

are large and unpredictable. A careful study indicates that theoretical bottom velocities are not applicable. Experimental velocities were used in smooth plotting the season's radio-acoustic work, and, for the inshore and intermediate areas on the continental shelf where there were sufficient positions determined by returns from three buoys, the final results are accurate. At this point it is desired to emphasize the important advantage in the use of *three* instead of two radio-acoustic ranging stations. The use of at least three sono-radio buoys simultaneously makes for efficiency and increased accuracy. It certainly decreases the uncertainties in the velocities of sound. It "fixes" the probable velocity to be used for the area for the time of the survey. That the correct locations of the buoys are of primary importance, of course, is self evident. Theoretical velocities are corrected and used where applicable. Serial temperature and salinity observations are needed for correcting echo soundings and should not be omitted.

The successful use of sono-radio buoys to replace station ships on the Atlantic coast has been tested and proven. That this is indeed a great advance in our hydrographic methods, from the standpoint of economy and efficiency, is very evident. The release of our tenders from dangerous station ship duty is an important consideration.

Sono-radio buoys are entirely automatic, and like all things mechanical do require adjustment and attention. It is logically assumed that certain minor electrical defects and limitations will be overcome and the automatic features of these buoys progressively improved by Dr. DORSEY and his efficient assistants. Some of the improvements made in the proper functioning of the sono-radio buoys during the 1937 season may be mentioned briefly. During the 1936 season, bomb returns were complicated by an unpredictable apparent lag, which was roughly an inverse function of bomb size, and distance to buoy and which could be traced definitely to the electrical circuit of the sono-radio buoy. This keying circuit lag has been reduced to a constant of 0.02 second and is not affected by the size of the bomb used. There was an improved technique in the tuning and adjusting of the sono-radio buoys prior to placing them on station.

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## SPECIAL ASPIRATING THERMOMETER FOR MEASURING THE TEMPERATURE OF THE AIR AT SEA

by

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(Translated from the Italian).

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1. The problem of the determination of temperature at sea should be examined from two view-points as follows:— a) a measurement of the temperature of the air and b) a measurement of the temperature of the water.

The importance of such determinations is very great owing to the fact that a knowledge of the superficial thermal distribution, in conjugation with that of the air in immediate contact with the sea water, is of considerable interest to a large number of scientists.

In fact, the relations which exist between the two oceans, aerial and marine, are subsidiary to the sciences of meteorology, oceanography (physical and biological), of fisheries and navigation. But while, on the one hand, the sciences of meteorology and oceanography find in thermal exploration a solid basis of support for the solution of their fundamental problems, the arts of fishing and navigation may extract from a study of thermometric data some elements of great utility which contribute not a little to the realisation of well-defined objectives.

2. On board ship the use of the sling thermometer for the measurement of air has been proposed by a large number of investigators. It should be stated, however, that with the results obtained from the measurement of the air at sea, it has not been possible up to the present to arrive at very satisfactory conclusions. Dr. RUSSELTVEDT in an interesting monograph recently published by him (1) shows in fact that Dr. LUTGENS, à propos the meteorological observations made on board the vessel PANGANI, revealed errors greater than 7° C.

In 1930 Dr. Finn SPINNAGR, examining the measurements of temperature made during the voyage of the vessel *Bergensfjord*, had occasion to note that the observational errors varied between 1° and 2° C.

The causes which determine these regrettable errors in the observed thermometric values depend principally on the fact that, on board ship, it is extremely difficult to obtain good results with thermometers placed in screens, owing to the heat radiated from the engine room and boilers.

Even when using screens placed on the sides of the bridge in such a manner that they project beyond the hand-rail into the open air, the problem cannot be considered as entirely solved.

Sling thermometers and aspirating thermometers have been used by various scientists on board ship but have not been introduced in common use at sea. In this case the operator taking a temperature measurement, must place himself in the shade, facing the wind and, as far as possible, removed from the smoke and the machinery hatch, also oriented in such a way that he can be screened from the radiating action due to the reflexion of heat from a surface, particularly if the latter is black.

In order to prevent the cord which holds the thermometer from breaking when being rotated, Professor J. THOULET has proposed a special arrangement (2).

