



SURFACE VEHICLE INFORMATION REPORT

J814™

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Coolants for Internal Combustion Engines

RATIONALE

SAE Five-Year Review. This document has been updated to include ASTM D6210. Many revisions have been made to clarify and expand on content.

1. SCOPE

- 1.1 This SAE Information Report is a source of information concerning the basic properties of engine coolants which are satisfactory for use in internal combustion engines. Engine coolant concentrate (antifreeze) must provide adequate corrosion protection, lower the freezing point, and raise the boiling point of the engine coolant. For additional information on engine coolants, refer to ASTM D3306, ASTM D4985, and ASTM D6210.
- 1.2 The values presented describe desirable basic properties. The results from laboratory tests are not conclusive, and it should be recognized that the final selection of satisfactory coolants can be proven only after a series of performance tests in vehicles.
- 1.3 The document describes in general the necessary maintenance procedures for all engine coolants to insure proper performance as well as special requirements for coolants for heavy-duty engines.
- 1.4 This document does not cover maintenance of engine cooling system component parts.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

Turcotte, D., Chiu, G., Fidorra, U., and Bowles, R., "Automatic Freeze Point Determination in Ethylene Glycol Based Engine Coolants," SAE Technical Paper 2000-01-1981, 2000, <https://doi.org/10.4271/2000-01-1981>.

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SAE WEB ADDRESS:

Full document details: SAE J814_202305

For more information on this standard, visit
https://www.sae.org/standards/content/J814_202305/

Documents

Document Sharing Hub

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM Volume 15.05, August 2107, containing:

- ASTM D1119 Standard Test Method for Percent Ash Content of Engine Coolants
- ASTM D1120 Standard Test Method for Boiling Point of Engine Coolants
- ASTM D1121 Standard Test Method for Reserve Alkalinity of Engine Coolants and Anti-rusts
- ASTM D1122 Standard Test Method for Density or Relative Density of Engine Coolant Concentrates and Engine Coolants by the Hydrometer
- ASTM D1177 Standard Test Method for Freezing Point of Aqueous Engine Coolants
- ASTM D1287 Standard Test Method for pH of Engine Coolants and Anti-rusts
- ASTM D1384 Standard Method for Corrosion Test for Engine Coolants in Glassware
- ASTM D1881 Standard Test Method for Foaming Tendencies of Engine Coolants in Glassware
- ASTM D1882 Standard Test Method for Effect of Cooling System Chemical Solutions on Organic Finishes for Automotive Vehicles
- ASTM D2570 Test Method for Simulated Service Corrosion Testing of Engine Coolants
- ASTM D2758 Test Method for Engine Coolants by Engine Dynamometer
- ASTM D2809 Test Method for Cavitation and Erosion-Corrosion Characteristics of Aluminum Pumps with Engine Coolants
- ASTM D2847 Practice for Testing Engine Coolants in Car and Light Truck Service
- ASTM D3306 Standard Specification for Glycol Base Engine Coolant for Automobile and Light Duty Service
- ASTM D3321 Standard Practice for Use of the Refractometer for Field Test Determination of the Freezing Point of Aqueous Engine Coolants
- ASTM D4340 Standard Test Method for Corrosion of Cast Aluminum Alloys in Engine Coolants Under Heat-Rejecting Conditions
- ASTM D4985 Standard Specification for Low Silicate Ethylene Glycol Base Engine Coolant for Heavy Duty Engines Requiring a Pre-Charge of Supplemental Coolant Additive (SCA)
- ASTM D5931 Standard Test Method for Density and Relative Density of Engine Coolant Concentrates and Aqueous Engine Coolants by Digital Density Meter
- ASTM D6208 Standard Test Method for Repassivation Potential of Aluminum and Its Alloys by Galvanostatic Measurement
- ASTM D6210 Standard Specification for Fully-Formulated Glycol Base Engine Coolant for Heavy-Duty Engines
- ASTM D6660 Standard Test Method for Freezing Point of Aqueous Ethylene Glycol Base Engine Coolants by Automatic Phase Transition Method

3. TYPES OF COOLANTS

3.1 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.

Clean potable water, low in chloride, sulfate, and hardness is generally acceptable. Brackish or undrinkable water should not be used. Softened, deionized, or distilled water is ideal to dilute engine coolant concentrate. With properly inhibited coolant concentrate, water meeting the requirements outlined in Table 1 is acceptable. Water impurities exceeding these levels can cause excessive scale, sludge deposits, and increased corrosion. These impurities are measured in parts per million (PPM) on a mass basis.

