WORLD METEOROLOGICAL ORGANIZATION

TECHNICAL NOTE No. 2

METHODS OF OABSERVATION AT SEA

PART II – AIR TEMPERATURE AND HUMIDITY, ATMOSPHERIC PRESSURE, CLOUD HEIGHT, WIND, RAINFALL AND VISBILITY

WMO-No. 40. TP. 15

Secretariat of the World Meteorological Organization – Geneva – Switzerland

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TABLE OF CONTENTS

МЕТОДЫ НАБЛЮДЕНИЯ НА МОРЕ

Вторая часть: ТЕМПЕРАТУРА И ВЛАЖНОСТЬ ВОЗДУХА, АТМОСФЕРНОЕ ДАВЛЕНИЕ, ВЫСОТА ОБЛАКОВ, ВЕТЕР, ДОЖДЬ И ВИДИМОСТЬ

Краткое изложение

Первая часть Технической заметки о методах наблюдения на море была посвящена общему вопросу измерения температуры воды на поверхности моря. Эта вторая часть рассматривает измерение температуры и влажности воздуха, атмосферного давления, высоты облаков, ветра, дождя и видимости.

Она дает комментарии различных экспертов и включает описание методов и процедур, рекомендованных метеорологическими службами для производства наблюдений на море.

Она дает также некоторые опытные результаты сравнений различных типов приборов.

METHODS OF OBSERVATION AT SEA

PART II. - AIR TEMPERATURE AND HUMIDITY, ATMOSPHERIC PRESSURE, CLOUD HEIGHT, WIND, RAINFALL AND VISIBILITY

1. Introduction

The making of weather observations aboard ships at sea involves many difficulties not encountered by observers at land stations. Many aspects of this subject were considered at the First Sessions of both the Commission for Maritime Meteorology (CMM) and the Commission for Instruments and Methods of Observation (CIMO) with a view to recommending those observational procedures which ensure that marine observations are as nearly as possible comparable in accuracy with land observations.

Information concerning the procedures in use and the experience gained by various Meteorological Services, which was collected by the Presidents of CMM and CIMO for presentation in working papers at the above sessions, has now been collated in this Technical Note.

Part I, dealing with the measurement of sea surface temperature, has already been published*) and the present Part II continues with a survey of the methods used in the observation of various other elements. Comments received by the Presidents of CMM and CIMO from Meteorological Services on the methods of observation of each element are prefaced, in most cases, by remarks made by Dr. C.F. Brooks of Blue Hill Observatory, U.S.A., in a letter to the President of CIMO concerning experiences during eastbound and westbound voyages across the Atlantic.

2. Measurement of air temperature and humidity

Air temperature and humidity observations at sea may be made by means of a hand-aspirated sling psychrometer, a ventilated psychrometer such as the "Assmann" or a portable louvred screen which must be placed to windward before readings are taken. By Resolution XXI of CIMO (1947) the two former methods are recommended as the most suitable.

In his letter to the President of CIMO, Dr. C.F. Brooks reviewed some of his own experiences of the practical application of Resolution XXI of CIMO (IMO Publication No. 68, p.46). This resolution was adopted by the Conference of Directors, Washington 1947, in Resolution 138, and recommends that :

"(1) for determining humidity or dewpoint at sea, fixed thermometer shelters be not used as they have the disadvantage of (a) a poor exposure under certain wind conditions, (b) wetting by sea spray;

*) See Technical Note Nº 2, WMO-Nº 26.TP.8

with tested thermometers by officer or quarter-master on the bridge) at some 10°F above the fresh-from-the-sea air temperature at the same time. Dr. Brooks agreed with the view that the element air temperature is at present most poorly observed.

These observations were submitted to the First Session of the Commission for Maritime Meteorology for the information and comments of members, the President of CMM adding his own comment, as follows:

> "Dr. Brooks specifically mentions ships of certain nationalities, and it does seem that the practice aboard ships of different nations, varies at present, presumably due to practical difficulties of changing over from one type of equipment to another. The International Meteorological Organization (IMO) certainly agreed at Washington that the screen should be discarded aboard ships in favour of the aspirated or ventilated type of instrument, but I feel there is little doubt that the selection of a suitable instrument for this purpose takes time. I am not in favour of the sling type for use by voluntary observers at sea, but that is only my personal opinion".

Further comments on the subject of the measurement of air temperature and humidity were received at the First Session of CMM from representatives of certain countries.

CANADA

The readings of wet- and dry-bulb thermometers on board ship continue to be of doubtful accuracy for the following reasons:

(a) The thermometers are not consistently exposed in the path of the fresh air from the sea;

(b) Thermometer ventilation is inadequate;

(c) Radiation effects are present;

(d) The thermometer reading moves from a relatively accurate aspirated value to a higher value before it is read;

(e) The wet-bulb is not properly maintained;

(f) The dry-bulb is wet with spray.

