THE PISTON CORE SAMPLER

by

B. KULLENBERG

Extract from *Svenska Hydrografisk-Biologiska Kommissionens Skrifter*
Tredje Serien : Hydrografi. Band I. Häfte 2.
GÖTEBORG (SWEDEN) 1947

The *piston core sampler* has been based on a method to procure samples for ground investigations, developed by the Geotechnical Department of the Swedish State Railways, the instigators being C. Caldenius and J. Olsson.

The method should be clear from fig. 3, showing a tube being forced into the sea bottom. Inside the tube there is a closely fitting piston, which is being kept immobilized immediately above the bottom. As the tube is going down, the friction will exercise a downward pull on the core, which is opposed, however, by the hydrostatic pressure on the bottom. The hydrostatic pressure will not allow a vacuum to be created between the piston and the top of the core so long as the frictional forces do not exceed the hydrostatic pressure. This will never be the case in a deep sea, but it may happen in shallow water. This will be discussed later. However, when the tube is penetrating the bottom the friction will always cause the pressure immediately below the piston to be diminished as compared with the hydrostatic pressure. The pressure difference between the mouth of the tube and the top of the core will automatically balance the frictional resistance to the core, which, therefore, will be a quite correct representation of the sediment column *in situ*. The one problem is the immobilization of the piston in the vicinity of the bottom.

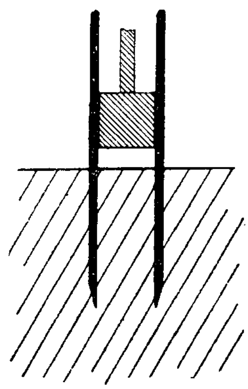


Fig. 1
Principle of the Piston Core Sampler.

Brief Description of the Piston Core Sampler.

For the sake of perspicuity a brief description of the piston core sampler will be submitted as a preliminary to a detailed account. The denotations refer to fig. 2.

A thick steel rube *a*, the length of which may be 20 m. or even more, is loaded with heavy weights *g* corresponding to the length of the tube and the consistency of the sediment. The tube is suspended from the release mechanism *h*, the most prominent part of which is the lever, one arm of which is about 15 times as long as the other one. The tube is suspended from the short arm and is balanced by a counter-weight *n* suspended from the long arm, the counter-weight having about one tenth the weight of the rest of the core sampler. The tube is suspended in such manner that it will slip off the release mechanism if the counter-weight is put out of function in some wav or other. The release mechanism is furnished with an eye for the steel cable that serves to lower the core sampler to the bottom of the sea. The counter-weight is suspended from a rope so as to hang at least one metre below the mouth of the tube. It is attached to the tube in a manner permitting it to move up and down the latter.

