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COMPARISON OF INTAKE AND BUCKET METHODS FOR MEASURING SEA TEMPERATURE

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The two reports (A) a comparison, based on Netherlands data, of intake and bucket temperature aboard merchant ships, by T. H. Kirk, and (B) a comparison of intake thermograph and canvas bucket methods of measuring sea temperature aboard British Ocean Weather Ships, by A. H. Gordon, have been prepared in consequence of C.M.M.* resolution 37, Toronto, 1947, which recommended that the problem of the accurate measurement of sea-surface temperature should be referred to the various meteorological services.

The results of report (A) suggest that the intake temperature is of the order of 1°F higher than the bucket temperature. The results of report (B) suggest that the intake temperature is of the order of 0·2°F higher than the bucket temperature while the ship is under way and 0·4°F higher than the bucket temperature while the ship is on station.

(A) *A comparison based on Netherlands data, of intake and bucket methods of measuring sea temperature aboard merchant ships*

Introduction

An investigation has already been made into the recorded differences between bucket and intake measurements of sea temperature made in certain British ships during the war years. The results are limited by the fact that no index correction had been applied to the ships' intake thermometers.

Additional material in the form of Hollerith cards has been made available by the courtesy of the Netherlands Meteorological Service. These data include sea temperature measurements by the bucket method and by the intake method, the intake temperatures being corrected for index error. No information is available as to how the intake temperature was measured and whether precautions were taken to avoid engine-room heating.

Data were selected from those Marsden squares having:

(*a*) Observations available for each month during the year.

(*b*) An appreciable number of observations available.

Data from those squares satisfying these conditions were examined, the number of observations available in each square being shown in Table I.

TABLE I

Squares	003	004	039	074	075	110	145	146
No. of observations	1182	323	1469	824	742	1556	957	458

The positions of these Marsden squares are shown in Fig. 1.

Seasonal Variations

Mean values of the quantity " Bucket temperature minus intake temperature " (B–I) were evaluated for each square during each month of the year. The results showed an appreciable amount of scatter, and to reduce this a grouping of the monthly means into seasonal means was made.

The standard deviation of a single observation throughout the year is shown in Table II.

*Commission of Maritime Meteorology of the International Meteorological Organisation.

TABLE II

Squares	003,004	039,074 075,110	145,146
Standard Deviations	0·69	0·81	0·92

These results suggest, as might be expected, that the scatter of the differences is a minimum in the equatorial region, where uniform conditions prevail, and increases toward the temperate zone where there is a much greater variety of weather conditions.

A statistical test of the results showed broadly an absence of seasonal change in the equatorial squares (003 and 004), but showed that there was a seasonal variation elsewhere which was a minimum in summer and autumn and a maximum in winter.

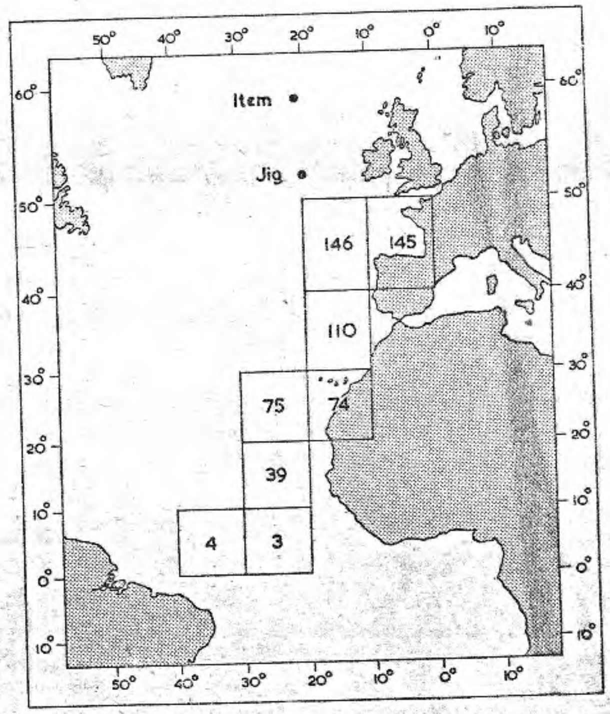

Fig. 1

Map of the North Atlantic Ocean showing the positions of the Marsden squares and Ocean Weather Stations which were used in the investigations.

