DRILLING WITH ETHANOL-BASED ANTIFREEZE IN ANTARCTICA

by

Morev V.A., Manevskiy L.N., Yakovlev V.M. and Zagorodnov V.S.*
Institute of Arctic and Antarctic Research
Leningrad 199226
Beringa 38

*Institute of Geography of the USSR Academy of Sciences
Moscow 109017
Staromonetny 29

An account is given on antifreeze-thermal drilling in Antarctica.

When drilling deep bore holes in glaciers, to compensate the hydrostatic pressure of the glacial strata the antifreeze liquids of the required density are used, such as kerosene with admixtures of density-increasing components and of liquids based on the ethyl spirit (ethanol). Each of the admixed components has its strong and weak points. Kerosene and the density-increasing components (CFCs) are toxic substances not mixing with water or decomposed by air. Use of such admixtures is associated with several technological difficulties.

As for ethanol, it has low viscosity, is diluted by water in any proportions, evaporates at even low temperatures, density of its water solutions is close to that of ice. In case of need, it is possible to introduce into ethanol solutions the components, that are not toxic, to increase density : high-density spirits, glicerine, for example. Such mixtures can be used for drilling glaciers of all types, including shelf glaciers, within the temperatures ranging from 0 to -60°C. As disclosed by long-term observations, the ethanol-based liquids in bore holes under low temperatures are not decomposing or forming ice crystals, produce no significant pollution of ice core, are ecologically safe, comparatively cheap.

Drilling in Antarctica with filling of bore holes with the spirit-water solutions started in 1974 in the marginal part of the ice sheet in the vicinity of the Mirnyi station ; the major components of the drill for the anti-freeze-thermal drilling-melting were tested then. Use of meltwater as a component of the antifreeze solution in the bore hole allowed to do without the facilities for pumping water from the bore hole to the surface. This considerably simplified construction of the drill, made it shorter, reduced weight of the drilling equipment, the volume and weight of the liquid to be pumped into the bore hole, thus facilitating its transportation to the glacier. The design of the drilling equipment, technology of drilling, composition of the liquid pumped into the bore hole are described in (*).

Drilling and exploration of the first bore hole have disclosed, that when filled by ethanol-based antifreeze mixtures, they can be operated for several years, giving rather high-quality ice core suitable for the majority

* Procedings of 2d Ice Core Drilling Technology, Calgary, 1982, by V.A. Morev et a.

of anlytical technologies. In the 1970-es drilling with filling of the bore holes with the ethanol-based solutions was implemented only on the shelf glaciers and the periphery of ice sheet. For this purpose an electrothermal drill was used, operating at temperatures as low as -36°C. Later on this thermodrill was amended to operate in cold ice in the central regions af Antarctica at ice temperatures -57°C. A new thermodrill, and its modification have two cameras with antifreeze. In the process of drilling-melting the drill inserts into the bore hole practically two volume units of antifreeze per one unit of meltwater ; part of liquid with low concentration of antifreeze goes to the drill and is pumped to the surface. Testing of this thermodrill started in 1982. Data on drilling in Antarctica with ethanol-based antifreeze are given by Table I.

Investigations of the accidents have disclosed the following causes of losses of bore holes : failure of the drill, mistakes of operators, infringement of the technology of filling the bore hole with antifreeze liquid (erroneous selection of density of the solution), inadequate information on the structure and thermal regime of the glacier in the region of the bore hole. These causes can be eliminated by preliminary investigation of the ice strata in the region of drilling (drilling of reconnaissance bore hole), adjustment of drill, training of operators, advancement of the devices controlling the regimes of drilling.

A seasonal base at Komsomolskaya station was organised in 1980/81, in the next season a bore hole 800.6 m deep was drilled.

In the process of drilling the bore hole was filled by the spirit-water solution. After temperature and inclination measurements, in February 1982 the bore hole was conserved. In January 1983 drilling of this bore hole was continued. During the 11-month long interruption of activities on drilling, the state of the solution filling the bore hole was not changed, and drilling went on without complications. When the bore hole reached the depth of 870 m the drill was frozen in the hole because of a wire failure inside the drill. An effort was made to pull the drill out of the bore hole, but the cable broke close to the surface. 870 m long stretch of the cable stayed inside the bore hole at depth of 110 m. Thus, the testing of a new modification of the antifreeze-thermal drill and of the technology of filling a deep bore hole in ice with temperature -53°C gives a solid proof of the possibility to use the ethanol-based filling liquids for long-term conservation of the bore holes in the glaciers with downward increase of temperatures.

Results of testing of the electrothermal drill ETB-5 provided the basis for drilling a new bore hole in Central Antarctica. The site for a new bore hole was selected in a little-known region of Eastern Antarctica in the area of B-dome 77°04 S L, 95°55 E L ; the camp site was conventionally named "Dome B". This is one of the most elevated regions of the continent, the camp being at 3850 m a.s.l. The glacier is underlain by lakes, its surface ice strata move at rates about 0.1 m/year. During several summer seasons the preparatory activities were carried out on the Dome B : assembling of a power-generating station, of drilling facilities, housing. Now the camp can accommodate 6-8 specialists to work during the summer seasons.

Drilling of a deep bore hole was started at the station Dome B in the summer season of 1986/87. In the first phase drilling was done by a special drill ETB-130 (diameter 130 mm) that pumps melt-water from the bore hole. During the first season 780 m were drilled. After temperature measurements the bore hole was filled by ethanol-based antifreeze solution and conserved. In the coming summer seasons drilling would be

continued first with the thermal drill ETB-5, and after reaching ice strata with temperatures above -36°C with the thermal drill ETB-3 ; diameter of the two latter drills is 108 mm. Increase of the bore hole diameter in its upper portion will speed up sinking-lifting of the drilling equipment in the coldest horizons of the bore hole, where viscosity of the solution used for filling the bore hole is minimal.

Now the experts on ice drilling are facing the problem of drilling a bore hole that descends into a sub-glacial lake, and of its conservation in the state that would allow for explorations later.

Table I - Basic Data on the Bore Holes Drilled in Antarctica with Antifreeze-Thermal Technology

Year	Site of drilling bore hole depth	Character of ice strata	Observations in the bore hole	State of the bore hole
1975	Lazarev Shelf Glacier, 374 m, down to the ground	firn 6 m	temperature, 5 months	sludge in the interval of negative temperature gradient
1975	the same, 356 m, the bore hole reached the sea	firn 6 m	temperature, oceanology, ground	sea water ascended 4 m, sludge was formed in the lower part
1976	the same, 412 m, the bore hole reached the sea	ice	temperature	the same, the lower 10 m blocked by sludge
1977	edge of glacier,region of Novolazarevskaya station, 812 m	firn 62 m	temperature	the drill is frozen, the cable torn off
1978	Sheklton Shelf Glacier, 202 m, the bore hole reached the sea	firn 62 m	temperature, oceanology	sea water in the lower portion, in 24 hrs a sludge block was formed
1978	Ross Shelf Glacier, the camp -9, 416 m, the bore hole reached the sea	firn 50 m	temperature	sea water in the lower part, the solution ascended 20 m ; sludge is probable in the lower part.
1979	edge of glacier in the vicinity of the Mirnyi station, m	firn 50 m	temerature	formation of sludge in the interval of negative temperature gradient
1982 - 1983	Komsomolskaya station, 870 m	snow-firn 120 m	temperature	conserved for 11 months, the drill was frozen
1988	Dome B, 780 m	snow-firn 120 m	temperature	filled with spirit-water antifreeze, conserved