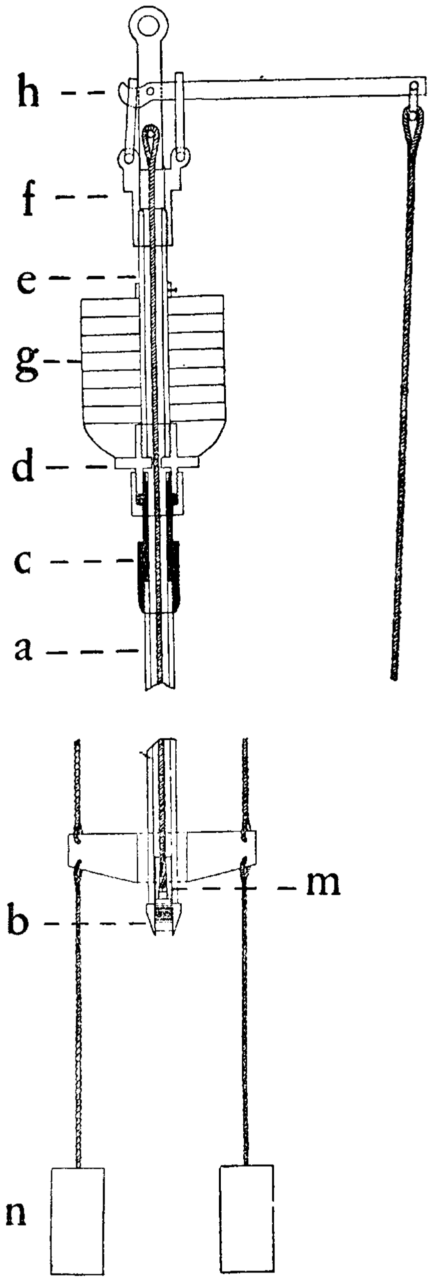


Fig. 2
The Piston Core Sampler.

The steel tube is lined inside with brass tubing. In the lower end of the tube there is a piston *m*, which fits closely within the brass tube and is able to move in this. The piston is connected with the release mechanism by a steel rope that runs up through the tube.

When the core sampler is approaching the bottom, the counter-weight will strike the bottom first, unloading the lever in doing so. Then the tube will slip off and drop into the sediment in a vertical position at a rather high velocity. The diminished tension of the cable will be announced on board the ship by a dynamometer, whereupon the winch is stopped, the piston being thereby brought to a stop just above the bottom. Now the sediment is forced to enter the tube, otherwise a vacuum is created in the tube below the piston. No matter how deep the tube penetrates the bottom the length of the core will be equal to the penetration depth, provided the water is not too shallow. The weight of the core sampler corresponding to a given penetration depth will be diminished by the fact that the apparatus is allowed to drop into the mud unhindered by the cable.

In its lower end, immediately above the mouth-piece *b* the tube is provided with a core catcher intended to prevent the core from slipping out of the tube when the core sampler is being hauled up through the water.

Detailed Description of the Piston Core Sampler.

The Coring Tube is a cold drawn steel tube with an internal diameter of 52 mm. and a wall thickness of 14 mm. As it will be exposed to great bending stresses when being forced down into a hard bottom, a rather hard steel has been selected. On the other hand the steel must not be brittle, as the tube would then be liable to break during the operations necessary to put the core sampler into the sea or to take it on board.

The tube may be given a length of 20 m. or even more, but it will not always be convenient to keep it as long as that. As the maximum length of the tube should depend on the penetration depth in a soft bottom, provided the space on board does not set a limit, it will not be possible to make the tube penetrate to its maximum length in a hard bottom. Then it is advisable to adjust the length of the coring tube according to the obtainable core length. In shallow water the core length will not exceed a certain value, irrespective of the penetration depth. Occasionally it may occur that the sediment is considerably less than 20 m. in thickness, in which case the tube may be bent on striking the hard material below the sediment. If the tube were manufactured in one single piece, it would then be completely destroyed, but if shorter tubes have been screwed together, only one of the short tubes will be destroyed.

Therefore the tube is composed of about 5 m. long pieces, which are screwed together. The joints will of course be weaker than the rest of the tube, which, however, has proved fatal only once. On that occasion a more than 20 m. long tube had stuck fast in the bottom, possibly being jammed between stones, and then the tube broke at a joint after very violent pulling, and 15 m. of the coring tube was lost. Though it has occurred in a few instances that the tube has been bent when striking hard material, the bend has never been localized to a joint.

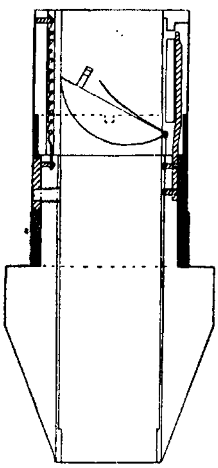


Fig. 3
The mouth-piece with the core catcher.

The cold drawn steel tubes have been delivered by the Sandvik Steel Works Co., Ltd., Sandviken, Sweden.

