Modification of the Surface Sampler with a view to the Improvement of Temperature Observation.

By

J. R. Lumby,

Fisheries Laboratory, Lowestoft.

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In the earlier paper (1) describing the Surface Sampler, I mentioned that the objects for which the apparatus was designed were two-fold, namely, to make easier the actual collection of samples from the sea surface, and to procure a better sample to be retained for salinity analysis, when the collection is made from commercial ships. Furthermore, certain modifications of the instrument were outlined which, it was considered, might lead to an increased reliability of the temperature observations. These ideas are put into practical effect in the modified Surface Sampler now to be described.

The difficulties attending the observation of sea surface temperature from ordinary sea-going ships are well displayed in the Instructions to Marine Meteorological Observers (2) from which the following quotation is made.

"Experience has shown that numerous difficulties exist in the making of accurate water temperature observations. In the first place it is not an easy matter to dip up from the sea, from the deck of a moving vessel, a sufficient quantity of water so that the influences which immediately begin to operate to change its temperature shall not make too great headway before the thermometric reading can be made. Often the bucket used can be only partially filled, even by the most skillful handling. Some vertical stiffening of the ordinary canvas bucket and an extra middle ring to prevent collapse on entering the water are desirable. Sometimes a small quantity of water of a different temperature is in the bucket when the final dip is made. In the case of canvas buckets evapora-

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If the temperature of the wet bulb is different from that of the water the latter is affected as soon as the water is dipped from the sea. By the time a bucket can be drawn upward through a distance of from 30 to 60 or more feet, landed upon the deck, and the thermometer immersed in the water for a suitable period of time the temperature of the water will have undergone a definite change — in the direction of that shown by the wet bulb.

Instructions that have heretofore been given for making water temperature observations provide that the water shall be drawn in a canvas bucket from a point forward of the ejection pipes and that the bulb of the thermometer shall be immersed for three minutes and read with the bulb still in the water in the bucket. At times, however, there is a rapid cooling of the water in the bucket due to strong cold winds and on such occasions a shorter period of immersion is desirable. With a reasonably active stirring the thermometer will indicate the water temperature in one minute. Experience shows that readings should be made only in buckets not less than two-thirds full and that the bucket should be protected from the sun and wind."

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A thorough study of the conditions governing the observation of surface temperature at sea, and the accuracy with which such observations are commonly made has been undertaken by Dr. BROOKS (3), in which he classifies the chief sources of error which obtain when the observation is made on a sample of water withdrawn from the sea, e. g. by means of a bucket. They are given as follows: —

"Sources of error in the bucket method. — In the course of an observation with any type of bucket there are numerous influences tending to make the final record depart from the actual surface temperature: (1) The bucket is not likely to have the same initial temperature as the sea surface; (2) the water sample being hauled up is usually cooled by evaporation; (3) the thermometer inserted is seldom at the same temperature as the water in the bucket; and (4) while it is resting in the bucket further cooling, or perhaps heating, of the water may take place; (5) when the thermometer is read it may not have reached the temperature of the water in which it is immersed; and (6) if it is withdrawn, to be read more easily, the temperature of the very small sample in the reservoir may change before the temperature is observed; furthermore (7) after the markings and numbers have become indistinct errors of reading creep in, and it is easy to see the same temperature as at the tion from the surface of the fabric operates to change the temperature of the content. Sometimes the temperature of the water drawn up has been affected by the discharge through ejection pipes.

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Though Dr. BROOKS concludes his study by recommending the use of thermographs installed in the condenser intake pipes in preference to bucket methods, the attempt to improve the "bucket" method has been persevered with, because in our organisation at least, there are practical difficulties in the way of installing thermographs; for example, on many routes the individual ships from which observations are obtained are frequently changed and it is easier and less expensive to transfer a Surface Sampler from one ship to another than it is to transfer a thermograph. Moreover, though observations at intake depth may on the average be comparable with surface temperatures in the open ocean, experience with the water bottle in marginal seas, in particular the North Sea, teaches that observations at 0 metres not infrequently differ from those at 10 metres by more than 1° C. Thus, if it is possible to obtain an observation from what is commonly called the "surface" and at the same time to reduce the errors attending such an observation — at least to such an extent that the desired accuracy is ensured — one has the satisfaction of knowing that the observations do in fact refer to the same depth from whatever ship they may have come, whereas the depths of condenser intakes naturally vary a good deal.

