The Marine Observer Vol XIX 1949. *

scheme. A meteorological logbook kept by Captain Toynbee (a former Marine Superintendent of the Meteorological Office) in 1857, and a modern synoptic logbook, kept aboard a British Selected Ship, emphasised the seaman's voluntary contribution to our meteorological knowledge. The importance of meteorology to the navigator, and particularly to the airman, was directly illustrated by a specimen flight forecast for a transoceanic flight and indirectly by the very existence of the numerous navigational aids on exhibit.

In a talk to the Institute that evening, Sir Robert Watson Watt emphasised the malevolent effect which the vicissitudes of the weather have upon the efficiency of astro-navigation, thus being one of the main reasons for the introduction of electronic aids. C. E. N. F.

A NEW BUCKET FOR MEASUREMENT OF SEA SURFACE TEMPERATURE

BY O. M. ASHFORD, B.SC.

(Reprinted from the Quarterly Journal of the Royal Meteorological Society)

Introduction

It has been known for many years that the standard method of measuring sea surface temperatures by taking a sample with a canvas bucket is liable to serious errors. This report deals with the development of an improved form of bucket and thermometer which should be capable of giving sea surface temperature to an accuracy of ±0·1°F., neglecting errors due to temperature gradients in the top few inches of the sea. This latter source of error is inherent in the bucket method of obtaining a sample, but can only be appreciable under calm conditions.

Sources of error

The chief sources of error in the bucket method are: (E_B) The initial temperature of the bucket is generally different from that of the sea. (E_C) The water in the bucket may change its temperature before the reading is taken owing to the processes of heat exchange and evaporation. (E_T) The initial temperature of the thermometer is generally different from that of the sample. (E_S) The thermometer is liable to scale errors. (E_L) Owing to thermal lag, the thermometer may take an appreciable time to indicate the true temperature of the sample. (E_X) If the thermometer is removed from the bucket when taking the reading, it may no longer indicate the true water temperature. (E_R) The thermometer may be read incorrectly.

Existing buckets

The standard British equipment is the M.O. canvas bucket Mk. II with a porcelain-mounted thermometer in a sea protector (see *Marine Observer's Handbook*, page 38). The most recent improvement is the introduction of a spring lid, as suggested by Commander C. H. Williams, R.D., R.N.R., which eliminates the loss of water formerly caused by the bucket swinging and hitting the top of a wave or the side of the ship. The most serious error is E_C, but E_T and E_L may also be large. While the reservoir of the sea protector is good from the point of view of E_X, it introduces an additional term into E_L, for with normal stirring there is little interchange of water inside and outside the reservoir. The Lumby sampler (Lumby 1927 and 1928) has not been used widely on account of its excessive weight and inconvenience in use. In this equipment E_B, E_T and E_L are eliminated by towing through the water for several minutes, and E_c is small on account of the celluloid insulating cylinder.

The German rubber pail designed by Dr. J. Georgi consists of a double-walled rubber bucket, an accurate open-scale thermometer and a heat-stirring device. E_c is very small and E_B, E_T and E_L are supposed to be eliminated by hauling two samples of water. One technique involves the use of two buckets; a sample of water is collected in one bucket and immediately poured into the second. While the thermometer is immersed in this sample, a second sample is collected in the first bucket. The thermometer is quickly transferred to the second sample and the reading taken. The very delicate nature of the thermometer is a disadvantage. In the German naval "scoop thermometer" the thermometer is permanently mounted in the bucket, and E_B, E_T and E_L are eliminated by towing. Unfortunately, owing to the very small size of the water container, E_c is very large.

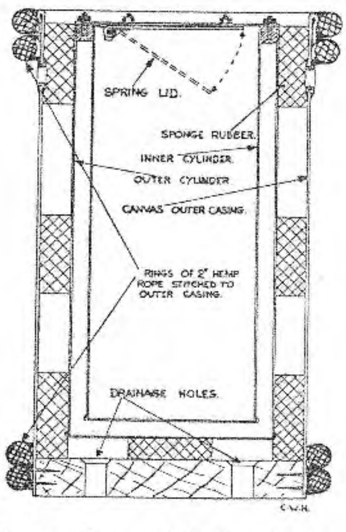

Fig. 1a. First model of new bucket.