Effect of Wind

Within the seasonal classification a further sub-classification was made to show the effect of wind. The classification of wind force into the groups 0–3, 4–6, 7 and over, is hardly satisfactory. The number of occasions of force 7 or over is too small to permit any firm deductions. Another factor which militates against any demonstration of the effect of wind is that any such effect may be due to the wind's action directly on the content of the bucket, in which case *relative* wind and not absolute wind would be the essential element. Any dependence of the quantity B–I on relative wind may to some extent be masked by the rough classification adopted.

It was found that in squares 003, 004, there is no appreciable variation with wind. On the other hand, the results for the remaining squares suggest a definite relation, higher negative values of the quantity B–I being associated with higher wind force.

Variation with Cloud Amount

A classification was made in terms of total cloud amount. For this purpose the observations used were those of daylight hours only (taken between the times of civil twilight), it being considered that observations at night lacked the requisite degree of accuracy. The results suggest a general increase in the negative magnitude of the quantity B-I with increase of cloudiness. The values averaged over the whole year show a consistency which could hardly be due to chance.

Effect of Daylight Hours

New seasonal means were evaluated for the period of daylight hours. The smaller values of these means when compared with those previously given show that the factors which make for differences between the bucket and intake measurements are of minimum effect during the day-time. These figures give evidence of seasonal variation similar to that already afforded by the full data.

Difference between Air and Sea Temperature

If any part of the observed difference between the bucket and intake measurements be due to heat exchange between bucket and atmosphere, then the difference between air and sea temperatures should be significant. A classification in terms of this difference showed that the largest negative values of B-I are associated with negative values, while small negative values of B-I occur when the difference between air and sea temperature is large and positive.

Variation with Depth

Mean values of B-I were taken out for different depths of engine intake. Statistical tests showed:

(*a*) that in squares 003, 004, the variations of the mean with depth need not necessarily be regarded as real but can be accounted for by the scatter of the observations;

(*b*) that for squares 039, 074, 075, 110, and also for squares 145, 146, mean at 3 metres depth is significantly different from the general mean but the variations at greater depths need not necessarily be regarded as significant.

This result in itself does not demonstrate a real variation of temperature with depth. All that can be deduced is that the discrepancy between bucket and intake temperatures is significantly less when the intake water is drawn from a shallow depth (3 metres). This difference may arise from variations in the technique of observation. It may also be due to the fact that in this case both bucket and intake methods are attempting to measure the same thing, this no longer being so with greater depths of intake.

Conclusion

There are three real factors which might account in some way for the above results. They are:

(*a*) Real differences of temperature with depth. There may be some evidence of this in the section headed " Variation with Depth ".

(*b*) Defects in the " bucket " method of taking sea-surface temperature when using an ordinary canvas bucket, e.g. errors due to loss of heat from the bucket during the process of measurement, this loss of heat being due to the combined effects of heat exchange and evaporation.

(*c*) Defects in the intake method of taking sea temperatures, e.g. heating effects in the ship itself during the process of measurement.

The results are most readily interpreted in terms of (*b*). The difference between air and sea temperature is obviously of great importance in the process of cooling which affects the bucket water after being drawn from the sea. The effect of wind is of importance in the same connection. Factor (*c*) would presumably be independent of wind, and factor (*a*) would give a result in the wrong direction, for increased wind would entail increased sea disturbance and hence smaller differences of temperature with depth. Seasonal variations may be due to both factors (*a*) and (*b*). Cloud amount is of significance in two ways; first, because absence of cloud implies heating of the bucket by the sun, and secondly, because an increase of cloud amount is usually associated with an increase of wind.

The results support previous opinions that the bucket method is subject to appreciable error due to cooling, unless the bucket itself is suitably insulated. No definite conclusions can be drawn regarding the accuracy of the intake method.

