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On the recording of the thermohaline layering with an improved bathysonde

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Summary: Some statements are made how the so-called bathysonde - a temperature, conductivity, and pressure measuring device - was technically improved. The working method of the instrument is described with some examples of measuring results from the Skagerrak, the Kattegat and the Mediterranean. Finally some problems are discussed which occur when evaluating in-situ-measurements of the electrical conductivity in the deep sea.

In April/May 1962 measurements of the thermohaline layering with an improved type of the so-called bathysonde were carried out. This bathysonde is the improvement of an instrument, which was developed by H. HINKELMANN at Kiel University in 1956 to 1958 and which is used since then by the Institut für Meereskunde, University Kiel. The principle of work is as follows: three probes are mounted in an underwater unit: a platinum wire thermometer for temperature measurements, a toroidal core assembly for measurements of the electrical conductivity and a Bourdon tube to measure the pressure. Each probe is the frequency determining part in an oscillator circuit. Thus we receive three frequency signals in different frequency ranges which can be transmitted to the ship simultaneously over the single conductor cable, carrying the device. Over a rotating contact at the winch these signals are led to the shipborne device. They are separated with the aid of suitable filters and then represented as DC-current by means of frequency measuring circuits. These signals may be used for recording temperature and conductivity in dependence from pressure, i.e. from the depth, on an X_1X_2Y-recorder.

During the last time the following improvements of the instrument were carried out:

1) a reconstruction of the measuring probes
2) an enlargement of the measuring range
3) an increase in the measuring accuracy.

The thermometer was improved with respect to its time constant by using a low-resistant platinum wire which is mounted in a thin gold tube to be protected against pressure. Thus we get a time constant of less than 0.2 sec. In order to protect the toroidal core assembly against pressure, it is mounted in a steel housing tightened with O-rings which at the same time serve for an electrical interruption of the current path in this housing. In the course of this report I shall have to tell you something about our experience with this construction. The pressure measuring pickup was made less sensible to shock by an alterated construction of the ferrite core which is connected to the Bourdon tube.

In order to use the bathysonde in every oceanic water, extended ranges were required which could not be achieved with the described construction, if the measuring accuracy of about 0.01°C and 0.01 mmho/cm should be achieved. To solve this problem, two changes had to be made: First all the frequency determining parts with temperature dependence were mounted in a thermostat and second the total ranges for temperature and conductivity were divided into a great number of sub-ranges. The best way is, to make this subdivision by switching the oscillators themselves. In this case the frequency stability of the oscillators needs not be extremely high. This means, however, a switching by transmitted frequency signals from board. One therefore will try to limit the number of switch positions in the underwater device to a minimum and to make the further subdivision in a special device on board. Thus we got the following construction: In the underwater unit are three oscillators. The two oscillators for temperature and conductivity may be switched on 10 different measuring ranges by frequency signals from a signal sender, mounted on board. Range 1 is always a whole range, switch positions 2 - 9 cover eachother overlapping sub-ranges. The three measuring frequencies are filtered on board, then the signals for temperature and conductivity are led into another unit to get once more five sub-ranges for each channel by a heterodyne circuit. The now received frequencies are transformed into DC-current signals and then recorded on a X_1X_2Y-recorder. The instrument delivered from the Kieler Howaldtswerke to our institute has a measuring range of -2 to +35°C at a relative accuracy of better than 0.02°C, of 20 to 70 mmho/cm at a relative accuracy of better than 0.02 mmho/cm with atmospheric pressure and of 0 to 2,000 m at a relative accuracy of about 1 % from the total depth range.

Thanks to the kind help of the Fisheries Institute in Göteborg, we could carry out the first measurements of the thermohaline layering with this improved instrument in the Gulmarfjord on board the research cutter "Hermann Wattenberg", University Kiel. Besides we have made measurements in the Skagerrak and Kattegat in spring this year. We are very much obliged to the Bureau d'Etudes Océanographiques which enabled us to make the first measurements in the deep sea on board the French research ship "Origny" in the Mediterranean. All these measurements were single measurements to test the new instrument and were combined with Nansen-bottle measurements to check the results. The evaluation of the measurements was made in the Institut für Meereskunde, Kiel University, and partly by Mr. PELUCHON, Bureau d'Etudes Océanographiques, Toulon, and by Dr. HINKELMANN, Institute for Applied Physics, Kiel University. In all cases, the measuring results of the Nansen-bottles were compared with those of the bathysonde. As these two measurements were not carried out simultaneously, the difficulty arose that they could not be absolutely identical, because of the slight drifting of the ship

- 4 -

and variations in time of the layering. In addition it was not possible to decide whether the two compared measurements were taken in exactly the same depth. Having these sources of errors in mind, we may draw the following conclusions from the hitherto received recordings for the evaluation. The deviations of the temperature record are less than 0.02°C. However, we had to realise that the frequency stability of the corresponding oscillator is not yet good enough over a period of several months. We noticed a deviation from the calibration curve of 0.05°C, which, however, can easily be corrected through a few comparing measurements. At present test series are made to show the exact magnitude of this frequency drift to get an explanation for the reasons causing these deviations.

Another problem is the evaluation of the conductivity record, because, when making in-situ-measurements, we have to consider both, the temperature dependence of the conductivity as well as its pressure dependence. Unfortunately, there are until now no complete investigations at hand on the pressure dependence of the conductivity, so that an accurate evaluation is impossible. To get inspite of this a first impression about the usability of the in-situ-measurement of conductivity, we have made in accordance with not yet published measurements of BRADSHAW the following formulation, which naturally can only hold for an approximation here:

$$C_p = C_1 + 1.2 \cdot 10^{-4}\ Sp$$

C_p is the conductivity in mho/cm under the pressure p; C_1 is the conductivity in mho/cm, calculated after THOMAS, THOMPSON and UTTERBACK with the temperature and salinity; S is the salinity in ‰; and p is the pressure in kg/cm^2. As ~~obviously~~ the probe is also pressure dependent we used the following formula for the evaluation of the measurements:

$$C_r = K\ (p)\ (C_1 + 1.2 \cdot 10^{-4}\ Sp)$$

C_r is the recorded conductivity in mho/cm and K (p) is the factor which gives the pressure dependence of the probe itself. K (p) was determined from the entire up to now available measurements. The function K (p) shows a first with the pressure decreasing and then increasing behaviour, where the differences amount to several per cents. With this determined curve an evaluation of the conductivity measurement is possible, however we cannot yet achieve the accuracy of better than 0.02 mmho/cm, which is achieved for the sea surface. We hope, the manufacturers of this instrument will be able to reduce the influence of factor K (p) in a reconstruction of the conductivity probe to get the accuracy of 0.02 mmho/cm in any depth down to 2.000 m.

To sum up, we may say, that now we are able to make accurate investigations of the temperature layering in the sea down to 2.000 m depth by continuous recordings with the bathysonde. Already the first measurements in the Mediterranean have shown that now we can exactly study slight variations in time and space of the temperature layering. After reducing the pressure dependence of the conductivity probe it should be possible in the near future to measure also the electrical conductivity in situ with an accuracy of 0.02 mmho/cm, provided that until then the fundamental determinations of the pressure dependence of the conductivity are at hand.