Engine Coolants —SAE J814c

SAE Information Report
Completely Revised October 1978

THIS IS A PREPRINT WHICH IS SUBJECT TO REVISIONS AND CORRECTIONS. THE FINAL VERSION WILL APPEAR IN THE 1980 EDITION OF THE SAE HANDBOOK.

Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

LAND
SEA
AIR
SPACE

PREPRINT

Report of the Nonmetallic Materials Committee approved March 1962 and completely revised October 1978.

1. Scope

1.1 This report is intended as a source of information concerning the basic properties of engine coolants which are satisfactory for use in internal combustion engines to provide corrosion protection, lower the freezing point, and raise the boiling point. For additional information on engine coolants see SAE J1034a, Engine Coolant Concentrate—Ethylene Glycol Type.

1.2 The values which are presented describe desirable basic properties. The results from laboratory corrosion tests are not conclusive, and it should be recognized that the final selection of satisfactory coolants can be accomplished only after a series of performance tests in vehicles.

1.3 The report also describes in general terms the maintenance procedures which should be applied to insure a properly functioning cooling system. It is not intended to cover maintenance of engine cooling systems and components which are discussed in detail in SAE HS 40, Maintenance of Automotive Engine Cooling Systems.

2. Types of Coolants

2.1 Water—Water has been the most commonly used constituent of engine coolants for internal combustion engines because it has the ability to transfer heat and can be readily obtained. Some properties of water, such as its boiling point and freezing point, limit its usefulness when used alone as a coolant. The natural corrosive action of water on metals is definitely undesirable. Some natural water impurities, such as sulfates, chlorides, and bicarbonates, can increase corrosion. Others, such as calcium and magnesium carbonate, reduce heat transfer by the formation of scale, particularly at hot spots. They can also contribute to radiator clogging if excessive additions of hard water are made to replenish coolant losses.

When water freezes, it forms solid ice and expands approximately 9% in volume. If water is allowed to freeze inside the cooling system, the resultant extreme pressure can cause serious damage. In order to prevent coolant freeze damage, an antifreeze compound must be added to the water. Because of the inherent properties of water, the increasing heat loads placed on the cooling system, and the design factors of modern engines, water alone or water with inhibitors is not recommended as an engine coolant.

2.2 Antifreeze Compounds—Coolant Concentrates

2.2.1 Water containing the proper amount of antifreeze will not cause freeze-cracking damage from expansion and can be circulated freely in the cooling system at temperatures lower than the freezing point of water. There are many requirements for an acceptable antifreeze. The most essential of these are:

1. The ability to lower the freezing point of water to the lowest winter operating temperatures likely to be encountered.
2. The ability to protect the cooling system metals from corrosion or deposits.
3. A minimum of undesirable effects on engine cooling and heat transfer.
4. No deleterious effect on rubber.
5. Chemical stability.
6. Low cost.
7. Little or no odor.
8. Minimum effect on automobile finishes.
9. An acceptable viscosity at low temperatures.
10. Low coefficient of expansion.
11. Usability for at least one year of service.
12. Easily checked freezing point.

In addition, low toxicity, suitable boiling point characteristics, low foaming and operating losses, and nonflammability are desirable. No one chemical meets each of these requirements to the fullest. However, there are materials which represent satisfactory compromises.

2.2.2 Ethylene Glycol Base Coolants—The most commonly used antifreeze material is ethylene glycol. A typical formulated glycol base antifreeze coolant will contain 85% min ethylene glycol, corrosion inhibitors, up to 5% total water, a dye, and an antifoam agent. Occasionally, up to 10% of other glycols, such as diethylene glycol and propylene glycol are also used.

When compared to water alone, solutions of glycol base coolant in water have higher boiling points, lower freezing points, and slightly lower heat transfer characteristics. See Table 1.