(B) *A comparison of intake thermograph and canvas bucket readings of sea temperature aboard British Ocean Weather Ships*

Introduction

In a preliminary report prepared in the Marine Branch in 1946 entitled " Report on Methods of taking Sea Temperature ", a large number of differences between observations of sea temperature measured by bucket and intake methods aboard British merchant ships were analysed. Frequency distribution curves suggested that the intake method gave results approximately half a degree Fahrenheit higher than the bucket method. However, it appeared from the wide scatter of the values that errors not necessarily connected with any method of observation were inherent in the observations. It emerged that these errors might occur, firstly, in the method of measuring the intake temperature, exact details of which were often lacking but which clearly varied from ship to ship, and secondly, as a result of cooling of the water in the bucket by evaporation and by conductive transfer of heat when the air was appreciably colder than the sea. (*See* report (A).)

The Design of the Experiment

Although it may not be possible to eliminate these errors entirely, the conditions under which the observations have been made aboard the Ocean Weather Ships have been designed to reduce their magnitude so that they no longer hide real physical effects.

These conditions are:

(*a*) The new Mark III canvas bucket* was used. This bucket has been constructed with a double-walled copper vessel inside, the space between the walls being filled with water. The water passes through a 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 bucket, the error caused by the temperature of the water in the bucket changing before the reading is taken, owing to the processes of heat exchange and evaporation, is quite small. The error caused by the initial temperature of the bucket being different from that of the sea can be eliminated by towing for about 30 seconds.

(*b*) The exact position of the thermograph element in the intake pipe is known (Fig. 2).

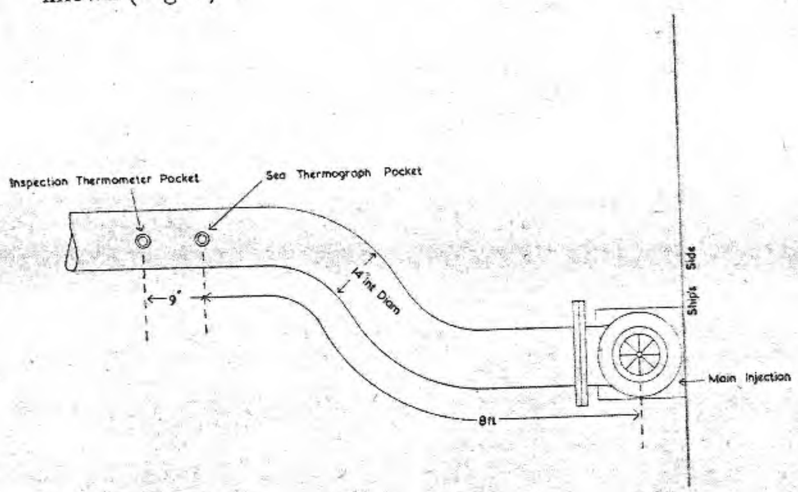

Fig. 2

Diagram showing the position of the thermometer in the engine-room intake pipe.

(*c*) The mean depth of the intake where the water enters the ship is 9 ft. below the surface.

(*d*) All observations have been corrected for index error and the thermograph has been corrected once every 24 hours by an inspector's thermometer placed in the intake.

(*e*) All observations were made by the meteorologists aboard the ships, whose duties are entirely of a meteorological nature.

Analysis of Observations

The differences between the values of sea temperature recorded by the intake thermograph and Mark III canvas bucket (first haul) were tabulated from the records of three Ocean Weather Ships during the period March-October, 1949.

* *The Marine Observer*, Vol. XIX, No. 144, April, 1949, page 107.

The observations from each ship were analysed separately according to whether they were made while the ship was on station or under way. The canvas bucket values were taken from the first haul, since mean differences between first and second hauls were slight.

Mean differences (first minus second haul) for a large number of cases were:

Weather Watcher	+ ·04°F
Weather Recorder	+ ·09°F
Weather Observer	+ ·05°F
Weather Explorer	0·0

Mean differences between intake thermograph and canvas bucket are shown in Table III for each voyage. All observations were read to the nearest tenth of a degree at the eight synoptic hours.

