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PRELIMINARY REPORT ON ANTI-FREEZING SOLUTIONS FOR AUTOMOBILE RADIATORS

The question of anti-freezing solutions for automobile radiators is brought very forcibly to the attention of users of motor vehicles each winter, and many inquiries for information regarding their use are received at the Bureau of Standards. An investigation was undertaken by the Bureau to establish the value of these compounds and sufficient data have been obtained to justify a preliminary statement. These tests were made on the metals (such as brass or copper and solder) that are used in radiator construction and in the same combinations that are used in such construction. This is necessary in order to obtain the electrolytic action which is largely responsible for radiator corrosion. Tests made without regard to electrolysis are practically worthless. This work will be continued, tests equivalent to service conditions will be made, and a more comprehensive report given at a later date.

The ideal anti-freezing compound is one that will prevent freezing of the radiator liquid without injuring either engine or radiator, that will not lose its nonfreezing properties after continued use, and that does not materially change the boiling point of water when dissolved in it.

There are two general types of these compounds--one a solution in water of alcohol or glycerine, or a mixture of the latter two, the other a solution in water of calcium chloride or the dry salt itself which contains sometimes small amounts of other substances such as salt, sal ammoniac, sugar, or syrup. Kerosene and similar oils, without admixture, are sometimes used.

Kerosene has a lower freezing point and higher boiling point than water, but the inflammability of its vapor makes it dangerous to use, and its high and uncertain boiling point might lead to the serious over-heating of the engine, or even to the melting of the solder in the radiator. It has a marked solvent action on rubber parts. These facts would seem to clearly indicate that this material should not be used.

The alcohol-water type is the most common and is not generally sold under any trade name, but recently there have appeared on the market a number of anti-freezing compounds of the calcium chloride type. These compounds are sold under a variety of names and startling claims are made for their effectiveness and lack of injurious effects.

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The effectiveness of all properly prepared compounds, that is, their ability to prevent freezing, needs no discussion. The injurious effects, however, can not be safely disregarded.

The alcohol solutions do not exert a greater corrosive action than water alone. This can be predicted from theoretical considerations and is well established in practice. However, wood alcohol sometimes contains free acid, such as acetic acid, which is objectionable, and for this reason wood alcohol should not be used unless it is known to be free from acids.

The calcium chloride compounds exert a greater corrosive action than water on the engine jacket, on the solder in the radiator, and on aluminum which is sometimes used in manifolds, pumps, and headers. The effect on engine jackets may be neglected since these are generally sufficiently heavy to permit considerable corrosion without being weakened. The effect on soldered joints may be serious, since tests made at the Bureau of Standards have shown the complete removal of solder from copper and brass when immersed in a hot 20% calcium chloride solution for four days. A number of such tests were made, and there was always a more rapid corrosion or eating away of solder in these anti-freezing compounds than in water.

Calcium chloride solutions corrode aluminum very rapidly. The effect is variable, depending on the kind of aluminum used; blisters appear on ordinary rolled sheet aluminum, and as these break the metal separates into scales or plates of corroded aluminum which open up like the leaves of a book; cast aluminum, especially the copper alloys, show very decided pitting and etching. These tests show conclusively that the corrosive action will be very serious, and it is difficult to reconcile these results with the current statement that the effect of calcium chloride solutions on aluminum is not very serious.

Another troublesome effect of calcium chloride solutions is experienced if small leaks occur in the radiator, the water jackets, or connections, and the solution comes in contact with the spark plugs and ignition wires. In some cases the drops of the solution may be carried back on the engine in a more or less atomized state, assisted by the fan when running. The salt deposited when the water evaporates is very difficult to remove, and when it cools absorbs water and becomes a good electrical conductor, short-circuiting the spark plugs and sometimes making it impossible to start the engine. The difficulty may disappear when the engine is heated up.

There are also certain conditions in the manufacture of calcium chloride which may result in a compound that will deposit large crystals in the radiator as the solution cools; this may prevent effective circulation.

Regardless of these objections, reports have been received to the effect that calcium chloride solutions have been used a number of years in the same radiator without producing apparent corrosion. Nevertheless, such solutions can not be recommended as safe, and they should not be used if there is any aluminum in the cooling system.

The chief advantage of calcium chloride compounds is that they are not volatile. The solutions can be kept practically uniform by adding water from time to time. Unfortunately, this is not true with the alcohol solutions, because the alcohol continually boils out, and it must be replaced frequently in order to maintain the proper proportion of alcohol. Glycerine is frequently substituted for part of the alcohol to reduce evaporation, but when glycerine is used the rubber connections may be affected somewhat seriously, depending on the quality of the rubber. The most practical method to maintain the proper quantity of alcohol in the solution is to determine the specific gravity of the liquid by means of an hydrometer and by reference to the appended table add the necessary quantity of alcohol to obtain the desired gravity. Care should be taken to have the solution thoroughly mixed, and as the specific gravities given in the table are obtained at 60°F, the specific gravity should be measured when the temperature of the solution is between 55°F and 65°F. The solution may then be kept at the proper strength from day to day by adding alcohol until the hydrometer reads the same as when first noted.

