A NEW HYDROMETER OF TOTAL IMMERSION WITH ELECTRO-MAGNETIC COMPENSATION.

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IN the present note, I intend to propose a new method for determining the specific gravity of liquids and especially the specific gravity of seawater, from which the salinity may be calculated with high degree of accuracy.

The different hydrometers which have been used or merely suggested for this kind of work may be divided into two groups: floating hydrometers and such as are worked by some method of total immersion. As regards the floating hydrometers, it may be mentioned that Nansen has made a very careful study of the errors and irregularities adhering to these instruments. Nansen arrives at the conclusion that the chief cause of their drawbacks lies in uncontrollable changes in the surface-tension of the water; he also discusses the precautions and corrections that are necessary in order to eliminate these influences. The number of the precautions to take is however so large, that several eminent oceanographers are inclined to discard the floating hydrometer as unsuitable for accurate work.

In order to avoid the errors arising from variations in the surface tension of the liquid, hydrometers of *total immersion* have been invented; and here I may refer to the papers of Guglielmo, of Reggiani and especially to the discussion presented by Nansen, who gives several references regarding this subject. It appears that the methods of total immersion are primarily of two kinds: such methods, where the hydrometer itself through the adding of small loads is brought to the point where it just sinks down totally in the liquid, and such ones where the specific gravity of the liquid is changed, in order to attain the same end. The ingenious method used by Nansen is a combination of these two principles. Very small changes in the density can be produced by raising or lowering the temperature of the liquid by means of a thin platinum spiral, heated by an electric current.

The objections against these methods, that, when properly used, seem to be very accurate, arise from the inconvenience of loading and unloading the hydrometer, or, if the heating method is used, from the difficulty of knowing if the hydrometer and the air contained in it have reached the temperature of the surroundings or not. And finally the hydrometer must then be adjusted to an unstable equilibrium, as the least change will bring the hydrometer to the surface or to the bottom of the vessel. A considerable time is therefore required for each determination.

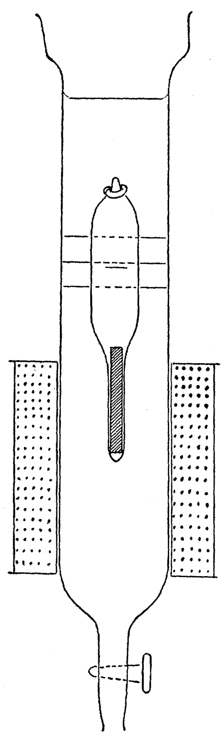

Fig. 1.

A third and indirect, very accurate, method is that of determining by titration the amount of chlorine contained in the seawater. This method is almost exclusively used by the international organization for the study of the North Sea. From the amount of chlorine in the water, its salinity as well as its density at different temperatures can be found from Knudsen's well-known hydrographic tables.

While I was engaged in certain investigations at Bornö Station, its director, Professor Otto Pettersson called my attention to the want of an improved method of total immersion more convenient than those described above, and as accurate as the chemical method. It then occurred to me that considerable advantage might be gained with a hydrometer of total immersion worked by electromagnetic compensation, *i. e.*, counterbalancing the buoyancy of a float completely immersed in seawater by an electromagnetic force acting on a piece of soft iron within the float.

The instrument constructed according to this idea is shown in Fig. 1. The float is drawn out into a narrow tube, that contains a rod of soft iron, 4 cm. in length, and some 3 mm. wide. The outer vessel, which contains the liquid to be investigated, has its lower part drawn out to the shape shown by the figure. It is surrounded by a coil, that has a length of about 12 cm. If the force acting on a piece of soft iron, which varies both with the intensity and the divergency of the E.M. field, is plotted against the vertical distance from the center of the coil (C), we would obtain a curve of the general type shown in Fig. 2. Suppose now that the electromagnetic force is counterbalanced by the buoyancy of the float, containing the piece of soft iron. The float will then come to rest in a position, where the E.M. force is equal to its buoyancy. The equilibrium is stable provided that the float is brought to rest at a place corresponding to a certain point (P) on the part AC of the curve. An increase of the current through the coil or a decrease of the buoyancy of the float, viz., the specific gravity of the liquid, will bring the float nearer to the center (A). If the float is always brought to rest at a fixed distance from the center, a certain current through the coil will always correspond to the same buoyancy. The adjustment is very sensitive at points corresponding to the maximum of the curve, where dl/df has its largest value.

