RECENT EXPERIENCES WITH A MODIFIED RUFLI ICE DRILL

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ABSTRACT

An electro-mechanical shallow depth ice core drill was built, with a few modifications, following the general *Rufli* ice drill design. Our equipment was tested in October, 1981 on a glacier in the Alps before it was shipped to Antarctica. The drill will be used to take ice cores from the ice shelf near the Georg von Neumayer station for mechanical and chemical investigations. *In situ* systems for measuring the deformation behavior of the shelf ice will be installed in the boreholes. Details of the drill, together with our experiences during drilling, are described.

INTRODUCTION

Boreholes are necessary in order to investigate the deformation behavior of shelf ice with depth by *in situ* measurements, and to procure ice cores for mechanical and chemical investigations. The layout of the equipment depends primarily on the drilling depth required. During the 1980/81 German expedition, boreholes down to 15 m depth were drilled in connection with measuring settlements of the Georg von Neumayer wintering station and the Filchner summer station using the SIPRE drill driven by a motor. For greater depths, this drill was not sufficient.

Electro-mechanical ice drilling systems for depths greater than 100 m have been developed by Rufli (1976) and Rand (1976). H. Rufli, University of Bern, Switzerland, helped us with the drill design, construction and the first tests. With this support it was possible to finish the shallow drill construction in half a year, so that it could be used during the 1981/82 Antarctic Expedition near the Georg von Neumayer station. Prior to this expedition, the drill was tested at the Kitzsteinhorn/Kaprun (Austria).

THE SHALLOW DRILL SYSTEM

Figure 1 shows a view of the electro-mechanical drilling system during the tests. The drill may be subdivided into the following parts:

(a) Drill with motor and anti-torque section
(b) Winch, including cable
(c) Electronic control system
(d) Mast with pulley.

The individual components are now discussed.

Cutter head, motor and anti-torque section

These parts are predominantly copied from the *Rufli* ice drill. The total length from the cutter head to the top of the anti-torque system is about 4.70 m. The cutter head (Fig. 2) is made of aluminum. Three bits that cut a core of 7.5 cm diameter are fastened to it equally spaced over the perimeter. The diameter of the borehole is 11.7 cm, which means that an annulus of 4.2 cm width is cut away by the blades. The shape of the bits used first were the

Figure 1. View of the drill system.

same as those of the SIPRE drill, because lack of time prevented testing other bits. Two core catchers, 3 mm wide, are also fastened at the cutter head, but during drilling the width of the core catchers was found to be too small because of the notch effect in the core. The core catchers are pressed against the core by a spring.

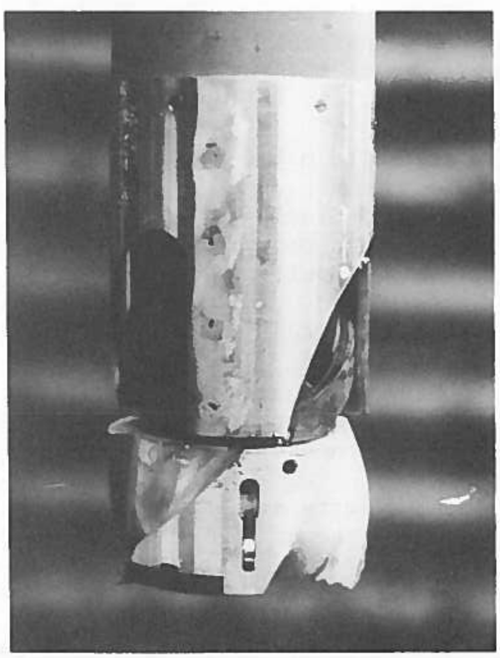

Figure 2. The cutter head.

The cutter head is fastened to the 2.20 m long core barrel. This is a PVC coated steel tube of inner diameter 81 mm. Two PVC spirals are screwed to its outside surface. These spirals transport the chips to two inlets at the upper end of the core barrel. To prevent chips from lodging around the core, a *Rufli disc* is used. This slides within the core barrel above the core.