The movements to which the hull of the ship is subjected in consequence of the undulating motion do not always allow the use of the sling thermometer because, with strong rolling, it is very difficult for the observer to hold himself upright and make the observation.

In Italy the problem of determining temperature at sea has been brilliantly solved by installing on board our ships a special model of meteorological screen with double walls and triple roof, in such a way that one has two screens one within the other. This type of housing offers particular advantages over the usual type because, with the system of double screens, the inner one of which is made in trellis-work, one is certain of obtaining a proper circulation of air around the bulbs of the thermometers which is renewed uninterruptedly — a condition *sine qua non* for the exact measurement of the temperature of the air. Further, the use of wooden laths forming blinds and inclined in contrary directions over the lateral walls of the screen, prevents the rain, even when driven by strong wind, from penetrating into the interior as far as the thermometer bulbs. Without this precautionary measure, the rain would considerably influence the readings of the instruments (3).

So far as the location aboardship of the screen is concerned, Professor L. MARINI is of the opinion that it is better placed near the bow and that, in order to avoid the detrimental action due to radiation from the cover onto the screen, it should be suspended by means of a tackle at a height of at least one and a half metres above the bridge. In default of this particular arrangement near the bow, Professor MARINI suggests suspending the screen from one of the external crochets of the bridge, on the windward side. Whatever the direction of the wind, proper orientation with regard to the projecting angles of the shelter protects the latter from detrimental oscillations which would otherwise be communicated to it by the movements to which the hull of the vessel is subjected, especially in heavy seas. If the screen has to be suspended above the average height of an observer on the bridge, the windows may be lowered as required to the necessary height, each time a temperature measurement has to be made, by slacking off the suspension tackle. The thermometers having been *rapidly* read, care must be taken to haul in the tackle and replace the screen in its former position, for the reasons explained above.

Nevertheless, although both the sling thermometer and the screen developed by the *Istituto Idrografico* have given good practical results, and although the use of those mediums is recommended in the meteorological instructions followed aboardship (4), one author at least has recently advised against the use of the sling thermometer and every and any kind of screen for measurements of air temperature on board ship.

3. In a comparatively recent and very interesting publication Dr. N. RUSSELTVEDT analyses the difficulties and causes of errors arising from the use aboardship of the sling thermometer and screen, and proposes the use of a special aspirating thermometer invented by him which appears to have given excellent practical results.

Figure 1 shows the front view and a section of the aspirating thermometer which we wish to describe here. The instrument in question includes the following parts: a) a ventilator similar to that of the ordinary aspirator used for regulating the circulation of air in fairly large enclosed spaces frequented by large numbers of persons; b) a sheath for protecting the thermometer; c) a non-return butterfly valve the object of which will be described in detail farther on.

The ventilator (*g*) is placed inside a suction cap (which acts as stator) in chromium. This cap (*d*) is fitted with a large ring by which the instrument is suspended when not in use. The key (*c*) is used to wind up the clockwork mechanism by means of which the ventilator rotates.

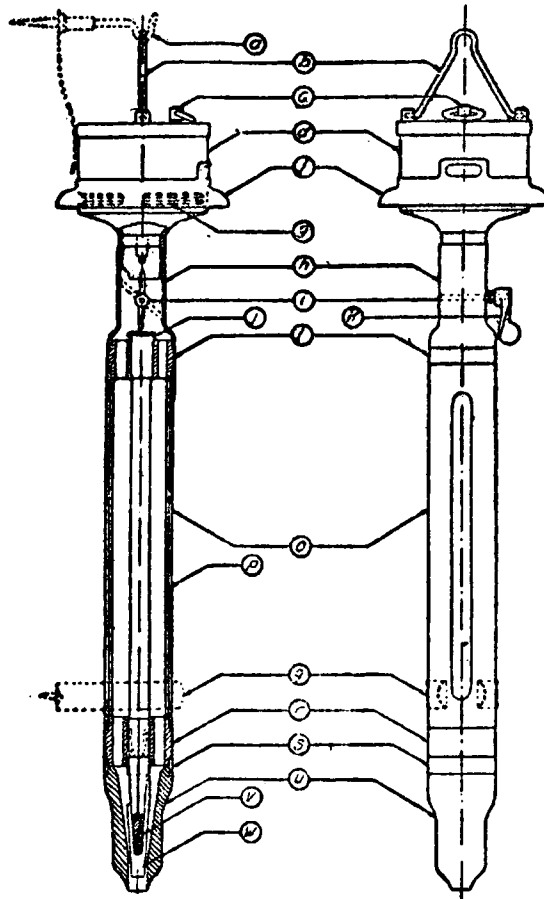


FIG. 1.