In the main the new instrument (see Figure 1) is similar to the old, except that it is somewhat larger (weighing about 11 kilos assembled and full of water), the thermometer is included in the apparatus, and an insulating cylinder of celluloid is fitted. The eyebolt J[1]) and the preventer wire K have been discarded for general use.

A brass tube (1) screwed to the base of the apparatus contains the thermometer (2), the upper and lower ends of which are held fast in contrivances resembling packing glands. The upper gland (3) is secured to the brass tube by a bayonet joint (4) and spring (5); the lower gland (6) acts as a guide for the bulb end of the thermometer and in conjunction with a set screw (7) placed near the top of the brass tube, prevents the thermometer from being totally withdrawn from the tube. The glands themselves consist of two parts, which when screwed one into the other compress a rubber washer (8) on to the thermometer.

[1]) The lettering in Figure 1 is the same as in Figure 1 of the earlier paper. The numerals indicate the new parts.

The celluloid insulating cylinder (9) is held away from the outer wall of the apparatus by ebonite distance pieces (10), so that the sample is insulated mainly by a water jacket. An ebonite block (11) is fitted on to the base plate to complete the insulation.

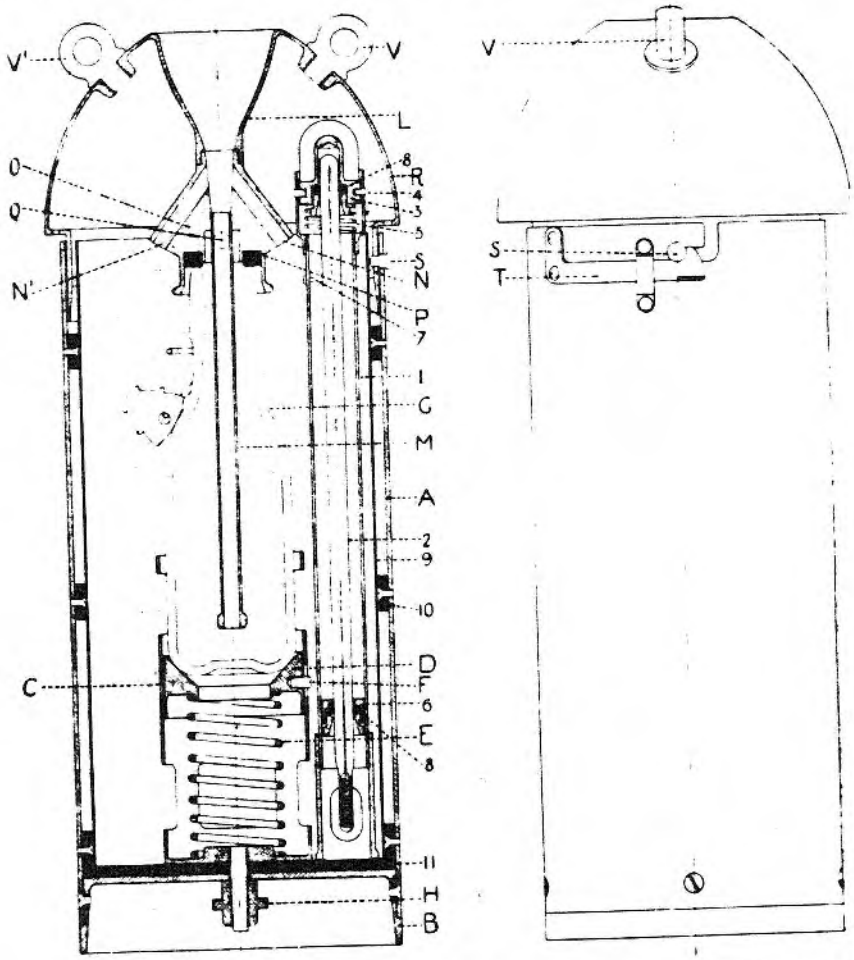

Fig. 1. The Modified Surface Sampler. The lettering is the same as in Fig. 1 of the earlier paper (J. du C. II. 3. 1927, p. 333). The numerals refer to the added parts of the design.