TABLE 1

Vol % Antifreeze	Freezing Point		Boiling Point[a]	
	°F	°C	°F	°C
40	−12	−24	222	106
50	−34	−37	226	108
60	−62	−52	232	111
70	−84	−64	238	114

[a]At 760 mm pressure (atmospheric). A higher boiling point is obtained by using a radiator pressure cap which permits the development of pressure within the cooling system.
Note: The above data represent industry standards that necessitate a minimum glycol content in the concentrated antifreeze.

Automobile manufacturers fill the cooling systems of cars at the factory year-round and across the country with approximately a 50% concentration of ethylene glycol water base antifreeze coolant. The higher boiling points of ethylene glycol water solutions have been found to be beneficial for hot weather operation and in high altitude areas. Glycol base coolant solutions should be used with thermostats having opening temperatures of 180°F (82°C) or higher. When a glycol base coolant is used, it is recommended that approximately a 50% concentration be maintained year-round to provide adequate corrosion protection and a sufficiently high boiling point. Concentrations over 70% result in a loss in freezing protection and an increase in viscosity at low temperature and therefore should be avoided.

2.2.3 Alcohol Base Coolants—Alcohol base coolants constitute an extremely small part of the coolant market. Methyl alcohol (methanol) is generally used as the base in these coolants. Although alcohol water solutions have lower freezing points than water, their boiling points are also lower than that of water. Because late model cars are designed to use glycol base coolants, and the engine overheating warning devices are keyed to the boiling point of this coolant, methanol base products are not recommended by vehicle manufacturers.

2.2.4 Other Antifreeze Coolants—Various other chemicals are used as antifreeze coolants in special applications.

2.2.4.1 An ethylene glycol, water and glycol ether combination is sometimes used for arctic service. This type of coolant is suitable for service down to -90°F (-68°C).

2.2.4.2 Propylene glycol is not as effective a freeze depressant as ethylene glycol, and because its specific gravity is very close to that of water, it is very difficult to obtain a satisfactory field check for concentration by hydrometer.

2.2.4.3 Inhibited glycol ether, specifically methoxy propanol, is available for use as a coolant for heavy-duty equipment. It is not as effective a freeze depressant as ethylene glycol, nor can the concentration be checked with a standard antifreeze hydrometer. It does not have the same sludge forming properties as ethylene glycol coolant solutions in the event of accidental leakage into the engine crankcase, but as with any aqueous coolant, chronic leakage can adversely affect engine service life and lubrication efficiency.

2.2.4.4 All specialty coolant products should be used with strict adherence to the engine manufacturer's and coolant manufacturer's recommendations.

2.2.5 Do not mix different types of coolants.

*3. **Properties***—Properties which are considered in testing and evaluating the concentrated antifreeze coolant and its solutions are described in the following paragraphs. The ASTM test methods for measuring these properties are listed below:

D1119, Ash Content of Engine Antifreezes, Antirusts, and Coolants.

D1120, Standard Method of Test for Boiling Point of Engine Coolants.

D1121, Reserve Alkalinity of Engine Antifreezes, Antirusts, and Coolants.

D1122, Specific Gravity of Engine Antifreezes by Hydrometer.

D1177, Standard Method of Test for Freezing Point of Aqueous Engine Coolant Solution.

The ϕ symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

D1287, pH of Engine Antifreezes, Antirusts and Coolants.
D1881, Foaming Tendencies of Engine Coolants in Glassware.
D1882, Effect of Antifreeze and Cooling System Chemical Solutions on Organic Finishes for Automotive Vehicles.

3.1 **Ash Content**—Ash content of an antifreeze coolant is the residue which remains after ignition. For most formulations, the ash content will be less than 5.0% by weight. While the ash results from the inhibitors used, it is not a measure of inhibitor concentration.

3.2 **Equilibrium Boiling Point**—Equilibrium boiling point indicates the temperatures at which the coolant begins to boil in a cooling system under equilibrium conditions at atmospheric pressure. The boiling point of a coolant is an important property, especially when high opening temperature thermostats are used or when the cooling system is operated at high ambient temperatures or under high heat load conditions. See Appendix, Table A-2.

