THERMAL ICE CORE DRILL 4000

by

Augustin L., Donnou D., Rado C., Manouvrier A., Girard C., Ricou G.
Laboratoire de Glaciologie et Géophysique de l'Environnement du C.N.R.S.
St-Martin d'Hères, France

INTRODUCTION

The "Laboratoire de Glaciologie et Géophysique de l'Environnement" has developed since 1968 a thermal drill system, which reached 905 meters in depth during the summer season 1977-78 at Dome C (Antarctica).

In order to reach deeper layers, we had to modify the system for working in a fluid filled hole.

In 1981-82 in Adelie Land two sets of equipment for drilling in a fluid filled hole were tested (1). The results encouraged us to build a thermal drill with a 4000 m cable and associated winch.

In 1984 the L.G.G.E. has conceived and built a core drill able to take back 8 metres long ice cores in order to reduce operating time. Its implementation has required the use of composite materials.

DESCRIPTION AND RUNNING

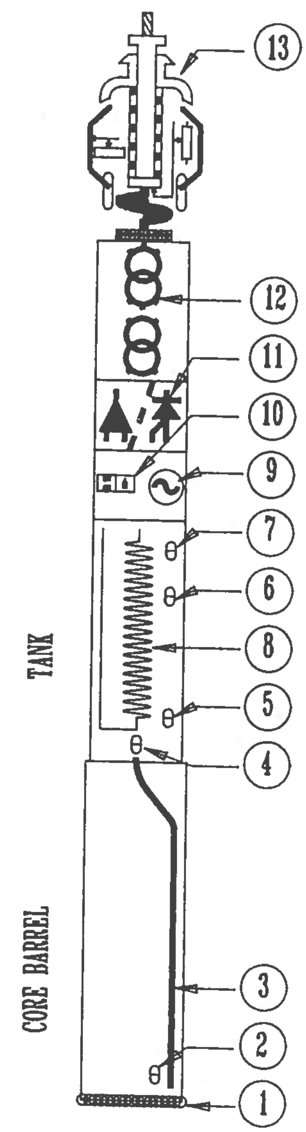

Figure 1 - Schematic diagram of the drill
(1) Bare resistance wire. (2) Temperature sensor : level of water in the hole. (3) Sucking tubes and its heating elements. Temperatures sensors : (4) sucked up water and running of the pump, (5) bottom of the tank, (6) middle of the tank, (7) top of the tank. (8) Tank heating element. (9) Pump. (10) Electrovalve. (11) Electronics. (12) Transformers. (13) Suspension.

The drill head is in contact with the bottom of the hole. The power is applied to the heater element, a bare resistance wire, causing the head to melt an annular space in the ice. The core passes into the core barrel. A temperature sensor is 10 centimeters above the drill head. This sensor gives us the level and the temperature of the water from melting. The melt water goes up in the three sucking tubes and arrives at the bottom of the tank where a temperature sensor gives information about the pump workings.

Three other temperature sensors allow checking of the water level in the tank.

When the temperature at the top of the tank is positive, we have to stop drilling.

Drilling fluid sucked up by the pump is replaced by meltwater in the tank. The electromagnetic pump always sucks drilling fluid, never water.

The electrovalve has two functions :

- It allows an air inlet at the top of the tank to empty it at the surface.

- This air inlet allows the filling up of the tank when the drill goes down.

The electronic section controls each part of the drill. Telemetering and remote control circuits are needed to transmit informations about drill operations from the drill to the control desk.

There are two transformers :

- A triphase one supplies the drill head.

- A single phase transformer supplies the electronic, the electrovalve, the electromagnetic pump, the water tank, the heater and the heater sucking tubes.

The suspension controls the pressure on heating head and also the verticality of the drill. There is also a device to measure hole diameter in this section. The anchoring of the cable is on the top of the suspension.

Except for the electronics, each part of the drill is at the same pressure as the drilling fluid. The total length of this thermal drill is about 22.4 meters.

DRILL HEAD

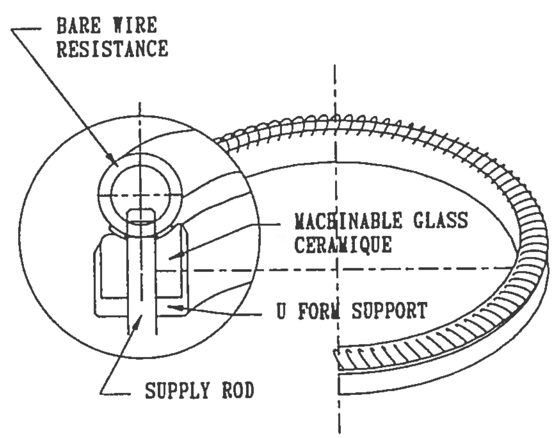

Figure 2 - Drill head

The drill head consists of :

- a spiral bare resistance wire fixed below a machinable glass ceramic insulator.

