

APPENDIX

CURRENT-MEASUREMENTS BY MEANS OF BUOY AND RELEASING CLOCK-WORK

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The positive result derived from experiments described above by Prof. NANSEN, was that it appeared clear, that if reliable measurements of slow currents in the open sea are to be obtained at all, there must be no direct communication between current-meter and ship on the one hand, nor between current-meter and sea-surface on the other. To realise these conditions an arrangement as sketched in Fig. 19 was then employed. *C* is the current-meter; above it is a clock-work *A* with an arrangement for releasing, at any particular time-intervals desired, first one messenger and then, if required, another one, which fall down on the current-meter. *B* is a floating-buoy which must be capable not only of carrying the weight of the clock-work, current-meter and wire but at the same time be capable of keeping the latter stretched taut. The whole apparatus is anchored to the sea-bottom by means of a big lead *L* fastened to the line, the latter thence following on to the winch on board.

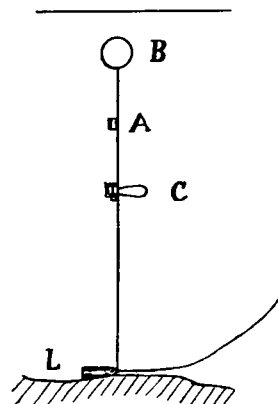


Fig. 19

The buoy is made up of glass balls as mentioned above by Prof. NANSEN (Fig. 8).

The clock-work is shown in Fig. 20 as it appears attached in due position to the line, and in Fig. 21 as it appears when taken out of its cylindrical case. It is made with Anchor action, and with springs and other parts of steel. To prevent rusting, the case *C* (Fig. 20) is therefore made as tight as possible and filled through a hole at *h* (Fig. 20) with an alkaline solution (oil would not do, since it would not mix with the small quantities of sea-water, which will inevitably penetrate into the case). A mixture of glycerine, alcohol and soap

solution has proved to be suitable in all respects¹⁾. To prevent the solution leaking out, the apparatus is always kept — when not in use — in a metal vessel containing pure water. The axis of the biggest cog-wheel which is driven by the spring is continued through the bottom of the case and ends in the short double-threaded screw *S*. The clock-work may be wound by a key *k* fitting into two holes in the end of this screw.

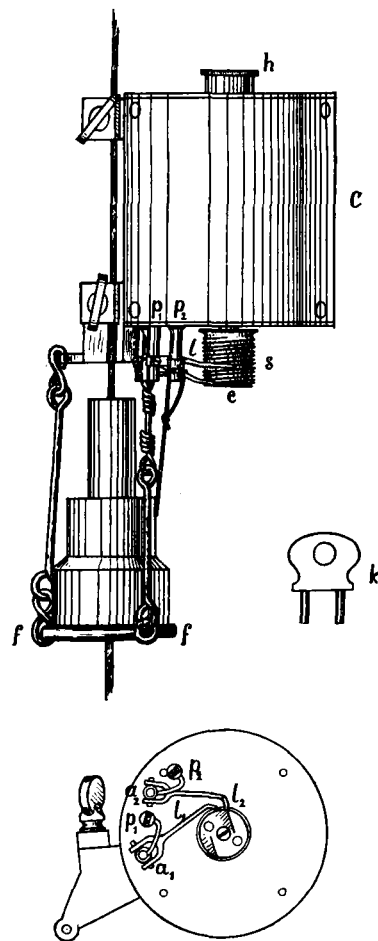


Fig. 20

between the release of the two messengers is always 5 minutes or a multiple of 5 minutes.

When the Pendulum current-meter is used, one messenger only is suspended below the clock-work. In the case of the Propeller current-meter the first messenger is not suspended directly from one of the hooks but rests on a fork *ff* which is again suspended from the hook, and on tilting lets go the messenger.

¹⁾ This mixture was devised by the maker of the clock-work, Mr. Aas, Christiania.

Other arrangements are essentially the same whether the one or the other current-meter be used. Here the use of the Propeller current-meter is described.