Table 1 - Water quality

Property	Requirement
Total Solids, Max	340 ppm
Total Hardness, Max	170 ppm
Chloride (as NaCl), Max	40 ppm
Sulfate (as Na ₂ SO ₄), Max	100 ppm
Acidity range	5.5 to 9.0 pH

When water freezes to form ice, it expands approximately 9% in volume. If water is allowed to freeze inside the cooling system, the resultant pressure can cause serious damage. In order to prevent damage caused by coolant freeze, coolant concentrate (antifreeze) must be added to the water. Premixed products are available that eliminate the need for mixing coolant concentrate and water.

Water alone or water with inhibitors is not normally recommended as an engine coolant. The boiling point increase, provided by a 50% glycol solution, is required to maintain the design cooling index of the cooling system.

3.2 Coolant Concentrate (Antifreeze)

3.2.1 Water containing the proper amount of coolant concentrate (antifreeze) will prevent freeze-cracking damage and can be circulated freely in the cooling system at temperatures well below the freezing point of water alone. There are many requirements for an acceptable coolant concentrate (antifreeze). The most essential of these are:

3.2.1.1 The ability to protect cooling system metals from corrosion or deposits.

3.2.1.2 Minimum loss of heat transfer capability.

3.2.1.3 No deleterious effect on nonmetallic cooling system components.

3.2.1.4 Thermal stability.

3.2.1.5 The ability to lower the freezing point of the engine coolant to the lowest winter operating temperatures likely to be encountered.

3.2.1.6 The ability to raise the boiling point.

3.2.1.7 Little or no odor.

3.2.1.8 Minimum effect on vehicle finishes.

3.2.1.9 An acceptable viscosity at low temperatures.

3.2.1.10 Low coefficient of expansion.

3.2.1.11 Effective for at least 1 year of service.

3.2.1.12 Easily checked concentration.

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

3.2.2 Glycol Base Coolants

The most commonly used antifreeze material is ethylene glycol. A typical ethylene glycol base antifreeze (coolant concentrate) will contain 95% minimum antifreeze grade ethylene glycol, corrosion inhibitors, up to 5% total water to dissolve additives, a dye, and an antifoam agent. Occasionally up to 10% of other glycols such as diethylene glycol and propylene glycol are included.

Propylene glycol base coolants are also used. Propylene glycol base coolants have been approved by some automobile manufacturers and by most heavy-duty truck manufacturers in the United States. Propylene glycol base coolants provide equivalent cooling system performance compared to ethylene glycol base coolants and have the advantage of having considerably reduced toxicity compared to ethylene glycol base coolants. A typical propylene glycol base antifreeze (coolant concentrate) will contain 94% minimum propylene glycol, corrosion inhibitors, up to 5% total water, a dye, and an antifoam agent. Occasionally up to 1% of dipropylene glycol is included. No other glycols are permitted.

Propylene glycol is nearly as effective a freeze depressant as ethylene glycol and is less toxic. However, because its specific gravity is very close to that of water, it is not possible to obtain a satisfactory field check for concentration by hydrometer. A simple hand-held refractometer, calibrated to read the freezing point of propylene glycol, is appropriate for this purpose. A dip-and-read test strip is also appropriate.

When compared to water alone, coolant solutions of glycol in water have higher boiling points, lower freezing points, and slightly lower heat transfer characteristics. See Tables 2 and 3.

Table 2 - Boiling and freezing points at atmospheric pressure

Volume % Antifreeze	Ethylene Glycol Base Freezing Point °C	Ethylene Glycol Base Freezing Point °F	Ethylene Glycol Base Boiling Point °C	Ethylene Glycol Base Boiling Point °F	Propylene Glycol Base Freezing Point °C	Propylene Glycol Base Freezing Point °F	Propylene Glycol Base Boiling Point °C	Propylene Glycol Base Boiling Point °F
40	-24	-12	106	222	-21	-6	104	219
50	-37	-34	108	226	-33	-27	106	222
60	-52	-62	111	232	-49	-56	109	228
70	-64	-84	114	238	-61	-78	112	234

Table 3 - Heat transfer characteristics at 99 °C (210 °F)

