Access hole drilling through the Ross Ice Shelf

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Two access holes were drilled by flame-jet through the 1,380-foot ice thickness of the Ross Ice Shelf. The first hole was completed on 2 December 1977 after an approximately 9-hour run. The second hole was made about 10 days later using the same equipment and drilling procedures.

The flame-jet drill is powered by an internal burner (similar to a rocket engine) whose reactants are compressed air and fuel oil provided at high pressure. A 600 standard cubic feet per minute flow of air at 140 pounds per square inch gage (provided by a standard compressor) was fed into a booster compressor capable of producing an output pressure of 1,200 pounds per square inch gage. We found that this high a pressure was not required. Using a 5/8-inch diameter burner exit nozzle, the initial air pressure (when starting the hole) was 300 pounds per square inch gage. The pressure at breakthrough was just over 500 pounds per square inch gage. This increase in pressure was caused by the back-pressure of the increased hydrostatic head within the hole.

Two phenomena peculiar to ice drilling were thought sufficiently serious to warrant special drilling techniques. First, possible freeze-in in the coldest ice nearest the top of the hole becomes less of a threat with increasing hole diameter. Freeze-in time varies as the square of the hole diameter. To maximize hole size, a drilling speed of only 2 feet per minute was used in the top 100 meters of ice to produce a hole diameter of more than 18 inches.

The second problem concerns hole closure by plastic flow in the warmer ice near the sea below. Time required for this type of closure varies directly with hole diameter. Because a hole of double-the-diameter requires four times as long to produce, it appeared best to drill as rapidly as possible in this region. A drilling speed of 6 feet per minute was used for the final 100 meters.

The second access hole was enlarged to an average diameter of 18 inches by flame reaming using the same drilling equipment and procedures used for drilling the hole. This hole was kept open for nearly 3 weeks; several additional flame reamings were required to maintain a minimum hole diameter greater than 12 inches.

The diameter (measured by caliper) showed large irregularities over the entire hole length. There were many zones where the diameter was narrow. Heat used to keep these above the 12-inch limit enlarged the diameter in other areas of the hole to more than 30 inches. Reasons for the formation of these irregularities are not well understood. They seem to occur at points where initial minor narrowing occurred. Each successive application of heat amplified the diameter difference between these zones. This may have been caused by a lack of adequate water circulation within the hole or by the formation of "cells" by reverse flow of the water within the large chambers between the restricting diameters.

The density of the water filling the hole during flame drilling is reduced appreciably by the presence of rising gases. Thus, the hydrostatic head was nearly 300 pounds per square inch less than the sea pressure of 500 pounds per square inch gage on breakthrough. Although this imbalance caused us no apparent difficulty (for the depths drilled at site J-9), it is doubtful that flame drilling beyond 3,000 feet in solid ice is practical. Pressure imbalance increases with depth and a point would be reached where the ultimate effect of hole closure forces could no longer be restrained.

This project was sponsored by the National Science Foundation under research agreement C-726-11, University of Nebraska.

Glaciological measurements on the Ross Ice Shelf

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Field work to complete the Ross Ice Shelf Geophysical and Glaciological Survey (RIGGS) in the 1977-78 field season was to involve remeasurement of 82 Kehle-type strain rosettes (Zumberge *et al.*, 1960) planted the previous season in a grid pattern on the ice shelf (Thomas and MacAyeal, 1977). In addition it was planned to remeasure detailed strain networks along two 40-kilometer lines near camp C-16 and along a 35-kilometer line on Crary Ice Rise (figure). Precise position fixes were to be made at most of the grid stations by two members of the U.S. Geological Survey using a Geoceiver.

Most of this work was accomplished: rosettes at 69 grid stations were remeasured, and all the detailed work near C-16 was completed. However, problems with the Litton inertial navigation unit in our Twin Otter airplane caused major delays. These problems began before the plane arrived on the ice so that the start of our field activities was delayed by 4 weeks. Thereafter, recurring breakdowns reduced the field season from a planned 10 weeks to less than 1 month. Cooperation between our teams and the two excellent pilots allowed us to work almost continuously during the brief periods of fair weather and a functional navigation system.

For part of the season a group of geophysicists from the University of Wisconsin at Madison occupied new stations, principally in the western part of the ice shelf. Whenever possible strain rosettes were planted at these new stations. Stations that have been reoccupied and those that may be remeasured in the future are shown in the figure. Major gaps in the data exist downstream from the Byrd Glacier and on Crary Ice Rise; other gaps doubtless will be revealed during data analysis.