3.3 **Reserve Alkalinity**—Reserve alkalinity is defined as the number of milliliters, to the nearest 0.1 ml of 0.100 N hydrochloric acid required for the titration to a pH of 5.5 of a 10 ml sample of undiluted antifreeze, antirust, or coolant additive.

Mildly alkaline pH solutions are generally less corrosive than strongly acid or strongly alkaline solutions. Neither pH nor reserve alkalinity is a sufficient criterion to indicate the efficiency of corrosion inhibitors. Different inhibitor systems have individual optimum pH ranges. Many of the very efficient corrosion inhibitors have very little effect on the reserve alkalinity.

The reserve alkalinity is most useful as part of a qualification test to indicate that: 1) A submitted lot is similar to a previously qualified sample, or 2) as a measure of the degradation of a coolant in service or under test. In the latter case, the rate of change of the reserve alkalinity is more important than the absolute value. The measurement gives an indication of the capacity of the system to neutralize acids which may be present or form in the system.

3.4 **Specific Gravity**—Specific gravity is the ratio of the weight of a given volume of liquid at 60° F (15.5° C) to the weight of an equal volume of gas-free distilled water at 60° F (15.5° C). Its measurement offers a convenient means of identifying a liquid or of determining the degree of dilution and hence the freezing point. While the specific gravities for pure methanol and ethylene glycol are 0.793 and 1.115 at 68/68° F (20/20° C), respectively, the specific gravities of the concentrated antifreeze, using either as a base, will be somewhat different depending upon the type and the amount of inhibitors used, on the amount of water present, and, in the case of ethylene glycol, on the amount of other glycols present.

3.5 **Freezing Point**—Freezing point is defined as the temperature at which ice crystallization begins in the absence of supercooling, or the maximum temperature reached immediately after initial ice crystal formation in the case of supercooling. The ASTM method of freezing point determination should be used when freezing point accuracy is desired, as in determining the limiting values for specifications. Hydrometers or refractometers are used in the field to determine the freezing point of coolants. (The field testers will give erroneous results for ethylene glycol based coolants if the content of other glycols, such as diethylene glycol or propylene glycol is too high.) Because of the limited accuracy of hydrometer-thermometer testers, the results should be viewed as an approximate freezing point rather than a precise measurement. (ASTM D1124 describes the hydrometer-thermometer field tester for engine coolants.) Freezing points can be determined more accurately by the refractometer type field tester. (ASTM D3321, Use of the Refractometer for Determining the Freezing Point of Aqueous Engine Coolants, describes the use of a refractometer for determining freezing points.) See Appendix, Table A-1.

3.6 **pH**—pH is a measurement of the hydrogen ion concentration and indicates whether a coolant is acid, neutral, or alkaline. pH measurements are sometimes used for production quality control, but they are not significant from the standpoint of predicting service life. The pH of a used coolant is not a dependable indication of either existing effectiveness or remaining life of the solution.

3.7 **Foaming Tendency**—Foaming tendency of a coolant is measured by the amount of foam generated during aeration under controlled conditions and the time required for this foam to subside. (If the coolant foams excessively and the system is open, coolant losses may take place through the overflow tube of the radiator.) Foaming tendency of the coolant may be tested in the laboratory according to the ASTM method. To provide satisfactory performance, the foam volume in this test is normally less than 150 ml. The time required for the foam to subside sufficiently for a portion of the liquid surface to be seen is normally 5 s or less.

3.8 **Organic Finishes**—Organic finishes shall not be adversely affected by the coolant. This is of particular importance to the vehicle manufacturer during assembly operations and to the car owner during coolant installation in the event of accidental spillage. Most coolant concentrates contain a dye as a positive visual identification that an antifreeze coolant is being used. It has been customary to identify methanol base concentrates with a violet dye. Many other colors are used for glycol base antifreeze coolants. Green through blue green is recommended in SAE J1034.

3.9 **Effect on Nonmetallics**—The coolant solution should not accelerate failure of the radiator hose, gaskets, and nonmetallic coatings on metallic gaskets. Many immersion tests, as well as other tests, have been proposed for this evaluation. Each supplier and consumer has his favorite procedure. The final evaluation, of course, is service experience. Preliminary indications are obtained when the coolant is tested for corrosion inhibition in simulated service and engine dynamometer tests.