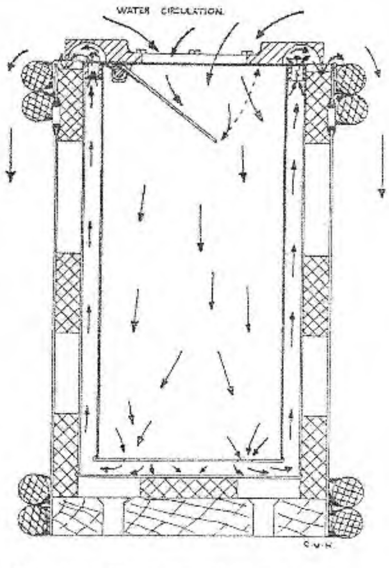

Fig. 1b. Final model of new bucket

New buckets

Attempts were first made to redesign the canvas bucket so that E_c would be greatly reduced. Tests showed that with the existing bucket E_c was equally great when the outside of the bucket was dry or wet and that the presence of the lid did not result in any appreciable reduction. The bucket was therefore remade as shown in Fig. 1a with a double-walled copper vessel inside, the space between the walls being filled with air. The brass spacer ring which supports the two cylindrical walls is watertight and is the only effective channel for the conduction of heat from the inside to the outside. The copper vessel is protected externally by sorbo rubber pads. With this bucket it was found that E_c was very small, especially when a lid was provided.

The good thermal insulation between the inside and outside of the bucket, and the action of the spring lid in reducing circulation of water through the bucket when it was full, resulted in a serious increase in E_s. The top of the bucket was therefore altered on the lines of the Lumby sampler, so that the water entered the bucket through a funnel (the spring lid having been removed) and passed out again through holes in the side immediately under the top of the funnel. With this model, however, E_c was greatly increased. Later it was discovered that E_c was not significantly larger if the space between the walls were filled with water instead of air, and the final design shown in Fig. 1b was produced. As this bucket is towed along, water passes through the spring lid (held open by the water pressure) into the bucket, through the holes in the bottom of the inner container, back up between the walls and out through the annular space under the lid. With this model

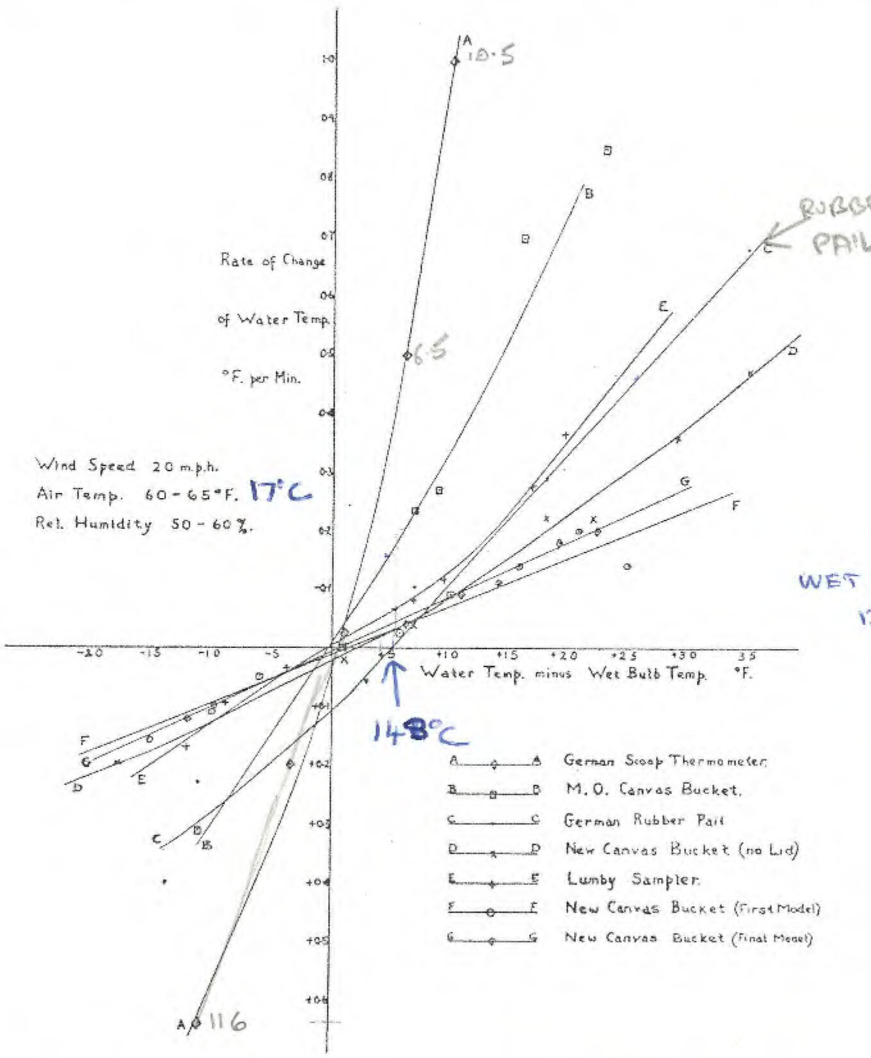

Fig. 2. Rate of change of water temperature in bucket as a function of the difference between the wet bulb temperature and the wet bulb temperature.