The Mouth-Piece (fig. 3) has a maximum external diameter which is 10-15 mm. larger than that of the coring tube. There are two reasons for this. Firstly, the friction on the outside walls of the tube will be diminished by the water descending in the wake of the mouth-piece. Possibly the force necessary to pull the sampler out of the bottom will diminish also. Kuenen has found that to be the case with a 4 m. long tube, but I have not been able to decide whether it is the case with a longer tube. Secondly, for the functioning of a core catcher installed immediately above the mouth-piece and intended to prevent the core from falling out of the tube, it is essential that the mouth-piece itself should be held back by the sediment with some force when the sampler is being pulled out of the bottom.

The internal diameter of the undermost part of the mouth-piece is about 1 mm. smaller than that of the lining tubes. This is intended to diminish the friction between the sediment and the inner walls of the tube; the device was introduced by Pratje. In the piston score sampler it is not necessary to diminish the froction in order to get long cores, as the friction is eliminated by the hydrostatic pressure. However, the friction will exercise o force on the peripheral parts of the core and, therefore, will be apt to bend the sediment layers. Hence it is essential to diminish the friction as much as possible.

The mouth-piece is lined with a brass tube that fits so tightly as to adhere to the inner walls of the mouth-piece.

The Core Catcher is installed in the upper part of the mouth-piece. It consists of a metal sheet that is shaped so as to form a part of a cylindrical surface, the diameter of which is the same as that of the lining tubes and it is able to shut the lining tube completely. When open, the catcher forms a part of the lining tube. It is able to move about a horizontal axis at its lower end, the axis being tangential to the lining tube.

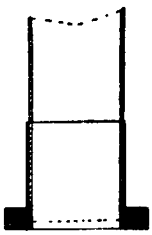


Fig. 4
Frame for the lining tube at the lower end.

During the descent of the core sampler the core catcher is held fast in its position against the wall of the tube by a pin attached to the mouth-piece. Then the free access of the core into the tube is not obstructed. When the sampler is being pulled out of the bottom, however, the mouth-piece, sticking into the sediment thanks to its larger diameter, will be held back two or three millimetres, and then the pin will release the catcher. This will be pressed two or three millimetres into the core by a rather weak spring, and if the core does not move, nothing more will happen. That will generally be the case. If the core starts to slip out of the tube, however, the core itself will force the sediment catcher to seal the lining tube, and then only the small part of the core situated below the catcher will be lost. In the case of the long cores obtained with the piston core sampler only a very soft sediment will be apt to fall out of the tube, and so the core catcher need rarely go into action.

The Lining Tube is made up of 70 cm. long brass tubes with 45.6 mm. internal diameter and 1 mm. wall thickness. It is necessary to have the lining tube made up of short pieces like this, because it would otherwise be difficult to take the sample out of it. At the top end the lining tube is supported by the coupling (fig. 2c and 6) and at the lower end it is kept in position by a frame as shown in fig. 4. The mouth-piece is screwed until it is stopped by the frame, whereupon every lining tube piece rests against the adjoining pieces. Thus, the coupling and the mouth-piece will keep the lining-tube pieces together longitudinally, and furthermore the adjoining tubes are kept together by short collars as shown in fig. 5. The space between the collars and the steel tube being very small, the lining tube is well supported.

The brass tubes should be carefully selected, as the diameter must be exactly the same everywhere. No ovalness must be allowed, as otherwise the piston may dash against some projection at a tube joint and utterly ruin every brass tube in its way. That has happened once during my experiments.

