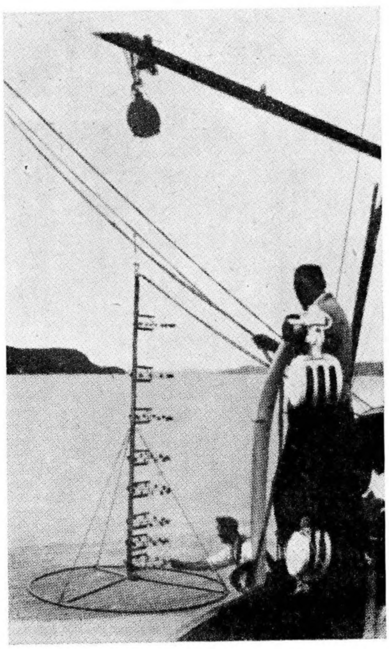

FIG. 1
The apparatus is lowered into the sea.

EXPERIMENTS ON TURBULENCE and FRICTION NEAR THE BOTTOM OF THE SEA

by Hakon MOSBY.

(Extract from *Bergens Museums Arbok* 1946/47. Naturvitenskapelig rekke, No. 3).

The internal friction in the sea is dependent on the turbulent motion, which is, accordingly, of severe importance to all oceanic currents.

Our conception of the nature and the mechanism of the turbulent motion is, as yet, incomplete. Theories and formulae are footing mainly on the results of small scale measurements in hydraulic and aerodynamic laboratories.

A control of the validity of the existing formulae, when applied to phenomena in the sea, and even possibly a better basis for the mathematical formulation itself, may be obtained through detailed measurements in the sea. In order to obtain a first, rough orientation, some preliminary experiments were carried out onboard the M/S "Armauer Hansen" in August 1946.

The following simple instrumental arrangement was used (see fig. 1). From the anchored ship a structure was lowered into the sea to rest on the bottom. This structure consisted of a 3 m. high iron tube, attached in its lower end to the three spokes of a wheel of 2 m. diameter, and braced by means of three guy-wires. Eight sections of larger diameter tubing were slipped over the tube, each section carrying two horizontal iron arms of 25 cm. length at a vertical distance from each other of about 10 cm. Between each pair of arms was mounted a cup wheel of about 40 cm. diameter, carrying 12 hemispherical brass cups of 4 cm. diameter. These wheels had a weight of nearly 200 gr.; they were mounted in simple brass bearings.

The cup wheels were calibrated in the hydrodynamic tank at Det geofysiske institut before and after the field experiments. They showed a fairly uniform speed of rotation at velocities down to 7—8 cm./sec. Denoting by v the velocity in cm./sec. and by n the number of revolutions per minute, we found

$$v = a + b.n.$$

The value of a came out the same in all cases, $a = 4$, while the value of b varied for the different cup wheels, from 5.8 to 6.4. These calibration results were obtained when the cup wheel moved through the water in position downstream in respect to the supporting tube. Facing upstream the wheel would rotate a little more slowly. The above calibration results must be very nearly valid for our measurements in the sea.

The large diameter of the cup wheels was chosen partly in order to avoid a too great disturbance from turbulence formed behind the vertical supporting tube, and partly in order to obtain a low rate of rotation of the wheels. The formula above shows that a current velocity of 1 knot would correspond to only about 8 revolutions per minute or 1 revolution in 7—8 seconds. With this rate of rotation an extremely simple mechanism could be used. A brass pin attached to the wheel axel, touched a weak contact spring in every revolution. The contacts operated a multicronograph onboard the "Armauer Hansen". Part of the electrical circuit was formed by the supporting wire.

The laboratory-made eight channel cronograph did not work satisfactorily; it was, therefore, soon substituted by eight small electric lamps in the circuit. The lamps would glow weakly due to the electric current steadily passing through the sea water, but indicate contact by a clear flash. On writing down to the nearest second the time for every contact, a very satisfactory record of observations could be obtained.

