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AIR MINISTRY

METEOROLOGICAL OFFICE

THE
MARINE OBSERVER'S
HANDBOOK

FOURTH EDITION

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MARINE OBSERVER'S HANDBOOK.

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THE MARINE OBSERVER'S HANDBOOK.

INTRODUCTORY NOTICE TO CAPTAINS OF SHIPS.

The Meteorological Office was instituted in the year 1854 as a department of the Board of Trade for the purpose of promoting and collecting trustworthy observations for the study of weather from British ships, on all navigable seas, as part of an international scheme for obtaining a more accurate knowledge of the meteorology of the globe, and more especially of supplying information as to the kind of weather which had been experienced, and therefore might be experienced again on any of the trade routes or on exploring expeditions. The work of the Office has been extended in many directions, and since 1854 the carrying trade of the world has been greatly modified by the substitution of steam and motor power for sail. But the weather is still a subject not only of interest, but of importance to seamen. Foreknowledge of bad weather is essential for safety of life at sea. The use of a vessel for dividend-earning purposes still depends upon the capacity of her officers to make the most of favourable weather and to make the best of bad weather. While wind has to some extent lost in importance, ocean currents, fog and ice have gained. Wireless telegraphy has placed in the hands of the navigator a means of communication whereby he can ascertain weather conditions from ships ahead and around him, and at the coast. By the synoptic method he can thus foretell with some degree of certainty the probable changes of wind and weather in the near future, which enable him to use the high speed of his vessel with greater economy. The constitution of the Office has also been altered, and now expenses are chargeable upon the votes of the Air Ministry estimates. Its original purpose, however, has been maintained throughout, and it still remains one of the principal objects of the institution to collect trustworthy observations from the sea, and to return the information thus collected in a form useful to seamen. A special division of the Office, in charge of the Marine Superintendent, who is a Master Mariner, is maintained for this purpose; the provisions for securing it remain practically unaltered and are as follows :—

The names of up to 500 ships whose Captains have undertaken regular voluntary observation for the Meteorological Office are published in a list at the end of *THE MARINE OBSERVER*, the monthly review of the Marine Division. The officers of these ships constitute the Corps of Voluntary Marine Observers.

The requisite numbers of these ships keep the Meteorological Log and make coded Wireless Weather Reports to the Office

for which purpose the Director of the Meteorological Office is authorised to lend to Captains, instruments which are of first-rate character, and have been properly verified.

The instruments supplied are :—

For keeping the Meteorological Log.—One barometer; four ordinary thermometers, with a screen; one copper case for sea surface temperature observations; two hydrometers.

In some cases a rain gauge and a barograph are added to the equipment.

A Meteorological Log Book and an Original Note Book for recording the observations are also supplied. The Note Book, formerly called the " Rough Book " becomes the property of the Captain of the observing ship.

For making Coded Wireless Weather Reports.—The instruments supplied are :—One barometer; three ordinary thermometers with a screen; one copper case for sea surface temperature observations.

A register and code card are supplied for recording and coding the observations; also a pad of telegraph forms for use between the bridge and the wireless house.

A number of packet steamers on selected Cross-Channel services, who make meteorological observations at mid-channel positions on their homeward run, and report by telegram to the Meteorological Office, are supplied with the following instruments for this purpose :—Two ordinary thermometers, with a screen, and one copper case for sea surface temperature observations.

Vessels observing regularly for the Meteorological Office to which official instruments are not lent, keep Form 911, Ship's Meteorological Report, using the ship's instruments, the barometer being compared with Standards.

As a return to Marine Observers for their voluntary work, a copy of a monthly magazine entitled *THE MARINE OBSERVER* is issued free to every observing ship. This magazine contains articles of interest and practical use at sea. The application of wireless telegraphy to weather work at sea is fully dealt with, and all the latest available information regarding cyclone tracks, ice, derelicts, etc., is published. A special feature of the magazine is " The Marine Observer's Log " in which are given reports and extracts from Meteorological Logs giving interesting accounts of phenomena experienced, photographs, and any other information of interest to mariners.

Sets of Ocean Meteorological Charts of normals for each month of the year are also issued to regular observing ships on request.

At the end of each financial year, the Captain and principal observing officer of observing ships which have contributed meteorological logs and W/T weather report registers classed " Excellent," covering not less than three months' observations, are presented with a specially bound and inscribed volume of *THE MARINE OBSERVER*.

For the purpose of giving information and advice to Marine Observers, supplying, inspecting, and maintaining equipment, etc., a number of retired Master Mariners act as marine agents for the Office at certain ports at home and the Dominions and Colonies; while at Liverpool a whole-time officer acts as the Port Meteorological Officer. *For the names and addresses of Nautical Officers and Agents of the Marine Division of the Meteorological Office see back of ice chart published monthly in the "Marine Observer."*

Marine Observers will greatly assist if they will send in Meteorological Logs immediately on completion through the Port Meteorological Officer or Agent, at the same time notifying him of any possible instrumental defects.

Defective instruments will then be replaced and new Log Books, etc., provided.

In London or at a base port where there is not an Agency, notification of defects should be sent to headquarters on arrival, with the Meteorological Log.

Vessels making voyages of less than two months' duration are requested to retain their logs until nearly filled up, but the log should be returned in all cases at least twice yearly.

W/T Registers and Forms 911 should in all cases be sent direct to the Meteorological Office, London. The Port Meteorological Officer at Liverpool and the Visiting Officer in London board vessels co-operating with the Meteorological Office, and the agents visit ships at their ports when circumstances permit.

Postage abroad incurred on behalf of the Meteorological Office in returning logs will be refunded. Postage from British Empire ports need not be prepaid, if the envelope is marked O.H.M.S., and addressed to the Director, Meteorological Office, London.

Captains and officers whether they observe regularly for the Meteorological Office or not are urged to report exceptional phenomena in air or sea. Reports of weather experienced in or near Tropical Cyclones or Hurricanes, also abnormal currents, are specially desired

Description of Registers.

The forms of return, which are issued to Marine Observers who are willing to co-operate with the Meteorological Office, for the record of observations required principally in connection with the work of the Marine Division, may be described as follows:—

The Meteorological Log.—A book ruled to contain, for a period of four months, entries under the headings: Date; Latitude and Longitude; Course and Distance; followed by four hourly observations of Wind, Direction and Force; Barometer, and attached Thermometer; Wet and Dry Bulb Thermometers; Observation of Clouds and Proportion of Sky

Clouded; Weather, and Fog Intensity or Visibility; Sea, Swell, and Sea Surface Temperature; also Estimates of Set and Drift, due to current experienced between noon and noon, or at shorter intervals of time; Specific Gravity of Sea Water at least once daily; and remarks of importance relating to phenomena observed, with the times of occurrence; changes of wind, etc. Space is provided at the end of the log for "Additional Remarks" and for recording Wireless Weather Reports made to "All Ships." For the keeping of the full Meteorological Log instruments are supplied by the Office.

How Meteorological Logs are dealt with.—On the receipt of a Meteorological Log in the Marine Division of the Meteorological Office, it is examined and classified according to the value of the observations contained in it. If it attains to a standard of "Excellent" or "Very Good" it is then extracted.

The Hollerith Electrical Sorting and Tabulating machine, which was used extensively for working up the last census of population in Great Britain, has been introduced in order to facilitate the computation of mean values from the observations received. Observations in logs are coded into a series of figures which are punched out from specially printed cards. These are stored in geographical order and according to date. When a sufficiently large number of cards have been so punched they are put into the Hollerith machine, which sorts them into the ten degree square in which each set of observations falls. Then, by further sorting, they can be divided into one degree squares, and after that, by further sortings, they can be grouped according to wind direction and wind force, or for any other element. Another machine can deal in a somewhat similar way with the barometric pressure and the temperature or any numerical values, adding up the sum punched on the cards and recording the number of cards passed through, from which figures are derived the mean pressure and temperature.

Since these machines can only deal with figures, the remarks and set and drift of currents, which cannot be suitably computed by the machine, are extracted into data books according to the square in which the observations were made.

It is found that with the introduction of this mechanical device for extraction, the necessity for neatness in the entries in logs is even greater than it was in the old system. Observers are therefore requested to use every care to facilitate the computers' work in this respect. A sample of a coded log and corresponding card is given on Plate I.

W/T Forms and Registers.—These are supplied to a number of Trans North Atlantic Liners fitted with continuous wave, for carrying out the service of special coded W/T weather reports to the Meteorological Office, London, and to the Weather Bureau at Washington.

