ELECTROMECHANICAL ICE CORE DRILLING SYSTEMS : A DISCUSSION

by

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INTRODUCTION

The following is a summary of comments presented during an open discussion on electromechanical ice core drilling systems at the Workshop on Ice Core Drilling in Grenoble, France on October 10, 1988.

Comments regarding the characteristics of existing ice core drilling systems are attributed to the respective laboratory or institution by the following abbreviations : AWI - Alfred Wegener Institute, Federal Republic of Germany ; ILTS - Institute of Low Temperature Studies, University of Hokkaido, Japan ; PICO - Polar Ice Coring Office, University of Nebraska-Lincoln, U.S.A. ; UBern - Physics Institute, University of Bern, Switzerland ; UCPH - Geophysical Institute, University of Copenhagen, Denmark.

The discussion of electromechanical ice core drilling systems proceeded with the identification of major drill components and the various approaches, design criteria, fabrication techniques, and field experiences related to each component.

DRILL HEAD

Cutters.

The cutting angle should be 45 degrees with a 15 degree relief angle. There should be a relief angle on the I.D., none on the O.D. UBern has tested a precutter on the I.D. which cuts a 1.5 mm etch on the core prior to cutting with the main cutters. Coarse chips should be produced by the main cutters, of which there are usually three or more. The cutter shapes recommended for use after pore close-off are : flat cutters with an inside radius (UCPH), double-angle cutters (PICO), round cutters (AWI).

Penetration Shoes.

It was generally agreed that penetration shoes are indispensable. Shoes should be used to control the patch angle which is recommended at 1.2 degrees normally, 1.3 degrees in warm ice, and 1.1 degrees in really cold ice.

Core Catchers.

Core catchers, also known as core dogs, should be positioned as low as possible in the head. They should have the same cutting angle as the cutters (30-45 degrees), and must be kept very sharp to achieve the best core-break. Springs should be used to keep the core dogs upright during drilling. Core dog mechanisms should be kept free of ice and snow chips. Alternative core-break techniques (e.g., sawing) should be investigated to enhance core quality at the break.

Rotation Speed.
The following recommendations were made : 1.2 revolutions per second or 100 rpm (UCPH, PICO), 50-150 rpm (UBern), although rotation speed may vary with the chip removal system selected.

Brittle Zone.
The ultimate goal is to drill to the brittle zone in an open hole while collecting good quality core.

BARRELS

Outer Barrel.
The clearance between the O.D. of the outer barrel and the borehole wall is recommended at : 1 mm (UCPH), 2 mm (PICO), 3 mm (ILTS). The outer barrel specifications vary as follows : 2 mm wall thickness with three ribs 2 mm thick attached to the inside of the barrel (PICO), 2 mm wall with five ribs 1.5 mm thick (UBern), 1.6 mm wall with ribs 0.7 mm thick (ILTS), while UCPH uses a 2 mm wall with a series of grooves 1 mm deep in order to conserve space.

Inner Barrel.
All participants use spiral flights attached to the O.D. of the inner barrel to move chips upward from the cutting head to the chip storage chamber. High-density polyethylene is the preferred material for the flights. The recommended pitch of the flights is : 180 mm per revolution for 78 mm core diameter (UCPH), or 45 degrees (PICO). Recommendations for the number of flights include : should match the number of cutters for the first 20 cm above the bits (PICO), and four flights for the first 15 cm, then two flights along the entire legth of the barrel (UBern). Flight thickness is recommended at : 3 mm (ILTS), 8 mm (PICO), 6.5 mm (UCPH). Clearance between the I.D. of the inner barrel and core is suggested at : 0.5 mm (AWI), 1 mm (UCPH), 1.5 mm (PICO), 2.5 mm (ILTS). All inner barrels should include some sort of suspended (not free floating) device to separate the stored chips from the ice core ; UBern, PICO and UCPH use a polyethylene disk or "little men" suspended by a string from one of the inner barrel chip ports. The I.D. of the inner barrel should be very smooth so the core is not affected by the barrel rotation.

Barrel Materials and Specifications.
The inner barrel should not be more out of round than one-half the clearance between the core and inner barrel wall : the greater the clearance, the more out of round the tubing can be. PICO requires a concentricity of < 0.1 mm and a straightness of 0.04 inch per 12 feet. Acceptable tubing can be gotten by personally selecting tubing from the manufacturer or vendor (UCPH, UBern), or by specifying custom tubing from a manufacturer such as Kaiser Rollmet (PICO). Irregularities between inner and outer barrel can be overcome by machining the flights so that the inner barrel rotates freely inside the outer barrel. While most barrels used today are steel, composite barrels should be experimented with since they can be made more round and straight than steel tubing, flights can be wound as an integral part of the barrel, and the inside of the barrel can be slightly tapered to allow easier core removal.

TORQUE RESTRAINT AND DETECTION ; SLIPRING

Anti-torque Mechanism.
A variety of anti-torque mechanisms have been used. UCPH uses three leaf springs clamped at both ends with a very sharp edge on the corner of the flat blade surface (see N. Reeh contribution in the Calgary Ice Drilling Technology Workshop volume). PICO uses three leaf springs clamped at both ends with the springs angled outward so the edge cuts into the hole wall. AWI uses three blades in the original design by H. Rufli. UBern's latest design uses rollers on the blades (or skates) which may protect the hole wall better in firn. ILTS cuts grooves in the hole wall.

Hammer.
Participants generally agreed that a hammer built into the drill as high as possible was a good idea. The deeper one drills, the more one is needed to break core and free a stuck drill. It was recommended that the hammer should weight a minimum of 10 percent of the total drill weigh and have about 10 cm of travel.

Rotation Detection.
Some device for detecting drill rotation is a good idea in both routine and test situations.

Slipring.
The slipring assembly preferred by UCPH is a simple version inside the drill hammer. PICO, UBern and AWI buy more expensive but excellent commercial sliprings from IEC Corporation.

Drill Recovery.
To ease recovery of a lost drill that breaks free of the cable, add a hook to the top of the drill for better grabbing by a fishing tool.

CABLE

There is a choice of cables, both in terms of electrical conductors, strength, durability, weight and armor material. The two primary choices are steel or kevlar reinforced cables, both of which can be bought with shielded conductors for the 300-400 m depth applications. Steel has the advantages of being stiffer, more durable and longer lasting, with the disadvantage of being heavier. Kevlar has the advantages of being lightweight with the possibility of including fiber optics ; and the disadvantage of being more elastic than steel. Cables seem to be a matter of personal preference.

TOWER AND WINCH

Tower.
There are essentially three tower options available : the vertical mast, a tilting tower or a horizontal tower. PICO uses a single round fiberglass mast 15 m tall, assembled in sections of tubing joined by aluminium couplers and guyed in place. The mast is 10-15 m tall, and is not stiff enough for a long drill. UBern uses a triangular ladder mast assembly which permits one to climb up the mast. AWI uses a single tubular mast. UCPH uses a tilting tower mounted on a sled. This short tower causes some problems with self-spooling of the cable on the winch.

Winch Base.
The winch base should be kept stable and level during drilling.

CONCLUSION

Each participant offered specifications of components and field experiences with new and existing components.