With the modified Surface Sampler the sources of error detailed by Dr. Brooks are guarded against in the following ways:—

The first point is that the bucket has not always the same initial temperature as the sea surface. The Surface Sampler is towed in the

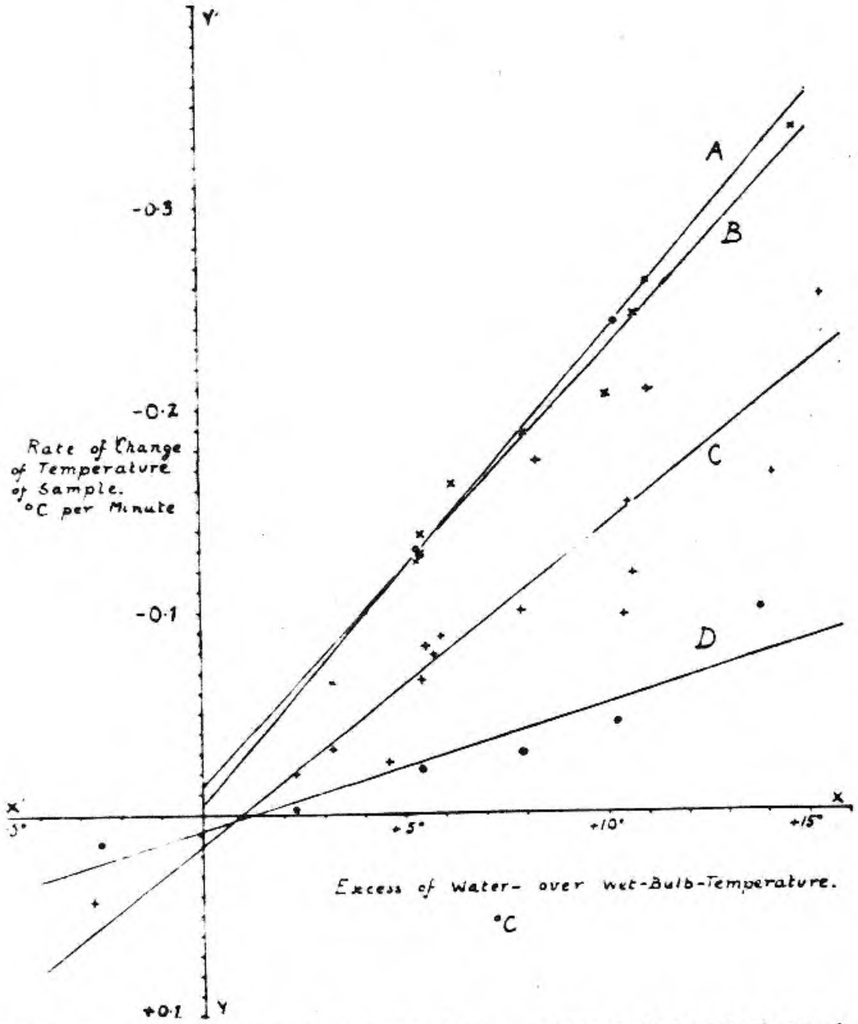

Fig. 2. Comparison of the rates at which the temperature of the sample changes in the several types of apparatus, for differing degrees of difference between wet-bulb and water temperature.

Curve A refers to Sampler with plain brass cylinder.
— B — - — coated internally with cellulose paint.
— C — - — with celluloid cylinder fitted tightly into brass cylinder.
— D — - Modified Surface Sampler.

sea for five minutes or longer, so that it has ample time to acquire the temperature of the water through which it is moving. Its initial temperature therefore has no effect on the final sample. Moreover, a full sample is always obtained.