3.10 **Storage Stability**—Storage stability of the concentrate cannot be determined conclusively by accelerated tests. However, it is evident that the packaged concentrate must be stable for at least two years under many different climatic conditions.

4. Corrosion Inhibition

4.1 **Corrosion**—If corrosion of the cooling system of an internal combustion engine is allowed to proceed without interruption, it not only shortens the life of metallic components but it also effectively decreases the operational characteristics of the coolant—that is, the transfer of heat from the engine to the air where it can be dissipated. For these reasons effective corrosion inhibition must be provided and maintained in the cooling system.

4.2 **Corrosion Testing**—Because of the elapsed time involved in the field testing of inhibitors and inhibited antifreeze coolants, accelerated tests are used to determine the quality of these products. The results from accelerated tests can be indicative of quality only if the tests incorporate many of the factors which affect corrosion in the cooling system. Some of the more important factors to be included are:

1. Coolant.
2. Flow.
3. Aeration.
4. Temperature.
5. Water quality.
6. Galvanic couples.
7. Corrosion products.
8. Hot spots.

As a test incorporates more of these factors, it more nearly simulates service performance, but it usually requires more labor and it becomes more costly. The generally accepted order of evaluation tests is:

1. Screening test (glassware corrosion test).
2. Simulated service test.
3. Dynamometer test.
4. Field service test.

Special tests are required to evaluate the performance of coolants with regard to specific forms of corrosive attack. These stepwise procedures are used to avoid the unnecessary expenditure of time and money on obviously poor materials, and to ensure that better materials will meet service requirements by the use of more rigorous test conditions. Vehicle service tests are desirable as the final evaluation method because of the difficulty in reproducing all service variables in accelerated tests.

4.2.1 Glassware Tests—A glassware test procedure can be used to evaluate all types of antifreeze coolants and inhibitors. The advantages of this type of test are its simplicity and brevity of operation (usually about two weeks). For these reasons, it is easy to screen a large number of samples with a minimum of effort.

Weighed specimens of metals common to the engine cooling system are immersed in a heated, aerated test solution for the entire period of the test. Corrosion products are removed from each metal at the end of the test, and the metal weight losses determined. Corrosion inhibition is evaluated on the basis of these metal weight loss values. Weight losses in a properly inhibited solution should be only a few milligrams at most. It is a common practice to establish weight loss limits based upon the performance of well inhibited solutions. A material is presumed to fail the test if the weight loss of any metal is above the limit.

A typical glassware procedure for the evaluation of coolants is that found in ASTM D1384, Corrosion Test for Engine Coolants in Glassware.

4.2.2 Simulated Service Tests—This test concept involves the circulation of coolant, at a preselected operating temperature, in a rig simulating an engine cooling system. Several automobile parts are generally used in the construction of equipment including a coolant pump, coolant outlet, radiator, and radiator hoses. By the use of a large reservoir, or an engine block, a volume of coolant equivalent to that in a cooling system can be used. Coolant flow rates within the normal operating range are achieved by driving the coolant pump with an electric motor. This test simulates the engine cooling system more closely than the glassware test and is more discriminating in coolant performance evaluation. Corrosion inhibition is measured from weight losses of metal specimens placed in the system and by visual examination of the components. If standard radiator hoses are used, coolant effects on the hoses can be observed. By sampling the coolant at intervals during the test, coolant concentration can be controlled and solution properties can be monitored. Experience with this test method has shown that it is a useful development tool, but for some specimen metals, repeatability between tests may not be consistent and reproducibility among different laboratories may vary widely. The use of components of different materials, such as an aluminum reservoir versus a cast iron one or an aluminum radiator versus a brass one, can significantly affect certain metal specimen weight losses. In view of these circumstances, it is desirable to gain experience by running multiple tests with coolants of known service performance.

