A Borehole Probe for Sampling Groundwater from Selected Strata

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Abstract

A description is given of a borehole sampling device capable of collecting groundwater samples up to a maximum depth of 200 m. The device is designed for sealing off specific portions of a borehole to enable the water between the seals to be pumped to the surface for age determination or, alternatively, collected in canisters for trace metal and chemical analysis.

Introduction

Borehole water plays an important role in the water supply system to many users, especially in rural areas. Because of its value for drinking or agricultural purposes, it is essential that as much as possible be learned about groundwater systems. Questions such as the source, the subterranean movements, the age and the chemical composition of the water, are of great importance. The chemical composition of groundwater is also thought to be valuable for the purpose of mineralogical exploration. Small quantities of metallic minerals from ore bodies may dissolve in groundwater and the determination of the presence of traces of these metals in the water could lead to the discovery of ore bodies.

The answers to many of these questions depend on the subterranean geological strata and it is of great value to be able to sample water which comes from specific strata. To do this a probe has been developed that will seal off a borehole below the water table and allow only the water from the surrounding geological material to enter the sampling device.

This paper describes the probe and shows how water samples for age determination, chemical quality and trace metal constituents may be taken without contamination.

Description of the Apparatus

The method of obtaining the samples is shown diagrammatically in Fig. 1.

Prior to the probe being inserted into the borehole, a dummy probe is lowered to ascertain that the hole is clear to the depth at which it is required to take the sample. At the required depth below the water table, two concentric rubber bellows are inflated to seal off the borehole above and below the sampling