The clockwork mechanism may be examined by means of a window cut in the lateral wall of the suction cap.

To avoid damage to the ventilator by striking against any surface, a protective edging (*f*), of suitable shape, has been provided.

The suction cap is placed in the upper end of the chromium sheath, the object of which is to protect the thermometer and serve as conductor of the air drawn in by the ventilator; the air enters by the lower end of this lead.

As shown in Figure 1, the sheath has two openings each 1 cm. wide  $\times$  16 cm. long and located opposite each other, their object being to allow easy reading of the thermometer through transparent openings.

A thin glass tube (*p*) in the interior of the sheath serves to protect the thermometer.

The valve (*i*) is interposed between the suction cap and the sheath; it is held in the open position by means of a spring but may be shut by means of the key (*k*). Parts (*l*) and (*r*) are insulating connections inside of which is a tube for the ventilation and passage of the thermometer. (*s*) is a metal ring joining the outside part (*u*) of the sheath with (*r*). The lower part (*u*) of the sheath is of bakelite, this being a good insulator, the internal part, on the contrary, is of chromium copper (*w*); (*v*) is the bulb of the thermometer. The two parts (*a*) and (*g*) shown by dotted lines on the figure, are the suspension system of the instrument, the upper part (*a*) consisting of a hook and spring; the hook is screwed to the wall at the place where the instru-

ment is installed, while the object of the spring is to protect the instrument from possible striking against the wall. The lower part (*g*) of the suspension system consists of a ring, in the shape of parentheses, through which the lower part of the instrument passes.

The aspirating thermometer described above is the invention of Dr. RUSSELLVEDT, and is constructed by the firm of C.A. LJUNGSMANN & SON, Oslo.

The mercury thermometer employed with the aspirator and housed in the sheath, must be constructed so that the mercurial column is fine but apparent; it should be provided with a well-marked and consequently clear scale. With such devices the reading of the instrument may be made with great rapidity, thus avoiding the detrimental influence of the radiations emanating from the observer acting on the thermometric column.

The thermometer used by Dr. RUSSELLVEDT for his instrument is designed to be only very slightly sensitive. This condition, the necessity for which has been confirmed by experience, is essential for accuracy of reading. Reliable values of the temperature can not be obtained with a very sensitive instrument, in view of the fact that, the exposure once finished, in the brief space of time between taking the instrument from the position where it is placed for observation and the reading, variations in the height of the column would occur with correlated prejudice to the accuracy of the observations.

One of the capital features of the aspirating thermometer is the valve situated between the base of the suction cap and the sheath.

The object of this valve is to cut off the passage of the air current in the interior of the sheath. In this way, the reading once determined at a fixed position, the valve is shut, the instrument moved to another place, and any momentary alteration of the height of the thermometric column through exterior thermal influences is thus fully avoided.

The ventilator being in operation, the valve should be used at the expiration of a period of exposure sufficient to allow the thermometer to enter into thermic equilibrium with the ambient air. It is therefore of the highest importance to know beforehand the time necessary for the thermometer to attain equilibrium. Such period of time, which may generally be taken as constant for each instrument, depends upon the construction of the instrument and varies with the weather for the same thermometer — an easily-understood fact, since the reasons are perfectly well known.

The length of exposure of the instrument depends on a constant *K*, designated by RUSSELLVEDT the *lag constant* (6). Let  $T_0$  be the value of the temperature of the air at the instant when the thermometer valve is shut and the ventilator in operation, and  $T_1$  the value of the temperature of the air at the position of exposure. If  $T$  be the temperature of the air, representing the new value of same obtained  $t$  minutes later, and indicating by  $C$  and  $C_t$  the differences  $T_0 - T_1$  and  $T - T_1$ , the following exponential equation is obtained :

$$(1) \quad C_t = C_0 - \frac{t}{K}$$

The lag constant *K* is given by equation (1) from an easy transformation :

$$K = \frac{t \log e}{\log C - \log C_t}$$

The value of the lag constant *K* is a function of the wind-force, of the position of the instrument referred to the wind and of the number of revolutions of the ventilator.

