EQUIPMENT AND TECHNOLOGY FOR CORE DRILLING IN MODERATELY COLD ICE

V.V. Bogorodsky and V.A. Morev
The Arctic and Antarctic Research Institute, Leningrad, U.S.S.R.

ABSTRACT

The equipment for thermal coring in ice as cold as approximately -30°C is described. Ethyl alcohol is used as the hole filler and its use together with glycerol is discussed.

INTRODUCTION

Glaciers in which the temperature is not lower than about -33°C are considered to be moderately cold. All polar glaciers, with the exception of the interior parts of the Antarctic Ice Sheet, fall into this category.

The depth of dry holes drilled in glaciers is restricted by the plastic properties of ice, which cause hole contraction. For successful drilling in such glaciers, it is necessary to fill the holes with fluid to compensate for the hydrostatic ice pressure. A solution of ethyl alcohol mixed with water was found to be a suitable filler. This solution permitted the use of light weight drilling equipment and improved the quality of the core.

DRILLING EQUIPMENT

The ETB-3 electro-thermal core drill was developed for drilling in moderately cold ice. It is shown schematically in Figure 1. It consists of the annular heater shoe fixed at the lower end of the two concentric barrels which are fitted with three core grippers. A piston slides inside the inner (core) barrel, which is initially filled with the anti-freeze solution by means of an inlet nozzle. At the upper end of the drill is a spring loaded cable termination. The drill is suspended in the hole by means of a single conductor armored electro-mechanical cable. power is transmitted through the central conductor and the armor (Morev, 1972; 1974).

The drill operates in the following way. The piston is set in its lowest position and the core barrel is filled with an ethyl alcohol-water solution of required concentration before the drill is lowered into the hole.

When the drill shoe is in contact with the bottom of the hole, the power is applied to the heaters causing the shoe to melt an annular space in the ice. The core passes into the core barrel and moves the piston upwards. As a result, the solution is expelled from the inner barrel through holes in the upper end. It percolates down the space between the concentric barrels to the base of the hole where it mixes with the new melt water.

When the core barrel is filled with core, the winch is suddenly reversed, and the jerk causes the core grippers to become engaged with the core which then breaks across. After raising the drill to the surface the operators put the drill on a tilting table where the core is removed and the barrel refilled with new anti-freeze solution. The drill is then ready to be lowered back down the hole.

The auxiliary equipment includes a winch with electric motor drive, a plumb bob and dynamometer (for measuring cable tension) and a counter for

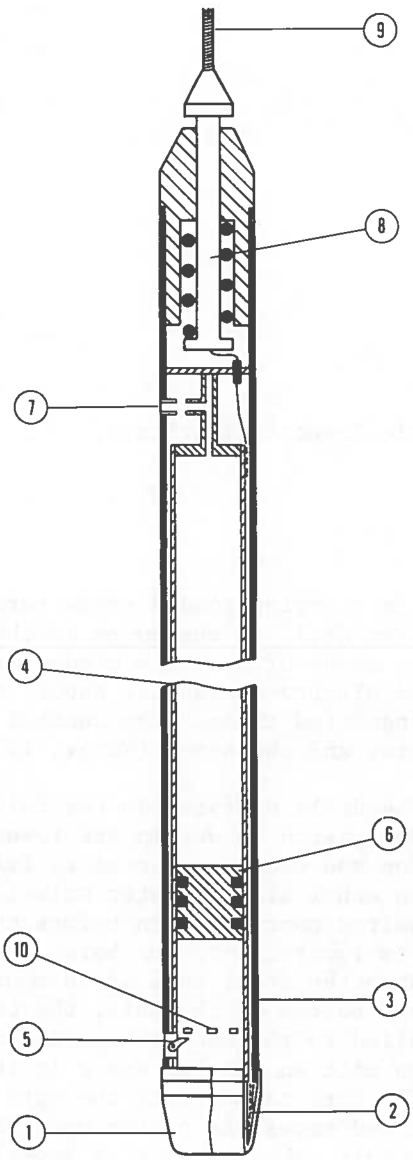

Figure 1. Schematic diagram of the ETB-3 electro-thermal core drill. (1) Heater shoe. (2) Nichrome heater wire winding. (3) Outer barrel. (4) Inner core barrel. (5) Core grippers. (6) Sliding piston. (7) Inlet for injecting anti-freeze into the core barrel. (8) Spring loaded cable termination assembly. (9) Electro-mechanical cable.

measuring the length of the cable in the hole.

The overall drill length is only 0.7 m longer than the core barrel. The use of small sized (8.6 mm diameter) cable meant a reduction in the size, weight and power rating of the hoist. Further, the utilization of the melt water for back filling the holes reduces the amount of special filler needed.

At present, we believe that this drilling equipment is the lightest and the most effective. The cores and the holes can be used for most common studies.

The drill specifications are:

Heater shoe outer diameter,	108 mm
Heater shoe inner diameter,	84 mm
Hole diameter,	112-120 mm
Core diameter,	78-80 mm
Core length,	1-7 m
Drill weight,	25-180 kg
Power consumption,	1-4 kW
Drilling rate,	2-6 m/h.

