*Journal of Marine Research, 79,* 101–105, 2021

# A bathythermograph

**by Athelstan F. Spilhaus[1,2]**

## 1. Introduction

In the study of the homogeneous layer in the ocean, Rossby and Montgomery (1935) found it desirable to have an instrument which would provide a continuous record of temperature against pressure in the surface layers of the ocean. A preliminary instrument named an "oceanograph" was constructed and used during the summer of 1934. The manifold uses to which such an instrument could be put presaged a widespread employment of the apparatus. This, however, did not come about because of certain inherent difficulties in Rossby's design. The record was made on a large smoked foil, and thus entailed the attachment of multiplying linkages to the actuating elements for pressure and temperature. Such multiplying linkages are uncertain in action in seawater, and, furthermore, the size of the instrument to accommodate them must necessarily be fairly great. At Prof. Rossby's suggestion, the author attempted to modify the oceanograph so that it would be more suitable for routine use. The modifications were made with the following aims in view:

(a) The instrument should if possible be small enough so that it can be lowered on an ordinary log line by hand if necessary, thus enabling it to be utilized on vessels not equipped with a hydrographic winch.
(b) The instrument should be sufficiently rapid in its response such that regardless of the rate at which it passes through the water no errors due to the lag of the thermometric element will be apparent.
(c) Care should be taken to eliminate hysteresis of the pressure element.
(d) The plates on which the record traces are made should be easily inserted and removed and easily evaluated.

1. New York University, New York, NY, USA.
2. Joint contribution from Woods Hole Oceanographic Institution (No. 167) and New York University.

Originally published April 9, 1938, in the *Journal of Marine Research* 1(2), 95–100.

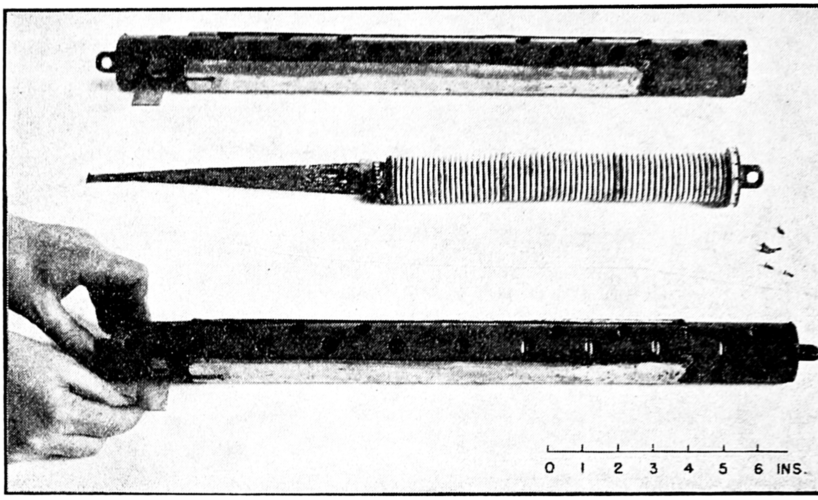


Figure 30. The bathythermograph.

## 2. Description of the instrument

The instrument finally evolved consists essentially of a pressure element comprising an hermetically sealed sylphon inside of which is a guide and compression spring to give the requisite pressure range. Mounted on the movable end of the pressure element is a straight bi-metal strip, and thus motion with pressure is at right angles to the deflection of the strip with temperature. At the end of the bi-metal strip a fine needle point is arranged to inscribe a trace on a small glass slide. The slide is prepared for the record by coating it with a thin layer of oil and then smoking the glass to slightly blacken it. The function of the oil is to prevent the smoked film being washed off by the seawater. In view of the fact that the motion of the inscribing point is in two dimensions, the plate which receives the record is held perfectly rigidly in the body of the instrument, and thus insertion and extraction of the plates are entirely independent of the sensitive actuating elements. Figure 30 shows the complete instrument in the lower photograph and indicates the method of insertion of the glass slide to take the trace, while the upper part of the illustration gives a view of the instrument partly disassembled to show the simplicity of the actuating elements. Figure 31 is a photographic enlargement of an original record from the small slide, and the accompanying key diagram shows the trace superimposed on a calibration grid. It can be seen that the record consists of two lines—one made during the descent of the instrument, and the other during the ascent. It can be easily shown that hysteresis of the pressure element and lag of the temperature element both act in such a way as to separate the ascent and descent traces; so that if either pressure hysteresis or thermal lag are present to a marked degree, two distinct traces would have been recorded. The coincidence of the two curves, however, insures that the instrument is functioning correctly. From the standpoint of thermal