A metal wire about 5 metres long and with a thimble at each end, is attached by one end to the buoy and by the other end to the current-meter. The clockwork is attached to the line somewhere between the two and with the screw *S* turned towards the current-meter. The end of the sounding-line is carried from the winch over the meter-wheel and then attached to the lower end of the current-meter¹⁾. The latter is put in working order, and the messengers are suspended under the clock-work, all this being done while the apparatus

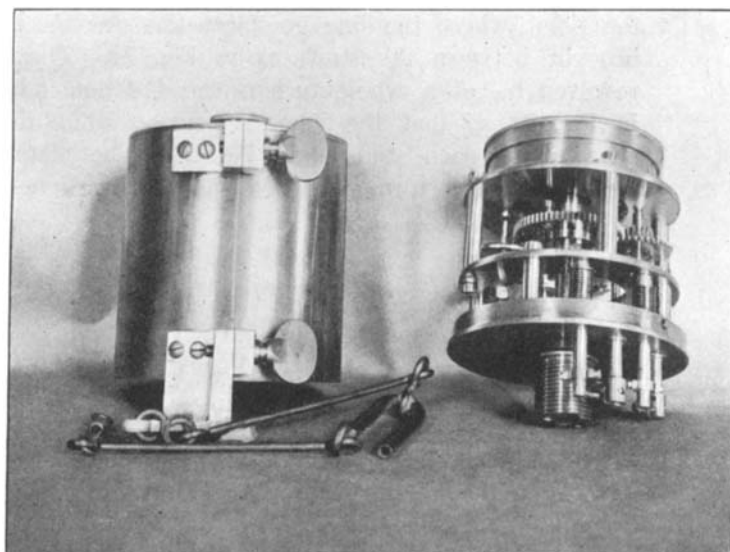


Fig. 21

is lying on deck. While the ship steams slowly ahead steering along the arc of a circle with the meter-wheel on the inner side, the Clock-work is wound and set so as to release the messengers at the desired moments; Buoy, Clock-Work and Current-Meter are let down into the sea. In setting the clock-work it must be borne in mind that the lead must have reached the bottom and the line up to the buoy have had sufficient time to attain its position of equilibrium before

¹⁾ The pendulum current-meter is hung up in its frame and the two lines attached the one to the upper and the other to the lower end of this frame respectively. The lead of the current-meter itself is connected to the lower end of the frame by a hempen line upon which the whole instrument will therefore hang on reversing the frame. (See Fig. 11.) This hempen line must be flexible and long enough to allow the current-meter to hang quite freely and vertical even if the frame be inclined a little.

the first messenger is released. The line is let out freely as it is pulled out by the buoy, which owing to its resistance to the water remains near the original spot.

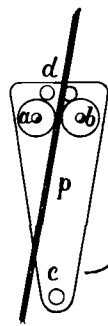
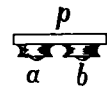


Fig. 22

When so much line is let out as corresponds to the distance above the bottom at which it is desired to measure the current, a lead is fastened to the line, the ship being stopped if necessary. A triangular iron-plate (*p* Fig. 22) with two brass studs *a* and *b* riveted fast at its broader end and with two holes at *d* and one at *c*, is used for fastening the lead to the line. The plate is laid along the line, so that the face bearing the studs is towards the ship, and with the end *c* directed towards the point where the line goes into the sea; the line is brought between the studs as in Fig. 22. Then *p* is revolved $\frac{3}{4}$ of a whole turn in the direction indicated in Fig. 22 so that the wire is bent as an *S* half a turn round each stud as in Fig. 23. The plate *p* is revolved half a turn more in the same direction, while

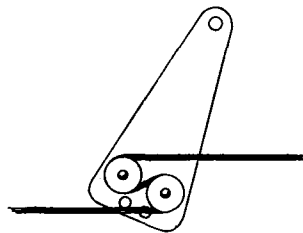


Fig. 23

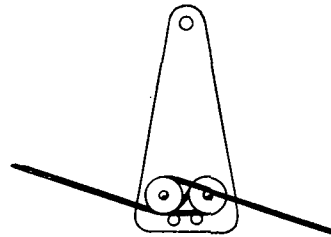


Fig. 24

bending it so that the stud *a* can freely pass by first the one end of the line (Fig. 24) and then the other, without catching them, with the result that both ends of the wire now come up towards *d* between the two studs. The wire is then secured by a string brought through the holes at *d* and knotted over it, by which the lead is also finally attached to *c* (Fig. 25). The whole operation may easily be completed within a minute or less.