The resistance wire is made of Kantal. Kantal is a magnetic material, made of 22 % chrome, 5,5 % aluminium and 75 % iron. The Kantal has a good thermal resistance : 1375°C. Its tensile strengh is 750 N/mm^2. The wire diameter is 1,3 mm and its developed length is about 3,8 m. The heating power is 7500 w at 50 Vac.

The resistance is supplied in 3 points by copper rods soldered with silver. The wire resistance is fixed by 3 other rods on the support.

The machinable glass ceramic support is made of six sections and inserted in the stainless steel U form, which protects it from mechanical shocks. Ceramic type is "MACOR". Its mechanical strengths are good. Its thermal resistance is 1000°C continuously.

The drill head is an interchangeable part. This set up allows quick reparations.

PISTON EFFECT

The drill moves like a piston in the fluid filled hole. To reduce the resistance of this effect and increase the speed of the drill in the hole we have found several solutions :

- Only the core barrel has a 145 mm diameter, the other parts of the drill have an outer diameter of 130 mm.

- Four bored holes at the top of the core barrel avoid imprisonment of air bubbles. They allow fluid passage inside the core barrel when the drill goes down.

- Core barrel section shape allows a good fluid passage along the tube in spite of its 145 mm diameter. So the piston effect is located at the drill head.

- Flap valves on the drill head allow fluid passage inside the core barrel when the drill goes up with the ice core.

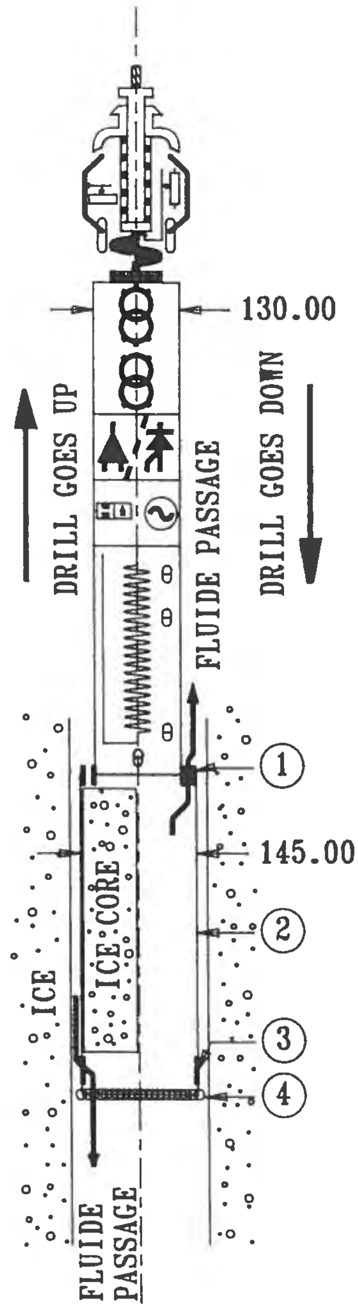

Figure 3 - Piston effect : Left part of the drawing : the drill goes up with the ice core inside the core barrel. Right part of the drawing : the drill goes down. (1) Four boring holes. (2) Core barrel section (see next paragraph). (3) Flap valve. (4) Piston effect zone.

CORE BARREL

The use of composite material is imposed by the length, the thickness and the particular shape of its section.

A combination of kevlar and carbon fibres gives an excellent tensile and compressive strength.

The core barrel was made in this laboratory. It was moulded around an aluminium core held vertically to avoid bending. The core barrel wall has seven fibre layers. First layer : fibreglass is teflon coated on one side. This surface allows easy release of the core barrel from the aluminium and also later for extracting the ice core from the drill. The second layer is made of kevlar fibres (300 gr mm^{-2}). The third is made of carbon fibres (200 gr mm^{-2}). The fourth is made of kevlar fibres again. Fibre-glass tubes are stiked on the fourth layer. They are used to insulate the three power supply rods, the temperature sensor and also used as sucking tubes. Then we find alternately a kevlar layer, a carbon layer and a last kevlar layer coated with white polyurethane.