The concentration of the solution used for drilling depends on the ice temperature, and may be determined from the nomograph shown in Figure 2. This nomograph shows that when filling the drill with 96 % ethyl alcohol, the coldest ice that may be safely drilled, has a temperature of -33°C. This condition restricts the use of the ETB-3 drill.

In glaciers with a positive temperature gradient (temperature increasing with depth) the concentration of the alcohol solution decreases with depth. The resulting density structure prevents liquid convection and ensures a long term life of the hole.

Observations at the Vavilov Dome (Severnaya Zemlya) were conducted at several bore holes for 2-3 years. A small quantity of ice crystals was always present in eutectic solution. The ice slush crystals were suspended in solution and partly sticking to the wall of the hole. It was observed that, provided the temperature gradient was positive, the crystals do not float up or form shuga (slush) plugs.

With an inverted temperature distribution convection of the liquid and the subsequent formation of shuga plugs is possible.

Convective fluid movement starts when the reversed temperature gradient, dT/dz reaches a critical value given by (Ostroumov, 1952; Krige, 1939):

$$dT/dz = C^4 \nu \kappa / g \beta R^4 \qquad (1)$$

where T is temperature,
z is depth,
C is a characteristic parameter,
ν is the kinematic viscosity of the fluid,
κ is the thermal diffusivity of

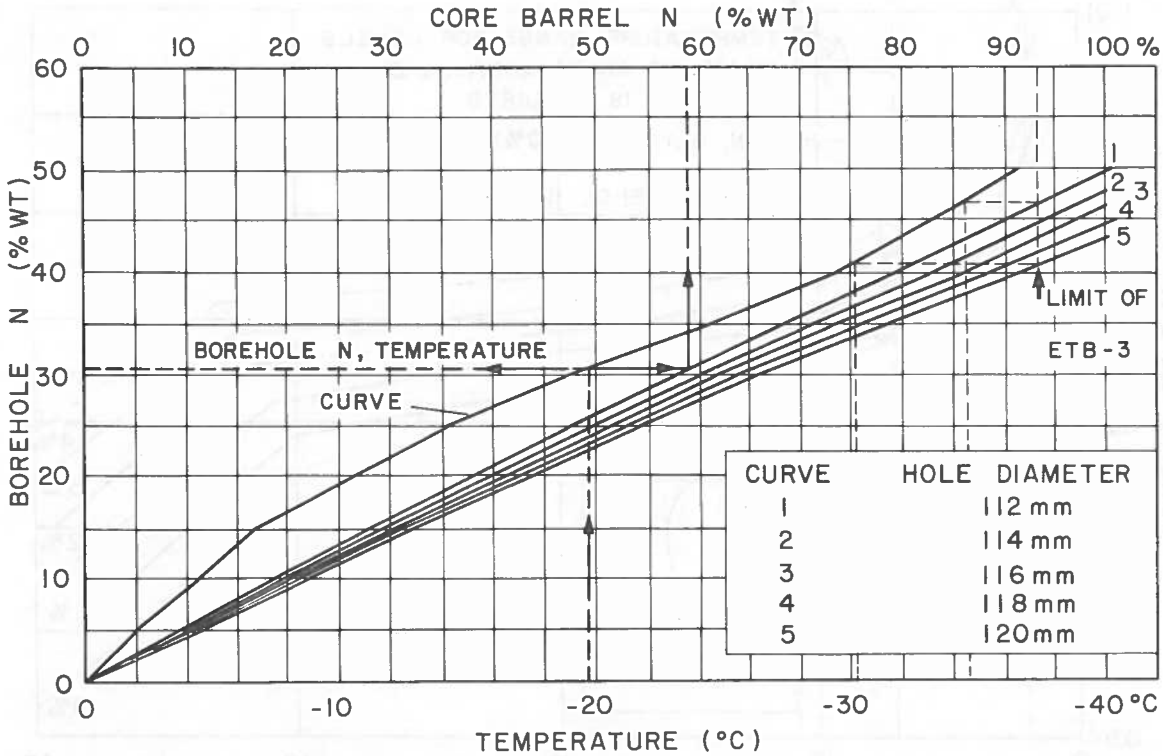

Figure 2. Nomograph for the estimation of solution concentration of ethyl alcohol to be mixed with melt water.

the hole fluid,
g is the acceleration due to gravity,
β is the coefficent of volume expansion of the fluid and
R is the bore hole radius.

The coefficient β is determined from the difference of eutectic solution densities as a function of temperature. The diffusivity of the solution is determined by the method described by Ostroumov (1952) using the relationship between the heat capacity of the ice and the solution at the eutectic point.

Using equation (1) values of the critical gradient have been computed for different temperatures. The results, which yield conservative estimates, are shown in Figure 3.

There were no problems encountered with drilling using the alcohol-water solution even with reversed temperature gradients 30-50 times the critical one. However, in these cases, some slush formation was observed some time after the drilling was completed. At Lomonosov Plateau (Spitzbergen) where the reversed temperature gradient is 6000 times greater than the critical one problems were encountered during the drilling.