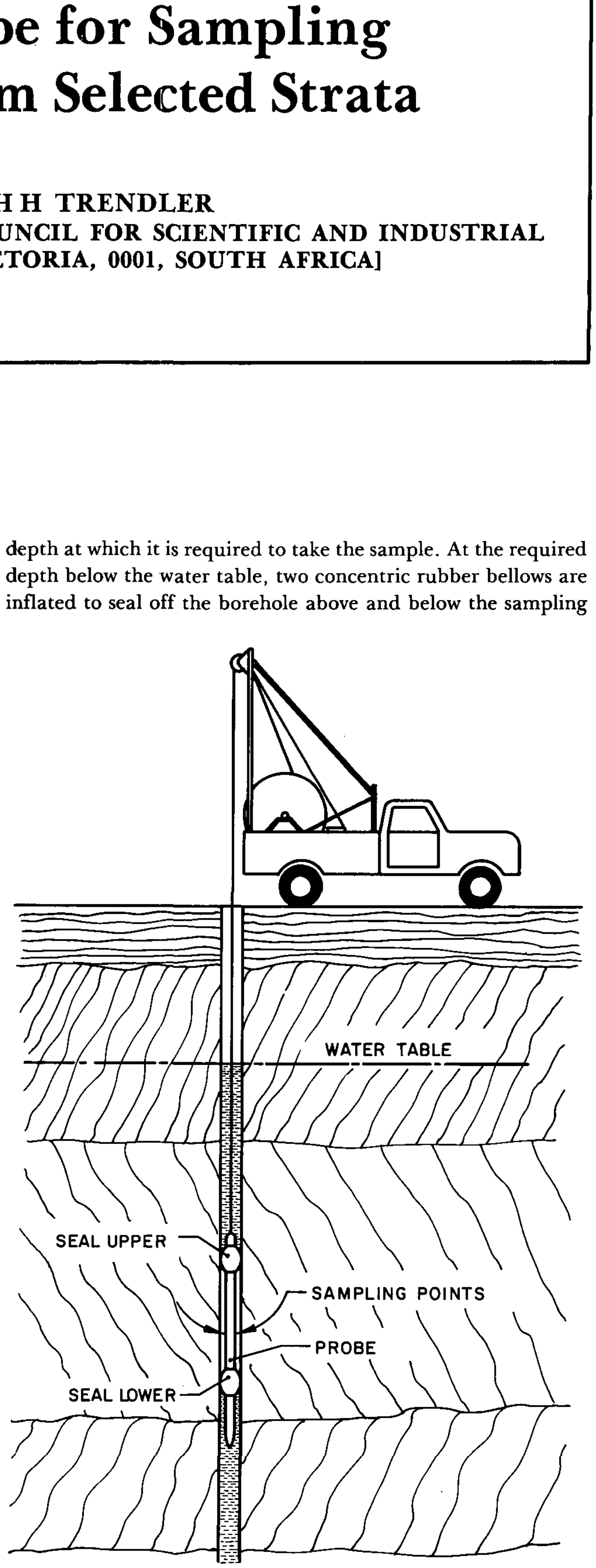


Figure 1
Diagram showing method of obtaining samples

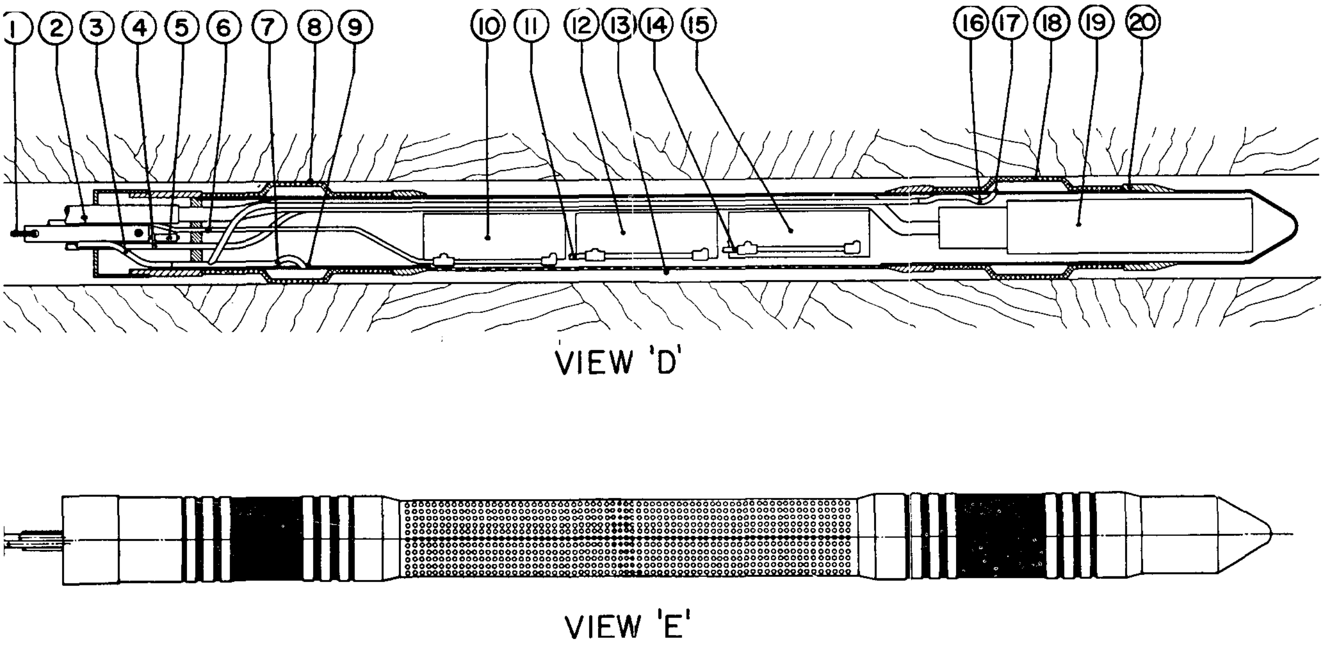


Figure 2
Schematic Diagram of Probe Assembly
(1) non-spin rope (2) plastic hose (3) plastic tube (4) electric power cable (5) water sensing mechanism (6)(11)(14) plastic tubes (7)(16) tubes (8)(18) rubber bellows (9)(17) holes through wall of pipe (10)(12)(15) sample cannisters (13) perforated door (19) submersible pump (20) removable end-piece
View 'E' shows the probe in its entirety (not to scale)

point on the probe. A submersible pump in the probe then pumps out the trapped water and allows fresh water seeping or flowing from the strata to fill the space between the two seals. The water is pumped out until it is clean, after which the relatively large sample volume (200 *l*) of water required for age determination by the carbon-14 method can be taken at the surface.

The sample required for the trace metal analysis must be taken very carefully, to prevent contamination, as dissolved metals are usually present in very low concentrations ($\mu g/l$). Contact with the usual iron or brass pumps and fittings cannot be allowed and, to obviate this, three special canisters have been incorporated in the probe housing.

The whole device consists of the probe, the sample holder canisters, a water sensing mechanism, a specially designed lowering device with electrical winch, clamps, and a drum to carry the electric cables and five plastic tubes. These are all mounted on the back of a two-ton truck, together with a dummy probe and a power supply for operating the pump and winch.

