaks. Leakage at the rate of one drop a minute means the loss of 1 gal. of solution in six weeks. A leaky cylinder head joint can cause coolant contamination, rapid rusting, foaming, overflow loss, and overheating. Engine coolant mixed with engine oil may cause lubrication failure and serious engine damage (Fig. 5). Defective water pump seals can also contribute to corrosion, foaming, and overflow loss.

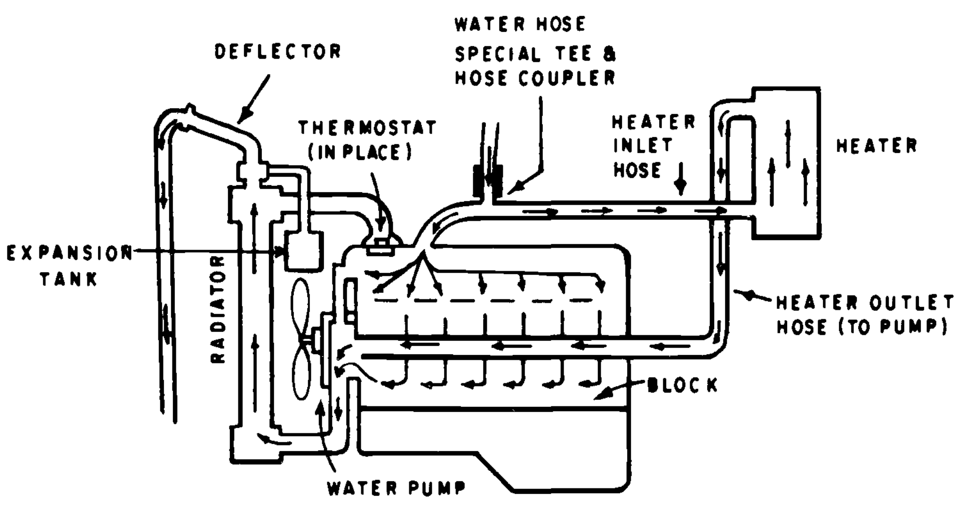

FIG. 4—*Flow diagram showing simplified method of flushing the cooling system.*

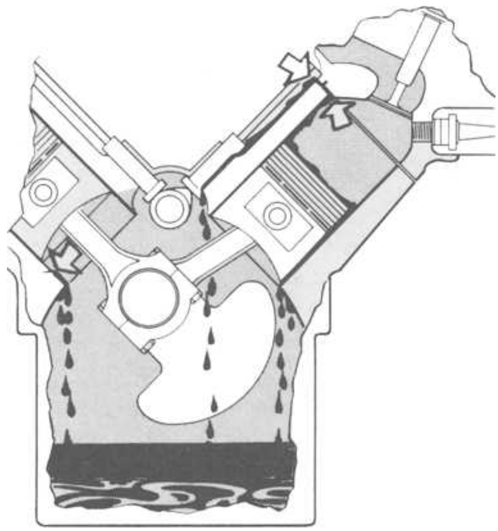

FIG. 5—*Leakage of coolant into the engine can occur through a loose cylinder head joint or cracks in the cylinder block or head. Either water or antifreeze coolant mixed with engine oil in sufficient quantities may cause lubrication failure and serious engine damage.*

Installing the Engine Coolant Concentrate

After inspection and completion of required service, determine capacity of the cooling system from a cooling system protection chart or car owner's manual. A 50% concentration (−34°F [−37°C] freezing protection) is generally recommended.

Recent surveys have shown that over-concentration and under-concentration are common sources of cooling system problems. A minimum concentration of 33 1/3% is required to provide minimal corrosion protection. Maximum freeze protection is obtained at 68% by volume. Concentrations over 68% will adversely affect heat transfer, raise freezing point, and may cause inhibitors to precipitate from the coolant when the engine is operating.

Consult your owner's manual to ensure that any air eliminators are used properly. Generally, the procedure is to close tightly all drain openings, pour in engine coolant concentrate, then fill with water of good quality to the proper level. Also, fill the coolant recovery system reservoir to the proper level with properly diluted engine coolant (see Fig. 6). (Avoid use of water containing excessive amounts of minerals, impurities, or suspended matter.)

With heater controls set on "high," run the engine until it reaches operating temperature. This procedure will release any trapped air and mix the coolant. Allow the engine to cool and inspect the coolant level in the recovery system reservoir. If necessary, add more properly diluted engine coolant. Do not overfill.