While steaming slowly ahead, more line is let out until the lead has reached the bottom. Owing to the buoy the lead sinks rather slowly, and it is advisable to give out line freely to prevent the operation from being slower than absolutely necessary. By occasionally applying a greater force on the brake until a hitch felt on the line announces that the lead has straightened it out, it is easy to find the proper speed and thus to avoid too great a hitch and consequent kinks in the line — a very necessary precaution. When no hitch is felt on braking it is known that the lead has arrived at the

bottom. The ship however is not stopped before it has moved some distance farther away from the spot so that there may be a part of the line lying along the bottom. The ship must then lie, as accurately as is possible, at that place — and keep the line steadily slack to prevent the lead from being dragged along the bottom — until both messengers are known to have been released; the line must all the while be kept perfectly slack, so that there is no possibility of a pull on the lead. According as the ship makes inevitable movements one has to take in or give out more line controlling on the meter-wheel and on the direction of the line that one does not come too near to the lead but remains always on the same side of it. The line may never be allowed to hang vertically.

When both messengers are known to have been released the ship approaches slowly towards the lead while the line is hauled in. When the buoy appears again at the surface, the ship moves to it, and the line is wound in carefully, so as not to reverse the current-meter or incline it too much — otherwise the shot indicating the direction of the current may fall out of their compartments ¹⁾. The buoy is fished up with a boat hook and the current-meter then hauled on board from below it. If the line between current-meter and lead is not very short, the latter has to be taken off before the buoy is fished up.

The whole operation may easily be performed without any difficulty (in good weather). It was found that in water of 70 m. depth about one measurement could be made each hour, if the clock-work be set so that the current-meter were allowed 10 minutes to come to rest after the lead had reached the bottom and be then allowed to run for 10 minutes. Probably it is possible to make measurements more quickly with a little practice.

The Buoy will as a rule not at once stand vertically above the lead on the bottom, even if there be no current; it will only come to this position gradually. And if the current-meter be set to begin the recording while the buoy is still moving, the Current-



Fig. 25

¹⁾ Dr. CARL FORCH has proposed a modification of the compass-box, by which this inconvenience may be avoided. A round disc fastened to the top of the compartments inside the compass-box so as to close them, has as many funnels as there are compartments; the funnels are arranged in a circle and protrude one right into each of the compartments. The shot fall through the funnels into the compartments and cannot fall out again on reversing the instrument. On removing the disc, the shot in the compartments can be counted and taken out. If the proposed improvement should be quite effective it would be necessary either to increase the size of the compass-box or to diminish the number of compartments in it.

The NANSEN current-meter is, of course, quite free from the above defect.

Meter will of course, give incorrect results. It is therefore of importance to know the time T , necessary for the buoy to take its position of equilibrium. This time will depend, among other things, upon the initial distance of the buoy from its position of equilibrium at the moment the lead reached the bottom. On the other hand it will be practically independent of whether this position of equilibrium is vertically above the lead or not, so long as its angular distance from the vertical is not great.

The following theoretical calculations of T may be of use until there is a definite solution of the question based upon direct experiments. In Fig. 26 B represents Buoy, Clock-Work and Current-Meter together, $OB = l$ is the length of the line between them and the sea-bottom, OX is its direction of equilibrium (supposed vertical) and x is the distance of B from this vertical. P is the buoyancy of B less half the weight in water of the line OB . If it be assumed

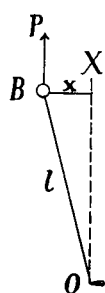


Fig. 26

that the latter always remains rigidly straight, the force P acting on B is then equivalent to the resultant of the forces, dependent on hydrostatic pressure and gravity, moving B towards its position of equilibrium.

The resistance R of the water against this motion is approximately proportional to the square of the velocity of the buoy and therefore

$$R = m \left(\frac{dx}{dt} \right)^2,$$

where m is a constant. But R is equal to the resultant of the moving forces acting upon B , since the force spent on accelerating or retarding it can be disregarded — i. e. $R = Px/l$ and consequently

$$\frac{dx}{dt} = \sqrt{\frac{P}{lm}} \cdot \sqrt{x},$$

where the expression on the left hand side is the velocity of the buoy and current-meter as they approach towards their position of equilibrium, This equation gives:

$$\sqrt{x} = \sqrt{x_0} - \frac{t}{2} \sqrt{\frac{P}{lm}},$$

where x_0 is the initial distance of B from its position of equilibrium. If by T we denote the time after which the latter will be reached (i. e. after which $x = 0$),

$$T = 2\sqrt{\frac{lm x_0}{P}}.$$

The coefficient m can easily be determined by experiments. For a preliminary estimation of the order of magnitude of T it may be

assumed according to some old experiments that $m = 100a$, when a is the sectional area of the buoy in sq. m., and P is measured in kg., dx/dt in m. per sec, l and x_0 in metres.