The value 40 was obtained for *K* in calm weather and with complete aeration, i.e. the ventilator making the maximum number of revolutions.

Let us consider now the methods of observation used in conjunction with the aspirating thermometer.

Let  $t_h$  (7) be the time required by the thermometer to indicate the variation of temperature  $\frac{T_0 - T_1}{2}$ . Introducing into (1)  $C_t = \frac{1}{2} C$ , by means of simple transformations we have :

$$(2) \quad t_h = K \frac{\log 2}{\log e}$$

whence, for  $K = 40$ : —  $t_h = 28^s$ .

Designating by  $T_1$  the value of the temperature of the air (an unknown value which must be determined) and by  $T_h$  that of the temperature at the instant  $t_h$ , we obtain :—

$$(3) \quad T_1 = T_h - (T_0 - T_h).$$

Equation (2) gives the time  $t_h$ , period of exposure of the instrument with the valve open; after which the reading  $T_h$  is effected on the thermic scale. With the value  $T_h$ , and noting that of  $T_o$  (which is obtained with the valve shut and after the instrument has been transported to the observation position) the equation (3) is solved, from which is deduced the required value of the temperature of the air.

From the preceding it is easy to understand how, the value of the lag constant  $K$  being obtained, the temperature of the air may be obtained without difficulty.

The sequence in practice of the operations necessary to obtain the values of the temperature  $T_o$  and  $T_h$  is as follows:— (a) putting the ventilator into operation by means of the clockwork mechanism; (b) transport of the instrument, with the valve open, to the position where the observation is to be made; (c) reading the temperature  $T_o$ , with the valve shut; (g) reopening the valve, shutting it again after  $t_h$  seconds, and reading the temperature  $T_h$  on the thermometer; (e) application of formula (3) and related determination of the temperature  $T_1$  of the air.

The method explained has been called by Dr. RUSSELLVEDT the *method of averages* (*mean method*), having introduced into (1)  $C_t = \frac{1}{2}C =$  half of the variation  $T_o - T_1$ .

The value of the temperature  $T_1$  may be obtained by means of another procedure now to be described.

If in (1) we put  $C = \frac{1}{11}C$  and if we designate by  $t_d$  the time necessary for the thermometer to enter into equilibrium with respect to the change of temperature  $\frac{10}{11}(T_o - T_1)$ , we obtain

$$(4) \quad t_d = \frac{K \log 11}{\log e}$$

whence, for  $K = 40$ , we obtain  $t_d = 96^s$ .

If we then designate by  $T_d$  the value of the temperature reached by the thermometer after  $t_d$  seconds of exposure, we obtain:—

$$(5) \quad T_1 = T_d - \frac{1}{10}(T_o - T_d).$$

This procedure has been named by RUSSELLVEDT the *decimal method* and is a little more laborious than that previously described because the thermometer requires a longer period of exposure. It is possible to demonstrate, however, that the *decimal method* should be preferred to the *mean method*.

4. The aspirating thermometer invented by Dr. RUSSELLVEDT and described by him in the above-quoted treatise upon which the author has largely drawn for the presentation of the present article, was tested during the winter 1931-1932, and the first two samples of the instrument were ready in the Spring of 1932. The two thermometers have been tried out on board ship at sea and have given such eminently satisfactory results that it was decided to install aspirating thermometers of this type on board a few large steamers.

So that the thermometers might be operated under good conditions, Dr. RUSSELLVEDT suggested keeping them in a closed locality (charthouse) or attaching them vertically by means of the suspension system as shown on Figure 1. The procedure for making the observations is as follows:— when the clockwork mechanism which operates the ventilator has been wound up by means of the special key, the thermometer is transported to the bridge, inside the weatherscreen, on the windward side. During the first phase of the observation, the valve rests in the shut position and in those conditions the reading ( $T_o$  in the analytical treatment developed above), will be made.