Meteorological Log kept on board R.M.S. Empress of Russia

DATE.		Latitude.		Longitude.		Current when determined at short intervals.	Course and Distance.	Wind at the time of observation.	Barometer.*		True Atmospheric Pressure at Sea Level. (Optional.)		Thermometers.		
Year	24 th 1925	Observed.	Dead Reckoning.	Observed.	Dead Reckoning.				No.	775	Heights of Caden above Sea.	50 feet.	The barometer reading corrected for Temperature, Height, Gravity &c., may be made other than the Standard, 32° F.	Dry Bulb.	Wet Bulb.
Month	Oct.						Each four hours.								
Day.	Hour.	The D.R. position is needed daily, in addition to that by Observation, but it should be the result of careful calculation, in order to give any value to the estimation of the current.					True Course.		Force 0 to 12.	Uncorrected Reading.	Atm. Altimeter Scale.	No.	No.		
Civil Time.							Distance by log.	Direction.							
24	24	1	8	9				12	06		1005.0	46	46		
164		4	49 48	169 22			570W	76	SE	6	1003.6	287	1005.0	46	46
		2	8	7				26	07		1006.6	46	46		
64		3	48 31	167 53			570W	66	VNW	7	1004.5	283	1006.6	46	44
		8		6				27	05		1010.5	49	48		
164	G.M.T. 00.47	NOON	48 00 48 04	166 16 166 22			568W	68	NWxW	5	1009.0	286	1010.5	49	46
		4	Current in last 24 hours N45 W 6 mi.												

Captain A.J. Holland R.N.R. from Vancouver to Hong Kong and Manila

[illegible]

4 a.m. 24th October, 1925.

[illegible]

W/T reports on receipt are plotted on synoptic charts, which give the forecaster exact knowledge of the conditions prevailing at sea. The knowledge of the existing weather over the sea prevailing to the westward of the British Isles enables him to foretell changes for longer periods and with greater accuracy than had he only reports from land stations.

Meteorological Report.—Form 911, is ruled in a similar manner to the Meteorological Log, but for observations taken at 8 a.m. and 8 p.m. only.

Space is also provided for “Additional Remarks” and for recording W/T weather reports made to “All Ships.”

These reports complete the network of observation over the oceans, which would be too costly to carry out by means of the Meteorological Log.

The forms are now classified on receipt, according to their neatness and the value of the observations contained in them.

Ice Report.—Form 912 is issued to all ships likely to encounter ice, in addition to the Meteorological Log and Form 911. It should be noted that the actual position of ice is required, and not the position of the ship.

Cyclone Forms.—Form 905 has been introduced for all ships which do not keep a full Meteorological Log, in order that as many observations as possible may be obtained from ships which encounter tropical cyclones. These are supplied on application. They are ruled for observations of the main meteorological elements.

Sea and Swell Observations.—Form 684 is issued to observers who are willing to make measured observations of the height, length, period and velocity of waves.

PART I.—INSTRUMENTS AND INSTRUMENTAL OBSERVATIONS.

CHAPTER I.

THE HANDLING OF INSTRUMENTS.

Meteorological instruments are very delicate to handle, and are costly. Great care is required in packing and special precautions are necessary for transport.

Instruments are supplied either by the Meteorological Office or its agents, and are delivered by hand to ships. The barometer will be found in its specially designed box, the thermometers and hydrometers in theirs.

Instruments, when not in use, and especially spare instruments that are stowed for a considerable period, should be inspected occasionally, and the store in which they are placed must be cool and dry. Instruments must never be jarred or subject to concussion.

Any accident to any instrument, even if no apparent damage is done to it, should be reported to the Meteorological Office. The constants of the instruments may well have been altered without any apparent difference in its working.

On no account should a barometer or any other instrument belonging to the Meteorological Office be sent to an instrument maker for repair, or an attempt be made to repair the instrument on board the ship. All damaged instruments should be returned by hand to an agent for the Office at ports where there are such agencies; or direct to the Meteorological Office from ports in Great Britain where no such agency exists. Instructions for their return are given on p. 9.

The Position for Instruments on Board Ship.

It is impossible to lay down any fixed rules as to the position selected for instruments on board ship as the best exposure will vary with different ships. The main points to be observed in deciding on the position for all instruments are as follows :—

They must not be exposed to suddenly varying conditions due to local causes, such as sudden draughts of air or sudden changes of temperature.

They must not be exposed to the direct rays of the sun.

They must be out of the way of unauthorised persons.

The light used by night should fall on the instruments from the same direction as the day light. By day and night the light should come from behind or the side of the observer.

In addition to these a special point to be observed for the barometer is :—

It should not be too high up in the vessel ; to minimise pumping, when practicable it should be near the centre of gravity.

The position of the thermometer screen requires great attention. In the tropics heat reflection takes place freely from sunny decks and off brightly polished metal. The thermometer screen should be protected as far as possible from this indirect heating.

Hot draughts or even the warm radiation of the hull may cause errors.

The position of the screen for observations, to aim at, is the one where the air will come direct on to the screen from the sea before passing over any part of the ship. It should therefore be to windward.

The lighting arrangement should be especially carefully considered to make sure that it cannot affect the temperature of the thermometer.

Usually the bridge in a steamer or the poop in a sailing vessel is the most suitable position for the instruments with the exception of the barometer. For the latter the chart-house is often the most convenient position, but this is not always the best owing to its exposed position and its distance from the centre of gravity of the ship.

The Shipping and Unshipping of Instruments.

The Marine Barometer is so constructed that it swings on gimbals and so preserves itself nearly erect, when the ship is rolling. In order to give the instrument swinging room it is supported by a bracket which is securely screwed on to a bulkhead. The height of this arm should be so regulated that the top of the mercury at its highest probable position should be half an inch or so below the Observer's eye. A barometer that is too high is almost certain to cause errors of parallax.

The bracket having been screwed to the bulkhead, the instrument should be carefully lifted, the hinged

part of the suspension arm bent back, and the barometer shipped into the bracket. The mercury should then fall gradually, and the instrument will be ready for observation in about an hour; but as local temperature affects the instrument slowly, it may be well not to record observations from it for some hours after first fixing. Sometimes in a new tube the mercury does not readily quit the top of the tube. If, after an hour or so, the mercury has not descended, tap the cistern end, rather sharply, or make the instrument swing a little in its gimbals, which should cause the mercury to fall in the tube. If this method does not succeed, the force of the tap must be slightly increased, but violence must not be used.

Whenever a barometer has to be unshipped and placed in its box, first lift the instrument out of its bracket, and bring it gradually into an inclined position to allow the mercury to flow very gently up to the top of the glass tube, avoiding any sudden movement which would cause the mercury to strike the top of the tube with violence; as the absence of air there makes the force of the blow little different from that of a solid rod of metal, it might break the tube. The barometer should then be taken lengthwise and laid in its box. To be carried with safety it should be held with the cistern end upwards, or lying flat; and it must on no account be subjected to jars or concussions. In ships of war barometers should always be unshipped when heavy guns are fired.

The Barograph, when used on board ship, should be carried in a cradle slung fore and aft from the deck above, or a spring suspension bracket may be used. It should be located in a position where it will be least affected by concussion, vibration or movement of the ship. During gunfire the pen's point should be moved from the paper.

The Louvred Screen for the thermometers is of three types.

The Old Type, known as the shipboard screen which has a solid back, must be exposed in a shaded position and can be hung on a bulkhead, rail or an awning spar. The back of the screen should not be in contact with the bulkhead, particularly if it is of steel or iron, but should be separated from it by means of battens or chocks so as to leave an air space.

The New Types, which are known as the Portable (large) and the Modified (small), are louvred on all four sides and may be exposed in sun or shade, preferably slung from an awning spar, so as to have an unimpeded circulation of air flowing through them. It is essential that the air should not have been in contact with any part of the ship before reaching the screen.

In both cases the screen should be at a height of about 5 feet from the deck, so that it is at a convenient height for reading the thermometers.

It should be clear of local heating for the reasons given on page 28, and therefore the position may need to be changed with shifts of wind and/or alterations of course.

The two thermometers are secured into position and the water vessel is so placed that the wick from the wet bulb is well immersed. This water vessel should be placed in the holder provided for it, which is below and a little to one side of the wet bulb of the thermometer. The side remote from the dry bulb is selected in order that the latter may not be affected by moisture rising from the water.

The Thermograph should be slung in a screen on deck in a similar way to the barograph, in a position such that, while not being under the influence of the heat of the ship, it is not exposed to spray.

How to Pack Instruments for Return.—Experience has shown the advisability of giving directions for packing instruments; even with the utmost care breakages occur through mishandling in transit, especially when instruments are sent by rail or are transhipped at ports and are so handled by persons unacquainted with their construction.

Instruments should always be packed in the boxes specially designed for them and carefully enclosed in cotton wool or some soft elastic packing, and the boxes should be marked with a bold label "Glass—fragile instruments."

The address of the Office to which instruments should be consigned is Meteorological Office, Exhibition Road, South Kensington, London, S.W. 7.