Clock-work and two messengers weigh together 2 kg., and the current-meter nearly the same. If the distance from the sea-bottom to the current-meter be 500 m., and a steel-wire of 2 mm. diameter (weight 2 kg. per 100 m.) be used, the weight of the instrument and half the wire will be 9 kg. The buoy when made up of 33 glass-balls would have a buoyancy of 26 kg. and consequently $P = 17$ kg.

The buoy of 33 balls may be made to have a section of about $\frac{1}{4}$ sq. m. The sectional area the line itself exposes to the current is one square metre, but its resistance against the motion of the buoy is much smaller than it would be if this whole area were connected to the buoy itself. A part of the line which is at a distance l/k from the sea-bottom, will — if the line be supposed to remain straight the whole time — have a velocity which is k times smaller than that of the buoy itself; and will consequently experience a resistance which is k^2 times smaller than if it had taken part in the motion of the latter. As the distance which it has to move is also k times smaller than in the case of the buoy, the resistance which it causes to the motion of the buoy is k^3 times smaller than when rigidly connected to it. By integration it is found that the sectional area of the line has to be divided by four to give the resistance it causes to the motion of the buoy. The whole cross-section to be taken into account is then $a = 0.25 + 0.25$ or 0.5 square metre, so that the expression for T becomes

$$T = 2 \sqrt{\frac{500 \times 50}{17} x_0} = 77 \sqrt{x_0}.$$

If x_0 be 100 m., T is thus 770 seconds or nearly 13 minutes, after which time the apparatus would have come to absolute rest.

For $l = 100$ m. and $x_0 = 50$ m. it would be $T = 3$ minutes.

These time-periods will, however, probably be somewhat longer owing to the fact that the line is not rigidly straight as was assumed. It is furthermore very possible that the resistance of the thin line per unit of area exposed to the current is greater than in the case of a broader body. In any case the results obtained above, show that the time required is not too great to allow current-measurements to be satisfactorily carried out by the method here described at within some hundred metres from the sea-bottom, and if the buoy will upon the whole take a stable position in the current. The latter question which is very important must be investigated by experiments.