The core barrel is inserted into an outer barrel (106 mm internal diameter; 110 mm external diameter) and fastened at the gear and motor section. This steel tube is coated with a light colored PVC layer to prevent heating by solar radiation. The coupling between the core barrel and the motor unit is identical to that described by Rufli (1976) and consists of a lever-spring system.

The 450 W, 140 V DC motor runs at 3000 RPM which is reduced 1/17 by a gear unit to give a maximum speed of the cutter head of about 175 RPM. The speed of the motor is measured by a tachometer and indicated at the control panel. The current is transmitted from the cable to the motor using a sliding copper connection inserted in a PVC frame.

The anti-torque system (Fig. 3) used in this drill is based on the Swiss design. To prevent the drill from turning relative to the borehole wall, three steel knives are pushed against the wall to oppose the torque from the cutter head. The pressure of the knives against the wall increases with the turning moment of the drill. The knives move within slides to which adjustments can be made.

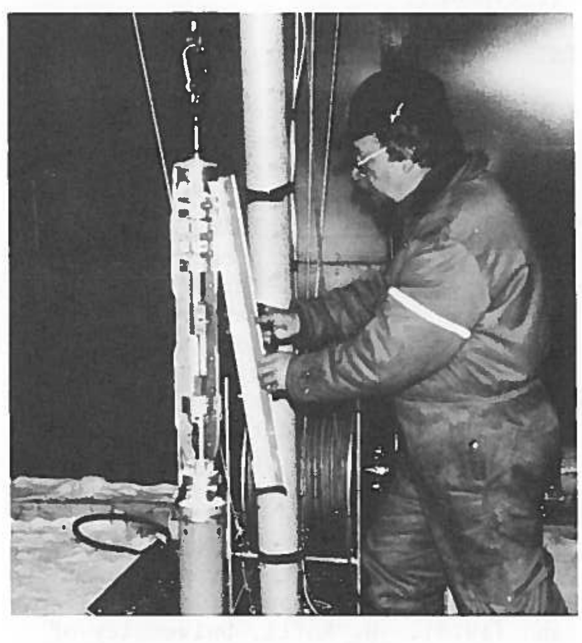

Figure 3. The anti-torque unit.

Cable and winch

The steel armored cable has seven conductors and is manufactured by the Norddeutsche Seeabelwerke, Nordenham, West Germany. It has a diameter of 10 mm with an area of 0.35 mm^2 for each conductor. It weighs 27 kg/100 m. The seven conductors are used in the following way: one pair for the current to the drill motor, one pair for the speed sensor for the drill motor, one pair for the strain gauge positioned inside the anti-torque section, and one conductor for ground.

The tensile strength of the cable is about 3600 kg. The connection between the drill and the cable is welded. Twisting of the cable is prevented by a safety hook. The bending radius of the cable is restricted to 25 cm.

The winch (Fig. 4) is mounted on a ground plate and connected to the mast. The drum has a diameter of 50 cm and is driven by a 140 V DC motor to a maximum speed of 3000 RPM. The speed is gear reduced by 1/71 and further reduced by two pulleys connected with a cone belt to 1/3 for a total reduction of 1/213. This speed can be continuously adjusted by a motor controller on the control desk. All parts of the winch are dimensioned for the maximum tension of 3600 kg. This resulted in a total weight of about 250 kg in spite of using aluminum in the construction.