The mean differences are based on a total of about 170 observations while on station and about 40 observations while under way for each voyage.

Statistical tests applied to the differences in Table III show:

(*a*) the mean difference between bucket and intake while on station is significant to the 5 per cent level;

(*b*) the mean difference between bucket and intake while under way is not significant.

TABLE III

Mean Difference between bucket and intake methods of measuring sea temperature

SHIP	VOYAGE		MEAN DIFFERENCE BUCKET MINUS INTAKE (°F)		INTAKE RATE OF FLOW	
			ON STATION	UNDER WAY	ON STATION	UNDER WAY
Weather Recorder	9th March to 14th April	ITEM	+ 0·01	+ 0·30	290 tons/hr.	340 tons/hr.
	2nd to 28th June	ITEM	+ 0·62	+ 0·61	260	340
	14th July to 8th Aug.	JIG	— 0·41	— 0·55	280	360
	24th Aug. to 20th Sept.	ITEM	— 0·11	+ 0·10	240	360
Weather Watcher	2nd to 27th June	JIG	— 0·65	— 0·10	644 g/min.	2000 g/min
	14th July to 8th Aug.	ITEM	— 0·97	— 0·45	644	2000
	24th Aug. to 19th Sept.	JIG	— 1·00	— 0·50	644	2000
	5th Oct. to 1st Nov.	ITEM	— 1·11	— 1·15	644	2000
Weather Explorer	14th to 25th April	ITEM	— 0·41	— 0·45	1300 g/min.	1300 g/min.
	12th to 31st May	ITEM	— 0·04	0·00	1300	1300
		Mean	— 0·41	— 0·22		

Conclusions

The results suggest that the intake method gives readings about half a degree higher than the bucket while on station and about a quarter of a degree higher while under way, although the latter difference is not a significant one.

The former difference may be caused by:

(*a*) Transfer of heat from the engine-room to the intake pipe. This explanation is borne out by the fact that the difference is less while under way when the rate of flow of water through the pipe is greater than while on station.

(*b*) Cooling of the bucket by evaporation and by transfer of heat on occasions when the air is substantially cooler than the sea. On the average the air is 1°F cooler than the sea at JIG and 2·5° cooler at ITEM during the period covered.

(*c*) Stratification of the water. There is a tendency for a vertical circulation to develop so that warm water is moving to the top and cooler water sinking. However, there might be occasions when the temperature of the water underneath the skin surface was warmer either as a result of a vertical or horizontal current or because the surface water is cooled by the air and vertical circulation has not developed sufficiently to equalise the difference.

(*d*) Cooling of the surface water directly by evaporation due to the loss of latent heat.

Editor's Note:

These investigations seem to show that in a relatively small vessel such as a weather ship, in which the condenser intake is not too deeply immersed, the thermometer is mounted close to the ship's side, and the intake temperatures are read from a distant reading thermograph directly by the officer responsible for making the observations, then the intake readings will, when the vessel is under way, not be appreciably different from the readings taken by the insulated bucket method.

In the case of the observations referred to in Mr. Kirk's paper, a large number of different merchant ships of varying draughts were involved in which the intakes were at varying depths, and in which the temperatures were taken under varying circumstances, and the bucket employed was not of the insulated type. It is difficult therefore to form a real comparison between the two types of readings.

In order to complete the investigation, steps are being taken to analyse some "controlled" observations taken aboard merchant ships in which the position of the thermometer in the intake and its accuracy are known, and an insulated bucket is used for the "bucket" observations. The results of this will be published in due course. In the meantime, aboard British Selected Ships the bucket method should always be used, except in the case of certain large and fast passenger ships proceeding at full speed, in which case the intake method can be used. If an insulated bucket is for any reason not available, a note should be made in the logbook to that effect. If the engine-room intake temperature is recorded at any time this fact should be specifically mentioned, and steps should be taken (preferably in consultation with the Port Meteorological Officer) to check the accuracy of the thermometer in use.

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