The second point concerns the cooling of the sample (or warming, if the air is warmer than the water) while being hauled. In the modified Surface Sampler the sample is insulated by the celluloid lining and a water jacket. From Figure 2 (Curve *D*) it can be seen that, with an excess of 15° C. of the water temperature above the wet-bulb temperature, the average rate of change of temperature in the sample (over the first five minutes) was estimated to be less than −0.1° C. per minute. With an excess of 5° C., the rate would be about −0.02° C. per minute, so that in such circumstances an interval of 4 to 5 minutes could elapse after the apparatus left the sea before the temperature of the sample altered by 0.1° C.

Before the design was finally adopted, experiments were made to determine a suitable method of insulation. I stated in the earlier paper that lagging the outside of the cylinder with sheet rubber (which, incidentally, might have served to protect the apparatus to some extent from damage caused by knocking against the ship's side) proved of no advantage.

Coating the inside of the brass cylinder with cellulose paint was found to be equally ineffective. A celluloid cylinder of $1/16''$ material fitted tightly inside the brass cylinder of an old type instrument produced an appreciable improvement. As there was insufficient room to include a thermometer as a fixture in the apparatus, the diameter of the brass cylinder and thus the size of the whole instrument were increased, to provide room for the inclusion of a thermometer, and for a water jacket between the celluloid cylinder and the outer brass wall. This arrangement, namely, the provision of a water jacket in addition to the celluloid cylinder, together with the increased bulk of the sample obtained, is again a further improvement.

Figure 2 illustrates this progressive improvement. It shows the rates at which the temperatures of the samples would change under varying conditions of difference between wet-bulb and water temperature, in the several types of apparatus.

To obtain these comparisons, experiments were made on shore in the manner described in the previous paper for series *B* and *C*. The instruments were immersed in a tank of water (of which the temperature was varied as necessary), withdrawn after not less than 10 minutes and placed on a ledge before an open window. Successive readings of the temperature of the water sample were then made; the values for the rates of change of temperature are average rates over about the first 5 minutes after withdrawal from the tank. Points are plotted on the graph (Figure 2) with these values as ordinates and the corresponding differences between wet-bulb and water temperature as abscissae. To these points straight lines are fitted ($y = a + bx$). A comparison of the gradients of these lines $\left(\frac{dy}{dx} = b\right.$, see table below) brings out the three following facts. Firstly, an increase in the excess of water temperature over wet-bulb temperature has about the same effect on the rate of change of temperature of a sample in the plain brass cylinder (curve A) as on the rate of a sample in the brass cylinder coated internally with cellulose paint (curve B). Secondly, this effect is decreased to about two thirds of its original amount, when a celluloid cylinder is fitted tightly inside the brass cylinder (curve C). And finally, with the modified instrument (curve D), the effect is decreased to a quarter, as compared with the plain brass cylinder.

For curve A, $b = -0.023$
— B, $b = -0.022$
— C, $b = -0.016$
— D, $b = -0.006$

Thus adequate precaution is made against alteration of the temperature of the sample while hauling, provided that the process of hauling is not unduly prolonged.

Returning to the points enumerated by Dr. Brooks we may take Nos. 3, 4, 5 and 6 together. He states that in the ordinary "bucket" method errors may spring from the insertion of a thermometer not at the same temperature as the sample, from alterations of the temperature of the sample while waiting for the thermometer to acquire that temperature, from the thermometer being read before reaching the temperature of the sample and, finally, from the thermometer being withdrawn from the sample for reading. In the modified Surface Sampler none of these sources of error are present; for since the thermometer is a part of the apparatus, it has always the same temperature as the sample and there is therefore no necessity to wait before reading the thermometer, when the sample has been brought inboard and the head of the apparatus removed. For the same reason it is impossible to read the thermometer before it has acquired the temperature of the sample and, provided the set screw (7. Figure 1) is in position, the bulb of the thermometer cannot be withdrawn from the sample.

AT NIGHT

Points 7, 8 and 9 deal with errors due to inaccurate reading, to inaccurate thermometers, and to forgetfulness on the part of the Observer. These matters are not guarded against, except in so far as it is possible to promote the interest of Observers in their work by maintaining liaison with them and to provide for periodic examination and recalibration of the thermometers in use.

