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THE DENSIGRAPH

(An apparatus for continuous density recording of seawater)

by

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When studying the different properties of water, and especially of sea-water in the fjords, in order to find the variations with depth of density, temperature and oxygen content it seems increasingly necessary to search for methods which will enable us to record these variations continuously

Dealing with temperature recording, the thermosonde (Mosby) and the bathythermograph (Spilhaus) have practically solved this problem. Especially, bathythermograms taken in a fjord have shown how extensive variations some times may be recorded within one meter, variations which perhaps never would have been observed when using reversing thermometers.

When studying the density of the water no apparatus exists which records the variations continuously. During some years we have, therefore, tried to find a method which might solve this problem.

Two different ways have been followed. In the first one it was tried if the absorbtion of the penetrating rays from a radium source might be used for determining the density. In spite of the fact that this method never has been brought so far as to be used in practical work, we will shortly mention it in an appendix, as the laboratory experiments have shown that this method with more technical elaboration perhaps will be the best path to follow in the future.

On the other hand we have succeeded in constructing a densigraph depending upon direct measurements of density. This apparatus has been used in our laboratory for about a year. As the principle of this densigraph is the same as the principle of an apparatus for rapid measurements of density of surface seawater samples, used in our laboratory for some time we should firstly like to describe this apparatus.

Apparatus for rapid density measurements of seawater samples.

The apparatus (fig. 1) consists of three vertical tubes of about 0.5 cm inner diameter, brought to communicate at the bottom through a T-shaped tube. Tube 1, the shortest one, is about 100 cm long. Tube 2 is about 5 cm longer, and the upper part of it is widened to a small funnel. Tube 3, the longest one, consists of two parts, a vertical part and a shorter oblique part. The oblique part forms an angle to the horizontal plane of about 15°.

Tube 1 and 2 are filled with water, but tube 3 is filled with a liquid which does not mix with water. Here was used petrol coloured with sudan red. The length of this tube is adjusted, so that the petrol column,

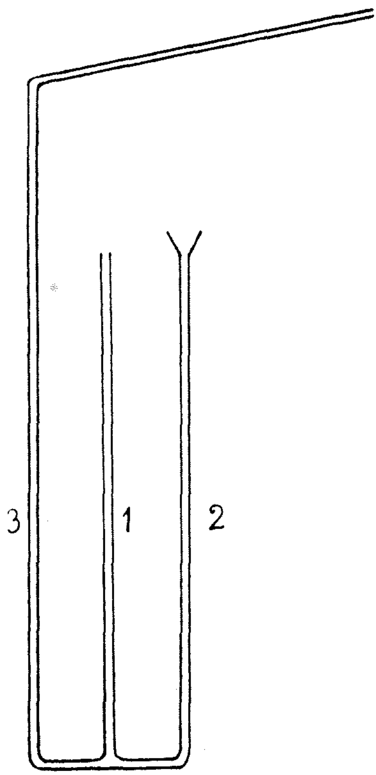

Fig. 1.

which is balancing the system, reaches some cm into the oblique part of the tube, when tube 1 is exactly filled with fresh water at room temperature.

The weight of the water column depends on the length of tube 1, and as the weight is balanced by the weight of the liquid column in tube 3, the height of the petrol column is a measure for the density of the water in the apparatus. As the level of the petrol moves in the oblique part of the tube, the sensitivity of the measurements is great. Behind this oblique part is placed a scale. When the density of a water samples is to be measured, the water is filled into the funnel of tube 2: then the old water flows out of tube 1, and as the volume of these tubes is only about 40 ml, all the old water is soon exchanged, and the density is recorded by means of the petrol level. The apparatus has to be calibrated during a series of measurements by means of waters of known densities.

This apparatus works rapidly, needs no reagents, less water than a usual aerometer and the density it determined with an accuracy of about ± 0.0002.

By using a greater diameter on the bottom part of tube 3, the sensitivity can be highly increased.

Apparatus for continuous density determinations of seawater.

The apparatus described above will directly act as a continuous density recording apparatus if the water is continuously filled into tube 2 and more rapidly than it will flow out of tube 1. In this case tube 2 will soon be filled, excess of water will flow over the edge of the funnel at the same time as a continuous stream of water flows through the apparatus. The length of the water column in tube 2 is fixed, and the weight of the water is balanced by the liquid in tube 3. Thus the variations in density of a waterstream can continuously be recorded by continuous recording of the variations in the petrol level. This can easily be done, for instance photographically, by a moving film. One will only have to make certain that the water is filled smoothly into the funnel and that no temperature-variations influence the length of the petrol-column. Arranged in this way the apparatus may be placed on board ships and be able to record the density variations in the surface-water during a cruise, if surface-water by means of a small pump is continuously feeding the apparatus.