GERMAN RUBBER PAIL [C]
NO CHANGE IF T PAIL = 14.8°C
SOME EVAP BUT SHOWS
THAT EVAP MUST BE (BY >50%)
REDUCED. IF NO EVAP
ZERO WOULD BE AT 9°F ON
X AXIS. NOT TRUE OF [BRASS]
SCOOP.

E_c is quite small and E_s can be eliminated by towing for about thirty seconds.

Experimental results

So far we have only made qualitative statements about the various errors. A series of tests was carried out in a wind tunnel to determine the actual value of E_c under controlled conditions. The procedure was to dip the bucket in a large bath of water long enough to ensure that its temperature was steady and to suspend it in the wind tunnel with a wind speed of 20 m.p.h. taking readings of the thermometer at minute intervals. By starting off with water at different temperatures it is possible to simulate conditions in which the sea temperature is both lower and higher than the air temperature. The results are plotted in Fig. 2, from which it will be seen that the new bucket is superior to any of the other buckets tested. The observations with the Lumby sampler were made with the funnel-shaped head removed, which corresponds to the conditions when a reading is being taken on board ship. With the head in position, the curve is approximately the same as that of the new circulating bucket.

The effect of the lid with the new bucket is interesting, as earlier tests with the old canvas bucket showed that having a lid made no appreciable difference to the rate. The probable explanation is that the rate is so rapid with the old bucket that the improvement effected by having a lid is swamped by experimental errors. It should be explained that this lid was a flat disc which covered the top of the bucket; there was a small hole in the centre of the disc to admit a thermometer. The German rubber pail has such a lid in normal use, and when tested without the lid it showed a considerably increased rate of change of temperature.

A few tests were made with a view to distinguishing between cooling due to evaporation and cooling due to heat exchange. Each bucket was tested with its outside wet and dry in succession, but in no case was there any significant difference in the rate of cooling.

A further test was carried out with Commander C. H. Williams on board the M.V. *Trepassey* sailing down the Thames. The conditions at the time were cloudy, dry bulb 50·5°F., wet bulb 48·0°F., mean water temperature 54·5°F., wind force 4. Samples of water were collected in the various buckets and readings of the temperature of the samples were taken at minute intervals. Even under these moderate conditions the superiority of the rubber pail and the new canvas bucket was apparent. The mean rates of fall of temperature in °F. per minute were: German scoop thermometer 0·135, M.O. canvas bucket Mk. II 0·12, German rubber pail 0·025, new canvas bucket (first model) 0·015.

Tests were made on board H.M.S. *Blythe* in the English Channel to determine the relationship between E_s and the time the bucket was left in the sea. The procedure was to fill the bucket with water about 25°F. warmer than the sea, and to empty it after several minutes. It was then thrown quickly into the sea, and left trailing for the required length of time with the ship steaming at about 8 knots. After the temperature of the sample had been measured, a second sample was collected as a check on the true sea temperature. The results given in Fig. 3 show the remarkable difference between the first and final models of the new bucket. During these trials, which were made on three separate outings, the true sea temperature observations were consistent in each case to within ±0·1°F., which illustrates both the accuracy which can be achieved with the new bucket and the uniformity of sea surface temperatures on certain occasions.

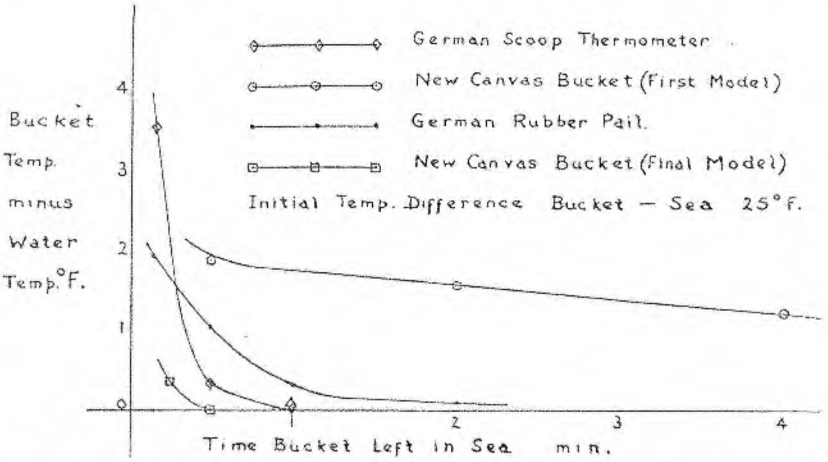

Fig. 3. Error due to bucket having different initial temperature (E_B) as a function of the time the bucket is left in the sea.