The lining tube will be exposed to a certain amount of pressure when the core sampler is going down into the sediment and, sometimes, especially much when the sampler is being

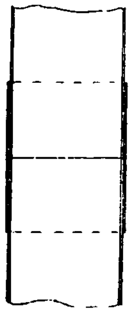


Fig. 5
Collar keeping adjoining pieces of the lining tube together.

pulled out of the bottom. If, for instance, the penetration depth is smaller than the length of the coring tube, then the piston will be at a certain distance below the top of the collecting tube when the core sampler has stopped. As soon as hauling begins, the pressure below the piston will decrease considerably and that will go on until the piston is stopped at the top of the tube. This is due to the fact that the friction between the core and the walls of the tube will be much larger after the sampler has stopped than before. Further, a sucking in of sediment from below the mouth-piece will also make the pressure decrease. In most cases there will be no such sucking in, but the vacant space will be filled with water leaking in from the space between the lining tube and the coring tube. Water may leak in through any joint between adjoining brass tubes, and hence the core may be divided into several pieces, with water between them. This is a very unsatisfactory condition, and it should be avoided by always forcing the core sampler down into the bottom to its full length.

However, it might occur that the pressure below the piston decreases so much as to make the lining tube collapse, which has happened three times. Obviously the strength of the brass tubes is only just sufficient to stand the strain, and so it might be better to exchange them for steel tubes. This would involve some risk of contaminating the sample, as steel would be much more affected than brass by water and sediment. That might be avoided by the use of stainless steel, though. Another method would be to line the steel lining tube in its turn with brass tubes, split longitudinally into halves and fitting closely to the steel lining tubes. That would at the same time make it easier to take the sample out of the lining tube without disturbing it.

The Coupling is intended to facilitate the removing of the upper part of the core sampler from the collecting tube, which operation has to be performed every time the core sampler has been employed. The coupling is made up of three pieces. The largest one (fig. 6, A), being made of steel, has an axial bore with a diameter of 50 mm. except at the ends, which are wider and are provided with female screw-threads. At the lower end the bore has a diameter of 75 mm., and the screw-threads at this end are intended to fasten the coupling to the to of the coring tube. The second piece of the coupling (fig. 6, B) is fastened here. It is a brass ring with male screw-threads, the outside diameter being 63 mm., and the inside diameter being equal to that of the lining tube, i.e. 45.6 mm. At the top end of both pieces there are four square slits, about 10 × 10 mm., as an extra outlet valve for the water. The object of the brass ring is to support the top end of the lining tube. The third piece of the coupling (fig. 6, C) is a steel ring with an inside rim at the lower end. There is an outside rim near the top end of the larger piece (A), and the steel ring (C) can only be moved until the two rims come together. The ring has an inside diameter of 110 mm., and it has female screw-threads intended to fasten the coupling to the upper part of the core sampler. It has four canals near its upper end, serving to let out the water. As the steel ring can be turned without moving the rest of the coupling, nothing but the steel ring has to be turned when the coring tube is to be fastened to, or unfastened from, the rest of the core sampler.

The Weight-Stand is a steel (fig. 2e) with a steel cylinder fastened to each end of it. The tube may be exchanged in order to adjust its length according to requirements. Its dimensions are the same as those of the coring tube, i.e. the outside diameter is 80 mm. and the wall thickness 14 mm. It has male screw-threads at both ends.

The steel cylinder at the lower end (fig. 2d), "the connecting piece", has an outside diameter of 110 mm. It has an axial bore of 75 mm., which, halfway, is narrowed to a diameter of 30 mm. The interior rim thus obtained serves as a piston catch to stop the piston when the core sampler has gone down into the mud to its full length.

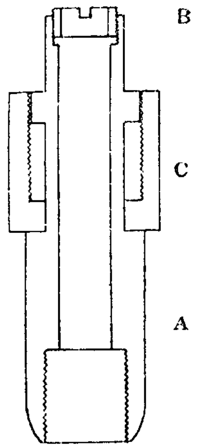


Fig. 6
The coupling.

Externally a thick shelf runs round the middle part of the cylinder, serving to support the weights necessary to force the core sampler down into the bottom. Below the shelf the cylinder has male screw-threads corresponding to the female screw-threads in the steel ring of the coupling. Above the shelf it has female screw-threads serving to fasten it to the weight tube.