All instruments except mercurial barometers should be invariably consigned by passenger train, not by post, at the railway company's risk. The company will charge their "glass" carriage rates, which are 50 per cent.

higher than the ordinary rates. Railway companies will no longer accept mercurial barometers for transmission by rail at company's risk, because of their fragile nature and the high cost of repairs when damage occurs.

A barometer of which the inner glass tube is broken, so that mercury is seen to escape from the instrument, should be sent to the Office by passenger train at owner's risk, but before despatch it is very important that all loose mercury should be emptied from the instrument and from its wooden box; otherwise the mercury will attack the brasswork of the frame and silvering of the scales, causing much damage *en route*. The loose mercury should be placed in a strong glass or stone bottle, securely corked and packed carefully inside the box.

If it is desired to forward to the Office a mercurial barometer of which the glass tube is unbroken, special arrangements will be necessary to avoid breakage during transit, so that a letter asking for instructions should first be sent to the Office. In this case when possible a Dooly will be sent with full instructions.

CHAPTER II.

THE BAROMETER.

The barometer is an instrument with which to measure the weight or pressure of the atmosphere. Two kinds are in use for observations at sea, the mercury and the aneroid.

The principle of the mercury barometer was discovered by Torricelli in 1643; but the instrument was not utilised by seamen until a century had elapsed, and its form had undergone several modifications in the interval. A mercury barometer consists of a glass tube, closed at one end, which is filled with pure mercury, all air being carefully excluded; the tube is then inverted, and its open end immersed in a small cistern, also containing mercury, so as to prevent air entering the tube. Great care is taken to exclude the air, as its presence, even in minute quantity, will vitiate the readings of the instrument. The pressure of the atmosphere on the surface of the mercury in the cistern maintains the mercury in the tube at a height which corresponds to that pres-

sure, and measurements with the instrument are made by reading the height of the column in the tube above the surface of the mercury in the cistern. A small hole in the upper part of the cistern, H, Fig. 1, admits access to the superincumbent air; and a washer of leather permits of the atmosphere exerting pressure, but prevents

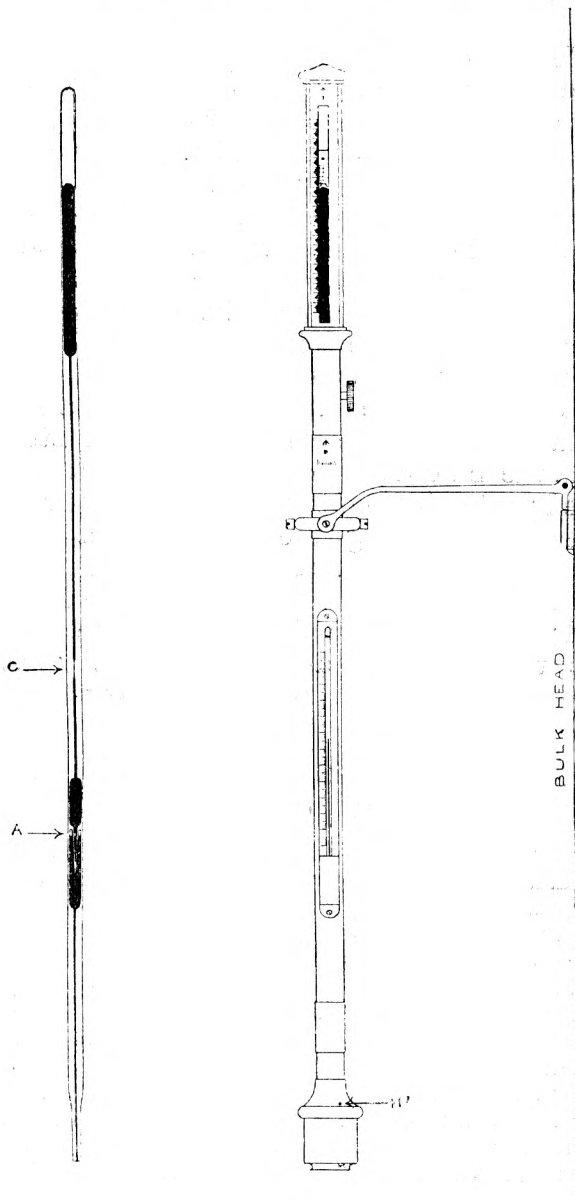


FIG. 1.

the mercury escaping from the cistern. English instruments are graduated either for mercury inches and decimals of an inch, or for centibars and millibars; the average pressure at sea level in the British Isles being 29.92 in., or 1013.2 millibars, though the highest recorded is 31.11 in. or 1053.5 millibars, and the lowest is 27.33 in. or 925.5 millibars.

In all mercury barometers of the Kew pattern issued by the Meteorological Office the glass tube is considerably contracted for the greater part of its length not only in order to prevent unsteadiness of the mercury column or "pumping," as this is called, but also to strengthen the tube, and to lessen the weight of mercury.

The tube is furnished with an "air trap" to prevent air working into the space at the top of the mercury column. The air trap consists of a small funnel or "pipette," which is introduced between the cistern and the wider portion of the tube (*see* Fig. 1).

By means of this arrangement any air entering the tube becomes imprisoned at the shoulder A, and therefore cannot interfere with the efficiency of the instrument.

In marine barometers of this pattern a part of the contracted portion of the tube is further constricted with the object of reducing the pumping caused by the labouring of a vessel in a seaway. In Fig. 1, a Meteorological Office barometer is shown suspended from a bulkhead; a principal section of the tube, in which A indicates the air trap, and C a specially contracted portion of the capillary tube, is also shown.

The Measurement of Barometric Pressure in Pressure Units.

Until recently it was the custom to measure the barometer height in inches, that is to say, the weight of the atmosphere being balanced against the weight of a column of mercury, the alteration in the weight of the atmosphere was given in terms of the alteration of the mercury column in length. Meteorology is now being developed along even more scientific lines than formerly, and for the purposes of science it is found that the C.G.S. (centimetre-gramme-second) unit of pressure is more convenient to handle. It is more truthful in that it is not a unit of length but of pressure. This will, perhaps, be more easily understood from considering the following case. If a water barometer were constructed, the height of the column of water that would be required to balance the atmosphere would be about 34 ft. in length and the variation due to a change in pressure of one millibar would not be 0.03 of an inch as it is in the case of a mercury barometer, but would be more in the nature of 0.41 of an inch. The use of the C.G.S. unit is more convenient, since it has been found that to read

the barometer to $\cdot 01$ of an inch is barely accurate enough for scientific work, whereas to read to $\cdot 001$ of an inch is not practicable, at any rate at sea. On the millibar scale, however, $\cdot 1$ is a quantity that satisfies our requirements; it is readable and it has a sufficient accuracy.

The inch, being a unit of length, requires a tiresome numerical calculation in order to convert barometric readings into a real estimate of pressure, and it is pressure that has to be expressed. For the purpose of estimating the probable changes that have taken or may take place in the distribution of atmospheric pressure a measure is wanted of the force requisite to move a given mass of air; just as a measure is needed for estimating the power which is required to drive a vessel of a given tonnage a given length or distance in a given time.

The **Gramme** is the metric unit of mass. It is the thousandth part of the standard kilogramme of the International Bureau of Weights and Measures.

The **Metre** is the unit of length, in the metric system, and the centimetre is one-hundredth of a metre. The metre was originally intended as a geographical unit and was taken as one ten-millionth of the earth's quadrant.

The **Second** is the universal unit of time.

The unit of **Velocity**, in the C.G.S. system, is the velocity of a centimetre per second.

The unit of **Acceleration**, in the C.G.S. system, is an acceleration of one unit of velocity per second.

The unit of **Force**, in the C.G.S. system, is the force which produces an acceleration of one centimetre per second in a mass of one gramme. It is called a **dyne**.

The unit of **Pressure**, in the C.G.S. system, is the dyne per square centimetre; but as this unit is exceedingly small a practical unit of atmospheric pressure is substituted, which is one million times as great: the megadyne per square centimetre. This unit is equivalent to a pressure of $29\cdot 53$ in., or $750\cdot 1$ millimetres of mercury, at the freezing point of water in latitude 45° , and is the normal air pressure at 106 metres above the sea. For expressing this unit the name **bar** has been adopted by meteorologists. It is the hundredth and thousandth parts of the **bar**: the **centibar** and **millibar** respectively, which are adopted as working pressure units in the C.G.S. system.

Barometers for the Mercantile Marine, which are issued by the Meteorological Office, will in future be fitted with two scales. On one side of the tube and of the vernier the scale is graduated as formerly, to read to half-hundredths of an inch; on the other side the graduation is in centibars and millibars and can be read to tenths. Some barometers still in use are fitted with millibar scales only.

Attached thermometers are graduated in centigrade degrees from the Absolute zero of temperature, which is 273° centigrade below the freezing point of water or -459° on the Fahrenheit scale. This zero represents, so far as our present knowledge goes, the temperature at which the whole of the heat of any substance whatever would have been converted into some other form of energy. The principal advantage of the absolute scale for meteorological work is that all negative values are avoided, and all calculations of the pressure and density of air are reduced to simple proportion.