Although there are many variations in procedure, a recommended test procedure has been developed under the sponsorship of ASTM Committee D-15. This method is listed as ASTM D2570, Simulated Service Corrosion Testing of Engine Coolants.

4.2.3 Dynamometer Tests—Inhibited engine coolants can be evaluated by an engine dynamometer test procedure. The advantage of this method over either the glassware test or the simulated service test is that test conditions such as load, speed, coolant temperature, and heat transfer are obtained and varied through the operation of a standard automobile engine. The performance of the engine is monitored throughout the test to ensure the reproduction of the proper service conditions. This type ot test is more significant if the radiator, pump, and engine combination is the same as that normally used in a single vehicle, since the flow rate can affect the continued performance of the coolant.

Corrosion protection is determined by the measurement of weight losses of metal specimens in contact with the coolant, and by the inspection of parts at the conclusion of the test. Inhibitor stability is determined from changes in pH, reserve alkalinity, and solution appearance. Quantitative analysis may be obtained for the inhibitors known to be present. Although this test is expensive to run, it provides more meaningful results than other laboratory tests.

ASTM D2758, Method of Testing Engine Coolants by Engine Dynamometer, prescribes a 700 h test in a standard passenger car engine.

4.2.4 Field Tests—The final test of any coolant is its performance in cars in the field. Closely controlled tests can be made under the supervision of technical personnel. General field tests can be conducted in a large number of cars to provide a broad service pattern. Metal specimens may be installed in the coolant stream to determine corrosion rates. The coolant can be sampled periodically to determine its chemical and physical properties. The condition of the cooling system and components should be examined visually at the end of the test. Information should be obtained from the participants concerning their observations regarding cooling system performance. If at all possible, vehicles from different areas of the country should be utilized for the tests, which will involve a range of antifreeze coolant concentrations with a variety of local waters.

ASTM D2847 is a standard recommended practice for testing engine coolants in vehicle service. Metal corrosion specimens, mounted in special capsules, are installed in the coolant flow of the test vehicles. The test duration in terms of time or mileage is consistent with the recommended service life of the coolant under test.

4.2.5 Cavitation Tests—Cavitation erosion corrosion of water pumps constructed to aluminum can be a serious problem because of the rate at which damage may occur. This type of corrosion is usually the result of pump design and cooling system characteristics. At certain coolant velocities, low and high pressure areas develop that cause the formation of vapor bubbles which implode on the surface of the metal and cause segments of metal to be removed. The composition of the coolant has been found to have a contributing effect on cavitation erosion, and it is often necessary to evaluate coolant formulations under cavitating conditions. Many different methods have been used to induce cavitation for laboratory studies, but it is preferable to use an operating pump under controlled conditions.

ASTM D2966, Method of Test for Cavitation-Erosion Characteristics of Aluminum in Engine Coolants Using Ultrasonic Energy, is intended as a screening test. Aluminum specimens are totally immersed in a 15% by volume antifreeze coolant solution for 20 h at 180 ± 3° F (82 ± 2°C) in an ultrasonic tank. The capability of the coolant in preventing cavitation-erosion damage is determined by comparing the average weight loss incurred by the specimens in the test solution with that of specimens in a reference coolant solution.

Final evidence of satisfactory cavitation-erosion prevention should be confirmed by ASTM D2809, Test for Cavitation Erosion Corrosion Characteristics of Aluminum Pumps with Engine Coolants. In this procedure, test coolant is pumped through a pressurized, simulated automotive cooling system at a temperature of 235° F (112°C) for 100 h. The pump is driven by an electric motor at a high speed and cavitation occurs. After the test, the pump is examined and rated by a numerical system.

4.2.6 Aluminum Corrosion Transport Tests—Aluminum corrosion transport deposition may occur with engines containing aluminum cylinder heads or other aluminum heat rejecting (from metal to coolant) surfaces. While the metal loss from aluminum surfaces may be relatively small and have no effect on the strength or durability of the aluminum components, the volume of corrosion products deposited in coolant passages of radiator or heater cores will reduce heat transfer and may result in plugged passages. The presence of certain corrosion inhibitors in the antifreeze formulation can affect this type of corrosion.