Design of thermometer

As pointed out above, the standard Meteorological Office thermometer mounted in a sea protector is unsatisfactory on account of the large thermal capacity of the mount, and the lack of interchange of water inside the protector with that outside when stirred in the usual way. The water equivalent of the thermometer and mount is about 35 gm., so that if its temperature differed from that of the sea by 20°F. and the water sample weighed 2,500 gm. (an average value), E_T would be 0·3°F. For the purposes of the above tests a German "powder" thermometer was used with the new canvas bucket. It consists of a mercury in glass thermometer with a cylindrical bulb, spring-mounted in a duralumin tube. Holes at the bulb end of the tube allow free access of water to the bulb. This thermometer is very satisfactory apart from E_S—it has no reservoir, and the temperature may change rapidly if the bulb is lifted out of the water. A new thermometer for use with the new canvas bucket is at present being designed. This thermometer will probably be mounted in a duralumin tube and provided with a 4 in. length of stem between the bulb and the lowest graduation mark, thus enabling the readings to be taken without removing the bulb of the thermometer from the water in the bucket.

Conclusion

It is considered that the introduction into general use of the final model of the new bucket, in conjunction with an improved thermometer on the lines indicated, will result in a big improvement in the accuracy of reported sea temperatures. For routine purposes the bucket ought to be left trailing for about thirty seconds, although in many cases a shorter time would suffice. The alternative of using the first model of the bucket and relying on two samples being collected at each observation would not be so satisfactory. Hauling a water sample is quite a strenuous job, especially on fast-moving ships, and the temptation to report the temperature of the first sample would often be hard to resist.

It would be interesting to follow up the experiments to distinguish between errors due to evaporation and heat exchange, although the combined effect is so small with the new bucket that the question is largely of academic interest. It is suggested that tests under controlled humidity conditions (as well as controlled wind speed) would be a profitable line of attack.

The work described above was carried out in the Instruments Branch of the Meteorological Office, Air Ministry. The writer would like to thank Mr. N. E. Rider, Commander C. H. Williams, R.D., R.N.R., Port Meteorological Officer, London, and Lieutenant P. G. Satow, D.S.C., R.N., H.M.S. *Dryad*, for their valuable assistance.

Note.—With reference to Mr. Ashford's interesting article, a large number of observations were made in certain voluntary observing ships in the North Atlantic during the war with the object of investigating the problem of sea temperature measurements. Simultaneous readings of sea temperature by the "bucket" and intake were made at regular intervals during many voyages, and at the same time the wind force and direction, weather and wet and dry temperatures were recorded. Owing to security regulations during the war it was impossible to record the ship's position.

A thorough analysis of these observations was made in the Marine Branch in consultation with the Instrument Branches, and the results clearly showed the liability to inaccuracy with the canvas bucket when the wind was strong, the air temperature much lower than the sea and when humidity was low. Under such conditions it was noteworthy that the intake temperature was very frequently higher than that of the "bucket." On other occasions the intake temperature was found to be lower than that obtained by the bucket method.

The general conclusions that were reached as the result of these investigations were :

(1) Intake temperatures tended to be unreliable, owing to uncertainty as to the accuracy of the thermometers used and the position in the engine-room at which they were located, and also owing to lack of knowledge concerning temperature gradients between the surface and the intake at varying draughts.

(2) Although the thermometers used for surface temperatures were accurate, these needed redesigning and the canvas bucket itself was very unreliable under certain conditions. It was decided that the "bucket" method was in general preferable to the intake method as it was more likely to indicate the true temperature of the surface water, but that it was necessary to design and improve the bucket to attain real accuracy.

It was largely as a result of these investigations made in voluntary observing ships during the war, and consequent consultation between the Marine and Instruments Branches, that the insulated bucket discussed by Mr. Ashford was produced.—ED.

REFERENCES

C. F. Brooks. 1926. *Monthly Weather Review*, **6**, p. 241.
J. R. Lumby. 1927. J. Cons. Int. Explor. Mer. II, **3**, p. 332.
J. R. Lumby. 1928. *Ibid.*, **3**, p. 340.
Air Ministry. 1936. *Marine Observers' Handbook*, Met. Off., London.