There is, of course, always present a far greater measure of the personal element in "bucket" methods than in those where mechanical registration apparatus such as a thermograph is employed. For this reason, in spite of the fact that cooling of the sample while hauling has been guarded against to some extent, this precaution would be unavailing against what could only be termed carelessness and lack of interest. Nevertheless, observations can be obtained under the ordinary routine of a sea-going ship which may be relied upon to a much greater extent than can those obtained by the old methods employing canvas buckets and the like, the fulfilment of the requirements of which cannot reasonably be expected in such circumstances.

To effect this, full consideration must first be given to the conditions under which the work is carried on. Secondly, instruments must be provided which make it practicable for observations to be made under these conditions to the desired degree of accuracy. This latter criterion, it is claimed, is met by the modified Surface Sampler.

It is possible to form an estimate of the reliability of observations made with the Surface Sampler by using Dr. BROOKS evaluation of the errors from canvas bucket observations[1]). He finds that, on the average, the quartermasters observations were 0.5° C. (1° F.) below sea temperature. The initial coolness of the bucket seems to account for 0.1° C., cooling while hauling accounts for 0.15° C., cooling while waiting to take a reading for 0.1° C., and "cooling by or of the thermometer, the average error in reading and from inexactness in time of observation" account for the remaining 0.15° C.

With the Surface Sampler the error due to initial coolness of the bucket does not arise. As for the cooling while hauling, the most usual depression of the sling wet-bulb below sea-temperature seems to have been about 8° C, for which depression the rate of change of temperature of the sample would be — 0.04° C. per minute (see Figure 2). If the error which arises when hauling the Surface Sampler is taken to be the same as the combined errors due to cooling when a canvas bucket is hauled and time allowed for the thermometer to settle down, namely, 0.25° C., then 6 minutes could elapse while the Surface Sampler is hauled, its head removed and the thermometer read. I found that the rate of change of temperature of the sample for the canvas bucket with a depression of the wet-bulb $6^1/_2$° C. below water temperature (see previous paper,

[1]) loc. cit. p. 247.

p. 337, Table 1, columns 4, 7 and 12, series C) was — 0.11° C. to — 0.12° C. per minute. Since the combined error due to cooling of the canvas bucket while being hauled and while the thermometer is being read, is 0.25° C. for a difference (we have assumed) of 8° C. between sling wet-bulb and water temperature, it follows that the canvas bucket was brought inboard, the thermometer immersed and read in not longer than 2 minutes.

The time required to haul the Surface Sampler and to read the thermometer can certainly be no longer (and is probably shorter, in consideration of the fact that there is no necessity to wait for the thermometer to reach the temperature of the sample) than the time required to haul a canvas bucket and obtain a temperature observation.

2 mins

If 2 minutes is allowed, therefore, for hauling the Surface Sampler and reading the thermometer, the average error due to cooling during this time (2 minutes) would be 0.08° C. (say 0.1° C.), under the same conditions as for an average error with the canvas bucket of 0.25° C.

Errors from cooling by or of the thermometer do not arise, and the average error due to inaccurate reading of the thermometer and inexactness in noting the time of observation may be put at 0.1° C., the same as for the canvas bucket.

The total average error with the Surface Sampler, estimated in this way, is not more than 0.2° C., which is to be compared with an average error of 0.5° C. for the canvas bucket. This comparison is further displayed in the following table:—

Muddles systematic & random errors.

Average Error due to:—	Surface Sampler	Canvas Bucket
Initial difference of temperature between apparatus and sea	0° C.	0.1° C.
Cooling while hauling	0.1	0.15
— while obtaining observations		0.1
— by or of thermometer	0	0.05
Inaccuracy in reading	0.05	0.05
Inexactness in time of observation	0.05	0.05
Total...	0.2	0.5

Adaptation for use from Light Ships.