Checking Freezing Point/Boiling Point

A variety of field testers are available for checking the freezing point of the engine coolant. Based on an ASTM study [*6*], the refractometer tester, which measures refractive index, is the most accurate for checking the freezing point.

Check Accuracy of Tester. Test the instrument with solutions of known freezing protection. A 33% solution of ethylene glycol engine coolant in water protects to 0°F (−18°C) and a 50% solution should indicate −34°F (−37°C) protection.

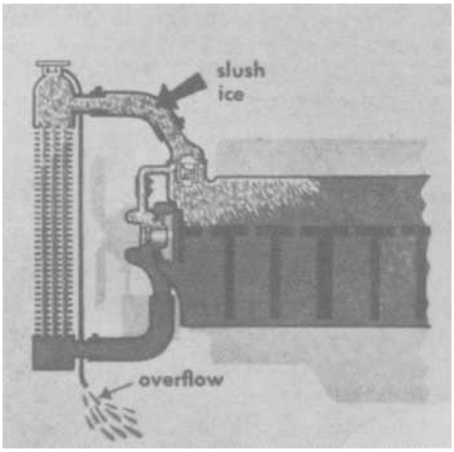

FIG. 6—*Insufficient antifreeze coolant protection, or incomplete mixing of solution, may result in slush-ice freezeup in the radiator, stoppage of circulation, loss of coolant through the overflow, and serious engine overheating.*

Freezing point testing of coolant in vehicle engines should be conducted after approximately one hour of engine operation. Sample the coolant after the engine has cooled. Use caution when removing the radiator pressure cap. Carefully turn to first notch to vent system pressure, then remove cap. If coolant overflows when cap is vented, immediately retighten and permit system to further cool. If additions are made, run the engine to ensure adequate mixing prior to freezing point testing of coolant. Before reading a hydrometer tester, fill and empty it several times to warm it up. Carefully read instructions furnished with each tester.

Recommended Period of Use

Car manufacturers recommend that the factory-fill coolant be used for one to two years. Previous surveys [7] on the performance of coolants in automotive service indicated that about one third showed appreciable loss of freezing protection, loss of inhibitor reserve, and rust in solution at the end of one year. Before two full years, most coolants require change. Based on these data, major engine coolant manufacturers recommend that their products be used for one year, preferably changing each Spring or Fall.

It can be argued that if the original coolant concentration is maintained and the cooling system kept clean, the coolant service life will be extended. While this may be true in some cases, the habits of motorists as well as the everyday practices of service station attendants make a two-year recommendation impractical.

Cooling System Chemicals

Stop-Leaks

Cooling system leakage may develop as a result of the following: 1) loose cylinder head or other gasketed joints; 2) loose hose clamps; 3) fracture of radiator seams and joints; 4) corrosion perforation of radiator tubes or other thin walls of the system; 5) deterioration of hoses or gaskets; and 6) corrosion of metal joints. Since leaks have a tendency to get worse rather than better, the best way to assure permanent correction is through mechanical servicing or replacement of leaking parts.

Copyright© 1989 by ASTM International www.astm.org

Stop-leak compounds are effective in closing minor leaks. After leaks are closed, a reserve of stop-leak material in the coolant is usually necessary to reseal old leaks opened up by vibration, corrosion, etc., and also to seal any new leaks that may develop. Stop-leaks should be considered as adequate only for short term "band-aid" uses. As soon as practical, the leak should be properly repaired.

Most stop-leak products consist of small pieces of natural fibers (vegetable or inorganic). Before considering the use of any particular stop-leak preparation, its suitability and also compatibility with the coolant in use should be known. The solids in stop-leak compounds may result in plugging or excessive deposit formation in the cooling system.

When a leak develops, it should be examined to determine the nature and seriousness. Stop-leaks should not be used as a substitute for mechanical servicing because they may give a false sense of security. For instance, a stop-leak may prevent seepage at a hose connection through cracks developing in the inner lining. Continued driving without replacement of the deteriorated hose may finally result in complete rupture, loss of coolant, and possibly overheating damage to the engine before the driver is aware of what has taken place.

Field service experience has proved that stop-leak materials cannot be depended upon to correct cylinder head joint leakage due to high combustion pressures at the joint and thermal stresses in the joint metals.