Several test methods have been used to evaluate engine coolants for aluminum corrosion transport deposition including car tests. The accelerated laboratory tests involve circulating the test coolant in an apparatus so that the coolant is heated by an aluminum part and cooled with a copper, brass, or aluminum part. Performance is evaluated by the amount of corrosion (weight loss) from the heating aluminum part and/or the increase in weight of the cooling part. If the cooling part is a radiator or heater core, evaluation is based on loss in heat transfer or visually observing the quantity of deposits in the water passages.

5. *Maintenance of Engine Coolants*—Satisfactory performance of the coolants previously discussed depends upon the use of the proper coolant, periodic changes, coolant volume, coolant concentrate, cleanliness, and tightness of the engine cooling system.

5.1 **Coolant Volume**—It is important that the engine coolant be maintained at the level specified by the vehicle manufacturer. The proper level for most modern cars is shown in the coolant recovery tank or container which collects the overflow coolant when the coolant expands and from which the coolant is drawn back into the radiator when the coolant cools. The level marks are usually labeled *cold* and *hot* or *full cold* and *full hot* because the proper level is associated with the temperature of the coolant. In cars that do not have a coolant recovery system the level may be shown by a mark on the tank of the radiator. Periodic inspection of the coolant level in the recovery tank should be made to ensure that the coolant is at the proper level.

If overheating should occur even though the coolant level in the recovery tank indicates sufficient coolant, the level in the radiator should also be checked after the coolant has been cooled to ensure that the radiator is full. (Air can be trapped in the radiator, particularly after the system has been drained and filled, and the air may not be released through the recovery tank.) When it is necessary to add coolant to either the radiator or the recovery tank, add a 50-50 mixture of an ethylene glycol coolant concentrate and water or a coolant of the same type as that already in the system. Do not add water alone or an alcohol water mixture because neither one meets all the requirements for a satisfactory coolant; that is, adequate corrosion inhibition, proper freezing and boiling protection, and satisfactory heat transfer characteristics.

Loss of coolant may usually be attributed to one or more of the following: ing:

5.1.1 Overflowing, After-boiling, and Overheating—Overflowing is the loss of coolant during normal driving. The loss occurs because the system has been filled above the manufacturer's recommended level when the system was cold. As the coolant temperature increases, the coolant expands and is forced out of the coolant recovery tank, or radiator in the case of older model cars. Proper coolant level minimizes the possibility for loss of coolant through overflow.

After-boiling is the boiling of the coolant in the engine block after the engine is stopped when the vehicle has been driven at high speeds or has been under a heavy load, such as pulling a trailer or climbing a hill. The residual heat in the engine causes the coolant temperature to rise above its boiling point, because the coolant is no longer being circulated and cooled.

Overheating may be defined as a condition where the coolant temperature exceeds the normal operating range as indicated by the coolant warning light or temperature gauge. When this occurs, it is best to reduce the load on the cooling system by shifting the transmission to neutral and turning off the air conditioner. It also helps to reduce coolant temperature by increasing the engine idle speed for two or three minutes to increase fan cooling and coolant pump output. Other factors can contribute such as thermostat, radiator cap, or fan belt malfunction, radiator tube plugging, or the accumulation of corrosion deposits or scale in the radiator that reduce heat transfer. In addition, the use of coolant solutions with lower boiling points than that provided by the recommended ethylene glycol water mixture can also be a factor in after-boiling or overheating. After-boiling or over-heating can be minimized by ensuring that components are operating properly and that a satisfactory coolant is used and maintained.

5.1.2 Coolant Leakage—Leaks usually occur because of loose fitting parts or through cracks or pin holes caused by corrosion or deterioration of materials. Susceptible locations are hose connections, gasketed parts such as the cylinder head or thermostat, core hole plugs, pump seals, and radiator or heater core assemblies. When a leak occurs, the source should be identified and the leakage rate determined before attempting to stop the leak. The leak often can be corrected by tightening a clamp or bolt, but in many cases it may be necessary to replace the component part. Minor leaks may be sealed through the use of commercial stop-leak materials, but one is cautioned that this is never a substitute for mechanical repairs when the leak is sufficiently bad. Furthermore, overuse of stop-leak products contributes to the solids in the cooling system, which can affect heat transfer and tube plugging.