The cylinder at the top end of the weight tube (fg. 2 f) has an axial bore 75 mm. in diameter. At the lower part it has female screw-threads, serving to fasten it to the tube, whereas the bore is smooth in the upper part. At the top the cylinder is fitted with two loops opposite to each other. In one of the loops there is fastened a link as shown in fig. 7 a, serving to suspend the bulk of the core sampler from the short arm of the lever. The link is able to turn round the bolt at its lower end, which is run through the loop. In the other loop there is fastened a safety link as shown in fig. 7 b, serving to fix the lever in a position perpendicular to the tube. This will make it impossible for the tube to fall off the release mechanism accidentally during the operations necessary to put the core sampler into the sea. The safety link should not be removed until immediately before the lowering of the core sampler is to begin, when all preparations are completed and the sampler is hanging in the water in a vertical position.

The Weights. (Fig. 2 g). The undermost weight is a complete cylinder, rounded off at the lower end, and with a central bore for the tube. The other weights are semi-circular iron plates with a notch for the tube, each weighing 20 kgs. Underneath, they are provided with two holes to receive pegs in the top of the subjacent plates. They are laid cross-wise over each other, two in each layer, being thus mutually fixed in their position by the pegs. Above the uppermost layer a steel clamp is fixed to the tube with a screw, serving to prevent the weights from jumping off at occasional jerks. The arrangement now described has proved to be a convenient one when working the heavy gears on board a rolling ship.

The Release Mechanism (fig. 8) consists of the lever and a stand for the latter. The lever is a wrought iron bar, 2 cm. thick, 5 cm. wide, and 85 cm. long. It has a bore for the axle a few cm. from one end, and another one near the other end, serving to suspend the counterweight. The bulk of the core sampler is hung on the short arm in the link referred to before. The arm is 5 cm. long, and it is shaped like a beak so as to make it easy for the suspending link to slip off as soon as the arm has been lowered to a sufficient extent. The other arm, which is depressed by the counterweight, is 70 cm. long.

The lever-stand (fig. 9) is made up of a short steel rod undermost and two wrought iron bars welded to the rod. At the uppermost end the bars are welded to a wrought iron ring to which the long sounding cable is fastened when the apparatus is to be lowered to the bottom of the sea. Halfway between the ring and the rod, both bars have a bore-hole for the bolt serving as an arbor for the lever.

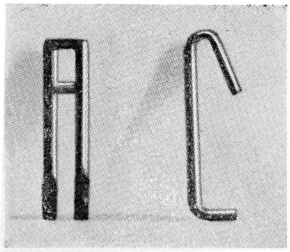


Fig. 7
Suspending link (a) and safety link (b).

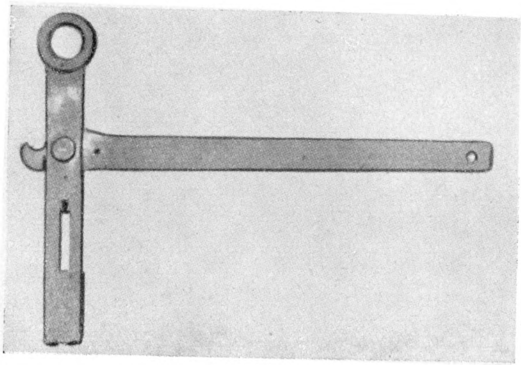


Fig. 8
The Release Mechanism.

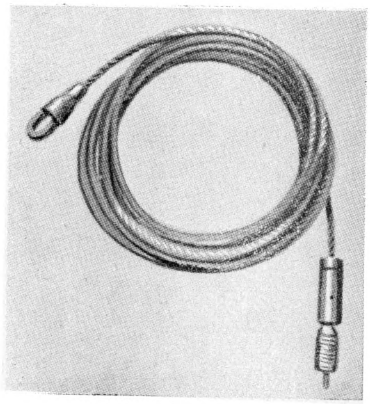


Fig. 11
The piston attached to the piston rope.