The Probe (Fig. 2)

Fig. 2 shows a schematic section of the probe (view D) and the complete probe (view E). Its length is 3,9 m, its diameter 0,127 m and its unfilled mass 90 kg. All metallic parts likely to come into contact with the water are made from pretested and analysed stainless steel which do not contaminate the samples.

The probe is comprised of three sections: an upper section, centre section and a lower section. The upper section is equipped with connecting points for a non-spin rope, the power cable, electric cable for the water sensing mechanism and the five plastic tubes. One of the plastic tubes delivers compressed air for the sealing bellows, three are for operating the sampling canisters and one enables water to be pumped to the surface. The centre section consists of a perforated plate which acts as a door to allow access to the three sample canisters. The lower

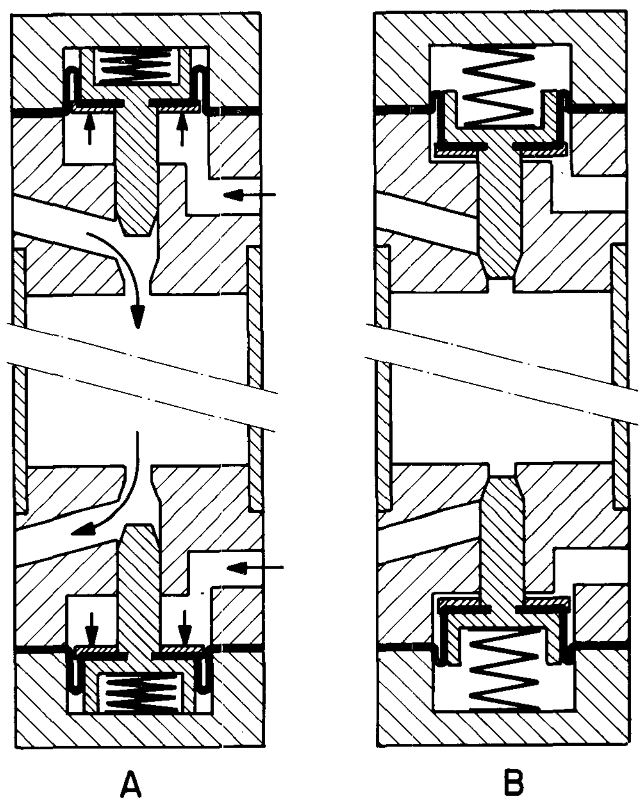


Figure 3
Schematic section of Sample Canister
(A: open position, B: closed position)

section houses the submersible pump with its electric motor.

The end-piece of the tube has a screw thread and is removable for easy service and maintenance of the pump and its filter. Two rubber bellows are mounted on the probe and cover two holes which are drilled through the wall of the pipe and connect to two tubes. Compressed air is supplied through these tubes to inflate the bellows.

The Sample Canisters (Fig. 3)

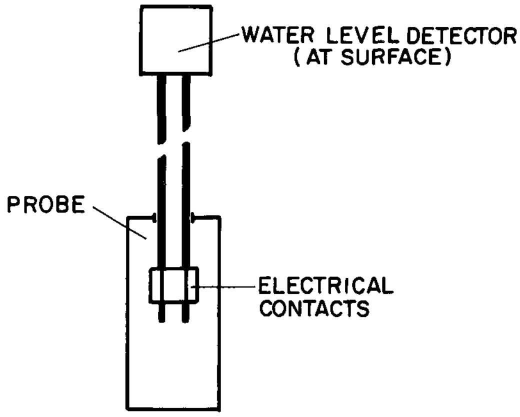
Fig. 3A shows the sample canister schematically in its open position. In this position water from the sampling space can flow freely through the canister. When the compressed air supply is turned off, the spring closes the valves, trapping the water sample in the canister. Fig. 3B shows the valves closed. All these canisters may be filled at one depth, or each at a different depth.

Each of the three sample canisters has a capacity of 1 *l* and is made of stainless steel, coated with 0,3 mm thick nylon. The plunger valve and its guide are manufactured from high-density polyethylene to avoid contamination even when the water sample is left in the canister for long periods of time. All other material which is not in direct contact with the sampled water, is of stainless steel.

