DESIGN AND LOGISTIC REQUIREMENTS FOR ICE CORING AND SAMPLE RETURN FROM REMOTE HIGH ALTITUDE LOCATIONS

by

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ABSTRACT

Ice coring and sample return from remote locations above 5,000 meters accessible only by foot or pack animals presents some interesting design challenges. Projects in Peru and China have demonstrated that good quality cores to bedrock can be retrieved and samples returned in a frozen state for detailed laboratory analysis.

A description of the drilling systems, power sources applicable to high altitudes, and equipment/core packaging for long rough journeys will be considered.

Electromechanical and thermal drilling systems will be discussed along with the use of composites, solar, wind and mechanical generation systems.

INTRODUCTION

During the 1984 Drilling Symposium in Calgary, I proposed a drill system based on the use of Kevlar reinforced electromechanical cable and lightweight components that could be dissassembled for use in remote areas of the world. A limit of 25 kg for any single piece was established to allow for backpacking equipment into remote mountain areas. This equipment is also robust enough to handle drilling conditions and the cold ice of Antarctica.

From a design standpoint, a way of reducing core break from over 2,000 kg force to under 100 kg was the first requirement. The second requirement was to reduce cable weight without creating high resistance in the conductors to allow use of thermal or electromechanical drills. The third and fourth requirements were to keep power generating equipment manageable and provide light yet comfortable shelter for living and processing core.

In 1979, an attempt to drill a 100 m core on the Quelccaya Ice Cap in Peru failed because a helicopter could not carry equipment to the summit. Since the equipment was too heavy to backpack attempts at drilling were abandoned.

As a result the PICO hand auger was developed to push the coring capability deeper while a more portable system was developed. A primary consideration was that this system had to be robust enough to handle much colder ice in Antarctica and Greenland.

In 1981 drilling at South Pole using

inefficient coredogs to break the core caused breaks approaching 3,000 kg with 10 cm core were experienced. Efficient core breaking devices were developed and successfully tested the following season reducing the core break to less than 100 kg.

Once this was demonstrated the way was clear to use kevlar reinforced electromechanical cable, reducing the cable weight by a factor of three. This made it possible to reduce mechanical requirements to a point where all the mechanisms involved could be kept under 25 kg. Thus the system could be trasported anywhere a person could walk.

This system was successfully used in 1983 on Quelccaya to drill two holes of 163 and 154 m to bedrock at an altitude of 5,700 meters. During the summer of 1987 the system was again used on the Dunde Ice Cap in China to drill three holes to bedrock at 135 m. In the same time period similar systems have been used in Greenland and Antarctica to collect nearly 1000 m of core annually in boreholes to depths of 300 m.

Flexibility is the key to design of this system. Since permanent magnet DC motors are used throughout many power sources from solar to engine driven generators are available.

Solar power is the favorite since it does not contaminate the area, is noiseless, and requires no maintenance. It also does not work on stormy days when one should not be drilling anyway.

Solar panels can be expected to provide from 110 to 130 % of their rated performance largely because of reflected light from the snow surface and increased efficiency in colder climates. This is indeed refreshing compared to a 50 % decrease in engine driven generators at the 5000m level.

A standard set of reversing switches rated to twice the expected voltage should be considered since decreased atmospheric pressure increases likelihood of arcing. The addition of a variable resistor provides the necessary motor speed control. There is no need for batteries or any electronic widgets rendering the system virtually indistructable.

Since renewable energy sources are desirable from a standpoint of no contamination windpower is always a consideration. Of the many types of generators available, the vertical axis wind turbine is an example. Few areas of the planet have the favorable steady winds of 30-60 km/hr. The technology is off the shelf but siting is a problem.

The least desireable but sometimes necessary use of engine driven generators is inevitable. Because drilling on Dunde was done in the stormy season, a single cylinder ultralight two cycle engine made by Rotax was chosen to drive a 5 kW alternator. This engine is rated at 20 kW at sea level which extrapolated to the 500 mb level is 10 kW. The system functioned flawlessly and arcing in the generator was not a problem.

In this case the AC voltage was varied using an auto transformer, then rectified with a bridge diode. To date we have experienced no failures with this system despite the low inductance of the DC motors.

Two drill types have been used, on thermal and the other electromechanical. Since ice caps at low latitude, high altitude locations are generally warmer than -10°C, both give good quality core.

The thermal drill used on Quelccaya consists of a ring of stainless steel 5 mm thick which has several wraps of hermetically sealed heater brazed to it. This heater is 1.2 mm in diameter and can dissipate in excess of 50 W/cm. Since the heater length in this case was 2 m over 8 kW could be dissipated. In a 10 cm ring 5 mm thick. At 4 kW film boiling begins to occur around the heating element limiting the power.

The robust nature of this heater is demonstrated by the fact that the heater and core barrel were dropped several feet onto concrete but continued to function through the entire season and is still functional.

A pressure test of the heater was conducted demonstrating a capability of surviving 1,500 bars of pressure suggesting no theoretical limit to its depth capabilities. Since the rest of the drill is a 5 mm thick 10 cm tube, there is nothing to limit the depth capaility.

A standard PICO electromechanical drill was used on Dunde in 1987 providing good core and 100 % recovery to the bottom. The only change required was to increase penetration rate to 1.3° from the normal 1.2° to compensate for the warmer ice.

More extensive use of composites in the drill barrels would aid in the transportability of this drill. This is mainly a consideration because of their ability to resist damage when encoutering rocks.

Packaging equipment for transport by horse or man is interesting. Generally the packaging must be light, strong and humane. Hardigg shipping containers made of polyethylene meet all the above criteria. Generally size should be limited to 60 cm x 20 cm x 60 cm for comfort to the animal.

Solar panels were packaged in canvas bags padded by 2 cm of foam protected on the outside by .5 cm plywood. This provided protection adequate for the panels to survive being rolled on by the horses.

Retrieving ice core from remote areas as ice core has become a reality. To do so means keeping it below freezing for periods of up to 5 days in 30°C heat.

Insulated Shipping Containers of California supply boxes of expanded polyurethane foam bonded to cardboard inside and out. The bonding process provides a trong and lightweight box that can be tied a horse with 50 kg of core and survive the trip.

The addition of a eutectic mixture such as blue ice around the core tubes provides a cold storage mechanism twice as effective as dry ice. By choosing a mixture that freezes at -5°C the material can be frozen at night on the glacier surface in preparation for the return trip.

Using the above mechanisms, 100 m of ice core was successfully returned to Ohio State University for analysis.

CONCLUSION

We have shown that it is possible to work in high altitude remote environments and retrieve good quality scientific ice core samples. Additionally, it is possible to retrieve these samples from the field in a frozen state and return them to the United States for analysis.

To do so requires a multidisiplinary approach and a lot of experience to cope with the different conditions in ice and environment. With available equipment it appears that a practical system limit is 7,000 m with an engine driven generator and unlimited with solar power. The only limiting factor is human performance which, at that altitude, remains unknown.

Low tech solutions generally are the best performers. Simple systems are required since the investigating team is working near the edge of human performance with potentially dangerous machinery.

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