THE PICO INTERMEDIATE DRILL SYSTEM

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Abstract

The PICO intermediate drill is an electromechanical drilling system designed for continuous coring in firn and ice to a maximum depth of 600 m in an open hole. The drill collects 10.2 cm diameter core in runs of 70-150 cm length. A new cutting head includes three bits and core-catching dogs. The surface components, mounted on a platform, include a Lebus winch with grooved drum containing 700 m of seven-conductor electromechanical cable, a dual tower device, a 2.5 kW motor for high-speed raising and lowering of the drill, a 1.25 kW motor for control of penetration and core break, and a control panel. The winch platform, operators and core processing station can be accommodated inside a modified Hansen WeatherPort shelter. A 30 kW, 208V AC turbocharged diesel generator powers the winch and drill. The total weight of the drill system including winch platform, drills, generator and shelter is 6600 kg.

Introduction

The design of the PICO intermediate-depth core drilling system was based on information and experience gained in the design, modification and operation of the USA CRREL shallow drill (Rand, 1976), NSF-Swiss drill (Rufli et al., 1976) and the RISP wireline core drilling systems (Hansen, 1976). The main design criteria for the PICO drill system were: (a) to drill as rapidly as possible through firn and ice to a maximum depth of 600 m in an open hole; (b) to collect 10-cm diameter core in runs 70-150 cm long; and (c) to be transportable between drill sites by LC-130 aircraft using minimal tracked vehicle support at each drill site.

The downhole portion of the drill was designed and built at PICO in 1979, and has been used in conjunction with other winch systems during the 1979-80 and 1980-81 seasons at South Pole Station to a maximum depth of 108 m. The winch platform was designed and assembled at PICO during 1981-82, and was used with the downhole components of the PICO drill during 1982 at South Pole Station to collect core to a depth of 237 m.

Components

The PICO intermediate drill system consists of the following components: the downhole coring drill; the cable; a platform housing a winch, tower and instrument panel; a shelter; and a generator.

The downhole component of the drill collects a 10.2 cm diameter core and cuts a 14.1 cm diameter hole. It can be used in either firn or ice in an open hole. The drill consists of an antitorque section, a motor, gear reducer, outer barrel and rotating inner barrel, and the cutting head.

The antitorque system consists of three leafsprings, 120° apart. Its function is to prevent the rotation of the outer barrel and motor section while contributing toward vertical stabilization and centering of the drill during descent. Two sets of leafsprings are available for use in either firn or ice. The primary set has 3.175 mm thick x 25.4 mm wide skates of rectangular cross-section, having a double radius section of 35.5 cm and 40.6 cm, and an arc length of 81.5 cm. The material is 1095 carbon steel tempered to a C50-C56 Rockwell hardness. The second set of springs is made of 5056 steel, with identical radial configuration and temper, but with a 4.57 mm thickness x 35 mm width. Both sets of springs are available with square and 15° angle edges to provide options for use in various firn and ice conditions.

The drill is powered by a 440V, 3-phase motor which is regulated by a frequency controller that allows for a wide range of drill speeds (60-200 rpm) at the cutting head. The motor is coupled to a 17:1 cyclo-reducer, to provide adequate cutting torque, through a splined shaft that is coupled to the rotating inner barrel. Upon removal of a spacer ring, the combination of motor and gear reducer provides a hammer which can be used during penetration and core break. An optional 200V DC motor can be installed. It is encased in a protective barrel that prevents melting of snow around the motor section when the drill is used in warm ice. The controller used for the DC motor has a maximum output of 300V DC at 6 amps.

The aluminum cutting head houses the three cutters and three core-catching dogs. The function of these core dogs is dual: to create regions of stress concentration for ortho-axial core break, and to hold the core inside the inner barrel during the raising of the drill. An internal taper of the cutting head assists in gripping the ice core. The cutters and core dogs are made of 440-C stainless steel.

As the inner barrel and cutting head rotates, penetrating over the core, the chips are carried up two spiral flights fixed to the outside of the barrel. A reverse spiral at the upper end of this barrel forces the chips through a port where they fall into a chamber above the core. The spirals are made of ultra-high molecular weight polyethylene attached to the inner barrel by screws.

The electromechanical cable is a Vector A10182 standard logging cable with seven conductors, each #20 AWG or 0.36 mm diameter with Tefzel insulation. The breaking strength is 59600 N and the cable weight is 0.42 kg/m. Although the catalog specifies a 1.0033 cm outside diameter, a design value of 1.05 cm was used when specifying the winch drum. The cable is terminated and joined to the top end of the drill by an IEC slip-ring assembly that eliminates twisting of the cable if the drill section should spin downhole during antitorque failure.