(a) In 1947 the IMO recommended "that observations be taken on the windward side at the level of the bridge of the ship". The necessary criterion is that the thermometer be exposed in the path of fresh air from the sea before it has been modified by heating from the ship. Some modification to the IMO recommendation may be needed to ensure consistent and proper exposure of the thermometer.

(b) With insufficient air movement past the thermometer (minimum current of four knots), thermometer readings will be inaccurate. It is necessary then

(b) The mean dry- and wet-bulb temperatures, each with the standard deviation of a single observation with respect to the mean, computed from the Netherlands observations in the years 1949-1952, with the number of observations.

It appears that the mean dry-bulb temperatures for the years 1949-1952 are in good agreement with the long-period means, the largest differences amounting to 0.2°C. Any excessive variability of the wet-bulb temperature due to inaccuracy of the observations, would be shown up by a larger standard deviation. In most months, the standard-deviation of the wet-bulb temperature is, indeed, higher than that of the dry-bulb but this is to be expected because the wet-bulb temperatures follow, besides the changes of the dry-bulb temperatures, also those of the humidity. The upper limit of the range of the wet-bulb is the same as that of the dry-bulb, but the lower limit lies appreciably lower, so the variability must be greater.

It is remarkable that in the months of the SW monsoon the standard deviation of the dry-bulb is substantially higher than in the other months, a phenomenon which is not shown by the standard deviation of the wet bulb, resulting in the former being higher than the latter.

It is not yet possible to formulate a definite opinion about the reliability of the wet-bulb observations on account of the small number of observations and the arbitrary choice of the test-square, but the data of Table I*) do not make an unfavourable impression. An exception has to be made for the standard deviation of the wet-bulb for the month of December, which is rather high. The frequency distribution shows that this is not the result of a few isolated observations, but is due to the whole distribution being rather scattered.

Before 1949 the air temperature aboard Netherlands selected ships was observed with a fixed thermometer in a screen and from 1949 to 1952 with a sling psychrometer.

It has been stated above that in the test-square in the Indian Ocean the mean dry-bulb temperatures for the years 1949-1952 are in good agreement with the long-period means (see Table I), the largest difference amounting to 0.2°C.

To detect possible differences in the accuracy of the two different methods, the mean temperatures with standard deviations of the Netherlands observations were computed for every single year in the period 1921-1948 in the same test-square but only for the month of January. The results are given in Table III**). It appears that the standard deviation of the psychrometer data is significantly less than that computed from the fixed thermometer observations. This result suggests that the psychrometer observations are indeed more accurate than those carried out with the fixed thermometer.

When considering these results one must not forget that the fact that observations before 1940 were made six times daily and those after the war

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*) Table I, see page 6
**) Table III, see page 7

TABLE III. MEAN AIR TEMPERATURE, MONTH OF JANUARY

Indian Ocean, 8°-10°N, 68°-70°E

Year	Mean °C	St. Dev. °C	Number of observ-ations
1921	27.0	1.0	65
1922	27.3	0.8	69
1923	27.1	0.9	42
1924	27.1	0.7	54
1925	26.6	0.9	58
1926	27.4	0.9	78
1927	27.2	0.9	83
1928	27.6	0.9	86
1929	27.2	0.8	93
1930	27.4	1.0	86
1931	27.4	1.0	52
1932	27.4	0.9	49
1933	27.1	0.7	37
1934	26.8	1.1	50
1935	26.9	1.0	47
1936	27.2	1.0	35
1937	27.2	0.7	45
1938	27.5	0.9	48
1939	26.8	1.2	49
1947	26.7	1.5	7
1948	27.7	1.4	10
1921-1948	27.2	1.0	1143
1949-1952	27.3	0.6	54

only four times daily might influence the standard deviation and also the mean). To eliminate this factor, the means with standard deviation for two sets of observations, one for the years 1921 - 1939 and the other for the years 1949 - 1952 for one and the same hour have been computed, also for the month of January. To obtain a sufficiently large number of observations, a greater area had to be taken, so the work has been done for the square 4°-6°N, 84°-96°E in the Indian Ocean. In this square the 0600 GMT observation coincides with the local noon observation and 1800 GMT with local midnight. The results are exposed in Table II, (see page 6).

As was to be expected the variability of the temperature during day-light is larger than during the night, but in both cases the standard deviation of the psychrometer data is smaller than that of the screen observations. This confirms the supposition that the introduction of the sling psychrometer has improved the quality of the observations.

The fact that the standard deviation in this square is larger than in the square 8°-10°N, 68°-70°E (Table I) is in agreement with the general course

(b) Readings obtained from the Assmann and sling psychrometers were on the average between 0.4° and 0.6°F higher than those obtained from screen and hand psychrometer.