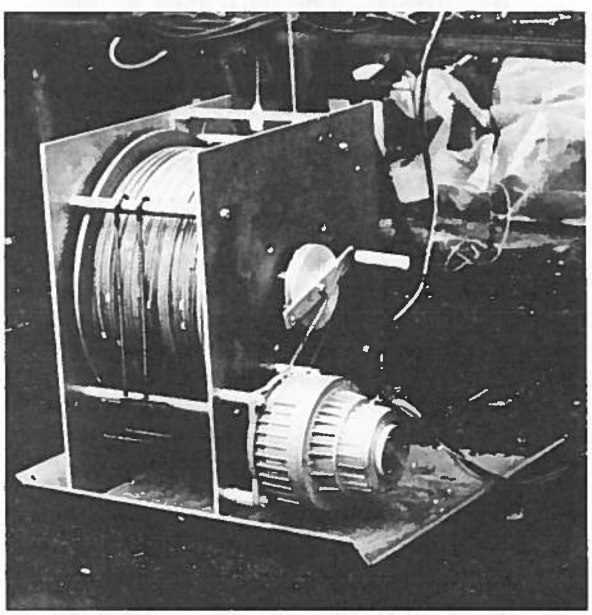

Figure 4. The winch including motor.

Mast and pulley

The mast of the drill (Fig. 1) is composed of two aluminum tubes with a length of 2.30 m, including the pulley. The total height of the system is 5.50 m. The base of the tower rests on a ball joint fixed to a 0.90 m square base plate, which is connected to the winch base plate. The mast can be anchored by three guy wires. The outer diameter of the tube is 120 mm and the inner diameter 114 mm. It is possible to transport the motor and the anti-torque section inside these tubes to economise on space and to prevent them from damage during transport.

The pulley, with a diameter of 50 cm, is fastened to the top of the mast. The depth of the drill is determined by counting the passage of magnets positioned around the circumference of the pulley. An accuracy of ± 10 cm was achieved, but this seems to be insufficient to determine the position of the cutter head satisfactorily.

ELECTRICAL SYSTEMS

General data

On the one hand, the electrical system can be based on sophisticated electronic technology. On the other hand, the possibilities for repairing these parts in Antarctica are very limited. Therefore, two systems were developed with different methods of operation: a system with motor controllers and a system with electrical resistances. Both systems use 380 V three phase current with a minimum power of 3kW.

Motor controller system

Using this system, a desired value for the speed of the winch motor or the drill motor can be adjusted on the control panel. The current intensity needed to keep this value constant is regulated automatically. The electronic parts are contained in two boxes. The first contains an easily transportable control unit (Fig. 5a) that is connected by cables with the second box that contains all necessary electrical circuitry (Fig. 5b). These parts weigh 200 kg. Because some parts of the electronic system require a temperature above 5°C, a 2 kW thermostatically controlled heater is installed inside the second box. During operation, the electronic parts produce enough heat energy to keep the temperature above this level.

The following information may be read off at the control panel:
(a) speed, current and voltage draw of the drill motor and the winch motor
(b) the depth of the drill
(c) the tension in the cable
(d) additional information about the temperature levels inside the electrical system can be monitored by a multicolored light display.

System using electrical resistances

Electrical resistances are used for controlling the drill motor, the winch motor and the electrical brake. All parts of this system including the indicating meters are installed on one control panel that can be easily transported. Operating this system is not as convenient as the other system, but it may be repaired more easily. This unit was also tested during the expedition and was found to operate satisfactorily.

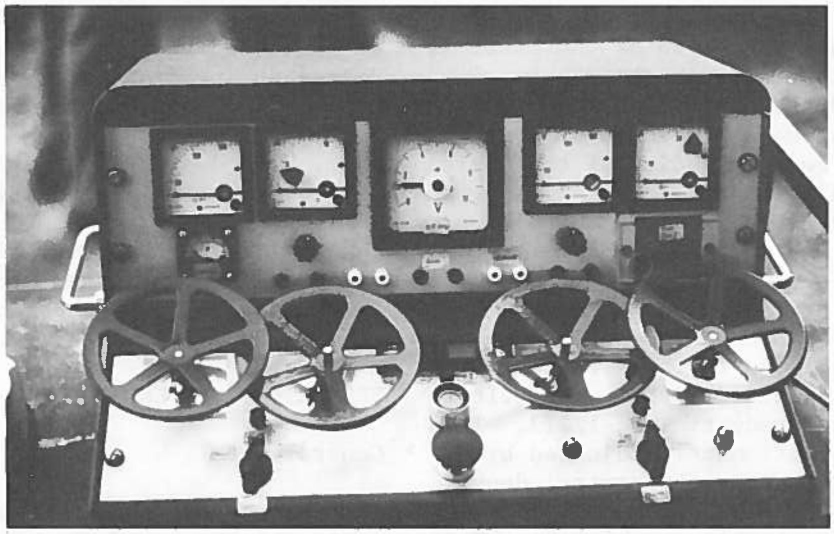

Figure 5a. Control panel for the system with the motor controller.