Cleaners

Rust deposits and particulate contaminants in the cooling system may shorten engine coolant inhibitor life as well as reduce cooling efficiency. Flushing and cleaning of the cooling system should be carried out prior to installing the new coolant (see p. 8, section on **Installation and Service**). Procedures for both preventive and corrective cleaning of the cooling system can be found in automotive maintenance literature [*1,8,9*].

Preventive Flush. In systems where rust and dirt are found in the presence of grease and oil, a cooling system flush with a chelator cleaner is recommended.

Corrective Cleaning. If the cooling system is fouled with rust deposits that cannot be loosened with a preventive flush, corrective cleaning using an acid may be necessary. It is important that the vehicle or engine manufacturer's recommendations be followed for cleaning and flushing cooling systems. Highly alkaline cleaners should not be used in aluminum engines or radiators because of their corrosive effect on the aluminum. Only cleaners recommended for aluminum engines and radiators should be used in such vehicles.

The use of most acid cleaners must be followed by a neutralizer. The importance of neutralizing these acid cleaning solutions and completely removing the resulting salts from the cooling system by draining and thorough flushing cannot be overemphasized. The use of a flushing gun, employing compressed air and water, will assist in removing acid residues. Field tests have shown that a small quantity of acid cleaner solution left in the cylinder block will deplete coolant inhibition causing a high degree of corrosive attack. Contamination of the cooling system by acid cleaning compounds is usually caused by: 1) failure to use a neutralizer; 2) incomplete draining and flushing of the cylinder block; or 3) inadequate flushing of the car heater or other accessories connected to the cooling system. Chemical cleaning of a corroded system can open up leaks that were previously plugged by corrosion deposits. Even the simplest type of cleaning is time-consuming. The most practical and economical approach to the maintenance of a cooling system to prevent corrosion (Fig. 7) is a good preventive maintenance program which includes a fresh filling of the correct, well inhibited, engine coolant and good quality water each year.

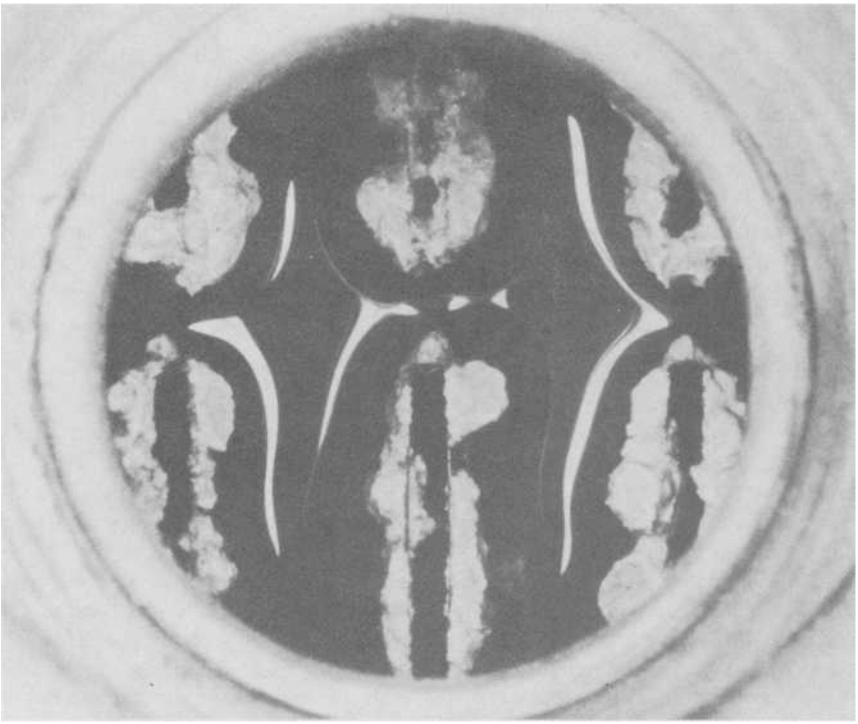

FIG. 7—*Radiator solder corrosion deposits at the tube to header joint, as viewed through the filler neck. This special form of corrosion can be minimized by radiator manufacturing techniques as well as recommended coolant maintenance practices.*

Antirusts

If year-round protection is not provided by the use of an inhibited engine coolant, such as in some heavy duty engines, then it is necessary to add an effective antirust to the coolant water.