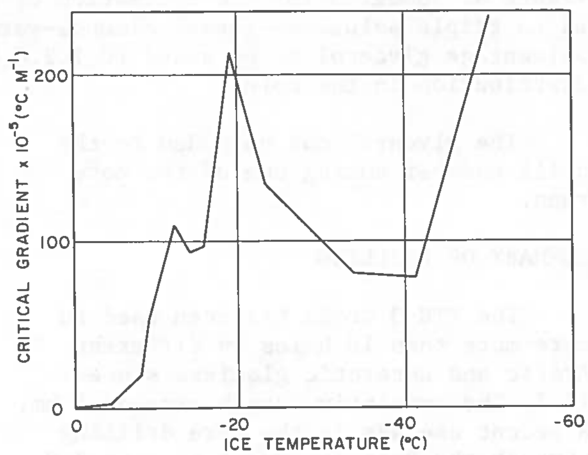

Figure 3. Plot of critical gradient versus temperature of the solution.

For long term bore hole life, where a reversed temperature gradient exists, a loading fluid, such as glycerol, should be added. The quantity of glycerol that should be added depends on the temperature distribution in the hole and may be estimated from the nomograph given in Figure 4. The maximum quantity of the glycerol should be released at the point of minumum ice temperature.

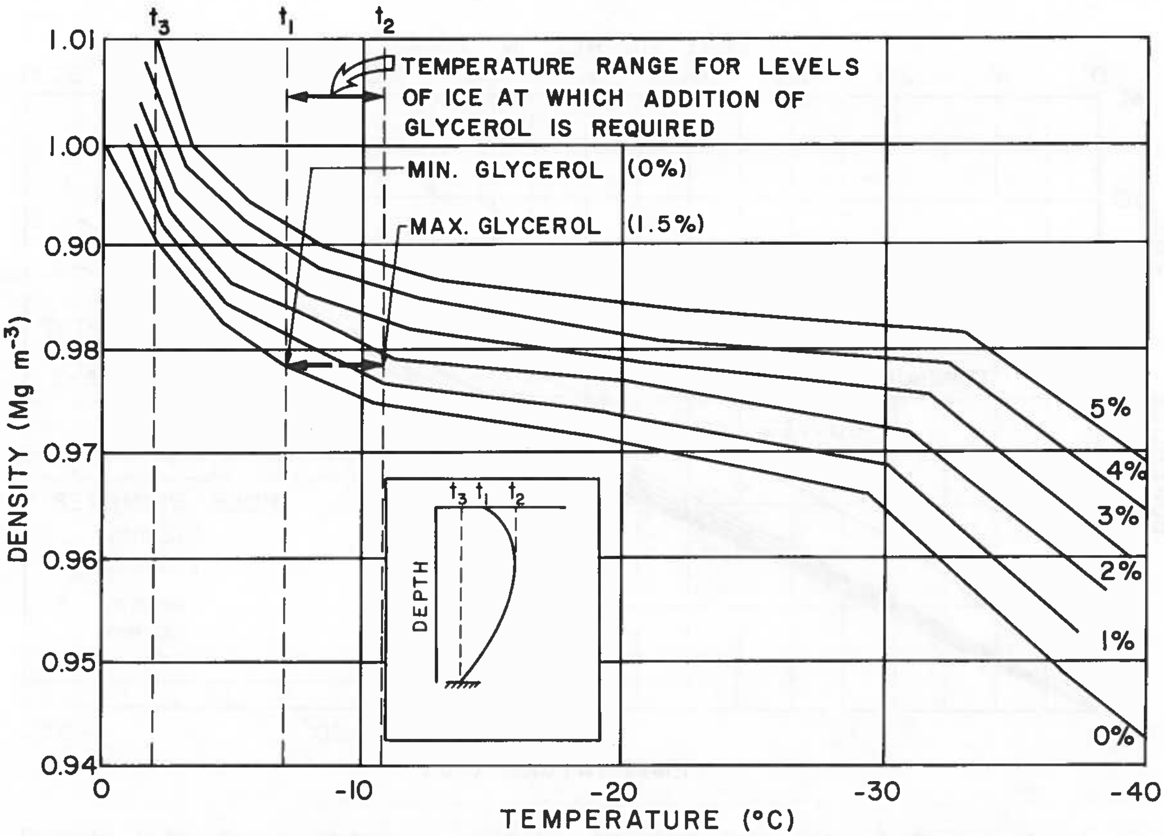

Figure 4. Nomogram for the estimation of the required amount of glycerol to be added to triple solutions (ethyl alcohol-water-glycerol). Each curve corresponds to a percentage glycerol to be added (0,1,2,3,4,5 %) according to the temperature distribution in the hole.

The glycerol can be added to the drill chamber during one of the core runs.

SUMMARY OF DRILLING

The ETB-3 drill has been used to core more than 10 holes in different Arctic and Antarctic glaciers since 1972. The cumulative depth exceeds 5 km. A recent use was in the core drilling through the Ross Ice Shelf at site J-9 (Zotikov, 1979).

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