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DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
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Anti-Freezing Solutions for Automobile Radiators

At the Bureau of Standards, the freezing points of various solutions have been determined and the corrosive effects of such solutions upon the metals commonly employed in radiator construction have been investigated. Inasmuch as electrolytic action is largely responsible for radiator corrosion, corrosive effects were studied upon the combinations of metals ordinarily used in radiators.

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 non-freezing 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 anti-freezing 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. Kerosene and similar oils without admixture and solutions of glucose or honey in water are sometimes used.

Honey

The objections to anti-freezing solutions of honey in water are that low percentage mixtures do not have a sufficiently low freezing point and high percentage mixtures are so viscous that they circulate very slowly or not at all. Freezing of these solutions is not likely to cause bursting as slush begins to form at the freezing point but does not become solid until a temperature several degrees lower is reached. The use of these solutions does not remove the other ill effects of freezing, such as injury to the circulating pump and overheating of the engine due to lack of circulation.

The following table gives the properties of honey-water solutions:

| Percentage (by volume) in Water | Freezing Point | | Density at 21°C |
	°C	°F	g/cc
33 1/3	- 6	+21	1.165
50	-11	+12	1.222
66 2/3	-20	- 4	1.275
75	-26	-15	1.307
100	--	--	1.403

Alcohol, when added to honey-water solutions, lowers the freezing point but may cause the sugar to crystallize out from the honey and thus increase the likelihood of clogging of the water system.

Glucose

Glucose solutions are even less effective than honey. Dextrose is the active component of commercial glucose and no proportion of dextrose and water can be found which freezes at a temperature below 25°F (-5°C). Solutions containing glucose behave like those containing honey in that they freeze very slowly, first to slush and finally solid.

Kerosene

Kerosene should never be used in a cooling system in which the liquid is not circulated by a pump. Its use in any system is undesirable as the inflammability of its vapor makes it dangerous and its high and uncertain boiling point may lead to the serious over-heating of the engine or even to the melting of the solder in the radiator. It also has a slight solvent action on rubber.

Calcium Chloride

Calcium chloride preparations are sold under a variety of names. Their ability to prevent freezing if properly prepared is unquestioned. Solutions of calcium chloride and water are known to have a corrosive action 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 solder and aluminum is especially serious. Certain calcium chloride preparations contain a small amount of a soluble chromate added for the purpose of retarding this corrosive action. Laboratory tests at this Bureau indicate that such preparations have practically no corrosive action on the metals used in the construction of automobile radiators with the exception of aluminum.

Another troublesome effect of all calcium chloride solutions is experienced if the solution comes in contact with spark plugs or ignition wires. The salt deposited when the water evaporates is very difficult to remove and when it cools it absorbs water and becomes a good electrical conductor causing short-circuits which are not easy to locate as they disappear when the engine is heated up.

Alcohol and Glycerine

In general the alcohol solutions are considered the most satisfactory. They do not have any appreciable corrosive action. This can be predicted from theoretical considerations and is well established in practice. Wood alcohol, however, sometimes contains free acid which is objectionable and for this reason should not be used unless it is known to be free from such acids.

The chief objection to alcohol is that it continually boils out of the solution and 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. 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 non-freezing solution is
prepared by using the table, assume that the lowest tempera-
ture 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 is
0.7 gallon or a little more than 5.5 pints. This should be
added to enough water to make 3.5 gallons, i.e., the water
used will be 2.8 gallons, 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 sho uld 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 alco-
hol 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.

The appended table of freezing points was 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 solu-
tions, and ten to fifteen degrees lower for the more concen-
trated solutions.

As an example, a 30% solution of denatured alcohol be-
gins 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 consider-
ably lower than that given in the table for any given per-

centage 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 in-
terfere with circulation.

Table giving the freezing points and specific gravities of some alcohol and glycerine anti-freezing solutions

Percentage (by volume) in water and freezing points.

Solution	10% °C	°F	20% °C	°F	30% °C	°F	40% °C	°F	50% °C	F
Denatured alcohol	-3 (0.988)	+27	-7 (0.978)	+19	-12 (0.968)	+10	-19 (0.957)	-2	-38 (0.943)	-18
Wood alcohol	-5 (0.987)	+23	-12 (0.975	+10	-19 (0.963)	-2	-29 (0.952)	-20	-40 (0.937)	-40
Glycerine Sp. Gr., 1.2537)	-2	+29	-6	+21	-11	+12	-18	0	-26	-15
Denatured alcohol & glycerine*	-4	+25	-8	+18	-13	+9	-22	-8	-32	-26
Wood alcohol and glycer- ine*	-4	+25	-9	+16	-15	+5	-24	-11	-35	-31

*Glycerine and alcohol are mixed in equal propor-
tions. 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 slight-
ly below that to which it naturally sinks, and is then al-
lowed 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 hydrom-
eter 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.)

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