The winch platform houses the winch, tower assembly and control panel. The 2.36 m x 2.49 m aluminum platform is supported by three wide-flange skis, and has four levelling jacks for use in positioning and stabilizing the unit during drilling. The winch, tower and control panel are bolted to the platform, and for transport or storage the entire unit is encased in an angle-iron and plywood container.

The Lebus winch has a drum grooved with 19 wraps between flanges that allows for orthocyclic winding of the cable. The drum capacity is 700 m, of which 600 m is available for use downhole, with the remaining 100 m providing a base wrap.

The winch drive system for lowering and raising the drill, and the drive mechanism for the control of penetration rate and core break, are permanently attached to the platform. A 2.5 kW permanent magnet motor coupled to the winch drum through a 54:1 hub reducer provides controllable line speeds from 15 cm/sec to 1 m/sec for raising and lowering the drill. A 1.25 kW permanent magnet motor is coupled to the main shaft through an electromechanical clutch, the 54:1 hub, and an 11:1 reducer with a 2:1 sprocket ratio. This provides delicate control of the drill's penetration rate and enables the operator to control core-break line tensions and speed whenever difficult core break situations arise. Speed control over this motor creates line speeds from zero to 5 cm/sec. The maximum line tension at low speeds is 49000 N. Both motors have regenerative braking, although this feature is intended for use only on the 2.5 kW motor system. On the side of the 54:1 hub reducer and directly attached to the drum is a disk brake, while on the opposite side an 8-conductor, 500V AC, amp, slip-ring is mounted on the shaft. The brake unit is mounted on a location allowing for easy inspection/servicing, and functions as a locking device or a drag-stopping brake.

The dual tubular steel tower system, 9.144 m long, can be assembled by joining five 1.83 m sections per tower in the horizontal position. The two tower sections are held together by a top connecting bridge upon which is centered the grooved sheave. Sheave cleaners and cable restraints are included on the sheave assembly to keep the sheave free of ice and the cable in place during high-speed raising and lowering of the drill. A two-point reactive load system provides a direct reading of the cable tension by way of a load cell on one side of the bridge. The sheave shaft is connected to a bi-directional depth counter and line speed indicator. After horizontal assembly the tower is raised to the upright position through use of a linkage system and cable grip hoist. The dual tower provides a rigid structure and allows the drill to hang free between them. The use of a 9.144-m tower system eliminates the need for a fleet angle compensator to be used in winding the cable on the drum. The high tower also allows the drill to be kept in the vertical position at all times, thereby reducing the risk of bending components, and eliminating the requirement for a pit or trench for use during removal of the inner barrel after each run. At the base of the tower, on the winch platform, is a combination cable guide and hole cover through which the cable passes. This device assures vertical alignment of the cable as it passes over the 60.9 cm diameter top sheave, through the platform, and down the borehole.

All instruments for the control and monitoring of the winch and drill are grouped on one panel, mounted 1 m above the platform surface overlooking the winch drum, tower and hole opening. Inside the heated panel are housed all necessary transformers, chokes and electronic equipment. Gauges are provided that allow the operator to monitor continuously the winch and drill current and voltage.

The generator is a 30 kW, 3-phase, 208-120V, 60 Hz unit, using a turbo-charged diesel engine proven operable at elevations up to 3700 m. The generator is mounted on skis for towing over the snow surface. A plywood shelter is used to ensure adequate cooling of the engine and to prevent blowing snow from entering the control panel.

A modified Hansen WeatherPort with arch dimensions of 4.57 m wide x 12.2 m long x 2.05 m high and covered by a 6-piece canvas cover, protects the winch system and drill operators from wind and blowing snow, and provides a core processing work area.

Drilling Program at the South Pole, 1982

The 1982-83 antarctic field season provided the first opportunity to test and use the complete intermediate drill system in a field situation.

Drilling took place in the center of the taxiway oval at Amundsen-Scott South Pole Station. The drill, platform and shelter were set up on a wooden platform after drifted snow and the past year's accumulation were removed from its surface (see Figure 1). A core processing and science trench (3 m deep x 3.5 m wide x 15 m long) was excavated parallel to the drill shelter, roofed with timbers and plywood, and a stairway and tunnel were constructed which served to connect the drill platform with the science trench. It took four people 2.5 days to assemble, erect and supply electrical power to all surface components of the camp (generator, two laboratory vans and the drill shelter).

Drilling started at a depth of 108 m in a hole drilled by PICO in 1980-81 with the same downhole drill. The DC drill motor was used all season. Bits with a 45° cutting angle were used first. These produced very fine chips which packed around the core inside the inner barrel, and caused the core to be twisted off at the base before completing a run. Attempts were made to remedy the problem by reducing the clearance between the core and inner barrel wall, increasing the cutting angle of the bits to 55°, and sharpening the cutters, but problem persisted.