The reading  $T_o$  having been effected, the instrument is placed outside the handrail, with the sheath opening turned downwards and against the wind. At the same time the valve is opened and from this instant the exposure is considered as having begun. After the lapse of  $t_h$  or  $t_d$  (8) seconds of exposure, the valve is shut and the value read on the thermometric scale through the windows cut in the sheath will give the temperature  $T_h$  or  $T_d$ . The temperature  $T_1$  of the air at the instant when the observation is made will finally be obtained by using, according to circumstances, one of the two following relations:

$$T_1 = T_h - (T_o - T_h); \quad T_1 = T_d - \frac{1}{10}(T_o - T_d)$$

If the limit of approximation of the measured temperature is fixed at 1/10th degree, either the *decimal* or the *mean* method may be used for the determination of  $T_1$ ; and that is the case always when the value of  $C$  is  $\leq 2^\circ$ .

If thereafter  $2^\circ \leq C \leq 3^\circ$  has been obtained, only the *decimal* method must be applied.

It may happen that the difference between the temperature of the locality where the instrument is usually installed and that of the exterior is greater than  $3^\circ$ . In such a case it is necessary, before carrying out the observation of  $T_1$ , to bring the temperature of the thermometer as nearly as possible to that of the air.

For this purpose the ventilator mechanism is wound up a few minutes before the observation is to be taken (6 or 7 minutes are amply sufficient in practice) and, meanwhile, the instrument is transported to the bridge. The thermometer is suspended from one of the sides of the charthouse (where care will have been taken to have ready a suspension system similar to that fitted up in the place where the thermometer is usually installed), in such a way that no possible spray may reach it.

About five minutes afterwards the measurement of the temperature may be proceeded with in the usual way.

For self-evident reasons it is indicated that the thermometer be placed on the windward side during the preliminary exposure made outside the charthouse.

It is recommended to test from time to time the ventilator rotating device, and when variations are observed, it is necessary to calculate new values for  $t_h$  and  $t_d$ . Another precautionary measure is to transport the thermometer from a locality at a lower to a locality at a higher temperature and *vice versa*, so that it may be ascertained whether in such circumstances the methods of measurement explained above give adequate values for  $T_1$ .

#### NOTES

- (1) N. RUSSELLVEDT: *Measurement of temperature on board ships*. Geofysiske Publikasjoner, Oslo, Vol. II, 1936.
- (2) J. THOULET: *Instruments et opérations d'Océanographie pratique*. Paris, Chapelot, 1908.
- (3) L. MARINI: *Manuale per le osservazioni meteorologiche a mare*. Mem. R. Comitato Talassografico Italiano, Venezia, 1912.
- (4) *Norme per le osservazioni meteorologiche a bordo delle navi*. Istituto Idrografico della Marina. Genova, Editions 1910-1912 and 1930.
- (5) N. RUSSELLVEDT, *loc. cit.*
- (6) N. RUSSELLVEDT, *loc. cit.*, p. 5.
- (7) In the analytical treatment which follows, the symbols used by the author in the original treatise have been retained.
- (8) It should be noted that the indices  $h$  and  $d$  affixed to the signs  $t$  and  $T$  refer to the times and temperatures of the *mean* and of the *decimal* methods respectively.

## AUTOMATIC BRAKE SOUNDING MACHINE

by

F. G. ENGLE, COMMANDER, RETIRED; U. S. COAST AND GEODETIC SURVEY.

(Extract from *Field Engineers Bulletin* N° 11, Washington-December 1937).

Sounding machines, with improved control mechanisms and automatic brakes, designed by Commander ENGLE, were used for the first time during the past season by the Ships *Surveyor* and *Discoverer*. The Commanding Officers of these two vessels report that the machines proved to be definitely superior to sounding machines formerly used and the automatic brake was a very desirable feature. This ingenious device permits the wire to pay out rapidly and stops the reel automatically when the bottom is reached. This results in a saving of time and more accurate soundings as the wire is not allowed to pay out after the lead strikes bottom. Commander ENGLE's description of the sounding machine follows.

(EDITOR).