A diagram illustrating the graduation of a Kew pattern barometer in millibars and inches and of its attached thermometer in centigrade degrees from the Absolute zero and in Fahrenheit is given below (Fig. 2):

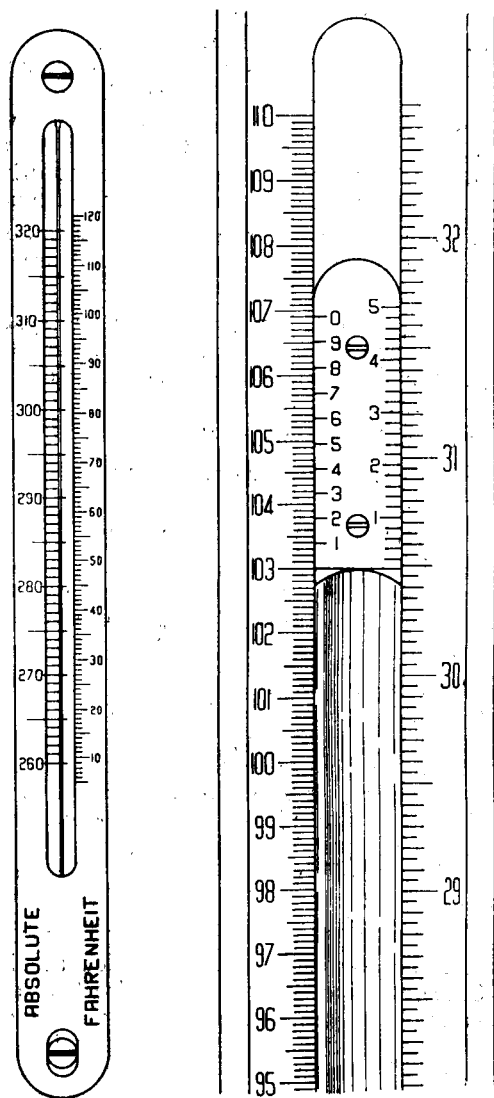


FIG. 2.

Instructions for Reading a Mercury Barometer of the Kew Pattern graduated in Millibars.

The reading of the attached thermometer should be made before the reading of the barometer, as heat from the presence of the Observer will affect the thermometer

more quickly than the barometer. On no account should the barometer be touched before this reading has been taken.

The temperature is read to the nearest whole degree on the scale graduated from about 265° to 305° and is entered in the appropriate column of the register.

After the temperature of the instrument has been read, the barometer may be touched with the hand, but care should be taken to do this as lightly as possible.

Tap gently with the finger until the tapping no longer affects the shape of the mercury surface in the tube. Turn the milled head at the side of the instrument, until the lower edge of the vernier and the lower edge of the sliding piece at the back of the instrument, which moves with the vernier, are in line and appear just to touch the uppermost part of the domed surface of the mercury. If a piece of white paper is placed behind the instrument it assists the eye. Figs. 3 and 4 illustrate this. If the

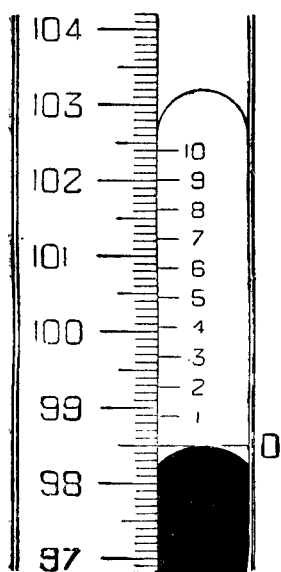


FIG. 3.

READING THE SCALE.

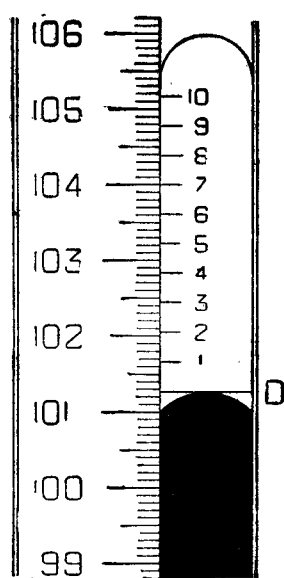


FIG. 4.

eye is not in line with both the bottom of the vernier and the sliding piece at the back, errors of parallax will come in, which are illustrated by Fig. 5. The vernier is read in just the same way as that of a sextant. The reading will be speedily mastered by examining Figs. 3

and 4, that of Fig. 3 being 985·0 millibars and that of Fig. 4 being 1012·7 millibars.

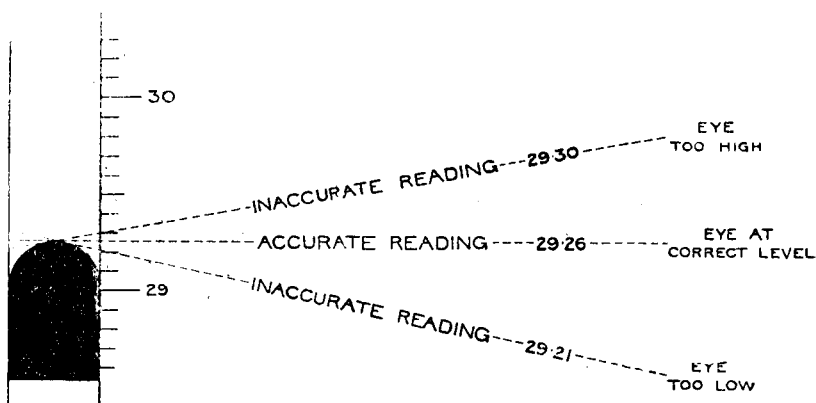


FIG. 5.

Correction and Reduction to Sea-Level of Millibar Barometers.

Note.—Barometers graduated to read in millibars are provided with an attached thermometer graduated according to the Absolute scale of centigrade degrees (*see* p. 14) and the references to temperature in the following instructions are to the readings on that scale. In quoting the temperature the degree mark is omitted and instead of it a small "a" follows the number. Thus 273a on this scale corresponds with the freezing point of water, that is 0°C or 32°F, and 283a corresponds with 10°C or 50°F. A step of 10a in temperature is the same as a step of 18°F.

The reading of a mercury barometer will give the weight of the atmosphere under certain conditions. These conditions will alter with time and place. The main variations that affect the reading of a mercury barometer are those of—

- (a) Temperature;
- (b) Height above sea level;
- (c) The value of gravity.

If, however, we reduce our barometer readings for standard values of these factors, then the barometer readings at two places or at two times can be truly compared. To take them in turn:—The temperature of the mercury, which will be the same as that of the whole instrument, will cause the volume of mercury, and thereby its specific gravity, to alter. That will readily be seen, when it is remembered that the mercury in a thermometer expands with heat. The mercury in a barometer will, therefore, rise in the tube with increase of temperature.

As a barometer is taken up above the level of the sea, there is less atmosphere above it; the weight of the atmosphere is, therefore, by that much the less. So the barometric pressure decreases with increase of height above mean sea level.

The value of the attraction of the earth for any body varies over the earth's surface, owing to the fact that the earth is not a sphere, but has a greater radius at the equator than the poles. So at the equator the weight of a mercury column of given length is less than at the poles. A greater column is, therefore, required to balance the atmosphere, so there the barometer will read too high.

Other corrections are due to the facts that the brass scale of the instrument expands with heat, that capillarity tends to depress the mercury in the tube, and that there is a varying quantity of mercury in the cistern. These latter corrections are due to the instrument itself and allowance can be made for them in the process of construction. There is with every instrument a final small error which is measured exceedingly carefully at the National Physical Laboratory, and of which a certificate is pasted in the case of all instruments.

With millibar barometers this certificate is put in a slightly different form from that in which it is put with inch barometers. In the latter the index correction is given as so many thousandths of an inch to be added to or subtracted from the barometric reading; in the former the *standard temperature* is given; that is to say, a temperature is calculated at which the reading of the barometer in latitude 45° and at mean sea level is comparable with that of any other instrument. If the temperature of the instrument is not at this particular reading, a correction will have to be applied.

If the latitude is not 45° , the reading will not be correct at the standard temperature, but there will be a temperature at which the reading would be correct, if it were so chosen that the latitude correction would just balance the temperature correction. We call this temperature, at which the readings of the barometer need no correction the *fiducial temperature* for the barometer in the particular latitude. For a station barometer with fixed latitude the fiducial temperature remains the same, but at sea the fiducial temperature changes with latitude.

To allow for the height of the barometer above sea-level the fiducial temperature can be adjusted, because, in the ordinary circumstances in which the barometer is used at sea, the allowance to be made for 100 ft. of height lies between 3.3 mb. and 3.9 mb., and a correction of 3.6 mb. for 100 ft. would be sufficiently accurate in most cases.