(c) The distribution of the differences in the readings of the screen and hand psychrometer for both wet- and dry-bulb temperatures approximated closely to a normal distribution, but this was not so in the case of the differences between the readings of the screen and Assmann psychrometer or of the screen and sling psychrometer.

(d) The standard deviation of the differences between the readings of the screen and the Assmann psychrometer and of the screen and hand psychrometer for both dry-and wet-bulb temperature, were less during the night than during the day.

3. Measurement of atmospheric pressure

Discussion at the First Session of CIMO (WMO) on the measurement of atmospheric pressure aboard ship was based on information collected from various Meteorological Services concerning : (a) any new improvements in mercury barometers used on board ship, (b) aneroids used on board ship, and any developments of such instruments since the CIMO (IMO) meeting in Toronto in 1947, (c) barographs used on board ship, and especially information on damping devices etc. to overcome the defects of an ordinary "land" barograph when used at sea. Extracts from some of the reports received follow.

3.1 Mercury barometers

UNITED KINGDOM

The only improvement reported was in the barometer used by the United Kingdom, where the gimbal screws are now made of phosphor bronze to reduce wear.

UNITED STATES OF AMERICA

The U.S. Navy has been using a marine-type, fixed-cistern mercury barometer. The U.S. Weather Bureau does not use this type of instrument on shipboard, but has installed precision aneroid barometers on selected ships instead.

A rather critical relationship exists between the value of "falling height" and the response of the instrument to pressure changes. The problem is to arrive at the proper dimensions of the constricted portion of the barometer tube to give the proper value of falling height, and at the same time to provide the required accuracy under mass-production techniques.

Unless further investigation of the problem proves otherwise, it seems advisable to make use of precision-type (rather than commercial grade) aneroids

Performances:

(a) Measuring range : 700-780 mmHg
930-1040 mb

(b) Accuracy : ± 0.3 mmHg

(c) Temperature error : 0.01-0.02 mmHg/C°

(d) Hysteresis error : 0.2 mmHg.

Test results:

Three actual tests on board Ocean Weather Ships have been carried out since January 1953. The mean half rolling amplitudes were 14°, 19° and 23°. The performance of the instrument, however, was satisfactory, giving a variation of accuracy of ± 0.3 mmHg or less, temperature error within 0.01 mmHg/C° and hysteresis error within 0.2 mmHg. The tests will be continued.

UNITED KINGDOM

Measurements of pressure at sea are not required to be as accurate as those on land. There are reasonably priced, robust, aneroids with sufficient accuracy (say 90% of the readings accurate to within 0.5 mb) but all seem to suffer from some sort of zero drift. This cannot be satisfactorily compensated by simple spot checks since, at the spot check observation, the instrument may well have a casual error of as much as 0.5 mb. If the aneroid were reset on this basis, the errors would range between 0 and 1.0 mb (instead of -0.5 to +0.5 mb). Thus to obtain an aneroid with a 90% accuracy of ± 0.5 mb, which has to be reset to allow for zero drift at intervals, it would be necessary for casual errors not to exceed 0.2 mb. We have so far been unable to find a reasonably priced robust instrument with this accuracy.

UNITED STATES OF AMERICA

Aneroid barometers have been used most successfully on Ocean Weather Ships and selected ships for a number of years. The experience of the United States with each category is discussed below.

A. Ocean Weather Ships

In co-operation with the United States Coast Guard, a special installation has been developed that vents the pressure measuring equipment on board ship to the free air by means of a static-pressure tube and head. A precision aneroid barometer, which is itself airtight except for an opening for connection to a static tube, is mounted securely to the bulk head and is connected to one branch of the static tube. A marine microbarograph is installed within a special airtight chamber that is connected to a second branch of the static tube. The chamber consists of a base secured to the bulk head and a cover box. The cover box is equipped with a rubber gasket that is cemented to its lower flange to provide an airtight seal, so that the pressure of the air surrounding diameter as the inside of the collar. The disc end of the nipple is fitted with a small brass disc about .05 inch thick. This small disc has three holes drilled in it about 3/16 inch apart. A pipe plug threaded to match the inside of the nipple is screwed into the end of the nipple opposite the disc. The plug has four holes drilled into it near each corner. Glass wool is packed into the inside of the nipple between the threaded plug and the brass disc attached to the end of the nipple. The lag of response to pressure changes introduced by this glass wool can be controlled by turning the threaded plug, thereby changing the pressure on the glass wool. A reducer is screwed onto the outer thread of the nipple. The smaller end of the reducer is of the proper size for attachment to the static tube being used.

