LIQUID FILLERS FOR BORE HOLES IN GLACIERS

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ABSTRACT

An evaluation is made of the different types of liquid fillers that could be used in bore holes in glaciers.

INTRODUCTION

Liquid bore hole fillers are used to compensate for the hydrostatic pressure exerted by the ice during and after drilling. Fillers may be either hydrophobic or hydrophyllic.

PROPERTIES OF FILLERS

Liquid fillers should meet the following requirements:

(1) Their freezing temperature should not be warmer than the glacier temperature.
(2) Their density should be equal to or greater than the density of glacier ice but it should be less than the density of water.
(3) The viscosity of the filler should not interfere with the motions of the drill.
(4) The fillers should be non-toxic and they should not lead to contamination of the environment or the ice core.
(5) Their electrical conductivity should be low.
(6) They should be easy to handle and safe to work with under all conditions.
(7) They should be easily available and inexpensive.

The hydrophobic fillers, which are petroleum based, should be loaded. The known loading liquids such as trichloroethylene and tetrachloromethane are toxic and strong solvents. If used, they should be handled with special care. The safety measures required are not always feasible in the field.

The hydrophyllic, or water based solutions, are found to be most suitable for filling bore holes. A number of different salts were studied (NaCl, $CaCl_2$ and $MgCl_2$) as well as liquid hydrocarbons (alcohols, glycerol and ethylene glycol). It was found that methyl alcohol is the most appropriate filler, but its toxicant properties preclude its safe use. As an alternative, ethyl alcohol was chosen as the filler. The density of its eutectic solutions lie between the densities of ice and water. Its viscosity is sufficiently low that winching operations are not adversely affected by the presence of the hole fluid. The use of this fluid does not lead to contamination of the environment, nor does it appear to compromise any of the bore hole or core studies. Thermal drills used in conjunction with an alcohol-water solution are easy to operate, light weight and reliable. The efficient use of the melt water to back fill the hole obviously lessens the amount of filler solution required to be transported to the drill site.

It is known by measurement that the filler poured into the bore hole will achieve the temperature of the surrounding ice in 7-10 days. In those glaciers where the temperature gradient is positive, the solution density increases with depth. This precludes convection in the solution and promotes a longer bore hole life.

If the temperature gradient in the ice (and hence the bore hole) is anywhere negative, then this section of the fluid column is liable to undergo convection. This may be accompanied by shuga (slush) formation. In order to stabilize this section of the bore hole by maintaining a constant density or by increasing it slightly, glycerol should be added.

The properties of the solution to be used are determined in the following way. The freezing temperature is determined both from reference data and from laboratory tests. The densities of the eutectic solutions may be calculated from Mendeleyev's (1934) formula:

$$\rho_t = \rho_{20} + D(20-t) - E(20-t)^2 \qquad (1)$$

where D and E are empirical coefficients, t is the solution freezing temperature and ρ_{20} is the solution density at 20°C.

The solution density values obtained from equation (1) were determined experimentally to third place accuracy.

The freezing temperatures and densities of triple solutions were also obtained experimentally.

Figure 1 shows the dependence of the freezing temperature of the ethyl alcohol-water solution on its concentration.

Figure 2 shows the dependence of the density of the ethyl alcohol-water eutectic solutions on the solution temperature.

Figure 3 shows the dependence of double and triple solution viscosity on temperature.

APPLICATIONS

In temperate glaciers, the pure melt water becomes the filler. However, the upper layers of the glacier may loose heat and freezing of the upper borehole water may take place. If it is necessary to preserve the hole, the upper 10-20 m should be cased and this part of the hole should be filled with an anti-freeze liquid.

In cold glaciers with a positive temperature gradient, the water-alcohol solutions prolong the holes life. In glaciers with a complex temperature distribution, triple loaded solutions are recommended, to ensure that they have constant or increasing density with depth.

Alcohol-water fillers have particular applicability when thermal drills are being used.

REFERENCE

Mendeleyev, D.I. (1934) Collected works. vol. 3, p. 266-274.