Cutters with a 78° angle from horizontal and no adjustments for penetration eventually produced good core in 70-cm runs with penetration rates of .5 cm/sec to a depth of 215 m. Thereafter, core quality deteriorated, with frequent cracks and wafering occuring, and with the length of runs reduced to 30 cm and less. Unsuccessful attempts were made to drill using a new head and bit configuration designed and built at the University of Bern. Problems encountered with this head were that penetration was limited to 10 cm/run due to chips packing behind the cutters, and that packing around the core dogs resulted in failure to catch the core. Drilling was finally stopped

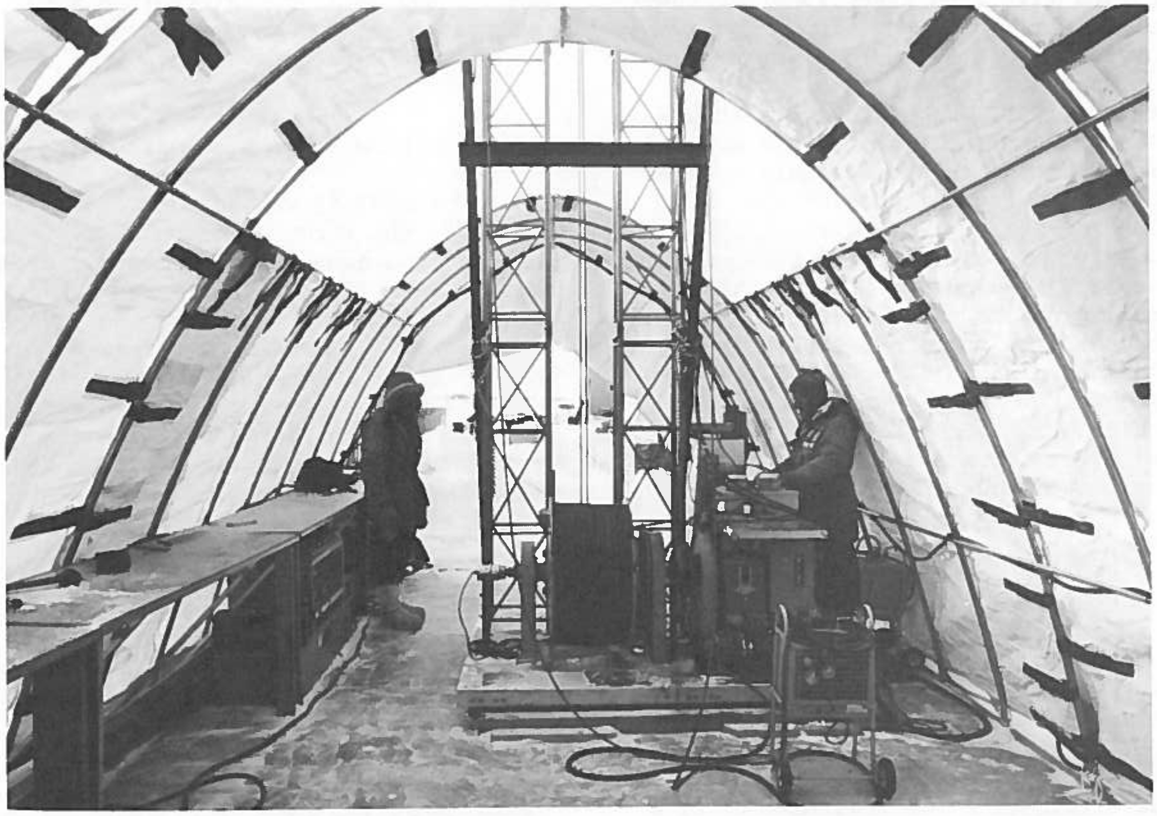

Figure 1. Winch platform including winch drum, tower assembly and control panel inside the canvas-covered drill shelter at the South Pole, December 1982.

at a depth of 237 m.

In summary, the new winch and drill system worked well; we experienced no mechanical failures, and only one electrical problem with the load cell readout which was later bipassed. The tower system took 6 manhours to assemble, yet was erected easily, provided a stable tower throughout the one-month season, and simplified and expedited the removal of the inner barrel after each run. The drill shelter with its 6-section canvas cover and Velcro tie-down straps was easily erected in 8 manhours, and provided a satisfactory windbreak throughout the field season. The drill head and bit designs are being reviewed, and will be redesigned or modified to provide improved core quality, penetration rate, and run length in the system's next field application.

Acknowledgement

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