To make these corrections as simple as possible, tables have been made out and are given on pp. 84 to 89. They are used as follows :—

The height of the cistern above sea-level having been determined, the table on pp. 84 and 85 is used and the value of the *fiducial temperature* for various degrees of latitude is made out by adding or subtracting the figures given in that table to the *standard temperature*.

These values should be hung up near the barometer, as they will not alter, unless the height of the cistern is changed by an alteration in the draught of the vessel.

Having determined the adjusted fiducial temperature for the suitable latitude, the table on pp. 86 to 89 is used to compare it with the attached thermometer. Enter the table with appropriate attached thermometer reading on the left hand side, and in the column under the appropriate adjusted fiducial temperature will be found the correction in millibars to be applied to the barometric reading.

This table is not absolutely accurate if the barometric pressure is either very high or very low. To correct exceptional readings the rule is "add 1 per cent. of the correction given in the table for each 10 millibars above 1,000 and subtract 1 per cent. for each 10 millibars below."

Example.—M.O. Barometer No. 922 has a standard temperature of 285.0a at 1000 millibars. In latitude 32° 39' N. the reading of the barometer was 1016.9 mb., and of the attached thermometer 293a. The height of the barometer cistern was 42 ft. above sea-level.

Forty-two feet, being about half-way between 40 and 45 ft., from the table on p. 84 we find that for this height in latitude 32° 39' to get the adjusted fiducial temperature we must add 2.4a, which makes it 287.4a.

Then by the table on p. 87 the row marked 293a for the attached thermometer meets the column marked 287a for the adjusted fiducial temperature in -1.0 mb.

The corrected barometer reading is then 1015.9 mb.

The method given above will be most expeditious when a large number of corrections are being made. Below is given an example of another method which may be useful when only one or two readings have to be corrected.

Table of Correction for Gravity
(corrections to be applied to standard temperature).

Latitude of ship	...	0	10°	20°	25°	30°	35°
Correction (degs. abs.)		-15.0	-14.0	-11.5	-9.5	-7.5	-5.0
Latitude of ship	...	...	40°	45°	50°	55°	60°
Correction (degs. abs.)		...	-2.5	0.0	+2.5	+5.0	+7.5

Example—

Standard temperature of barometer	...	...	284.2a
Ship's latitude 52°N., correction	...	...	+ 3.5a
			<hr/> 287.7a
Divide height of barometer in feet above sea level by 5 and add			
Thus: height 42 feet ÷ 5	...	...	+ 8.4a
			<hr/> 296.1a
Adjusted fiducial temperature	...	...	296.1a
Subtract observed temperature of attached thermometer at time of observation	...	...	- 289.0a
			<hr/> + 7.1a
Divide by 6	...	...	+ 1.2
Call the result millibars and add it to or subtract it from the observed reading of the barometer according to its sign—			
Observed barometric reading	...	...	1017.1mb.
Correction as above	...	...	+ 1.2mb.
			<hr/> Corrected barometric reading
	...	...	1018.3mb.

Gold's Slide for use with Mercury Barometers, reading in Millibars.

Slides have been devised to be attached to the barometer to facilitate these computations.

These slides are attached by clips which embrace the cover of the barometer so that the slides can be fitted to any Kew pattern marine mercurial barometer.

The apparatus consists essentially of a thermometer and a slide worked from a rack and pinion. On the slide are engraved scales of height and correction to pressure, while on the fixed part are engraved scales of latitude and temperature.

To use the Apparatus.—Revolve the large milled headed screw until height of the instrument above the

water line, indicated on top right-hand scale coincides with the latitude of the ship (top left-hand scale).

The total correction to be applied to the barometer reading is then read off at the head of the mercury column of the attached thermometer by the scale to the right. The temperature is indicated by the scale to the left.

Barometers with these scales attached should be kept free from exposure to rapid changes of temperature, for these thermometers are rather more exposed than in ordinary barometers.

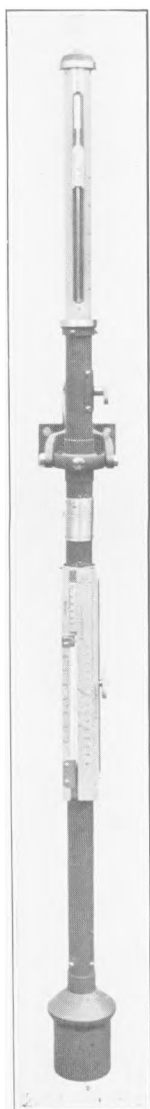
To check that the thermometer is correctly adjusted when the instrument is first placed in position, set the height scale so that zero height coincides with 45° on the latitude scale. Then read the value of the temperature scale corresponding to zero on the "correction to barometer scale." If this reading of the temperature scale is identical with the standard temperature of the barometer, the apparatus is in correct adjustment.

Instructions for the Use of a Mercury Barometer of the Kew Pattern Graduated in Inches.

Although it is hoped that the pressure unit (the millibar) will in time entirely supersede the length unit (the inch) for the measurement of all barometric heights, there are still in use so many inch barometers that a very brief description will be given here of the method of reading and correcting them.

Precisely the same precautions have to be observed in setting the instrument as have already been referred to for the millibar barometer (p. 15).^{*} The vernier is read in just the same manner also, with the exception that the scale being ruled in inches the vernier is divided to read in half-hundredths of an inch, that is to say, to $\cdot 005$ in. The divisions on the fixed scale are each $\cdot 050$ in. It is not usual, however, to record the height of the barometer at sea to thousandths of an inch; readings to hundredths are sufficiently accurate in temperate latitudes, but within the tropics an accuracy of half-hundredths or $\cdot 1$ millibar should be attempted.

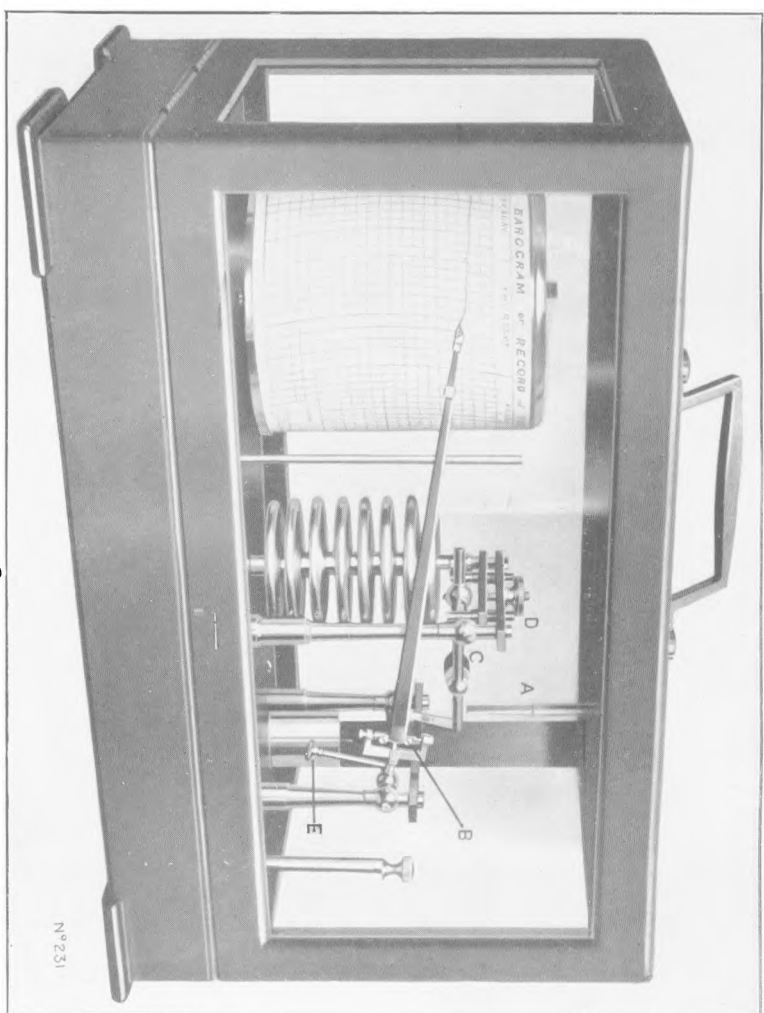
Tables of correction for temperature, height and gravity are given at the end of the book. In addition to these the index correction must not be forgotten. The causes of these corrections have already been explained in the case of the millibar barometer. The corrections



A Mercury barometer fitted with Gold's slide for effecting corrections.

To face page 21.

PLATE III.



THE BAROGRAPH.

in the case of the inch barometer, however, have simply to be added to, or subtracted from the reading.

Errors in Reading the Barometer.