Apparatus for continuous determinations of vertical density-variations in the sea.[1]

The apparatus described above is placed in a thick-walled container (fig. 2) closed in both ends and with a stopcock at the bottom. Tube 1 and 2 are in their whole length placed in the container, but tube 3 passes through the upper part of it, so that the oblique part can be seen and the movements of the petrol level be recorded outside the container. The tube is then bent back and passes into the container where it opens. In this way the air pressure over the three tubes always

[1] If desired a firm in Oslo will try to manufacture the apparatus.

will be equal. When the apparatus is lowered through the water, the pressure will cause the water to flow continuously into the container through an U-shaped tube which opens directly over the funnel of tube 2.

The density variation visible by the movements of the petrol column is continuously recorded by means of a special photographic arrange-

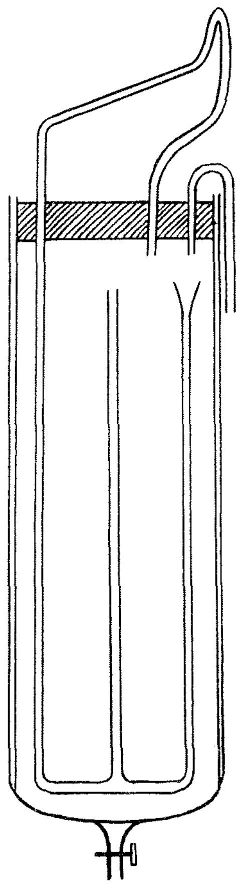

Fig. 2.

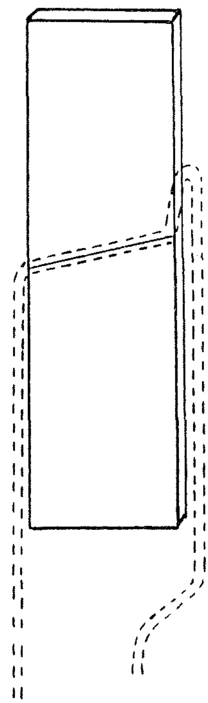

Fig. 3.

ment, fig. 3. A metal box 30 cm long, 7 cm broad and about 0.5 cm deep, open in the upper part, is placed vertically immediately behind the free part of tube 3. A very thin split is cut out across the box in such a way that this split in its whole length is absolutely covered by the oblique part of tube 3. A small watertight pocket lamp, placed in the front of the box about 10 cm away, illuminates the system. A photographic plate held in usual photographic caset moves in the box behind the split and photographs the petrol level in the tube. The caset can be opened within the box, and by an arrangement with a stop plate it is possible to shut it before it is taken out.

The caset is fixed to the piston of a syringe pipette, filled with air and locked. When lowered into the sea, the water pressure will force the piston into the pipette. In this way the movements of the photographic plate are regulated by water pressure, that is by depth. The movements will not be linear with the depth, as the piston goes half of its possible way with the first 10 meters, 2/3 by 20 meters and so on.

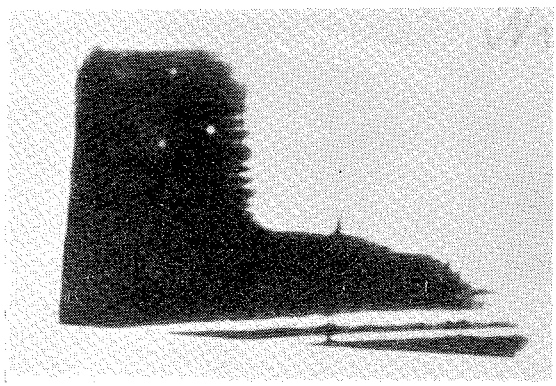

Fig. 4.

When available, an arrangement similar to that used for moving the slides in the bathythermograph will replace this arrangement.

The apparatus is very easy to use; it is not much more than twice as long as a usual water sampler and has about the same diameter. It is lowered into the sea with a speed of about 7 meters per minute, but may be taken up as fast as desired.

The apparatus will naturally not give the same accuracy in the density determinations as can be obtained by separate observations with the waterbottle, reversing thermometer and salinity titration. On the other hand it works many times as fast. The observations are available as soon as the photographic plate is developed and fixed, which has to be done on board, and the density variations are recorded continuously, giving a much truer picture of the density variations with the depths than can be obtained from diagrams drawn through the few points obtained by the usual method. Especially dealing with the discontinuity layers the densigrams obtained give a quite new picture as they have shown how waters of different densities often are forming definite strata.