5.1.3 Exhaust Gas Leakage, Air Leakage, and Foaming—Air can be drawn into the coolant at loose hose connections or through the water pump. Exhaust gas leakage into the coolant occurs between the combustion chamber and the water jacket, usually because of a loose gasket or a cracked casting. Gases that enter the system become entrained in the coolant, occupying space and increasing the volume of the coolant. Gases can also rise to high points in the system as foam. Antifoam agents are usually added to the coolant concentrate to reduce the formation of foam, but these agents may be dissipated rather rapidly.

The increased volume occupied by the gas-liquid mixture can cause coolant losses during thermal expansion. In addition, the entrained gases can reduce the transfer of heat from the casting to the coolant and subsequently to the outside air through the radiator. Any of these effects can contribute to overheating.

Continued aeration of the system accelerates depletion of coolant inhibitors and can contribute to increased corrosion and/or erosion in the system. Air leakage to the coolant can be minimized by maintaining a proper coolant level and by good maintenance to ensure satisfactory operation of parts and tight joints.

Exhaust gases are normally acidic and leakage into the cooling system contributes not only to foaming and overheating but to inhibitor depletion, accelerated corrosion, and a more rapid breakdown of ethylene glycol. Any evidence of leakage requires immediate mechanical repair.

5.2 **Antifreeze Coolant Concentration**—Essentially all liquid cooled engines are designed for aqueous systems. Since water alone is inadequate (See paragraphs 2.1 and 2.2), an antifreeze coolant concentrate is usually added. Most automobile manufacturers fill the cooling system with approximately a 50% ethylene glycol base coolant. This concentration will supply more freeze protection than is required for some areas. A concentration of approximately 50% is recommended to ensure adequate concentration of corrosion inhibitors. The maximum freeze point depression with ethylene glycol is obtained with 68% concentrate. To achieve higher boiling points for use at higher ambient temperatures, under heavy loads, or at higher altitudes, a maximum of 70% ethylene glycol base coolant can be used. When replenishing the cooling system, the proper proportions of water and glycol should be added to maintain the desired ratio.

Should the coolant freeze, the automobile should not be operated until normal circulation is restored by a suitable thawing operation. The coolant can form a slush which will clog the radiator, resulting in overheating, loss of coolant and consequent damage to the engine such as cylinder head cracking at the combustion chamber.

If the coolant becomes overheated, the entire coolant solution must be cooled down before opening the radiator cap. If the cooling system is opened, the pressure will be reduced to atmospheric, coolant above its boiling point will flash to a vapor and force out the liquid coolant. The risk of personal injury is very great.

5.3 **Coolant Replacement**—The vehicle manufacturer's and/or coolant manufacturer's directions for periodic changes should be followed. Periodic replacement of coolant solutions is required because the solutions may become corrosive due to chemical reaction, contamination, or inhibitor depletion.

5.4 **Cleaning**—A properly inhibited, normally functioning cooling system should not require cleaning. Cooling systems should be cleaned only when indicated by the appearance of rust or other sediment in the solution or persistent overheating. The type of cleaner to be used is indicated by the condition of the system and the metal components.

Conventional cooling systems, with brass, copper, and cast iron used in major components, can be treated with available flush-type cleaners for oily deposits and acid-type cleaners or chelators for rust deposits. Cooling systems utilizing aluminum components should use only those cleaners specified as safe for aluminum. In general these cleaners are neither strong acids nor strong alkalies.

Residual cleaning components (including neutralizers) should be flushed from the system because some cleaners, if left in the cooling system, may attack components and shorten the service life of newly installed antifreeze coolants.

Clogged radiators will not respond to chemical treatment and will require repair or replacement.