Tests on this head were made at the National Bureau of Standards. The following significant values taken from the report of the Bureau show the errors that may be expected at various wind speeds and positions of the disc:

P^a= static pressure at test location
P = pressure indicated by static head
Vs= air speed at standard conditions (15°C and 760 mm Hg)

Disc position	Vs Miles per hour	Error-inches Hg $p^a - p$
Horizontal	61.3	.00465
Tilted up wind 15°	49.7	-.0105
Tilted up wind 45°	20.7	-.00922
Tilted up wind 90°	16.2	-.00930
Tilted down wind 7.5°	49.8	.00110
Tilted down wind 15°	39.6	.0431
Tilted down wind 45°	39.8	.0330

Comparative readings based on port station mercury barometers are made before the ship departs and again immediately upon its return. These comparative readings have indicated that the precision aneroid barometers maintain their calibration very well. Variations between successive corrections seldom exceed ± .01 inch mercury.

Occasional damage to these precision aneroids has occurred because protection from mechanical vibration, shocks and concussion has not been provided, as is done in the case of the microbarograph installation. Provision of a simple shock mount and means of creating a suitable lag in response of the aneroids to violent pressure changes should overcome this difficulty.

Precision aneroids have been in use at U.S. Weather Bureau land stations for a number of years, in conjunction with mercury barometers, and the aneroids have given highly satisfactory performance. When these instruments are used, a constant correction to station pressure is determined by direct comparison with station pressures determined from the station mercury barometer. After this correction is established and the instrument is found to be operating satisfactorily, a comparison with the mercury barometer is made only once each week. Instructions require that the aneroids shall be kept within ± 0.3 mb of the station pressure determined from the mercury barometer.

predominate in the different types of ships, the chief causes of poor barograph traces are:

variations of pressure due to gusts of wind, and mechanical vibration. The experiments fell into two parts, one to reduce the effects of vibration and the other to reduce the effect of transient pressure fluctuations. As a result of the experiments, the following devices have been adopted:

The anti-vibration mounting for open-scale barographs consists of a metal tray to hold the barograph, suspended from fixed brackets by a number of elastic cords. The tray can swivel about an axis parallel to its longer edge, so as to prevent the ship's motion from throwing the pen off the chart. The supports are such that the period of oscillation of the shelf (with barograph in position) is about 0.5 sec. Favourable reports have been received from the Ocean Weather Ships concerning this mounting.

To prevent the barograph recording transient pressure changes, its movement is damped by use of a viscous oil. The barograph bellows is inside a brass cylinder filled with oil, and can only expand or contract by forcing oil to flow through the narrow annular gap where the rod passes through the bleeder valve. In this way, strain on the levers is eliminated and movement of the pen due to looseness in the pivots is prevented.

One difficulty in the use of oil for this purpose is the large variation of viscosity with temperature. It has been found that silicone fluids have a much lower temperature co-efficient of viscosity, but because they are relatively expensive, it is recommended that they are used only where wide variations of temperature are encountered, e.g., on voyages covering a big range of latitude. Normally an oil-damped barograph gives sufficiently good results. If the mounting described above cannot be used, e.g., because of lack of space, reasonable records may be obtained by standing the barograph on sponge rubber pads (2).

UNITED STATES OF AMERICA

The U.S. Weather Bureau has supplied all its Ocean Weather Ships and the majority of its selected ships with microbarographs having a scale-to-pressure ratio of 2.5:1. These marine-type microbarographs are adapted from the land-type in the following respects:

(a) A counterweight is placed under the base plate to bring the linkage system into balance.

(b) A counterweight is placed inside the clock drum to bring the drum into balance.

(c) The pen arm is held against the chart by mechanical tension instead of gravity.

The modifications listed above increase the stability of the microbarograph and conduce to better pressure traces. This modified microbarograph is currently being used on board ship by the U.S. Weather Bureau and U.S. Navy.

Marine-type microbarographs with a scale-to-pressure ratio of 2.5:1, as procured from manufacturers, must satisfy certain specifications; these are given in the Annex to Document 62 (CIMO-I).

FRANCE

Exactitude of measurements made with a fixed projector on the ship's bridge

During measurements of cloud height on board ship, the effects of pitch and roll may, in spite of the projector being mounted on gimbals, cause the light beam to waver. This instability may make readings difficult, with resultant inaccuracies in measurements, which should be avoided. For this reason, it seemed preferable to eliminate all gimbal type fittings and to fix the projector and the telescope directly to the bridge of the ship. In this manner, the light beam is always normal to the bridge and angular measurements are always made from the plane in which the bridge of the ship lies.