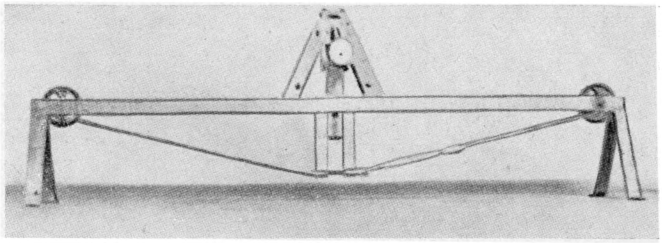


Fig. 12
The Dynamometer.

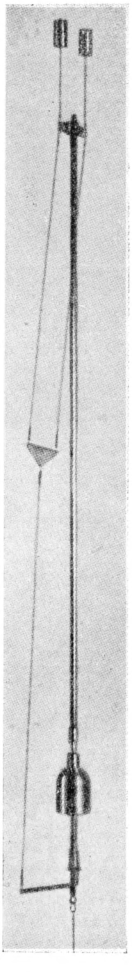


Fig. 13
The piston core sampler during the lowering.

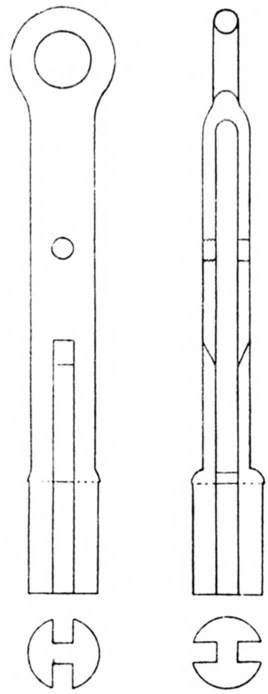


Fig. 9
The lever-stand.

The rod fits into the smooth bore of the cylinder which is fastened to the top of the weight tube. This is in order to fix the release mechanism in its proper position relative to the rest of the core sampler. The rod has two slits opposite to each other, and the slits are extended in the bars half-way to the arbor of the lever. The object of the slits is to let out the rope that joins the piston to the release mechanism. Originally there was a second bolt through the bars for the purpose of fastening the piston rope, but that has turned out to be inconvenient. The present arrangement, in which the piston rope is fastened directly to the eye of the core sampler, may seem provisional, but it has proved to be very practical.

The Piston is shown in fig. 10 in two slightly different patterns. In one of them (fig. 10 a) the piston rope has a spliced loop, and it is fastened to the piston by means of a bolt through the loop. In the other pattern (fig. 10 b) the rope is fused to the piston, which makes it possible to use a thicker rope than in the other method. The rope runs up through the tube, and it is fastened to the eye of the core sampler.

The bulk of the piston has a diameter that is 1 mm. less than that of the brass lining, and only the packings fit closely in the lining tube. The packings consist of a series of circular leather clips with slightly smaller brass plates between them. In the centre they have holes for an axial bolt and they are fastened to the bolt with a firmly tightened nut. The bolt is furnished with screw-threads at its upper end corresponding to female threads in the top-piece of the piston.

As soon as the counterweight has settled down on the bottom the coring tube with the
ll into the mud. If the tube
: top of the coring tube has
on catch. As the weight of
strain on the piston and on
rable velocity at the moment
oaded to be able to penetrate
between the piston and the
ton will go upwards with no
hole weight of the apparatus
will rest on the piston, and to this will be added the force necessary to pull the core sampler

Fig. 13 : To be reversed.

A retourner de 180°.