Volume % Antifreeze	Ethylene Glycol Base Viscosity	Ethylene Glycol Base Specific Heat	Ethylene Glycol Base Thermal Cond.	Propylene Glycol Base Viscosity	Propylene Glycol Base Specific Heat	Propylene Glycol Base Thermal Cond.
0	0.29 cP	1.01 Btu/lb/°R 4.22 kJ/kg/°K	0.39 Btu/h/ft ² /°R/ft 0.67 W/m/°K	0.29 cP	1.01 Btu/lb/°R 4.22 kJ/kg/°K	0.39 Btu/h/ft ² /°R/ft 0.67 W/m/°K
40	0.59 cP	0.90 Btu/lb/°R 3.76 kJ/kg/°K	0.26 Btu/h/ft ² /°R/ft 0.45 W/m/°K	0.62 cP	0.95 Btu/lb/°R 3.98 kJ/kg/°K	0.26 Btu/h/ft ² /°R/ft 0.45 W/m/°K
50	0.70 cP	0.88 Btu/lb/°R 3.70 kJ/kg/°K	0.23 Btu/h/ft ² /°R/ft 0.39 W/m/°K	0.75 cP	0.92 Btu/lb/°R 3.84 kJ/kg/°K	0.21 Btu/h/ft ² /°R/ft 0.37 W/m/°K
60	0.81 cP	0.83 Btu/lb/°R 3.47 kJ/kg/°K	0.21 Btu/h/ft ² /°R/ft 0.36 W/m/°K	0.95 cP	0.88 Btu/lb/°R 3.68 kJ/kg/°K	0.19 Btu/h/ft ² /°R/ft 0.33 W/m/°K

Note that the boiling point of these coolant mixtures is increased further by causing the cooling system to become pressurized. This is accomplished by using a cooling system pressure cap. See Table 10.

Manufacturers fill the cooling systems of vehicles at the factory year-round and across the country with approximately a 50% concentration of glycol base antifreeze coolant. The higher boiling points of glycol/water coolant 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 82 °C (180 °F) or higher. When a glycol base coolant is used, it is recommended that a 50 to 70% concentration be maintained year-round to provide adequate corrosion protection and a sufficiently high boiling point for automobiles and light trucks. Forty to 60% is recommended for heavy-duty engines. Concentrations over 70% result in a loss in freezing protection and heat transfer and an increase in viscosity at low temperature. In heavy-duty engines using SCAs (Supplemental Coolant Additives), glycol concentrations over 60% will contribute to inhibitor precipitation. Glycol concentrations below 40% are generally not recommended as they may not provide adequate corrosion protection.

The use of coolant concentrates without dilution as described above is not recommended. Most coolant concentrates have a freeze point of approximately –18 °C (0 °F). Also, the heat transfer properties are adversely affected.

3.2.3 Pre-Diluted Glycol Coolants

Glycol base coolants, already pre-diluted with deionized water, have been made commercially available for user convenience and for users in areas with poor quality tap water. These products should be used, as supplied, without further dilution with water.

3.2.4 Alcohol Base Coolants

Alcohol base coolants are now obsolete.

3.2.5 Other Antifreeze Coolants

Various other chemicals are used as antifreeze coolants in special applications.

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

3.2.5.2 Inhibited glycol ether, specifically methoxy propanol, has been used as a coolant for heavy-duty equipment. Most heavy-duty equipment manufacturers do not recommend its use because it degrades fluorocarbon-based rubber. It is not as effective a freeze depressant as ethylene glycol.

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

3.2.6 Different types of coolants should not be mixed.

3.3 Corrosion Inhibitors

The type of corrosion inhibitor system used in a particular vehicle is generally selected by the vehicle manufacturer. The coolant is designed and developed around the properties of the cooling system. It is important to follow the vehicle manufacturer's recommendations for coolant type when adding or changing the coolant.

A listing of the more common corrosion inhibitors and their functionality is provided in Table 4. It must be noted that the corrosion inhibitors contained in an engine coolant are carefully selected, balanced, and optimized to protect the various metals (aluminum, brass, copper, iron, lead, and steel alloys) present in an engine cooling system from corrosion. Certain corrosion inhibitors, while protecting one metal, may be ineffective or aggressive to other metals under certain conditions. For this reason, mixing coolants with different corrosion inhibitor chemistries may diminish the corrosion protection level of the coolants involved and is generally not recommended.