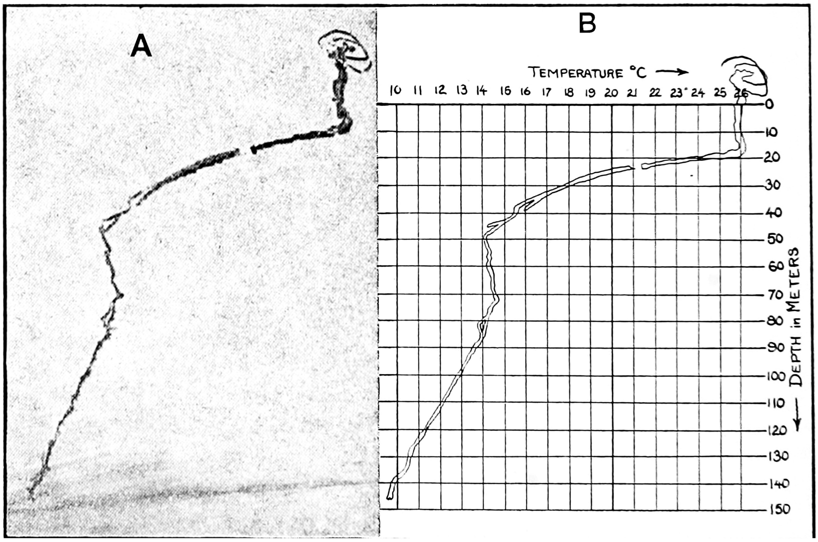


Figure 31. Photographic enlargement (A) from an original record of the bathythermograph, with key diagram (B) showing trace superimposed upon calibration chart.

lag the record is particularly remarkable when it is realized that in the case of the particular test in the photograph the instrument was sent down and brought up through the water at a rate of 100 m per minute. Thus the whole test down to a depth of 150 m was completed in 3 minutes. Evaluation of the record obtained is simply accomplished by projecting it by means of a miniature camera projector on to a calibrated screen. Tests were made by lowering the bathythermograph on the end of a log line and it was found that good records could be obtained by an ordinary seaman.

### 3. Some results of measurements made with the bathythermograph

On a cruise made by the "Atlantis," research ship of the Woods Hole Oceanographic Institution, measurements with the bathythermograph were carried out almost hourly for a period of two days, and remarkably sudden discontinuities in the thermocline and inversions of the thermocline were revealed. Figure 32 is a plot showing the temperature variation with depth on the horizontal and vertical axes respectively, while the time changes are set off along the oblique third axis. The bathythermograph records were traced directly on to this diagram from photographic enlargements of the original traces. This figure served to illustrate several points.

(a) Abrupt changes in the thermocline are shown, and it should be stressed that these changes must be actually present because they are in every case substantiated by the coincidence of the up and down trace of the bathythermograph.

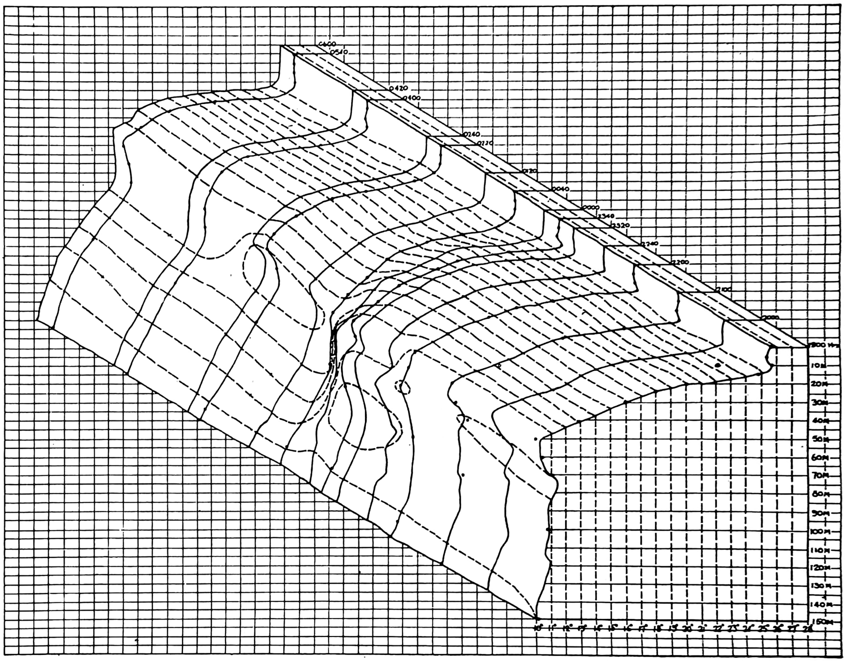

Figure 32. The variation of the temperature-depth profile with time, as determined from the bathythermograph traces and water bottle temperatures.