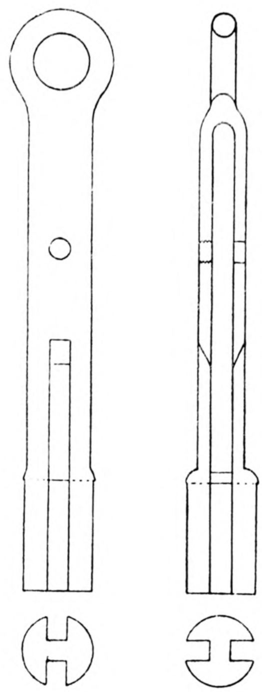


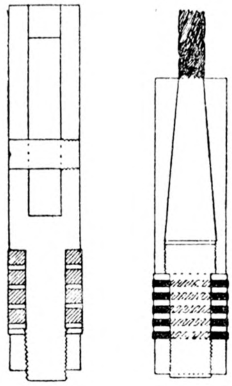
Fig. 9
The lever-stand.

The rod fits into the smooth bore of the cylinder which is fastened to the top of the weight tube. This is in order to fix the release mechanism in its proper position relative to the rest of the core sampler. The rod has two slits opposite to each other, and the slits are extended in the bars half-way to the arbor of the lever. The object of the slits is to let out the rope that joins the piston to the release mechanism. Originally there was a second bolt through the bars for the purpose of fastening the piston rope, but that has turned out to be inconvenient. The present arrangement, in which the piston rope is fastened directly to the eye of the core sampler, may seem provisional, but it has proved to be very practical.

The Piston is shown in fig. 10 in two slightly different patterns. In one of them (fig. 10 a) the piston rope has a spliced loop, and it is fastened to the piston by means of a bolt through the loop. In the other pattern (fig. 10 b) the rope is fused to the piston, which makes it possible to use a thicker rope than in the other method. The rope runs up through the tube, and it is fastened to the eye of the core sampler.

The bulk of the piston has a diameter that is 1 mm. less than that of the brass lining, and only the packings fit closely in the lining tube. The packings consist of a series of circular leather clips with slightly smaller brass plates between them. In the centre they have holes for an axial bolt and they are fastened to the bolt with a firmly tightened nut. The bolt is furnished with screw-threads at its upper end corresponding to female threads in the top-piece of the piston.

As soon as the counterweight has settled down on the bottom the coring tube with the heavy weight at its top will slip off the release mechanism and fall into the mud. If the tube is too heavily loaded, the piston will get a violent kick when the top of the coring tube has come down to the piston, which will then strike against the piston catch. As the weight of the apparatus may be as much as 1500 kg, this involves a hard strain on the piston and on the piston rope, especially as the core sampler may have a considerable velocity at the moment of the impact. If, on the other hand, the tube is not sufficiently loaded to be able to penetrate into the bottom to its full length, there will be no such collision between the piston and the catch. When the hoisting of the core sampler is started, the piston will go upwards with no perceptible resistance until it has reached the catch. Then the whole weight of the apparatus will rest on the piston, and to this will be added the force necessary to pull the core sampler



a b

Fig. 10
The Piston.

into the bottom to its full length, there will be no such collision between the piston and the piston rope must of necessity be strong. If the piston pattern *a* is used, it is difficult to use a rope of more than 10 mm. diameter, which is hardly sufficient when the sampler has its maximum weight and is sticking fast in the bottom. The piston pattern *b* should therefore be preferred.

The Counterweight consists of iron cylinders, suspended from an iron bar as shown in fig. 2. Sometimes the bar was equipped with four legs for the iron cylinders. The bar is connected to the coring tube by means of an iron ring in the middle of it. In this manner the centre of gravity of the counterweight will be located to the axis of the coring tube, and the core sampler will keep an accurately vertical position when suspended from its eye. That would not have been the case of the counterweight has hung vertically below its loop in the lever. Then the coring tube would have formed a small angle to the vertical, and, as the core sampler is very top-heavy, that would have increased the risk of its being upset when slipping off the lever.

When the core sampler is going down into the mud, the iron bar supporting the counterweight will settle down on the bottom, and it will be connected with the tube through the ring all the while. When the core sampler is being hoisted, the bar will keep near the coupling.

During the operations of taking the core sampler on board it is a great convenience to be able to hoist the apparatus by the counterweight rope, as the operations cannot be performed by means of the piston rope without this being sharply bent.