The importance of using a properly inhibited coolant during warm weather is readily appreciated when it is realized that cooling system corrosion is most severe during this period. This is a result of higher engine temperatures along with higher road speeds and mileage. During warm weather driving, when the thermostat is wide open, the high velocity of coolant entering the radiator may increase air entrainment and, hence, the rate of aeration and subsequent corrosion. The prevention of corrosion in the cooling system during warm weather months will help assure satisfactory performance of the engine coolant during the following winter. Both soluble chemical and emulsifiable oil-type antirusts for use with water are generally available, although most of them will not provide the satisfactory corrosion protection provided by a properly inhibited engine coolant.

Different proprietary antirusts may not be compatible with each other. The manufacturer's directions should always be followed with respect to mixture and dosage.

In cars equipped with a factory-installed air conditioner, it is possible to obtain temperatures below 32°F (0°C) at the heater core/evaporator unit; this can cause damage from freezing unless engine coolant is used. Today, all U.S. car manufacturers, as well as other recognized authorities, recommend the use of ethylene glycol engine coolant year-round for proper operation of the engine as well as temperature warning devices.

"Cool" Additives

Despite the claims of the radiator "cool" additive manufacturers, there are no data at present that substantiate lower operating temperatures or improved heat transfer resulting from the use of these products. Their benefits have not been demonstrated by any impartial test organization [*2,10,11*]. These products offer nothing that a properly inhibited ethylene glycol engine coolant, of the type and concentration recommended by the automotive manufacturers, does not supply, namely: low freezing point; high boiling point; good corrosion inhibition; and foam control. Most modern engines are designed to run with inhibited ethylene glycol engine coolant year-round. Operation with either water alone or water with additives is contrary to automotive manufacturers' recommendations and may lead to engine failure.

Supplemental Coolant Additives

These are mixtures for use principally in heavy duty engine cooling systems and are designed to supplement the corrosion protection of the engine coolant concentrate being used. The additional stresses and operational mileage or operational time that heavy duty engines experience, as well as important design differences, require use of these supplements according to a regular maintenance schedule. Heavy duty equipment owners should consult the engine manufacturers' recommendation for coolant and supplemental additive guidelines.

Automobile engine coolant systems properly protected by engine coolant meeting specification ASTM D 3306 do not require use of supplemental additives. Major coolant manufacturers discourage use of these supplements with their coolant in automobile cooling systems.

Adherence to suggested maintenance schedules and practices, including regular coolant system drainage and recharge with properly diluted fresh engine coolant concentrate, will provide your automobile cooling system with superior protection against freezing, boilover, and corrosive attack.

References

[*1*] *Cooling System Service Manual,* 3rd edition, Union Carbide Corporation, New York, NY, 1965.
[*2*] Beynon, E., Cooper, N. R., and Hannigan, H. D., *Soap and Chemicals Specialties,* Vol. 47, No. 2, pp. 44, and No. 3, pp. 52, February and March 1971.
[*3*] Rowe, L. C., Chance, R. L., and Walker, M. S., "The Development of an Antifreeze Coolant for Aluminum and Cast Iron Engines," General Motors Research Publication GMR-3819, PCP-160, Physical Chemistry Department, General Motors Research Laboratories, Warren, MI, October 1981.
[*4*] Wiggle, R. R., Hospadaruk, V., and Tibaudo, F. M., "Corrosion of Cast Aluminum Alloys under Heat Transfer Conditions," Technical Report No. SR-81-11, Research Staff Report, Ford Motor Company, Dearborn, MI, 1981.
[*5*] "Engine Cooling System Care," Consumer Fact Sheet, Chemical Specialties Manufacturers Association, Washington, DC, 1984.
[*6*] "A Study of Antifreeze Field Testers," *Materials Research and Standards,* Vol. 10, No. 6, pp. 33-35, ASTM, June 1970.
[*7*] Beynon, E., "Field Performance and Factory Installed Antifreeze Coolants in Passenger Car Service," Reprint No. 660128, Society of Automotive Engineers, New York, NY, January 1966.
[*8*] "Maintenance of Automotive Engine Cooling Systems," SAE HS-40, Society of Automotive Engineers, New York, NY.
[*9*] "Practice for Testing Engine Coolants in Car and Light Truck Service," D 2847, *Annual Book of ASTM Standards, Vol. 15.05.*
[*10*] Day, R., *Popular Science,* Vol. 198, No. 6, June 1971, pp. 38-42.
[*11*] *Automotive Cooling Journal,* Vol. 13, No. 6, Nov.-Dec. 1970, pp. 6-11.

ISBN 0-8031-1265-3