THE USA CRREL SHALLOW DRILL

John H. Rand
U.S. Army Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire 03755

ABSTRACT

The USA CRREL shallow drill is an electromechanical device designed for continuous coring in firn and ice to a depth of 100 m. The drill bores a 14-cm-diameter hole while obtaining a core 10 cm in diameter at a penetration rate up to 1 m/min in -20°C ice. The cuttings are transported by spiral brush auger flights to a container above the core-storage section. The core and cuttings are removed from the drill after each 1 m run. Additional components include: 100 m of a seven-conductor electromechanical cable, a 6.8-m tower, a hoist which is ski-mounted, and a three-phase 220-V AC gasoline generator. All the equipment has been designed to be transported in a Twin Otter ski-equipped plane and assembled and operated by two men. The total weight of the drill and associated components is 818 kg. The minimum estimated time required to drill 100 m and retrieve core is 15 hours.

Introduction

The USA CRREL shallow drill was designed with the following objectives: To drill as rapidly as possible through firn and ice to a depth of 100 m with a device which could be transported by light aircraft into the field. The design is based upon information and experience obtained over the many years of CRREL's active involvement in ice-core drilling.

The first version of the shallow drill was tested at Station Milcent, Greenland (70°18′ N, 44°33′ W) during the 1973 Greenland Ice Sheet Program (GISP-73) field season. Although the motor and antitorque system proved to be undersized, the principle of having an auger suspended by a cable and driven by a downhole electric motor was valid.

Since the University of Bern, Switzerland, was developing a similar drill the design of the CRREL shallow drill was modified so that it could drill to greater depths (up to 500 m) by increasing the length of the cable. To take advantage of the increased depth capability the overall diameter of the drill was increased so that the existing down-borehole sampling equipment could be used in the hole produced by the shallow drill. This change made it possible to obtain a larger diameter core which is desirable.

During the GISP-74 field season the modified CRREL shallow drill was tested at Station Crête, Greenland (71°07′ N, 37°18′ W). Results from this testing are covered later in this report.

Equipment

The drill and related equipment has been designed for continuous coring in firn and ice to a depth of 100 m. The drill itself is 3.6 m long and weighs 65 kg (Fig. 1). The hole that is bored is 14.2 cm in diameter and the core retrieved has a diameter of 10 cm. Incorporated in the cutting bit are two independent methods of catching the core. The first method is similar to that of the SIPRE hand auger, that is, machined along the inside circumference of the cutting bit is a taper of 1-3/4°. This surface, along with the loose cutting, produces a wedging effect when lifting the drill, thus breaking the core at that location. The second method is similar to the principle used with the thermal drill. This method has two spring-loaded lever arms which cut into the core when the drill is lifted upon the completion of the drilling cycle. The cutting bits and core catcher are connected by four bolts to the inner barrel bottom flange.

The inner barrel consists of a 2.5-m stainless-steel tube, 10.8 cm outer diameter with a 4-mm wall. Two spiral nylon brushes are epoxied on the outside of the tube to form a two-lead auger flight with a pitch of 10 cm. The cuttings produced at the bit are transported by the auger flights to an opening at the top of this section. They are then deflected to the inside of the inner tube. Upon entering the tube they fall to rest on top of the core as it enters from the bottom through the bit. The nylon spirals also act as a bearing surface between the inner and outer barrels.

The outer barrel consists of a steel tube 2.5 m long, 14 cm in outer diameter with a 4-mm wall thickness. The functions of this outer barrel are to provide a continuous surface for chips to move along, to aid in providing a rigid drill required to drill a vertical hole and to help reduce the effective torque that the antitorque system has to react against. The outer barrel is connected to the top of the motor and gear section enclosing the entire bottom length of the drill.

The motor and gear section is composed of a submersible pump motor coupled to a planetary gear adapted from an air motor used for grinding operations.

The specifications of this section are as follows: The motor is a 1.5-hp, three-phase, 220-V, AC, 60-cycle motor which rotates at a speed of 3450 rpm. The gear reducer, which has a ratio of 34:1, reduces the actual rotation of the output shaft to 100 rpm. The gear reducer is attached to the motor with a splined shaft connecting the two units.

The antitorque system consists of three leaf springs, 120° apart. The springs are 3.8 cm wide with a radius of 76 cm. The effective length of engagement with the wall of the hole is 76 cm.

To attach the drill to the cable, a termination is made where a small length of the armor braid is twisted around. The electrical leads continue straight through this termination. A low-melting alloy (Cerro bend) is used to provide a potting compound. This material melts at 70°C, and is poured into a cavity where the twisted armor braid is placed.

During the early stages of the shallow drill's development, the existing thermal drill's base and tower were used. Since then, a base and tower unit has been assembled. This consists of 100 m of cable, a generator, a hoist, and tower.

The electromechanical cable is 0.95 cm in diameter. It consists of two outer layers of steel armor which support the drill, and seven conductors which provide the electrical connection to the motor. The cable is spooled onto an aluminum drum in an orthocyclic winding pattern. The cable end is attached to a slip-ring assembly for continuous transfer of power.