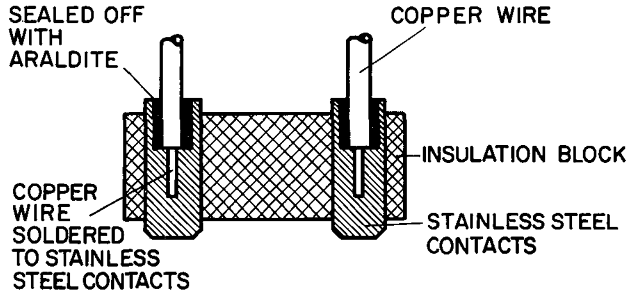
The Water Sensing Mechanism (Fig. 4)

The depth of the water in a borehole must be known before sampling can commence. A simple, yet very effective, device has been developed which enables the operator of the probe to ascertain this. Two stainless steel electrical contacts are set in an insulation block in the top of the probe. Insulated copper wire connects the contacts to a box on the surface containing a series of dry cells and a small transistorised circuit (Fig. 4C).

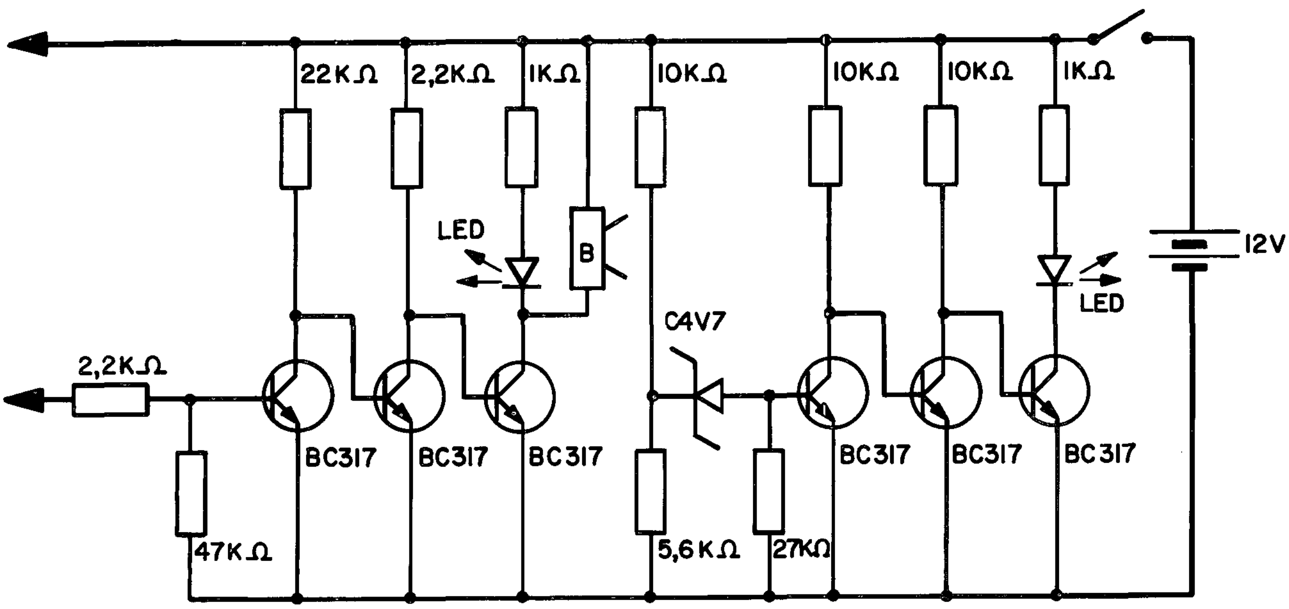
Figure 4
The water sensing mechanism



A. DIAGRAM OF WATER SENSING MECHANISM



B. DETAIL OF ELECTRICAL CONTACTS



C. ELECTRICAL DIAGRAM OF WATER LEVEL DETECTOR

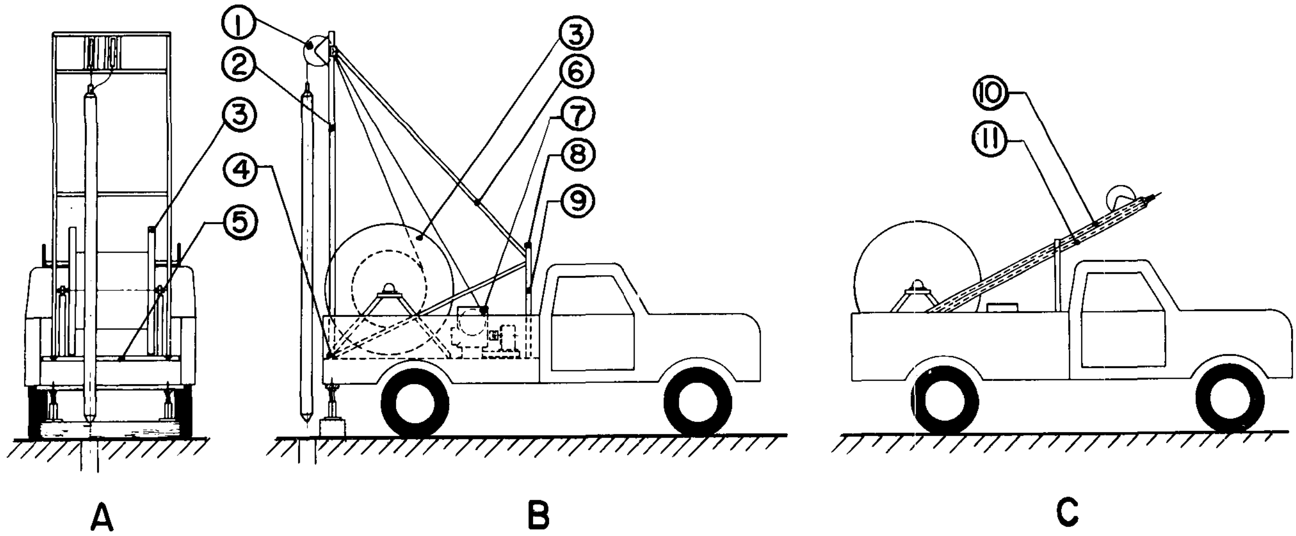


Figure 5

Equipment assembled in working position (view A and B) and stowed position (view C)
(1) pulleys (2) vertical beam (3) drum (4) lower mounting point (5) base-plate (6) struts (7) winch (8) attachment bolts (9) forward mounting beam (10) dummy probe (11) probe

When the electrical contacts touch water, the circuit is completed and current flows to activate a buzzer. The operator is, therefore, able to determine the relative depth of the water and lower the probe to the required borehole region.

The transistorised circuit is so designed that only minimal current is required to flow thorugh the leads to the probe, thereby reducing corrosion at the contacts and also enabling a very light connecting cable to be used.

The Electrical Winch

The winch, which is mounted on the back of a truck, is powered by a 2,2 kW, four-pole squirrel-cage TEFC reversing motor. A D.O.L. starter complete with isolator, enables the probe to be lowered, stopped and raised under the control of push-buttons. The probe is held at the required depth by means of an electro-mechanical brake. Power is supplied by a 7 kW, 220 V alternator driven by a 12 kW petrol engine.