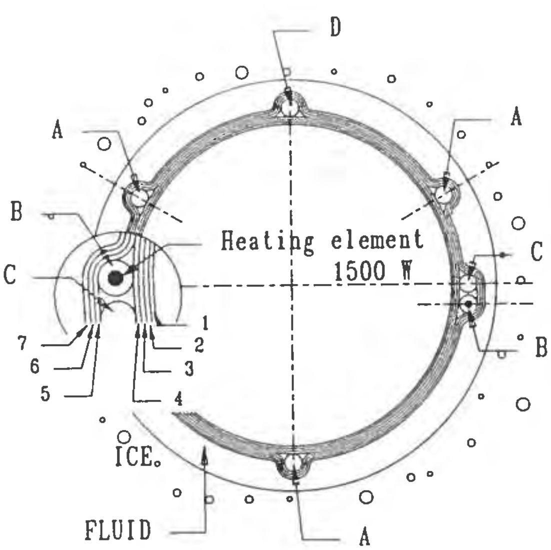

Figure 4 : Core barrel section. (A) Feeding drill head. (B) Sucking tubes. (C) Feeding heating elements of sucking tubes. (D) Tubes for temperature measurement. (1) Fibreglass and teflon. (2) Kevlar. (3) Carbon. (4) Kevlar. (6) Carbon. (7) Kevlar.

The resin used (E.P.O. 20-12 RESOLIN) is a bicomponent epoxy resin. Its reactive temperature is between 18 and 25°C. It is used for high performance composite materials. A cure during 24 H at 70°C gives 80 % of maximal mechanical strengths for pure resin. (Modulus of rupture 750 daNmm^{-2}, Modulus of elasticity 35000 daNmm^{-2}).

To insure a good mechanical link, stainless steel pieces were moulded with the core barrel on each of its extremity.

Core barrel dimensions :

Length	8,3 m
Outer diameter	145 mm
Inner diameter	125 mm

WATER TANK

As for the core barrel, the water tank is made of composite materials. After a first fibreglass layer with teflon there are three layers : Kevlar - Carbon - Kevlar. A layer of epoxy resin with silica micro-bubbles gives a good thermal insulation. Its thickness is about 5 mm. Then there are three other layers : Kevlar - Carbon - Kevlar.

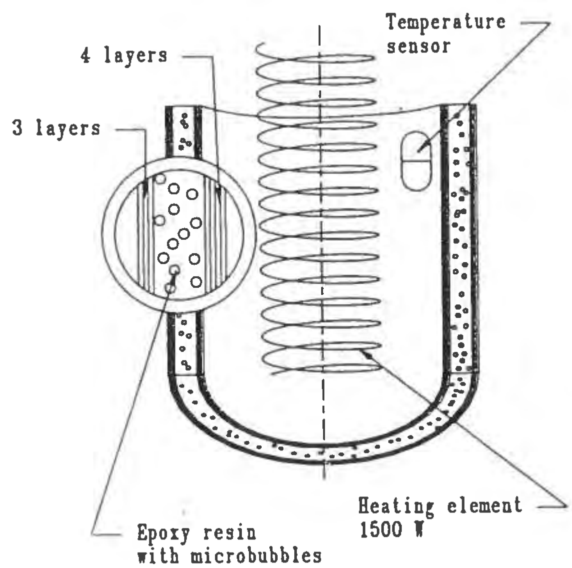

Figure 5 - Water tank

- Single phase transformers :

- Supply : Electronics, tube heater, tank heater, pump and electrovalve
- Surface tension fixed
- Out/put voltage is variable depending on the load
- Primary 1404 volts
- Secondary 335 volts

Dimensions :

Length	3 m
Outer diameter	130 mm
Inner diameter	125 mm

SUSPENSION

The suspension system is the top of the drill. It is directly connected to the cable. The cable is anchored with a double anchoring cone to the main piston. The piston holds the drill through a spring. A fluid shock absorber completes the spring action at its limit. It damps the stress when the ice core is extracted. The weight and the verticallity of the drill is controled through this connection. A threaded bush allows to regulate the tension of the spring.