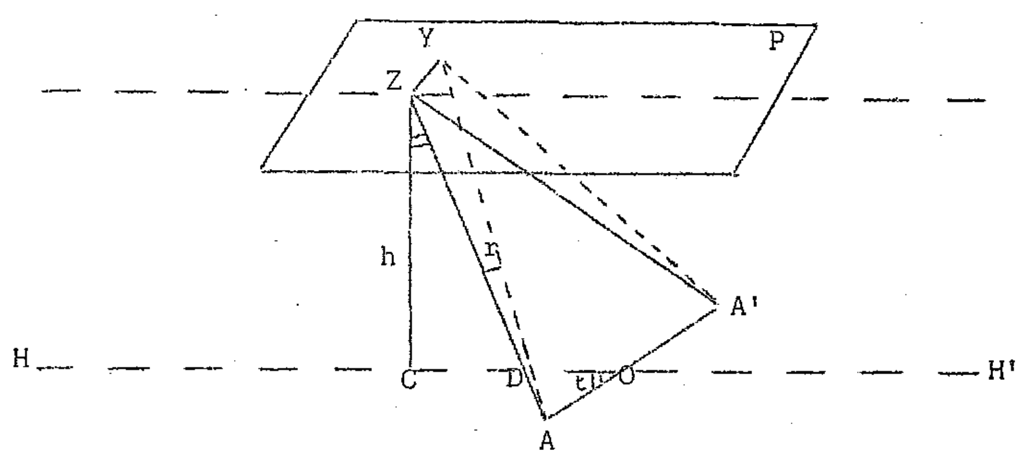
Calculation of the accuracy of measurements

The error resulting from the principle of this installation depends particularly upon the degree of pitch and roll. For meteorological frigates, the Navy Meteorological Service gives the following values :

Pitch :	Average : 5°	In bad weather : 15°
Roll :	Average : 20°	In bad weather : 35°

The length of the base between the axis of the telescope and that of the projector is approximately 60 metres. The following calculations are based on the supposition that the centre of oscillation of the ship is half-way between the projector and the telescope, taking into consideration also the numerical values shown above.

If, in the diagram below,
h = ceiling height
t = angle of pitch
P = a horizontal plane through the cloud,
B = AA' = the base on the ship
r = angle of roll;



With regard to Resolution 55 (CD Washington 1947) no new points of view can be given. The installation of cloud searchlights aboard all selected ships is not really practicable.

UNITED KINGDOM

Theoretically, it might be possible to use searchlight technique, but the very short baseline available between the bridge of a ship and her stern makes this method too inaccurate. A searchlight can in any case only be used at night and there would be difficulties of maintenance and power supply aboard the ship. The use of balloons, except aboard Ocean Weather Ships, is not really practicable owing to objections to having hydrogen on board. It seems doubtful if it is worthwhile resorting to expensive instruments for making this observation aboard selected ships at night when it could not be measured by day. The only apparatus known at present for day-time observations is elaborate and expensive. Experiments with rockets to obtain cloud height have also been made, but these have not been satisfactory. Cloud height observations aboard selected ships can, therefore, only be made by estimation.

UNITED STATES OF AMERICA

Dating from August 1947, the United States have made numerous tests on its Ocean Weather Ships to determine whether a suitable ceiling light could be developed for shipboard use. Several kinds of lights were employed in these experiments, including the standard United States Weather Bureau type ceiling light, 12" signalling searchlight, and a sealed-beam type light.

Best results were obtained while employing sealed-beam lights. It was found that reasonably accurate measurements of cloud heights could be obtained up to 3000 feet. For observational purposes the light was mounted near the stern of the vessel and adjusted so as to project its beam at an angle of 72° from the horizontal, pointing aft, while the alidade was rigidly mounted on one wing of the flying bridge.

In this type of installation the effective baseline of the average United States Ocean Weather Ships ranges from 100 to 125 feet. Although projecting the beam at an angle of 72° does not increase the mathematical accuracy of the observation, it makes possible a more accurate angular observation by the observer. Cost of the sealed-beam light and alidade together approximated $150.

Moreover, the observers also reported that the light was used to determine character and intensity of precipitation during darkness.

5. Measurement of wind

Observations of wind speed and direction at sea are made either by visual estimates based on the appearance of the sea surface or by means of anemometers or anemographs.

At which level is the wind speed required, and are corrections desired? Corrections would be difficult to apply because of the inherent errors in both methods of measurement.

Improvements in anemometer design, e.g., damping to compensate for extra movement because of the roll of the ship. Standardization of method of mounting is desirable to ensure ruggedness and uniformity of sampling.

Provision of improved reference material on the estimating of wind speed, outlining the factors involved in as simple a way as possible.

FRANCE

Notes on the effect of the motion of a ship on the readings of a ship's anemometer

(a) Let us assume in the first place that the ship has stopped in a calm, but is subjected to rolling which can be regarded as a pendulum-like motion.

Let R be the height of the anemometer above sea-level, at which level the axis of rotation is assumed to be located.