The simplest error that can be made in reading the barometer is that of making an actual mistake of 10 mb. or 1 mb. The only means of guarding against that is care. After a reading has been entered in the rough book, it should be checked to make sure that no misreading has been made. In making the first reading attention should be concentrated on accuracy in the record of the decimals, in the check reading attention should be concentrated on the tens and units.

Parallax has been mentioned on p. 15; it is due to insufficient care being taken that the eye is at the same level as the top of the mercury column, when setting the vernier.

It is found that the effect of having the door of the charthouse, in which the barometer is situated, open or closed, is to alter the height of the mercury column. This is especially true in strong winds. The doors should, therefore, be always closed while the barometer is being read, if there is much wind. This applies quite as much to the lee door as to the weather door.

When a ship is in a seaway, it will be observed that the mercury of the barometer oscillates up and down in the barometer tube; this is termed *pumping*. This is due to the following causes :—

(a) The mobility of the mercury being acted on by the heaving of the ship, and her vibration.

(b) The mercury being acted on by the rocking of the instrument.

(c) The effect of the wind gusts on the air pressure of the room in which the barometer is hung.

(d) The variation of atmospheric pressure following the change of height of the ship above mean sea-level due to her vertical motion on the waves.

Of these (a), (c) and (d) are oscillations about a mean position, the mercury being as likely to be high as to be low, while for (b) the oscillation will be always above the true position. For many years this latter was considered to be of such preponderating importance that the causes (a), (c) and (d) could be neglected and accordingly it was impressed on observers that the lowest position should be taken. This decision was incorrect for, though

the mean position between highest and lowest reading will be in excess of the true value, the error will not be so great as that involved in taking the lowest value. In future, observations should, therefore, be recorded for the mean position, to obtain which the vernier should be set by eye midway between the highest and lowest positions of the mercury column. Observers who wish to obtain a more exact mean should take three pairs of readings, in each pair one being of the highest reading obtainable and one of the lowest and the result recorded being the mean of the whole set. Thus, if observations were obtained as follows:—

<i>Highest Reading.</i>		<i>Lowest Reading.</i>
1007·6 mb. ...	...	1006·5 mb.
1007·5 mb. ...	...	1006·6 mb.
1007·7 mb. ...	...	1006·6 mb.

The mean reading would be 1007·1 mb.

An ordinary barometer with a tube of wide bore is so much affected by pumping that no useful reading is possible in a seaway. To obviate this, however, the tubes of marine barometers are constricted; this lengthens the period of the oscillation of the mercury and thereby damps down the effect of pumping to a large extent. One result of this constriction is that a lag is introduced in the movement of the mercury column, but this is seldom serious.

The Aneroid Barometer.

The aneroid barometer, an instrument specially adapted for noting changes in pressure, consists of a circular metallic chamber partially exhausted of air and hermetically sealed. By an arrangement of levers and springs a hand is worked which indicates the pressure.

The aneroid should be frequently compared with the mercury barometer, and corrected, when necessary, by means of the adjusting screw at the back. Whenever such an alteration of the index error is made the fact should be clearly stated in the log, or on any other records of observations, as a guide to persons consulting the data in future.

Readings of aneroids do not require correction for temperature or latitude, but only for height above sea-level and index error. The figure given for the correction of the aneroid barometer of ships in communication with the Meteorological Office is a combined result, and makes allowance for both height and index error.

In order to keep a check on the index errors of official barometers and to obtain the errors of ships' barometers,

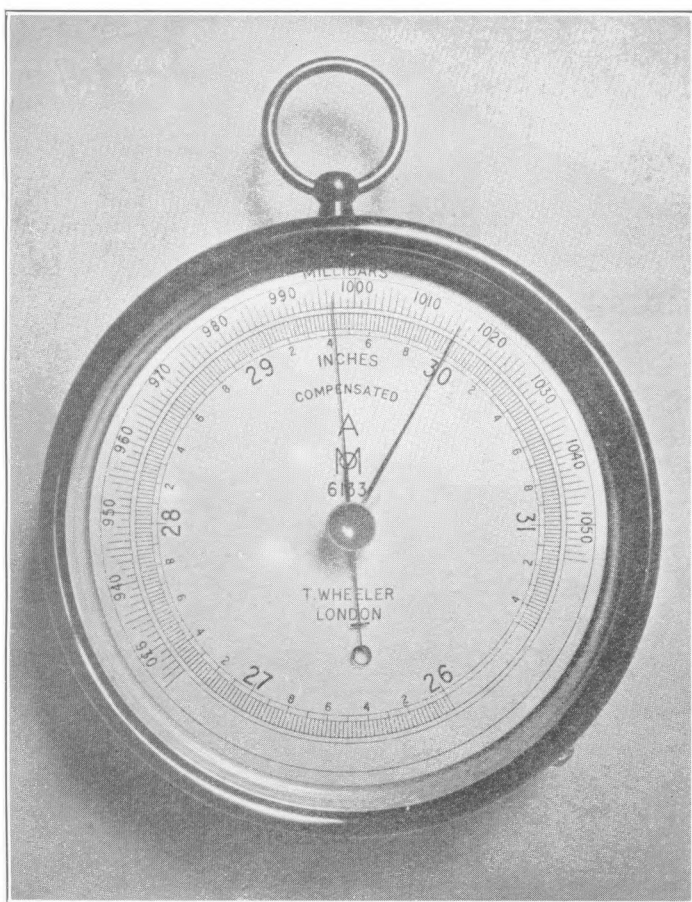


FIG. 6. The Aneroid Barometer.

both aneroid and mercury, the blue post-card method was devised. These post-cards, Form 913, accompany every log or form, and should be filled in in port and sent to the Marine Division at the end of each voyage. The index error will then be worked out and forwarded to the ship.

The Barograph.

A portable Barograph (Plate III), which is an aneroid barometer provided with a lever recording variations of pressure on a revolving drum, is a valuable supplement to the mercury barometer on board ships. It is not only useful in enabling an observer to detect casual

errors in the readings of the mercury barometer, but also gives a continuous record of barometric pressure for reference. Barograms, moreover, show minor fluctuations of atmospheric pressure which are seldom noticeable in the action of the mercury barometer, and without the uninterrupted evidence furnished by a sensitive self-recording instrument, are rarely detected.

Attention has been directed on several occasions by the Meteorological Office to the association of these minor fluctuations of pressure disclosed by the barogram, which are aptly described as the "embroidery" of the trace, with occurrences of rain, hail or snow showers, usually accompanying a squall. This "joggle" in the trace concurrent with showers, and not infrequently with a transient increase of wind, is an interesting feature in barographic records, showing as it does the close connection that exists between weather changes and variations in barometrical pressure.

The action of the barograph, briefly, is as follows :—

The circular metallic chamber, consisting of a series of vacuum metal boxes with elastic lids, is connected with the revolving drum by means of a lever carrying a pen filled with specially prepared ink. The rotation of the drum is effected by means of clockwork contained in the drum which is designed to complete a revolution in seven days.

The variation in the volume of these vacuum boxes, caused by changes in atmospheric pressure, is transmitted through the lever to the pen, which registers the changes in a continuous line on a printed chart fitted round the drum.

The timepiece may be regulated by moving the pointer on the balance of the clockwork. Should the timepiece be fast the pointer should be moved in the direction R.S. (*retard*, slow); if slow, in the direction A.F. (*avance*, fast); but frequent movement of the pointer should be avoided.

The setting of the barograph to time presents some difficulties, because ship's time changes from day to day during a passage, while the timepiece of the instrument, if in proper order, will keep the time at which it is originally set.

The rule should be to keep Greenwich Mean Time throughout the voyage. Time marks should be made each day at noon by ship's clock, when the other meteorological observations are made, and against each time mark should be entered the date and the latitude and longitude. The *corrected* height of the mercurial barometer should also be added.

It should be clearly stated on each barogram that the instrument was set for G.M.T., and the latitude and longitude at noon should be entered after the record has been removed.

For the purpose of making time marks all barographs issued by the Meteorological Office have a small lever termed a time marker which on being depressed moves the pen slightly.

Barograph and thermographs require constant attention and care. The thermograph being of necessity out of doors and so exposed to the moisture in the air, will frequently require to be cleaned.

The following notes are applicable to all self-recording instruments. Friction between the working parts of the apparatus must be avoided as far as possible. The bearings should be cleaned occasionally and oiled with a good clock oil, care being taken to remove excess of oil.

The most serious friction generally occurs between the pen and paper on which it writes. The pen should be well washed from time to time in water or methylated spirit.

A thin, clear trace should be aimed at, for if the trace be thick and blurred many of the smaller variations, which are most interesting meteorologically, become obliterated.

The point of the pen should be fine so as to give a narrow trace, but it must not be so fine as to scratch or stick to the paper. A new pen may frequently be improved by drawing the point once or twice along the oil stone, but any trace of oil should afterwards be carefully removed.