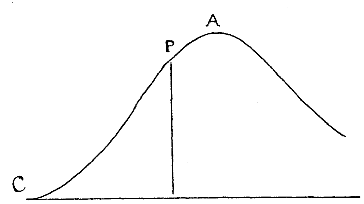

Fig. 2.

A determination is made in the following way. The water sample is poured into the vessel which has previously been washed out with another part of the same sample. The float is loaded with a fine platinum spiral of known weight until it very nearly sinks in the liquid. By sending a current through the coil the float is depressed until the mark etched on the float coincides with that on the wall of the envelop. The current is measured on a milliammeter and from the observed value the specific gravity of the water sample can be found from an empirical table obtained by standardizing the instrument once for all with a few samples of different salinities checked through titrations. The final adjustment is made by the E.M. compensation. The rough adjustment is realized by loading the float with a set of light platinum spirals of known weight. In this way the use of the instrument can be extended over the whole range of specific gravity occurring in oceanographic research, *i. e.*, 1.000 to 1.028, whereas the sensibility can nevertheless be kept as high as 0.00004 or even higher. This sensibility allows of measuring the salinity of a water sample with the degree of accuracy agreed upon as sufficient for modern research at the International Congress of Stockholm, 1899.

I may finally include here some observations made with a preliminary type of the described instrument. The load of the float was adjusted until the float was just nearly sinking in a water sample of a specific gravity corresponding to a salinity of about 23.4 pro mille. Varying the salinity, I must send currents of varying strength through the coil, in order to keep the float at the mark. With the aid of a current between 0 and 75 milliamperes, I may then control a range corresponding to a difference of salinity of about 2 pro mille. In Fig. 3 the relation between the current (y) and the corresponding salinity (x) is given by a curve. The observations are represented by circles. The permeability of the iron not being constant, the relation is evidently not a linear one. But if we confine ourselves to work with fields that are not too small, viz., with currents larger than 35 milliamperes for the special kind of instrument here used, the relation may practically be regarded as linear. It must however be noticed that the sensitiveness of the instrument is larger the less the current is and it may therefore sometimes be found favorable to work with small currents, which always can be attained

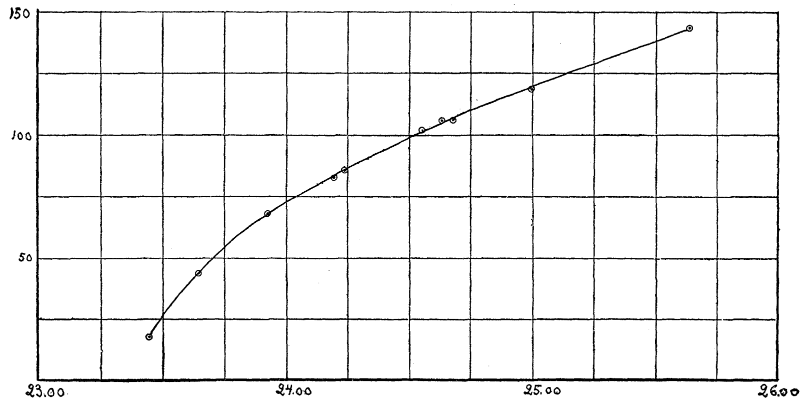

Fig. 3.

The Ordinates give currents used for compensation. The Abscissas represent satinity of water sample, given in pro mille.

through extending the use of loads. The mean deviation of the observations from the curve corresponds to less than 0.01 per cent. of salinity. The method may naturally be applied with advantage in all cases where the specific gravity of liquids is to be determined with high degree of accuracy, within relatively small intervals.

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