Let θ be the angle of roll at a given instant and α its maximum value. Lastly, let T be the period of rolling.

From the well-known laws concerning pendular motion an equation can at once be derived for the angular velocity $\frac{d\theta}{dt}$. Calculating the time from the equilibrium point we have :

$$\frac{d\theta}{dt} = \frac{2\pi\alpha}{T} \times \cos \frac{2\pi t}{T}$$

which is at a maximum when $\theta = 0$ and $t = T$, that is to say, when the ship passes through the vertical position. In that case

$$\frac{d\theta}{dt}\text{Max} = \frac{2\pi\alpha}{T}$$

and the maximum linear velocity of the anemometer is then given by

$$V_{Max} = R\,\frac{d\theta}{dt}\text{Max} = \frac{R\,2\pi\alpha}{T}$$

In the case of an Ocean Weather Ship, the roll may be as much as $\pm$ 30°, the period is of the order of 16 seconds and R = 16 metres. (The period T = the time required for the ship to heel over from + 30° to - 30° and return to + 30°).

In that case :

$$V_{Max} = 16 \times \frac{2\pi}{16} \times \frac{\pi}{6} = \frac{\pi^2}{3} = 3.3 \text{ m/sec.}$$

obtained.

Mr. G. Verploegh of the marine-section of the Royal Netherlands Meteorological Institute examined these series and has attempted to present his conclusions (not yet published) in a separate paper. Briefly summarized, it may be said that the standard error in the estimates amounted to 0.4 Beaufort units. It appeared, however, that in the long run the presence of an anemometer influenced the estimations of the wind force in an unfavourable way and therefore the instruments have been dismounted again.

From a study on the origin of the international equivalents and from other previous investigations, combined with the results of the observations mentioned above, Mr. Verploegh also drew up new equivalents in knots of the Beaufort scale. His equivalents, which hold good for the average observation-height at sea, are as follows :

Beaufort force	0	1	2	3	4	5	6	7	8	9	10	11	12	
Verploegh,	0	3	7	11	15	20	25	30	35	40	47	54	-	kts.
Paris 1946	0	2	5	9	13	18	24	30	37	44	52	60	68	kts.

UNITED KINGDOM

A wind recorder which can give a reading of gustiness has been installed in one of the British Weather Ships, but no records are yet available for study.

Aboard selected ships it seems that the most suitable method of observing wind is for the observer to estimate its force and direction according to the visual effect of the wind on the sea surface, in accordance with the traditional custom of seamen. It is not considered necessary to provide selected ships with anemometers.

UNITED STATES OF AMERICA

As a basis for evaluating the suggestion that 2 scales should be used for estimating wind speed from sea surface conditions, the United States arranged for vessels assigned to ocean station "Dog" to make the following comparative observations during 1951 :

Wind speed estimated from sea surface conditions.

Wind speed as obtained from the ships' anemometer.

Over 1300 comparative observations were made during eight patrols on Station "Dog" for the period extending from February through August 1951. Comparisions between these observations showed that there was some tendency on the part of the observers to under-estimate wind speed from sea surface which seemed to have hit the marks was from Captain F.S. Slocombe, who referred to a discussion with Captain J.C. Barbour, Supervising Examiner of Masters and Mates at Vancouver.

Captain Barbour had recalled to his mind a phenomenon which most deep sea sailors have noticed in very heavy storms, i.e., that a heavy sea appears to acquire an additional hump on its back and that this hump rolls over the crest of the wave and crashes with considerable force into the trough. It is this which causes damage to deck structures when the period of a ship's pitch happens to place her beneath the fall of this body of water. It was suggested it might be to this that the term "roll" of the sea referred.

Mr. Millar had obtained orally from Mr. Geo. Newsham, holder of the Master's Foreign-Going Certificate, a confirmation which was quite independent, somewhat as follows :

> "When seas are so large that there is danger of shipping "green ones", there is a rush of water down the approaching crest. The motion of the water seems to be divided into two components, so distinct that this onrushing water seems to be a separate body of water overlying the deep mass of the wave. The water deep in the wave moves only up and down. The other body of water seems to rush down the forward face of the crest and is likely to be shipped aboard."

Rear Admiral Jefford, Pakistan (19 May 1949) found it difficult to improve on the sentence "Sea begins to roll" which, he thought, conveyed to every sailor the actual picture of the phenomenon, but suggested that the following more elaborate definition might be of value to the non-sea-going part of the meteorological profession:

> "Waves become rollers, i.e., tops of waves curve over in the direction away from the wind, the whole wave thus assuming a concave form."

He added that it was this type of wave which is responsible for heavy damage to ships during bad weather if, in approaching a wave, a ship, instead of riding over it, as would be the case when the wave is just a hill of water, tends to drive through the centre of the wave with the result that the whole of the top wave structure collapses and comes down on a deck in a thundering mass. The same occurs when a vessel is running before the sea and is overtaken by a wave which collapses in exactly the same manner.