Excess of ink should be avoided. Special care must be taken not to let ink come in contact with the metal style which carries the pen, as this will cause the pen to adhere firmly to the style, so that it cannot be removed and cleaned. The ink may also cause the metal to become brittle and break. Should the style be accidentally inked, it should be immediately washed and slightly oiled. The pressure of the pen on the paper should be reduced to the minimum consistent with a continuous trace for which simple contact with the paper will suffice.

In instruments in which the elasticity of the style is used to keep the pen in contact with the paper, the pressure should be adjusted by means of the milled head near the base of the style, so that the pen falls away from the paper, when the instrument is tilted slightly.

CHAPTER III.

THERMOMETERS, HYGROMETER, HYDROMETER AND RAINGAUGE.

The Thermometer.

This instrument shows increase or decrease of temperature, but is not sensibly affected by changes of the pressure of the air. It consists of a glass tube of very small bore, closed at one end, and united at the other to a bulb, which is commonly filled with mercury. Thermometers intended for use in very cold climates are filled with spirit instead of mercury, which would freeze and solidify at the low temperatures of the Polar regions, whereas spirit would not freeze. Mercury freezes at a temperature of about -38.2° Fahrenheit (-39° Centigrade);

spirit (pure alcohol) becomes a thick liquid at -130° Fahrenheit, and solidifies into a white mass at -202° Fahrenheit. Almost all substances expand when they are heated, and contract when they are cooled, but they do not all expand equally. Mercury expands more than glass, and so, when the thermometer is heated, the mercury in the bulb expands, and that portion of it that can be no longer contained in the bulb rises in the tube in the form of thin thread. The tube being very minute, a small expansion of the mercury in the bulb, which it would be difficult to measure directly, becomes readily perceived as a thread of considerable length in the tube. When the instrument is cooled, the mercury shrinks, and the thin thread becomes shorter, as the mercury subsides towards the bulb. By observing the length of the thread of mercury in the tube, as measured by the graduation on the scale at its side, or marked on the tube, the thermometer shows the temperature of the bulb at the time, which thus indicates the temperature of the surrounding air, or of any liquid in which the bulb is immersed.

The indications of a thermometer are recorded in degrees, the scale for which is obtained as follows. There are two fixed points on the scale according to which thermometers are graduated, viz., that at which ice melts, and that at which water boils under standard pressure. In the thermometers in ordinary use in England, the distance between these two points is divided into 180 parts, or degrees. When surrounded by melting ice an accurate thermometer on this scale indicates thirty-two degrees (32°), and at the boiling point of water when the pressure is 29.92 inches of mercury, the reading is two hundred and twelve degrees (212°). This graduation was adopted by Fahrenheit, a native of Danzig, in the year 1721. Other graduations were devised about 20 years later; one by Celsius, a professor at Upsala, in 1742; and another by Réaumur, a French physicist, at about the same period. Celsius suggested that the boiling-point be called zero, and the freezing-point 100° . In the modern Centigrade scale, which is an adaption of the Celsius, and in general use at the present time in most continental countries, the freezing point is taken at zero, and the boiling-point at 100° . Réaumur framed a scale somewhat similar to the Centigrade, but divided the interval between the freezing and boiling-points into 80 divisions. This scale, which at one time was commonly employed on the Continent, is now almost obsolete.

The Absolute scale is yet another measure of temperature that has been introduced, based on the researches of the late Lord Kelvin, the late Dr. J. P. Joule, and others, who found the absolute zero of temperature to be 273° Centigrade below the freezing-point of water, or -459° on the Fahrenheit scale. This zero of temperature is based on the doctrine of the dissipation of energy, heat having for a long time previously been recognized as a form of energy. It represents, so far as our present knowledge goes, the temperature at which the whole of the heat of any substance whatever would have been converted into some other form of energy. The principal advantage of the Absolute scale for meteorological work is that all negative values are avoided.

In order to convert readings of the Centigrade scale to those of the Fahrenheit use the following rule: Multiply by $\frac{9}{5}$ and add 32. Similarly to convert from Fahrenheit to Centigrade: subtract 32 and multiply by $\frac{5}{9}$.

In Table VI. the conversion of temperature readings of the Fahrenheit and Centigrade scales to the Absolute scale is furnished.

The usual range of a thermometer in the shade in the open air, in England, is about 60° , viz., from 20° to 80° . In very hard frosts the temperature of the air sometimes falls below 20° , and on very hot summer days it rises above 80° . If the instrument is exposed directly to the rays of the sun, the mercury will rise much higher, and at night, if exposed to radiation* to a clear sky, may fall many degrees below what would be due to the temperature of the surrounding air. It is, therefore, necessary to take precautions for protecting the instrument from the direct rays of the sun, or from exposure to the clear sky at night, in order to obtain a correct indication of the temperature of the air.

The Hygrometer.

This instrument measures the humidity of the air. There are several kinds of hygrometer, but the easiest to make and to manage consists of a pair of thermometers placed near each other. It is known as Mason's Hygrometer. One of these thermometers is fitted with a single thickness of fine muslin or cambric secured lightly

* Radiation is the process by which heat is transferred from one body to another without altering the temperature of the intervening medium. The earth itself is always radiating into space. During the day normally the earth receives directly from the sun and indirectly from the atmosphere, including the clouds, more radiation than it gives out. At night the reverse is the case (v. Meteorological Glossary, p. 330).

round the bulb, and this coating is kept damp by means of a few strands of cotton wick, which are passed round the glass stem close to the bulb so as to touch the muslin, and have their lower ends dipping into a receptacle of water placed close to the thermometer. This thermometer will usually show a temperature lower than that shown by the other thermometer which is near it, the amount of the difference, commonly called the *depression* of the wet bulb, being dependent on the degree of dryness of the air.

A thermometer fitted in the manner described above is called a *wet-bulb* thermometer, to distinguish it from the ordinary thermometer, which has its bulb uncovered and is known as a *dry-bulb*.

The depression of the wet-bulb thermometer is caused by the evaporation from the moistened covering of the bulb. When the humidity of the atmosphere is very great, during, or just before rain, or when fog is prevalent or dew is forming, there is little or no evaporation, and the two thermometers read very nearly alike, but at other times the wet-bulb thermometer reads lower than the dry, because the water dries off or evaporates from the muslin coating, in which process it passes into the state of invisible vapour, and absorbs heat from the mercury in the bulb of the thermometer, which, consequently, indicates a lower temperature. As the air becomes less humid the evaporation is greater, and the fall of temperature of the wetted bulb is also greater, and accordingly the difference in readings between the dry and the wet-bulb is then also greater. The difference sometimes amounts to 15 or 20 degrees in England, and to more in some other parts of the world, but at sea the difference seldom exceeds 10 degrees except in fine, clear weather in the tropics.

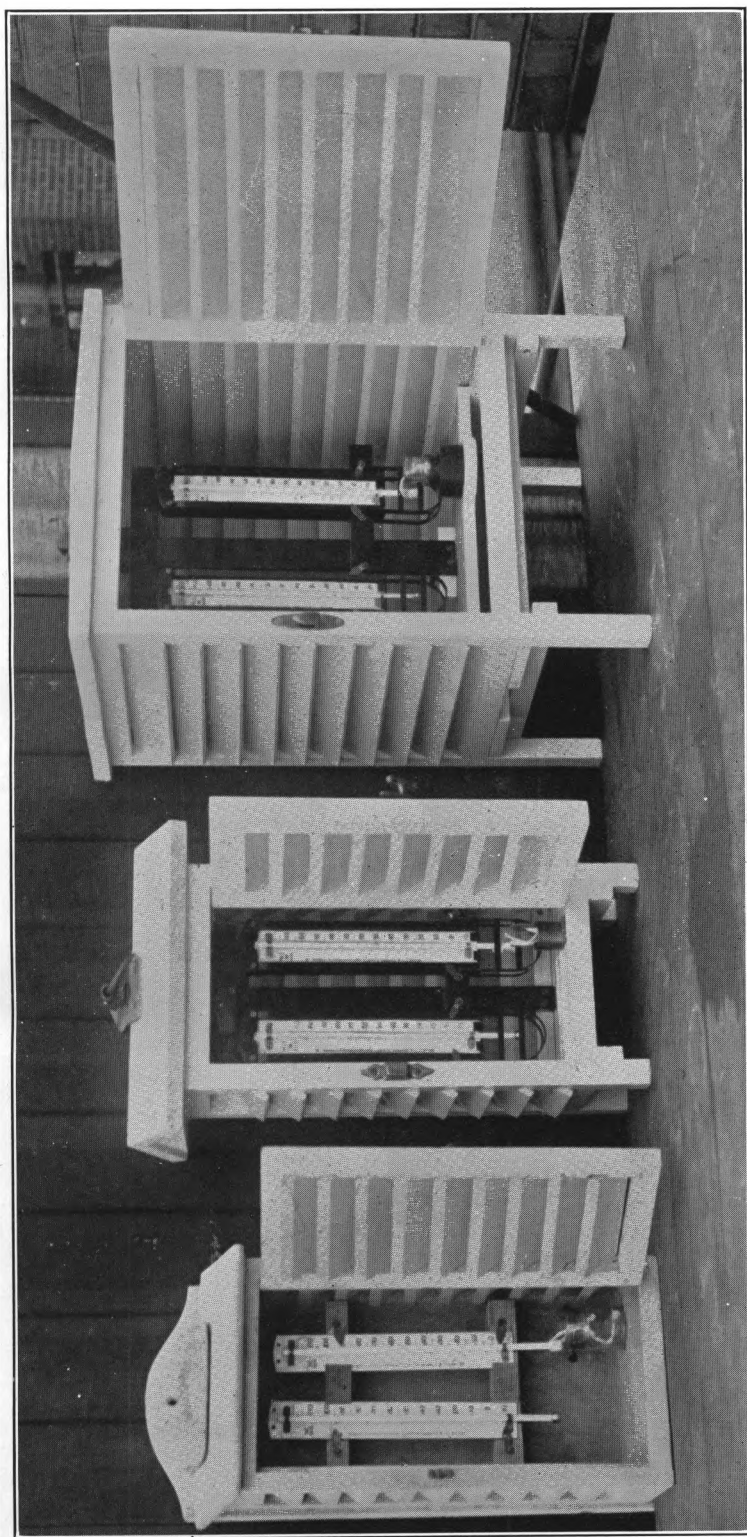
To ensure correct records of the temperature and humidity of the air, the dry and wet-bulb thermometers should be placed in a screen, the sides of which are protected from the sun and rain by "jalousies" or louveres, so as to let in the air freely.