In the figures 4, 6 and 7 some of our densigrams are reproduced. The right contour of the black shadow represents the σ_t-diagram. On the original slide 1 cm represents a σ_t-variation of about 3, that is a density variation of 0.003.

Adjunct the densigram fig. 4, a diagram from the same station is reproduced fig. 5. The solid line represents the diagram obtained by means of the densigraph. The dotted line is a diagram obtained by the ordinary technique, with watersamples from 0m, 5m, 10m and 25m.

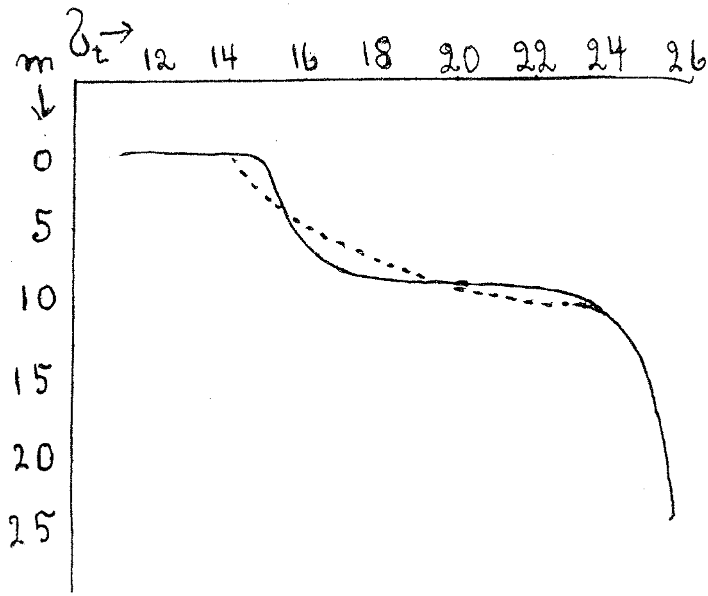

Fig. 5.

Fig. 6 and 7 reproduce densigrams from Oslofjord and Dramsfjord inside the thresholds. Remarkable is the densigram from Dramsfjord. Here the freshwater forming the upper layers is not recorded by the apparatus but the densigram shows how this freshwater is resting on the top of saltwater, coming in to full salinity between 8 and 11 metres.

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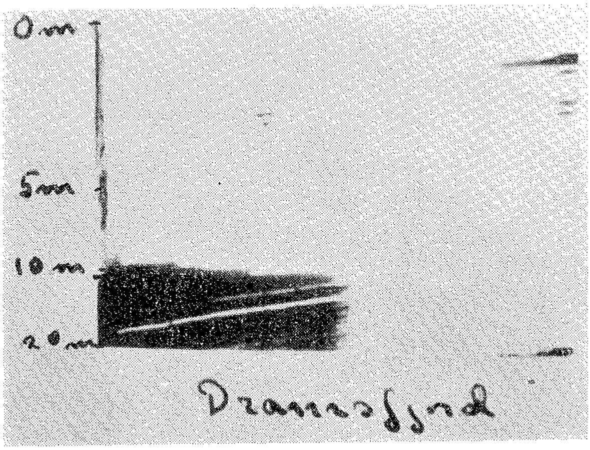
0 m
5 m
10 m
20 m
Dramsfjord

Fig. 6.


0 m
5 m
10 m
20 m
Oslo Vestfjord (Steilene)

Fig. 7.

Appendix.

As mentioned in the introduction we have tried to use the absorption of penetrating radioactive rays to determine the density of seawater. The absorption in a compound is a function of the density of the compound. A radio-active preparation emitting β and γ rays was placed symmetrically to two identical containers filled with water. Behind these containers, also symmertrically to the radium source, were placed two equal ionisation chambers loaded with an equal but opposite electrical charge. The isolated system of the ionisation chambers is in connection with the isolated system of an electrometer.

When the watersamples in the containers have the same densities, the absorption of the penetrating rays is equal. The ionisation effect in the two chambers will then neutralize each other, and no charge is being recorded in the electrometer. The system is balanced.

If the watersamples in the containers have different densities, the absorption will be different, the ionisation will be different, and we can measure the density difference by means of the electrical charge on the electrometer.

We had for our purpose a radium source of 0.25 mg.$RaBr_2$, and by means of this it was possible to record density variations in the laboratory, similar to those which are usually found in the Oslofjord. In order to make this into a practical apparatus, one will have to exchange the electrometer with a stable, sensitive amplifyer and to use a stronger radioactive source, both of which are not available in our laboratory.