Commander Frankcom, United Kingdom (18 July 1950) had consulted various maritime interests in this country and had also obtained some information from Captain Petersen of Germany, who originated this "Sea disturbance scale".

His personal impression was that "rolling of the sea" referred to the visible effect of a high sea when it rolls over or collapses, and he quoted from "Vade Mecum", a Sailor's Word Book by Admiral H.W. Smyth, 1867 :

> "Tumbling Sea: -The increased rolling (of the sea) before a gale."

mentioned under wind forces 9 and 10."Wind force 9: -Spray is blown off the wave crests more frequently. Wind force 10: -Spray is blown off over large areas".

Dr. Schumacher, Deutsches Hydrographisches Institut, Hamburg(5 April 1948) had visited Captain Petersen and thoroughly discussed with him the term"Rollen der See" and its meaning. The opinion had been expressed that, if a certain sufficiently large mass of water had come into oscillation,the sound connected with this oscillation is most clearly characterized by the term "Rollen"In the times of sailing ships, when scarcely any noise was caused by the ship, this was an indisputable feature. However, Captain Petersen had admitted that in the age of steamers and motor ships, one should confine oneself to visible characteristics. He had agreed also to the proposed additions about the"Gischt" given as a characteristic for wind forces9 and 10.

Dr. Kuhlbrodt, Branch M. M.A.N.W.D., Hamburg (10 June 1949) wrote further that he felt that if the suggestion to cancel those sentences in the Petersen scale for wind forces 9 and 10, which contain the term "Rollen" particularly in the acoustic sense were accepted, the description of wave ridges or crests respectively would be somewhat poor. He suggested an addition to the description, which might perhaps correspond to the sense of a visual feature of the "Rollen" :

For wind force 9 :

"High wave ridges with crests breaking steadily and heavily.Dense stripes of foam in wind direction. The froth is more frequently blown off the wave crests; froth may already impede visibility."

For wind force 10 :

"Very high wave ridges with long crests breaking heavily and shock-like. Sea white with foam. Froth is blown off over large areas and impedes visibility."

Conclusion

The decision of the First Session of CMM on the question is contained in Recommendation 9 (CMM-I) which recommended that (1) the expression "Sea begins to roll" be replaced by "crests of wave begin to topple, tumble, and roll over" and (2) the expression "rolling of the sea becomes heavy and shock-like" be replaced by "tumbling of the sea becomes heavy and shock-like".

6. Measurement of rainfall

In the letter referred to earlier, Dr. Brooks considered in detail the errors to which rainfall measurements at sea are subject, namely :

enough, should not be thrown out of balance by water adhering or by the rolling or pitching of the ship. The gauge if on deck should be amidships, so that the vertical currents will be at a minimum.

(ii) Tilted orifice. The rolling and pitching of the ship prevent the orifice of the gauge from maintaining a horizontal position, unless the gauge is mounted on gimbals. Since, however, the raindrops go with the wind more or less, it is not horizontality that should be sought but parallelism to the local wind. A gauge mounted as indicated in par. (b) (i) should, therefore, suffice, for the inclination and direction of the wind will change with the roll and pitch.

(iii) The admixture of sea spray is not much of a problem, for a hydrometer placed in the catch of the gauge will indicate the salinity. This, divided by the salinity of the local sea water, will give at once the percentage of the total catch that is sea water spray.

A photograph of a rain gauge on gimbals is published in an article describing the "Meteorological Programme of the seventh cruise of the "Carnegie" (5). The gauge is on the afterdeck.

A photograph of one of 2 gauges on the "Balaena" is published in an article on the scientific results of the "Balaena" expedition 1946-47(6). The legend reads : "One gauge was suspended on either side of the foremast. This thick deposit of rime occurred during 24 hours exposure to fog and had to be chipped off the suspension before the gauge was hoisted again ..." The text reads : "The instrumental equipment on the "Balaena" included two Snowdon rain gauges, which were not, however, found suitable for measuring precipitation in the Far South without considerable adaptation. Measurements were fairly successful, using modified gauges in different exposures for purposes of comparison from November until mid-February, but thereafter (when the season became stormier) had to be eked out by estimations".

Dr. Brooks thought that the "Balaena" location for exposure, from the yard-arm of the foremast, was the best, since it is high enough to be virtually in horizontally moving air and away from sheltering influences, also above spray most of the time. A gauge here, however, would still require a vertical and horizontal vaning (and a wind-shield) for the roll and pitch of the ship would be continually changing the direction and inclination of the wind striking the gauge.