The Drum

The drum carries the electric power cable for the pump unit, the electric cable for the water sensing mechanism, three plastic tubes for supplying air pressure to the valves of the sample canisters, a plastic tube for operating the bellows and a plastic hose for pumping the water to the surface. The cables and tubes are secured together by plastic cable ties to prevent separation and twisting. The drum rotates on two plummer blocks and can be stopped as required by means of a hand-brake.

The Lowering Mechanism (Fig. 5)

The mounting structure is manufactured from rolled standard steel sections. The electric power winch unit (7) and the drum assembly (3) are located on the base-plate (5). The complete assembly can be mounted on any lorry of suitable size and capacity.

Figures 5A and B show the equipment assembled in working position on a two-ton truck. The vertical beam (2) pivots about its lower mounting point (4) and is stabilised by two struts (6) which are attached to the forward mounting beam (9). For transportation purposes the two attachment bolts (8) are removed and the structure is folded into the storage position. The vertical beam also carries two pulleys (1).

When the tests at a specific borehole are finished the vertical beam, probe (11) and dummy probe (10) are stowed on the lorry as shown in Fig. 5C.

The Clamps (Fig. 6)

As the probe is lowered into the borehole, the electric power cable (4), the electric cable (5) for the water sensing mechanism and the plastic tubes (3) are secured to the wire rope (1) by clamps (2); the clamps are installed at approximately every 20 m. This obviates damage to the electric cable and plastic tubes which may result, due to the effect of their own weight.

Preliminary results

On arrival at the borehole the equipment was assembled in the working position, as shown in Figures 5A and B.