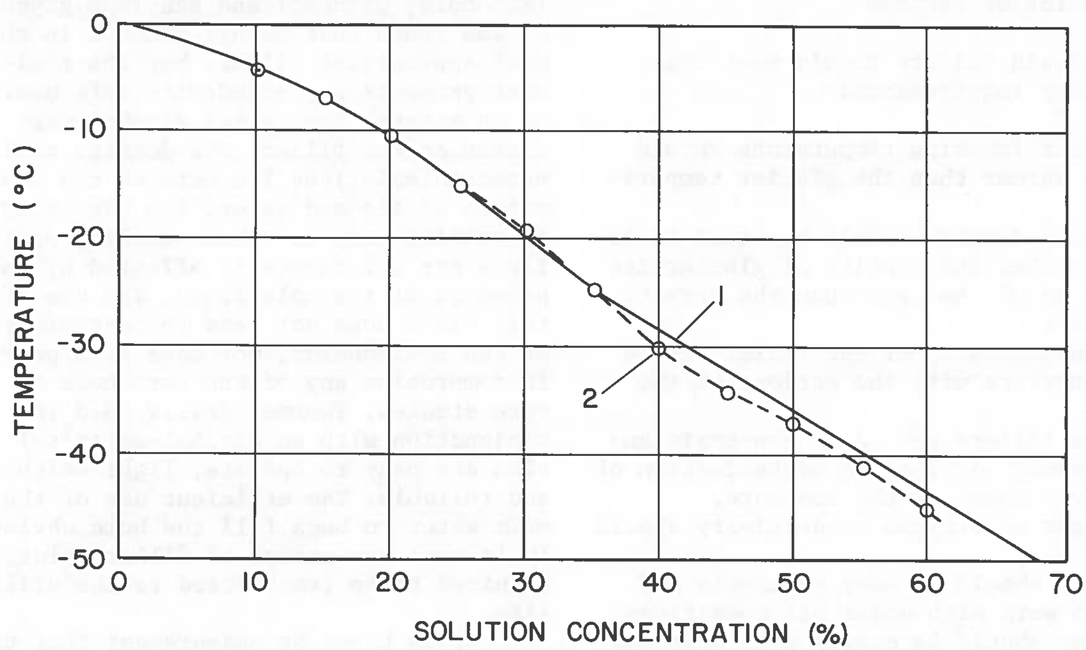

Figure 1. The dependence of the freezing temperature of ethyl alcohol-water solution on the solution concentration by weight. Curve 1 is calculated. Curve 2 is experimental.

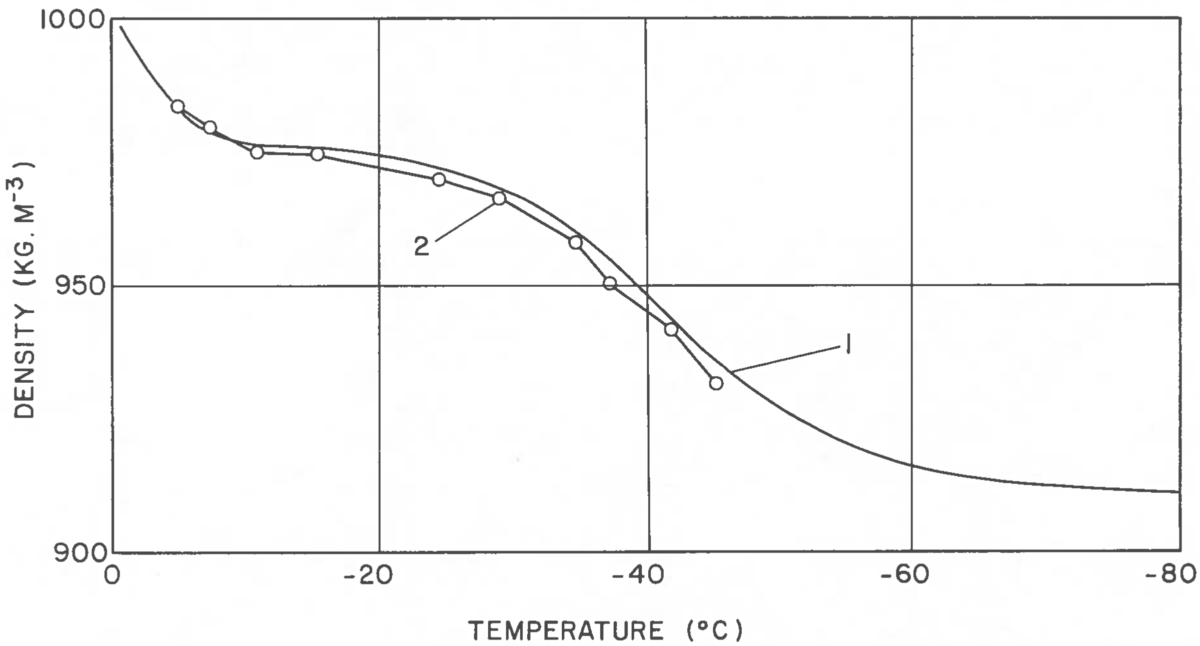

Figure 2. The dependence between the density of the ethyl alcohol-water solution and its freezing temperature. Curve 1 is calculated. Curve 2 is experimental.

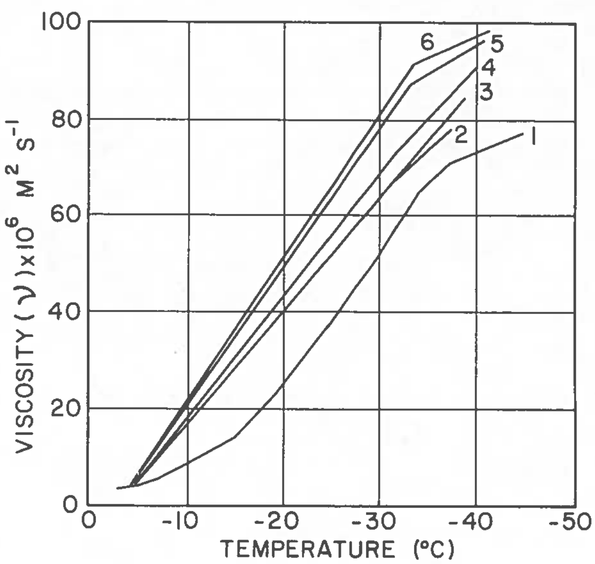

Figure 3. Dependence between the viscosity of an ethyl alcohol-water-glycol solution and its freezing temperature. Curves 1 through 6 correspond to 0 % through to 5 % glycol by weight.