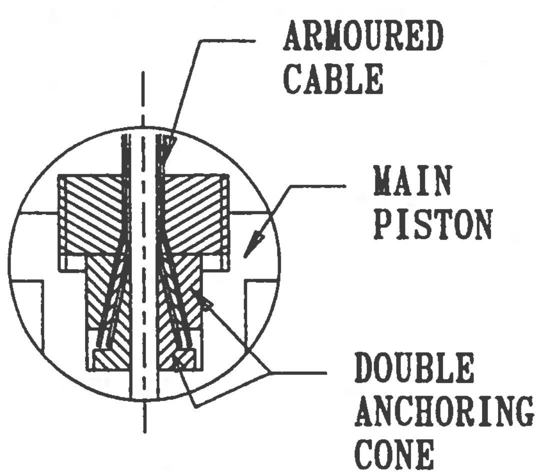

Figure 6 - Double anchoring cone

A sensor measures the linear displacement of the piston which is proportional to the pressure on the drill head. The top of the drill is centered by three pads maintained against the borehole wall. A second linear displacement sensor allows the measurement of the hole diameter through a link and a ring.

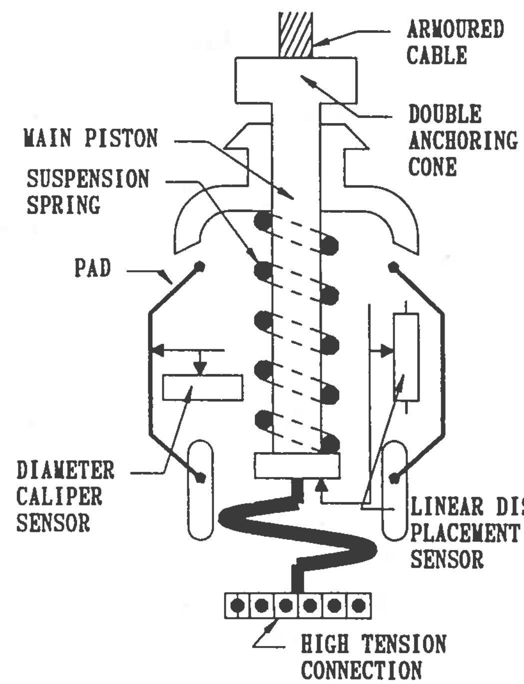

Figure 7 - Suspension

A high tension power unit supply allows to control supply voltage rapidly. All these elements are between three draw-bar. This set up allows adjustments, and manual interventions without disassembly.

Dimensions :

Length	1,5 m
Outer diameter	130 mm

Along the water tank axis, a bare electrical resistance wire heater is set up. It has a variable power along the axis to set a higher temperature at the bottom of the tank. Its maximum power is 1500 watts.

The control of the water filling is made by four temperature sensors located at different heights in the tank. This system gives informations on the pump running and the electrical power that has to be dissipated in the heating resistance.

Dimensions :

Length	5,8 m
Outer diameter	130 mm
Inner diameter	116 mm

PUMP AND ELECTROVALVE

The pump is connected to the top of the tank and sucks drilling fluid out of the tank. The electrovalve allows an air inlet at the top of the tank. A filter stops any particles which could disturb the pump operation. The pump flow is regulated by a manual valve. All these parts are standard industrial equipment.

Pump :
Electromagnetic pump GUINARD 2.9.300.10

- Power supply 220-230 volts
- Joints and ball valves : viton
- Suction head : 0,4 bars
- Tested several months in fluid at -60°C

Electrovalve :
Electrovalve JOUCOMATIC 14 00017

- Power supply 220-230 volts

Manual valve :
Valve SAGANA 2 F 4 AN

Filter :
Filter PORAL roasted bronze BL 32

Dimensions :

Length	0,5 m
Outer diameter	130 mm

ELECTRONIC COMPARTMENT

Electronic boards are fixed on stainless steel sections. The assembly is inside a fluid-tight compartment. This compartment resists 400 bars pressure.

The working of the electronics is described in "Telemetering and remote controls circuits for a 4000 m thermal drill" in this work.

Dimensions :

Length	2,8 m
Outer diameter	130 mm
Inner diameter	100 mm

TRANSFORMERS

Specially built transformers are located in a stainless steel tube. They are in an oil bath. A piston, which allows oil expansion, insures a seal with the outside.

Characteristics :

- **Triphase transformer :**

- Supply : drill head
- Surface tension 0 to 1236 volts
- Primary : 1236 volts
- Secondary : 60 volts

REFERENCE ARTICLES

(1) D. Donnou, F. Gillet, A. Manouvrier, J. Perrin, C. Rado and G. Ricou - "Deep core drilling : electromechanical or thermal drill ?" - Special Report December 1984 - Ice Drilling Technology - US Army Corps of Engineers.