A surface test was made to check the performance of the rubber bellows. It was observed that an increase in diameter from 0,12 to 0,25 m was obtainable under pressure, without damage to the bellows. The probe was then placed into a steel pipe of 0,16 m inside diameter and pressures of up to 1 000 kPa were supplied to the bellows whilst water pressure was applied to one side of the steel pipe. No leakage was observed. Two tests were made at a depth of 40 m in a borehole of 0,2 m diameter to test the probe, the bellows and the lowering mechanism.

Before the actual tests started, a dummy probe was lowered into the borehole to test the borehole for straightness and obstructions. No difficulties were encountered and the tests with the actual probe were started.

The probe was lowered and the depth of the water table was determined with the water-sensing mechanism. The probe

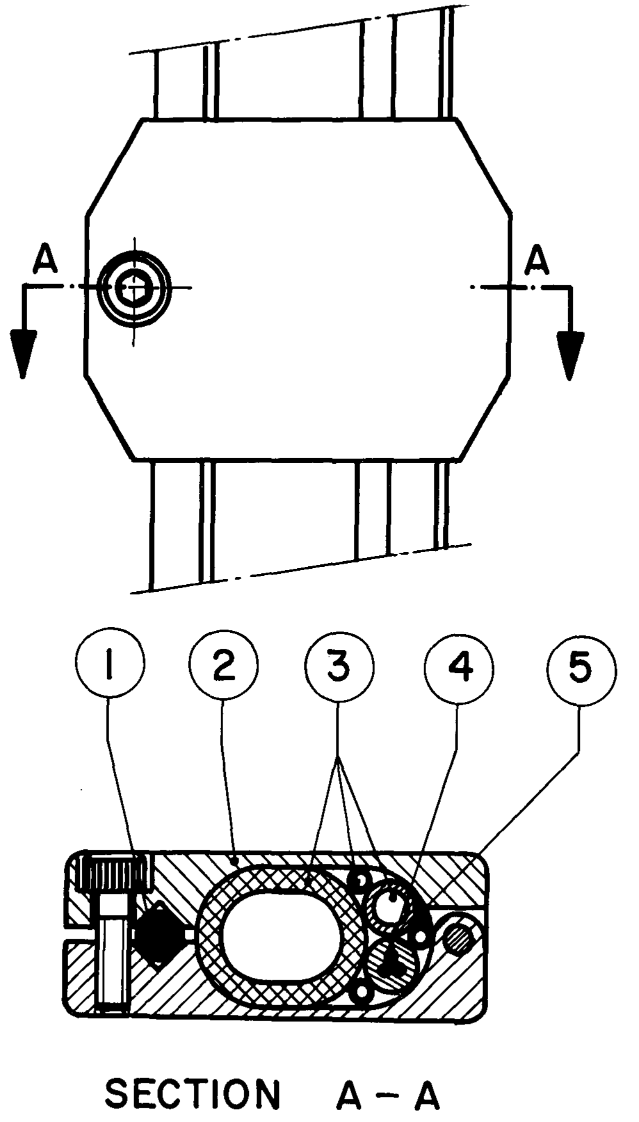


Figure 6
Clamp Assembly
(1) non-spin rope (2) clamp (3) plastic tubes (4) electric power cable (5) electric cable

was then lowered to the required depth and the bellows were inflated by compressed air to seal off the borehole. The required pressure was easily calculated, with the help of a water-sensing mechanism and the necessary calculated pressure was adjusted by means of a valve and read off on a manometer. The water between the bellows was pumped to the surface. Compressed air was then supplied to the first sample canister, opening the two valves, and allowing the sample canister to collect any groundwater that had seeped into the sealed off space. After five minutes the pressure was released, first from the valves of the sample canister and then from the bellows.

The probe was brought to the surface and, by activating the pressure valves, the sample canister was emptied.

If it is not desired to make use of the sample canisters as described in the previous paragraphs, the groundwater may be pumped directly to the surface and collected for age determination.

Conclusion

The probe and lowering mechanism have been designed, constructed and tested and the device has been found to operate successfully. Preliminary tests have indicated that the device will be able to pump water to the surface from specific strata for collecting water samples for age determination. The probe can also collect three 1 *l* uncontaminated water samples for chemical and other analyses.

Acknowledgements

The development of this probe was conceived and initiated by the Director of the National Physical Research Laboratory.

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