In order to illustrate how a nonfreezing solution is prepared by using the table, assume that the lowest temperature anticipated is 19 degrees above zero Fahrenheit and that denatured alcohol is to be used.

By reference to the table in the line marked "Denatured Alcohol", +19°F is found in the 20% column, and the specific gravity of that solution is 0.978.

If the radiator holds 3.5 gallons 20% of this must be alcohol and the remaining 80% water; 20% of 3.5 gallons (3.5 x .20 = 0.7) is 0.7 gallon or a little more than 5.5 pints. Hence a little more than 5.5 pints alcohol will be required. This should be added to enough water to make 3.5 gallons, i.e., the water used will be 3.5 gallons -0.7 gallon or 2.8 gallon; a little more than 11 quarts.

If the temperature of this solution is brought to 60°F and an accurate hydrometer is floated in it, the hydrometer should read 0.978. If the reading is higher than 0.978, more alcohol should be added with constant stirring until the 0.978 mark is reached. (An accurate hydrometer should read 1.000 when placed in water at 60°F and 0.834 in 180° proof alcohol at the same temperature. The denatured alcohol usually sold by dealers is 180° proof, which is the minimum allowed by law.)

A solution so prepared will not begin to freeze until its temperature is approximately +19°F.

A careful consideration of the question of anti-freezing solutions for radiators leads to the conclusions that (1) calcium chloride compounds should be used with caution, if at all, on account of their corrosive action; (2) kerosene or similar oils should not be used on account of their inflammability, high boiling point, and effect on rubber; (3) mixtures of glycerine and alcohol can be used, but the price of glycerine may preclude its use; (4) solutions made from either wood alcohol or denatured alcohol seem at the present time to be the most desirable anti-freezing solutions to use. If the wood alcohol is free from acid, there is little choice between the two alcohols. Wood alcohol costs more than denatured alcohol and is more volatile, but its lower freezing point allows a less amount to be used, which may counteract the above disadvantage.

Numerous tables have been published giving the freezing points of certain water solutions containing alcohol, glycerine, or a mixture of the two, but there is much disagreement in the figures given.

There is appended a table of freezing points obtained from actual measurements made at the Bureau of Standards, on solutions of commercial materials, which may be considered sufficiently accurate for practical purposes, since they agree fairly well with the most reliable scientific data.

The freezing point is taken to be that temperature in the cooling process at which crystals begin to form. The temperature at which the entire mass becomes solid may be several degrees lower than the freezing point of dilute solutions, and ten to fifteen degrees lower for the more concentrated solutions.

As an example, a 30% solution of denatured alcohol begins to freeze, that is, small crystals of ice form, at 7°F, but the solution does not freeze solid until a temperature of -5°F or lower is reached. Hence, a temperature considerably lower than that given in the table for any given percentage of alcohol would not injure the engine or radiator. However, it seems desirable to keep the solution at such a concentration that ice crystals will not form at the lowest temperature to be encountered, since such crystals may interfere with circulation.

Table Giving the Freezing Points and Specific Gravities of Some Alcohol and Glycerine Anti-freezing Solutions

Temperatures are given in degrees Centigrade and degrees Fahrenheit. The figures in parenthesis are specific gravities at 60°F.

Percentage (by volume) in water and freezing points.

Solution	10%		20%		30%		40%		50%	
	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
Denatured alcohol	-3	+27	-7	+19	-12	+10	-19	-2	-28	-18
	(0.988)		(0.978)		(0.968)		(0.957)		(0.943)	
Wood alcohol	-5	+23	-12	+10	-19	-2	-29	-20	-40	-40
	(0.987)		(0.975)		(0.963)		(0.952)		(0.937)	
Glycerine Sp.gr.1.2537)	-2	+29	-6	+21	-11	+12	-18	0	-26	-15
Denatured alcohol and glycerine*	-4	+25	-8	+18	-13	+9	-22	-8	-32	-26
Wood alcohol and glycerine*	-4	+25	-9	+16	-15	+5	-24	-11	-35	-31

*Glycerine and alcohol are mixed in equal proportions. Ten per cent glycerine and denatured alcohol means 5 parts glycerine and 5 parts alcohol should be added to 90 parts of water.

Method of Reading a Hydrometer

The solution is placed in a clear glass jar or cylinder and the hydrometer carefully immersed in it to a point slightly below that to which it naturally sinks, and is then allowed to float freely.

In taking the reading the eye should be placed slightly below the plane of the surface of the liquid and then raised slowly until this surface, seen as an ellipse, becomes a straight line. The point at which this line cuts the hydrometer scale should be taken as the reading of the instrument. (An accurate hydrometer should read 1.000 when placed in water at 60°F and 0.834 in 180° proof alcohol at the same temperature. The denatured alcohol usually sold by dealers is 180° proof, which is the minimum allowed by law.)