As an example two measurements made at 70 m depth in the

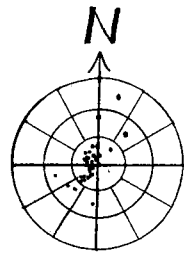


Fig. 27

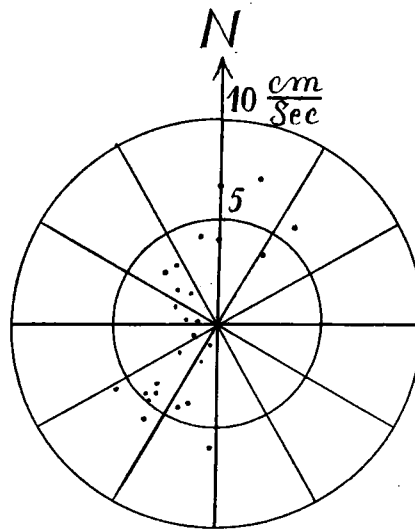


Fig. 28

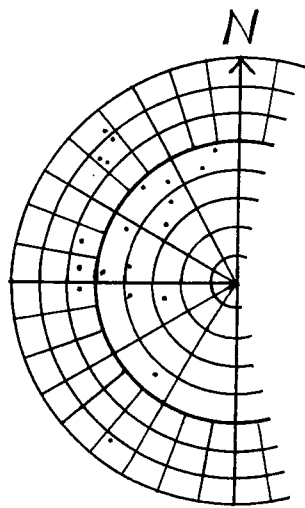


Fig. 29

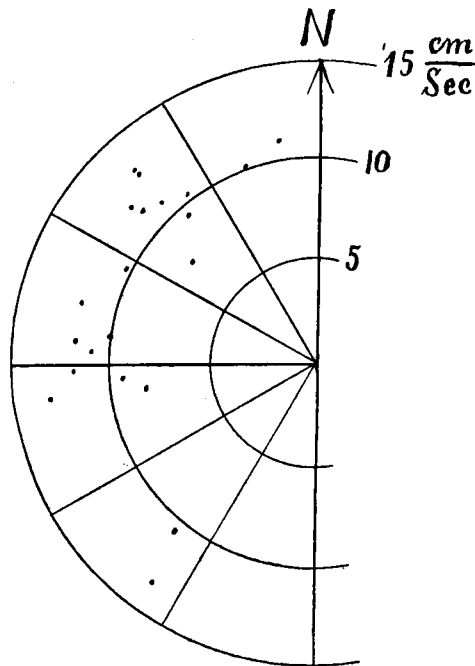


Fig. 30

Puddefjord at Bergen July 19, 1905 with the NANSEN Pendulum current-meter may be mentioned here ¹⁾).

Fig. 27 shows the dots made by the pendulum at 10 a. m. 20 m. above the sea-bottom. The wind was very slight, from the North. The current-meter had 7 minutes to come to rest before the messenger was released by the clock-work. Fig. 28 represents the directions and velocities of the current as calculated from the dots on Fig. 27 (the direction of the dots from the centre of the figure represents the magnetic direction towards which the water was moving). At 11 a. m. a new measurement was made 7 m. above the sea-bottom. At that time the tidal current had begun to run out, in other respects the conditions were unaltered. The current-meter was given 10 minutes to take its position of equilibrium, before the messenger was released. The result of this measurement is represented in Fig. 29 (the original dots), and Fig. 30 (velocities).

Improvement of the Ekman Current-Meter

A small alteration which has recently been made in the construction of the current-meter described in Publications de Circonstance No. 24, may be noticed here.

In instruments of this pattern hitherto used, the dial-plate has two doors; on opening them a wheel with 20 small compartments arranged in a circle is disclosed. The shot which are eventually to be dropped down into the compass-box to indicate the current direction, must be laid one in each of these compartments, an operation it is no doubt ordinarily somewhat inconvenient to carry out in bad weather.

This arrangement is therefore now replaced by another shown on about half scale in Fig. 31. *W* is one of the dial-work wheels, which is put in motion directly by the propeller and makes one revolution for each hundred revolutions of the latter. Its axis is at one place widened to a cylinder of 6 mm. diameter in which 3 half-spherical cups *c* are cut, and this cylinder moves inside a cylindrical encasement *e*. Two brass tubes *T* and *t*

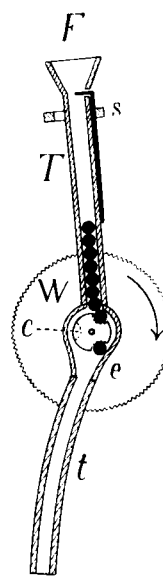


Fig. 31

¹⁾ The experiments made on this occasion were of only a preliminary nature and had for object chiefly the testing of the handiness of the apparatus, the time available being too short for a systematic investigation of the reliability of the measurements. The propeller current-meter was also used repeatedly with success but with negative result, since the currents were too slow. The propeller made but one to two revolutions a minute, whilst to work satisfactorily it must revolve at least 3.5 times a minute (corresponding to a velocity of 2 cm. per second).

are attached to the encasement, so as to open respectively just above and just below the cylinder bearing the cups c . The tube T serves as magazine for the shot. As the wheel W revolves and one of the cups c passes the lower end of T a shot drops into the cup; on further revolution the shot is carried round in the cup, and on reaching the upper end of t drops through it into the compass box. In this way 3 shot fall into the compass box for each hundred revolutions of the propeller.

A small spring s protruding into T at its upper end, just below the funnel F , prevents the shot from falling out even if the instrument be reversed. When T is being filled with shot this spring is pressed aside by the finger.

As it is a necessary condition for the satisfactory working of the mechanism just described, that the shot shall all be of equal size, a double sieve can be supplied by the Central Laboratory for separating out the right size. The shot might also be replaced by Bronze-balls such as are used for ball bearings. For special investigations where it is desirable to study the change of current direction with time Professor NANSSEN has suggested that each ball may be identified by engraving or plating in a different way.