(b) The temperature depth structure below 50 m is quite complicated, especially for those tests between 1900 and midnight. Thus it is evident that if water bottles were used these intricacies of the temperature curve would be entirely overlooked, owing to the necessarily wide spacing of the bottles below 50 m.[3]

(c) The sudden change in the character of the temperature depth curve below 50 m between the hours 0000 and 0040 is very remarkable, for the "Atlantis" could not have drifted very far in this short space of time.[4]

3. This was actually the case. At Station no. 18 (26 August 1937, 2203 hrs.) of the cruise on which the instrument was tested the water bottles were spaced at 1, 5, 10, 15, 20, 40, 70, 150, 200, 300, and 400 m and the smooth curve, drawn by Mr. C. O'D. Iselin through the points thus obtained, completely missed an abrupt change from the summer thermocline to isothermalcy which the bathythermograph indicated to exist at about 60 m. Accordingly, at Station no. 19, one hour and forty minutes later in the same water, the spacing was altered to 1, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 100, 150, 250, and 350 m and the discontinuity of the thermal gradient as indicated by the bathythermograph was established. The latter distribution of water bottles was thereafter maintained for subsequent stations in the same region.

4. In a personal communication, Mr. Iselin informed the author that the T-S correlation also changes at the same time and, as the drift of the ship could not have been more than a mile or two, he concludes that the mixing in the neighborhood of 100 m depth was very incomplete.

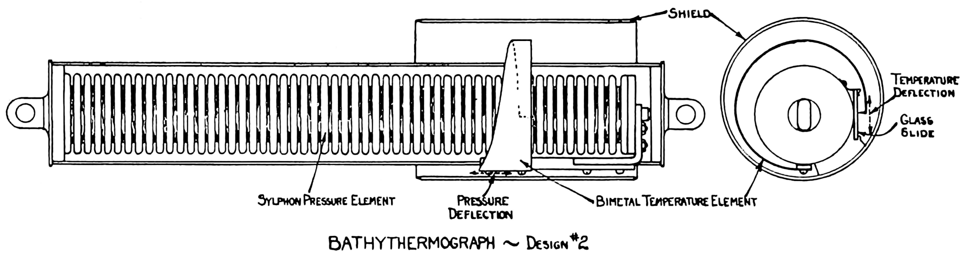


Figure 33. Design no. 2 for improved bathythermograph.

(d) The traces shown at the following hours were taken with the bathythermograph: 1900, 2000, 2100, 2240, 2320, 0000, 0120, 0240, 0420, and 0600; while the curve obtained from water bottle thermometer readings are shown at 1900, 2100, 2200, 2340, 0040, 0220, 0400, and 0540. Thus, comparison between the bathythermograph readings and the thermometer readings may be made directly for the two times 1900 and 2100 when both series were taken nearly simultaneously. Such small differences (never more than 0.2°C) as are evident may easily be accounted for by the difference in time between the water bottle temperature station and the bathythermograph test.

## 4. Further development

Though the result shown may be considered as very satisfactory, it is proposed to improve the instrument further by an attempt to utilize a design such as indicated in Figure 33. The improvement which such a design would incur is that the temperature element would be exposed directly to the flow of water and that all thermal lag by it would be eliminated. Furthermore, the size of the instrument, if constructed according to the design in Figure 33 will be cut down considerably and, though in the first design the coordinates are very nearly rectangular (because the length of the bi-metal strip is great compared to the deflection of its end), in the second design the coordinates will be perfectly rectangular. Finally it is thought that vibration will be entirely eliminated by the second design, and that, therefore, a finer trace and greater accuracy will be obtained.

It is hoped that this instrument can be produced, if demand is sufficient, cheaply enough to obtain it widespread application, not only by biologists and oceanographers, but also in the fishing industry- the apparatus being such that it can be handled by entirely untrained personnel.

REFERENCE

Rossby, C.-G., and R. B. Montgomery. 1935. The layer of frictional influence in wing and ocean currents. Cambridge: Massachusetts Institute of Technology and Woods Hole Oceanographic Institution. Papers Phys. Oceanogr. Meteorol. *3(3)*, 73. https://doi.org/10.1575/1912/1157