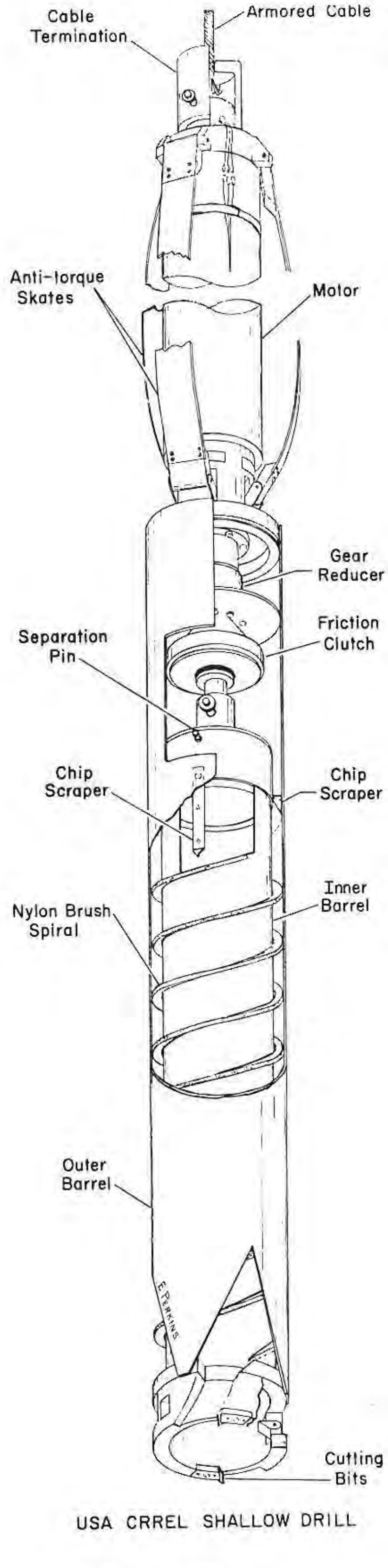

Figure 1. Schematic illustration of CRREL drill.

The drum is connected by a chain drive to a gear reducer. On the input side of this gear reducer and in line with a 3-hp motor, 3-phase, 220-V, 60-cycle, AC motor, a clutch is provided for the hoisting operation. The hoisting speed is 60 m/min.

Power for both the electric hoist motor and the drill motor is provided by a 5-kW, 3-phase, gasoline generator.

The tower section is in two parts. The lower section is a telescoping square tubular section. A mechanical screw jack is connected to a variable-speed DC drive motor which raises and lowers the internal section of this tower. This provides a method of controlling the penetration rate of the drill. In addition, it is this system which raises the tower to the vertical position. The top section is an aluminum-extruded tubing which is split lengthwise. This section also serves as a shipping container for the drill.

The entire rectangular aluminum base unit is mounted on three skis. The entire package can be easily disassembled and transported by light aircraft. The total weight of the drill and associated components is 818 kg. The unit can be towed behind a snow vehicle and transported across the snow at a good rate of speed. The entire operation has been designed so that two men can assemble and operate the system.

The drilling cycle starts when lowering the drill down the hole until the bottom is reached. The drill is located just off the bottom as the drill motor is started. The DC drive motor on the tower is started, lowering the tower and drill. Markers on the telescoping tower show when 1 m has been drilled. The drill motor is stopped, the winch slowly raised until core break is felt in the cable. The winch is fully engaged and the drill rises to the surface. Simultaneously the tower is returned to the original position. When the drill reaches the surface the core and cuttings are retrieved and the drill is sent back down again.

Performance

During the GISP-74 field season at Station Crête, several problems developed which made it impossible to continue the testing which was scheduled. Returning to the laboratory, modifications were made to the drill's gear reducer, reducing the final output speed to 100 rpm; several other modifications were made to the winch controls, making the overall system more adaptable for continuous drilling.

In September the drill was shipped back to Greenland for a drilling test at Dye 2. After field changes to the bits, the drill successfully drilled 100 m obtaining an excellent core. The drill was shipped directly from Dye 2 to Antarctica where two holes were drilled (Rand, 1975). The first 100-m hole was drilled in early November at the South Pole under the new geodesic dome. Excellent core was obtained in a record drilling time of 15 hr. Because of the -30°C temperatures the drilling was spread over a 2.5-day period. The second 100-m hole was located at J-9 on the Ross Ice Shelf (Fig. 2).

As mentioned earlier, with the successful drilling attempts of 100 m it is felt that with an increased length in cable and minor alterations to the base, this shallow drill could replace the well known thermal drill in drilling to intermediate depth in firn and ice.

Figure 2. Shallow drill in use during the 1974-75 austral summer field season, Antarctica.

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REFERENCE

Rand, John H., 1975, 100-meter ice cores from the South Pole and the Ross Ice Shelf: *Antarctic Journal of the United States,* v. 10, no. 4, pp. 150-151.