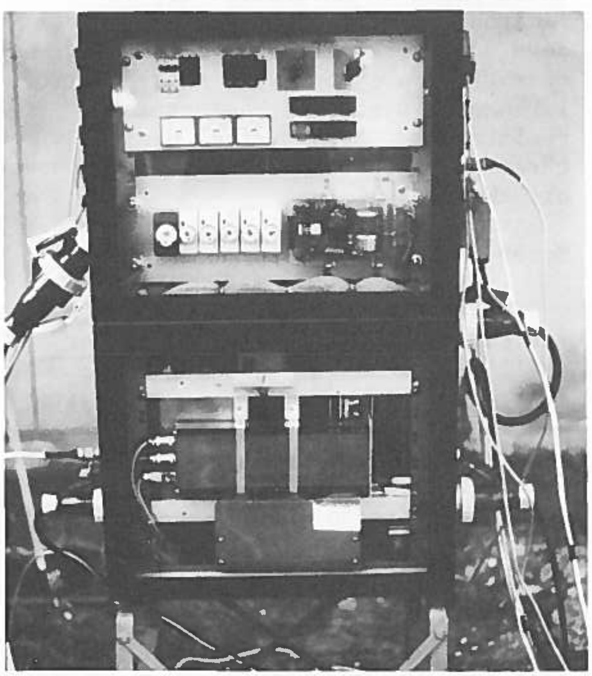

Figure 5b. Electronic rack for the system using motor controllers.

The information indicated on the second control panel is the same as before except the depth measurement is missing.

DRILLING DURING THE 1981/82 EXPEDITION

During the 1981/82 season the drill was deployed for two reasons:
(1) to obtain *in situ* measurements of the deformation behavior of the Ekstrom Ice Shelf, and
(2) to retrieve cores from those boreholes for mechanical and chemical investigations.

The conditions during drilling were good because of the proximity of the Georg von Neumayer station. The drilling took place inside a newly built shelter. Only the drilling time was restricted because of the installation of the measurement system into the boreholes and of additional research projects on the Filchner Ice Shelf. The borehole depths and the drilling times are shown as follows:

Borehole	Depth	Dates
B 3	73.60 m	13-17 Jan. 1982 (includes tests)
B 4	51.65 m	26-27 Feb. 1982 (12 hours drilling)
B 5	20.00 m	27 Feb. 1982

During the drilling of the B 3 borehole the quality of the ice core was unsatisfactory because of "discing" of the core below 45 m depth. By re-grinding the blades better results were obtained. At B 4 these difficulties did not appear.

The inclination of the borehole was later measured and at a depth of 45 m in B 3 an increase in slope of 0.5° was found. This possibly had an effect on core quality at this depth and below.

IMPROVEMENTS TO THE DRILL

The experiences derived from the 1981/82 expedition resulted in some improvements to be made in the drilling equipment. Those improvements are as follows:
(a) the installation of a new Kevlar armored cable with a weight of 13 kg/ 100 m and a breaking strength of 1000 kg.
(b) the manufacture of a new winch for this cable. This weighs about 100 kg.
(c) the installation of another anti-torque system using plate springs as used by Rand (1976), Gundestrup *et al* (1984) and Holdsworth (1984).
(d) the use of another depth measurement system using a mechanical device.
(e) several improvements were made to the electrical system to improve control of the motors.

This new drill will be used during the 1982/83 Antarctic expedition.

ACKNOWLEDGEMENTS

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