Even when used from ships which steam relatively slowly, (e. g. 8 knots) the Surface Sampler when towed remains in the water surface. At the English light vessels, however, from which routine observations are made, the tidal stream is far from reaching any such speed; in order to make the use of the Surface Sampler possible from these ships, floats have been provided under which the Sampler is slung (Figure 3) the only addition required to the Sampler being an eyebolt (*A*) screwed into the base. The float (*B*) is constructed in cylindrical form of tinned iron. The diameter of the cross section of the cylinder is 20.3 cms. and the height 38 cms. The weight is $1^3/_4$ kilo. It is fitted with a drain screw (*C*)

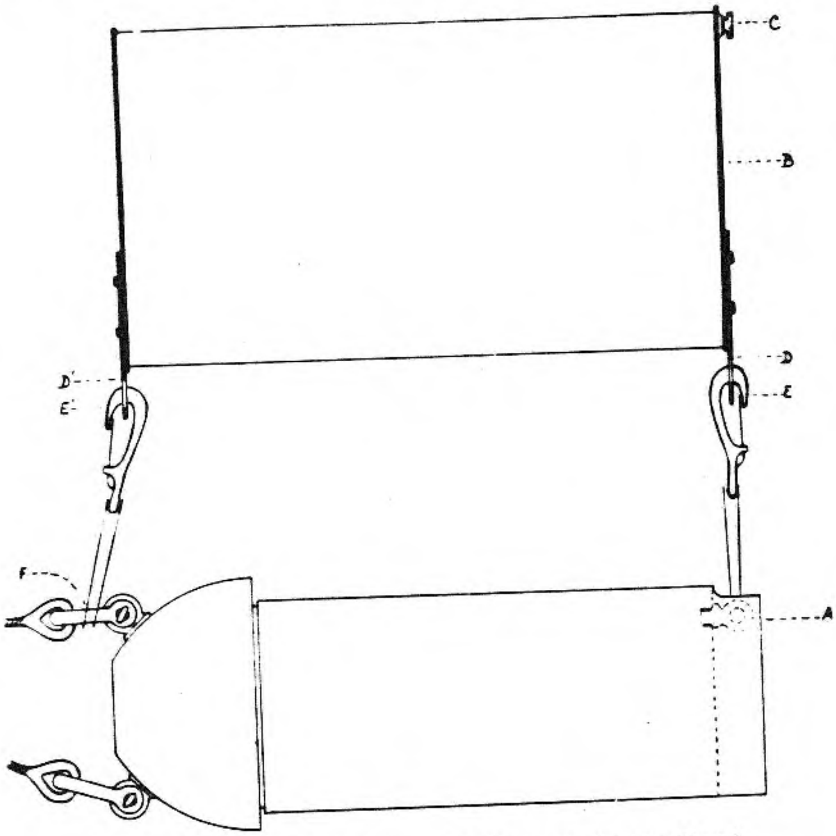

Fig. 3. Method of towing when used from moored Light Vessels.

and two projections (*D*, *D'*) on to which two spring hooks (*E*, *E'*) can be attached. These hooks are lashed respectively to one of the shackles (*F*) secured to an eyebolt in the head of the Sampler, and to the eyebolt specially provided in the base of the Sampler. The gear is worked in the same way as from other ships, except that it is left overboard for a longer period in order to give time for the slower flow of water to effect an efficient washing of the bottle in which the salinity sample is to be stored. The time recommended in these circumstances is half an hour to an hour.

It is to be noted that the sample in this case comes from some 15 to 30 cms. below the surface.

In conclusion, I again have pleasure in acknowledging my indebtedness to Mr. H. J. Garrood for his advice and help in the design, and to Messrs. Elliott and Garrood, Beccles for the drawing of the apparatus from which Figure 1 was prepared.

References.

(1) J. R. Lumby. Journal du Conseil. II. 3. 1927. pp. 332—342.
(2) U. S. Department of Agriculture Weather Bureau. Washington D. C. Circular M 4th Edition. Jan. 1925. p. 15.
(3) C. F. Brooks. U. S. Department of Agriculture, Weather Bureau. Monthly Weather Review. LIV. 6. Washington 1926. pp. 241—254. (See review on p. 385 of this number.)