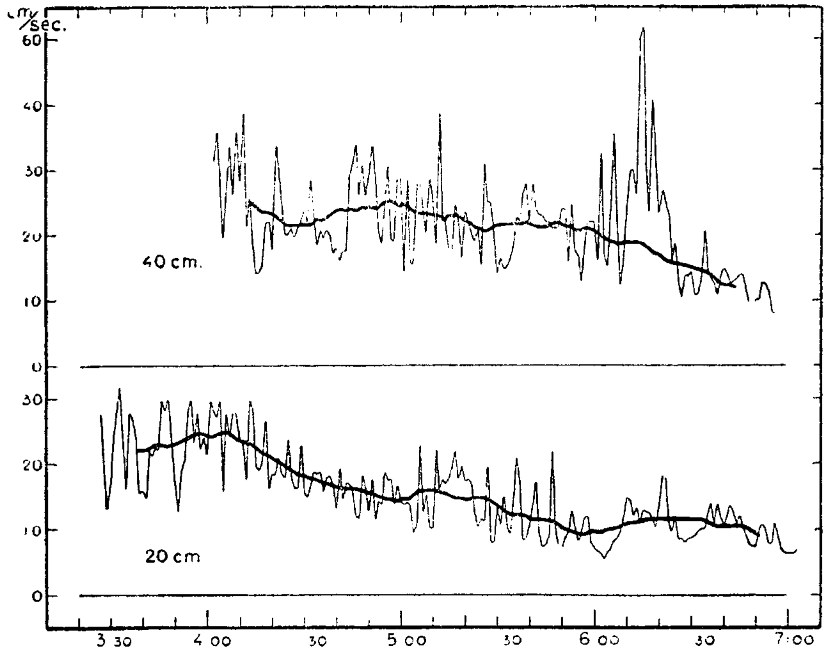

FIG. 2
Recorded variations of current velocity.

The handling of a monstrous instrument as this was expected to bring difficulties, but working under favourable conditions as we did, the whole operation of placing the apparatus on the bottom and taking it up again was carried out a number of times without a serious mishap. As seen from the picture, figure 1, the wire supporting the instrument was fed over a meter wheel attached to the gaff of the main mast, while the two quadruple core cables of 1 cm. diameter were let out separately and lashed to the wire in a number of points about 10 m. apart.

The whole instrument weighed about 40 kg. and at moderate depths down to 20—30 m. it could easily be ascertained when the stand reached the bottom, in

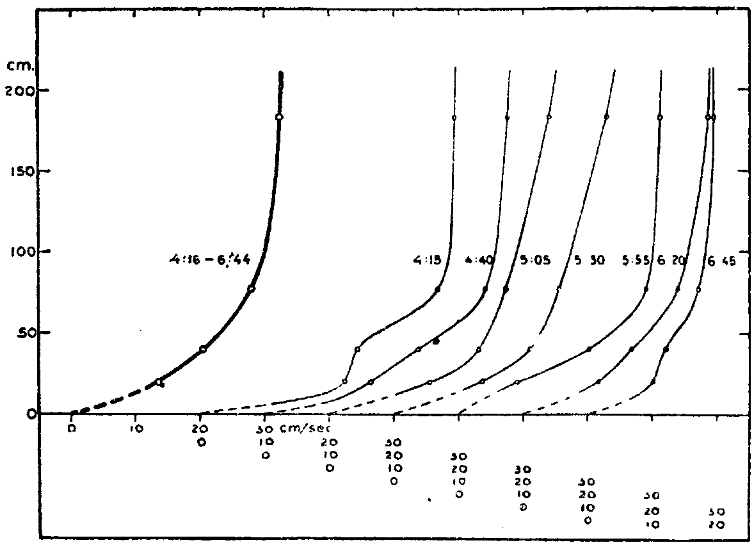

Fig. 3. Mean vertical velocity distribution.

spite of the heavy strain on the cables in a strong current. At greater depths a special arrangement will probably be useful for indicating when the stand touches the bottom, especially if the current in the upper layers is strong. Thus at a surface current velocity of about 1 knot and at a depth of about 80 m. it appeared difficult to know when the instrument was standing on the bottom.

As an example of the results obtained we may briefly demonstrate some of the measurements which were taken on August 30, at Alværstrømmen near Bergen. In this case the vessel dropped anchor nearly midstream; then she was moored to a little rock downstream and also at two points ashore. In this way she kept her position very nearly unaltered. The instrument was placed on the bottom at about 16 m. depth and at a distance of about 25 m. from the steep shore line.

One series of observations from this place covers about 3 ½ hours, from 3 h. 30 m. to nearly 7 h. 00 m. MET. The average velocity for every minute is plotted on fig. 2; the lower curve refers to the measurements at 20 cm., the upper curve to those at 40 cm. distance above the bottom. Measurements from higher levels are not reproduced here. It is seen that the variations are numerous and irregular. Consecutive means for 25 minutes are plotted on the same diagram, giving the heavy mean curves.

Figure 3 shows the average vertical velocity distribution during the period from 4 h. 16 m. to 6 h. 44 m. The curve is of a shape which may very well be interpreted by the usual logarithmic law. In the same diagram are shown also the 25 minutes means for the hours 4 h. 15 m., 4 h. 40 m.. ......6 h. 45 m. These curves are more irregular.

The results hitherto obtained, as those illustrated in fig. 2 and 3, shall not be discussed here, they may serve as a mere orientation as to the conditions prevailing near the bottom. But they must be said to encourage further work with similar but more precisely constructed instruments.