CANADA

The requirements for rainfall observations should be defined. IMO Publication No. 78 (WMO - No.8) does not include this item under Marine Observations. Forecasters would be interested mainly in intensity, climatologists in one was fitted in the M.V. "Hang Sang" on 16 April 1952.

As far as is possible in the limited space available, the gauges are fitted clear of obstruction caused by the ship's funnel and standard compass platform, and away from the up-draft caused by the bridge superstructure and ship's side.

Although it is not claimed that this method gives accurate absolute readings, the observations are of considerable value for forecasting purposes.

NETHERLANDS

Between 1929 and 1940 a number of Netherlands selected ships have carried out rainfall observations in the Atlantic. A simple rain gauge was supplied by the Royal Netherlands Meteorological Institute consisting of a catcher with a sharp upper edge and a surface of 400 cm^2 connected by a leaden pipe with a calibrated bottle with a mark for every 10 cm^3. The neck of the bottle was marked for every cm^3, making it possible to measure small quantities by putting the hand on the mouth of the bottle and turning it over.

The observers were instructed to note down for every watch the amount of rain caught (in cm^3) with the duration of the rain in minutes and, when possible, an estimate of the angle between the rain and the surface of the rain gauge. It was recommended to mount the rain gauge at least 1.50 metres above the superstructure of the vessel. The gauges were not mounted in gimbals.

During these years about 37,000 data of watches with rain have been received. It was the intention to compute from these data the mean intensity of the rain in different seasons and in different latitudes. From these intensities it would be possible to deduce the mean amounts of precipitation with the aid of the observations of duration of precipitation which have been carried out aboard Netherlands ships for nearly a century.

The Jevons effect (the influence of the wind upon the catch of a rain gauge), however, causes a serious difficulty. Definite data about the magnitude of the errors caused by this effect are not available and this is not surprising because these errors do not depend only on the velocity of the wind but also on the dimensions of the raindrops. For instance Koschmieder found on the Schneekoppe an error of about 25 % with a wind velocity of 7 m/s (7). Braak, however, gives as a result from measurements in the Netherlands at the same wind velocity a correction of only 7½ %(8).

A preliminary investigation showed that the corrections of Koschmieder applied to the rainfall observations of the Atlantic give intensities which are obviously too high but it will not be possible to find the precise corrections. Taking into account how little is known about the amounts of precipitations over the Atlantic, it will still be worthwhile to compute the results of these observations with a set of estimated corrections. The Royal Netherlands Meteorological Institute intends to undertake this computation

UNITED KINGDOM

A rainfall gauge for use at sea, primarily aboard Ocean Weather Ships, but possibly aboard certain merchant ships also is being developed by the Meteorological Office. The type of gauge is perhaps less important than the exposure; it seems that the higher the gauge is hoistered, the better. Some experiments were made aboard a small steamer in the Irish sea,and comparisons made with rain gauge readings on station and at stations ashore. The result showed that the shipborne observations were extremely erratic.Some extensive experiments have since been made aboard Ocean Weather Ships with a view to finding the best exposure and the best type of gauge, and the proposed new gauge has emerged from these experiments. It must be realized that it will be very difficult to form a true estimate of the reliability of readings obtained from a rain gauge at sea, but some indication may be obtained by preliminary experiments with the gauge in exposed places on shore.

UNITED STATES OF AMERICA

During 1950-51, experimental tests were made aboard several United States Ocean Weather Ships while on patrol to determine if a satisfactory method could be devised for obtaining accurate rainfall measurements at sea. Comparative observations were made of catches obtained with both rigid and gimbal-mounted gauges. The gauges were mounted on the roof of the balloon inflation shelter. Both gauges consisted of 8 inch funnel tops with flexible tubes running from the bottom of the funnels into separate measuring receptacles which were located inside the balloon inflation shelter. In the case of the gimbal-mounted gauge, only the funnel was mounted on gimbals while the tube connected to the funnel was run at an angle into the shelter in order to minimize the effect of the tube on the stabilizing action of the gimbals.

Results of observations showed that the catches obtained from gimbal-mounted gauges were slightly greater than measurements obtained from rigid gauges; averaging 4 % more for amounts of .50 inch or higher.

7. <u>Measurement of visibility</u>

The basis of the estimation of visibility at sea, in the absence of suitable objects, is the appearance of the horizon as observed from different levels.

Dr. Brooks, in his letter, commented on the fact that visibility can be measured fairly well by observing how low on the ship one has to go to see the horizon sharply. If the observer in the crow's nest sees a sharp horizon, the visibility is greater than the distance of sea horizon from his height. If his horizon is not sharp, then the visibility can be pretty accurately determined by the above method. The visibility cannot be accurately determined by sighting objects on board ship from any point beyond, say, 100 feet from the windward end, for the heat of the ship will increase the visibility.

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