Table 4 - Common corrosion inhibitors

Corrosion Inhibitors	Purpose/Protection
Azoles (BTZ, MBTZ, TTZ)	Copper, Brass, Solder
Borates	Iron, Buffering
Molybdate	Iron, Aluminum, Solder
Nitrate, NO ₃	Aluminum (pitting), Solder
Nitrite, NO ₂	Iron (cavitation)
Organic Acid Technology (Salts of Carboxylic Acids)	General Corrosion, Light Alloys, Solder, Iron (Cavitation)
Phosphate	Aluminum (Cavitation), Iron, Steel, Buffering
Silicate	Aluminum, Iron

There are three general types of coolant corrosion inhibitor systems: Inorganic (IAT or traditional North American), Organic (OAT), and Hybrid (HOAT).

3.3.1 Inorganic Systems

Inorganic systems had been used for many years, predominantly in North America. The corrosion inhibitors used are sodium or potassium salts of inorganic anions. Phosphate, silicate, borate, and nitrate were commonly used. The anions chosen and their amounts depend on the coolant manufacturer. The formulation would usually contain an azole compound as a copper corrosion inhibitor.

This type of coolant is being replaced with OAT or HOAT types as new vehicle factory fill.

3.3.2 Organic Acid Technology (OAT) Systems (also known as Organic Additive Technology Systems)

Organic systems use salts of organic anions as corrosion inhibitors. Sodium sebacate, 2-ethyl hexanoate, azaleate, and benzoate are common. Sometimes two or more organic anions are used in the same formulation. The formulation would also contain an azole compound as a copper corrosion inhibitor. Refer to ASTM D6210 for additional information on organic systems. This type generally provides longer service life than the inorganic types that reduce maintenance requirements and, therefore, the amount of waste coolant generated. Nitrated OAT is commonly used in light-duty systems to inhibit corrosion. Non-nitrated OAT is commonly used in heavy-duty systems to inhibit corrosion and reduce cavitation. Non-nitrated OAT systems typically require more maintenance due to the higher depletion rates of the inorganic acids.

3.3.3 Hybrid Organic Acid Technology (HOAT) Systems (also known as Hybrid Additive Technology Systems)

Hybrid systems use an organic anion as the primary corrosion inhibitor. Some inorganic salts are added to enhance certain properties.

HOAT systems can be divided into two general types.

The formulations of European origin usually use low levels of silicate as a major inorganic anion. The use of phosphate is generally forbidden.

The formulations of Japanese origin usually use phosphate as a major inorganic anion. The use of silicate and borate is generally forbidden.

This means that the two types of HOAT are not interchangeable. The inhibitors used in Europe and North America are not allowed by the Japanese OEM specifications and, conversely, the inhibitors used in Japanese coolants are not allowed by the European and North American OEM specifications. The vehicle manufacturer's recommendation for coolant should be followed.

3.3.3.1 These HOAT types also provide longer service life than the inorganic types. The inorganic anions can limit the service life. At least one vehicle manufacturer uses a system to replenish the inorganic material to extend the service life.

4. PROPERTIES

Properties which are considered in testing and evaluating the antifreeze coolant concentrate and its solutions are described in the following paragraphs. The ASTM test methods for measuring these properties are listed as follows:

ASTM D1119 Standard Test Method for Percent Ash Content of Engine Coolants

ASTM D1120 Standard Test Method for Boiling Point of Engine Coolants

ASTM D1121 Standard Test Method for Reserve Alkalinity of Engine Coolants and Antirust

ASTM D1122 Standard Test Method for Density or Relative of Engine Coolant Concentrates and Engine Coolants by Hydrometer

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

ASTM D1287 Standard Test Method for pH of Engine Coolants and Antirusts

ASTM D1881 Standard Test Method for Foaming Tendencies of Engine Coolants in Glassware

ASTM D1882 Standard Test Method for Effect of Cooling System Chemical Solutions on Organic Finishes for Automotive Vehicles

ASTM D3321 Standard Practice for Use of the Refractometer for Field Test Determination of the Freezing Point of Aqueous Engine Coolants

ASTM D5931 Standard Test Method for Density and Relative Density of Engine Coolant Concentrates and Aqueous Engine Coolants by Digital Density Meter

ASTM D6660 Standard Test Method for Freezing Point of Aqueous Ethylene Glycol Base Engine Coolants by Automatic Phase Transition Method

4.1 Ash Content

Ash content of a coolant concentrate 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.