The annexed engraving (Plate IV.) shows the forms of screen used for exposing the dry and wet-bulb thermometers on board ship; the screen should be placed in a suitable position about 5 ft. above the upper deck, in the open air, as free as possible from radiation or warm draughts of air from galleys, engine and boiler rooms, stokehold and funnel.

It cannot be too strongly emphasized that the temperature of the free air is required, not that affected by heat from the ship and that therefore the weather side is usually most suitable.

A single thickness of fine muslin or cambric should, as before mentioned, be secured round the bulb of one

METEOROLOGICAL OFFICE.
SHIP'S THERMOMETER SCREENS.



Old Pattern Fixed.

Modified, with
Thermometer Protectors.

Portable, with
Thermometer Protectors.

thermometer, and a few strands of cotton wick passed round the glass stem immediately above the bulb* touching the muslin; they should be long enough to reach two or three inches below the lowest part of the bulb, in order that their lower ends shall be immersed in a small vessel of water. By this arrangement the water is slowly conducted by capillary action to the bulb, from which evaporation takes place.

The glass, or other small holder of water should be as far as possible from the dry thermometer, as in Plate IV. Either distilled or rain water should be used, or, if this be not procurable, the softest fresh water available, to avoid the deposit of lime, or other impurity on the bulb.

The wet bulb is probably the instrument that needs most careful attention. It has already (p. 28) been explained how the muslin and wick are to be attached to the thermometer bulb. The muslin and wick should be well washed before use in water containing ammonia and occasionally during use. Both should be changed once a month or oftener. The water used should be the purest obtainable, as the effect of the constant evaporation is to cause any impurities to be deposited on the bulb. Should an incrustation be formed on the thermometer, it should be scraped off with a sharp penknife. Should it be thought that spray had reached the instrument the muslin should be at once changed, since the presence of salt in the water will be certain to vitiate the results obtained. The water vessel should be refilled after an observation has been made rather than before, since it takes at least 15 minutes for the instrument to resume its normal position. Care must be taken to see that the muslin is damp but not dripping. The wick must not be allowed to hang down in a bight, or water will drip down from the lowest point of the curve until the reservoir is emptied. If the reading of the wet bulb is above that of the dry, make sure first that there is no error of readings and that there is an excess when the known corrections have been applied. Then see if the moisture has been deposited on the bulb of the dry. If this is the case, wipe the bulb dry and read again after waiting a minute or two for the thermometer to take up the temperature of the air.

If there is no evidence of moisture, make two or three more observations of both instruments at intervals of

* To secure the strands to the thermometer, take a round turn with the strands middled on the bight and pass the ends through the bight forming a round turn and cow hitch.

about two minutes. It will usually be found in that case that the temperature is falling, and that the wet bulb eventually falls below the dry, although at first the dry may fall more rapidly than the wet.

In the first of these two cases the peculiarity is due to the fact that the dry bulb is acting as a wet bulb, and is giving a temperature below the true air temperature. This will usually happen when the temperature is rising. In the second case the wet bulb is lagging more than the dry in air in which the temperature is falling, and the wet bulb is reading too high.

The amount by which the temperature of the wet bulb is reduced below that of the dry is found to depend to some extent on the ventilation to which the instrument is exposed. On calm days the observer will frequently be able to reduce the temperature of the wet bulb by a degree or more by fanning it. It is therefore obvious that a screen exposed to the wind will reveal a greater difference than one sheltered behind a deck house.

During frost, when the muslin is thinly coated with ice, the readings are still valid, because evaporation takes place from a surface of ice as freely as from that of water, but if the muslin be dry, and there is no coating of ice, it must be first wetted and then allowed time to freeze, before the thermometer is read.

Sea Surface Temperature Thermometer.

When an ordinary thermometer is used for surface temperature observation it should be protected by a metal case having a water-tight space at the bottom which will hold sufficient water to surround the bulb.

The water employed for taking the sea surface temperature should be drawn in a canvas bucket from over the ship's side, forward of all ejection pipes.

The sea thermometer and its case should be kept carefully cleaned. It is essential that the bulb of the instrument should be under water at the time of reading, hence the reservoir around the bulb. If it is not covered evaporation will take place from the drops of water adhering to it, and it will tend to act as a wet bulb thermometer.

Sea water freezes at 28° F. in normal conditions. In freezing, crystals are formed that are free of salt, but intermingled with these crystals in the ice there is brine.

Thermometer Protectors.

In order to minimise the breakage of thermometers mahogany protectors are being introduced—these are illustrated in Plate IV. A protector consists of a

mahogany frame into which the thermometer is fitted by unscrewing a metal plate at the top. At the bottom of the bed is a metal guard to protect the bulb of the thermometer. This guard is open in the case of the protector for use with a dry or wet bulb thermometer, but in that for use in measuring sea surface temperature the guard is closed in, thereby forming the reservoir for retaining a small quantity of sea water around the bulb while the temperature is being read.

Reading Thermometers.

To avoid errors due to *parallax* (*vide* p. 15) the observer's eye must be at precisely the same height as the top of the mercury column of the thermometer.

In order to obtain satisfactory results from the observations of the dry and wet-bulb thermometers, the values must be known with accuracy; hence the observer should, when reading these instruments, estimate fractions of a degree to the nearest *tenth*.

The thermometers should be read as rapidly as is consistent with accuracy, in order to avoid the changes of temperature due to the presence of the observer. When observing by artificial light with a bull's-eye or lantern, care must be taken not to allow the heat from the lantern to vitiate the observations. A pocket electric torch will be found to provide the most suitable means of illumination.

The Thermograph.

A self-recording thermometer, or thermograph, may be employed with advantage on board ship for obtaining a continuous record of temperature, which, if studied in connection with the record of a barograph for the same period, will demonstrate the close relation existing between the fluctuations in temperature and pressure respectively.

The instrument will be found, after the observer has had a little experience with it, a valuable aid in foretelling changes in weather conditions. For instance, a marked rise in temperature, detected by a glance at the thermogram, if associated with a shift of wind to an equatorial quarter, will frequently give warning of the approach of an atmospheric disturbance before the barometer has commenced to fall.

Most thermographs are on the bi-metallic principle, that is to say, the temperature is measured by the

difference in expansion of two strips of metal. These strips are fixed side by side in a spiral, one end of which is secured rigidly to the instrument, while the other is attached to the system of levers which actuates the recording pen as the spiral coils or uncoils.

From the nature of the case thermographs for meteorological use must be exposed on deck, preferably in a louvered screen, and hence it is necessary to clean and oil their bearings much more frequently than is the case with barographs.

The instrument may be set by comparing its indications with the reading of a standard mercury thermometer placed beside it in the screen. The setting should only be attempted at times when the temperature is constant or changing slowly, and only when the pen is near the middle of its range. As the thermometer is in thermal contact with the body of the instrument (which takes an appreciable time to alter in temperature) it is apt to be somewhat sluggish when the changes of temperature are rapid.

The readings of the thermograph require frequent checking by comparison with standard instruments. A convenient plan is to place a standard maximum and a standard minimum thermometer in the screen with the instrument and to read and set these at regular hours, time marks being made at the hours of reading. It should be borne in mind that in cases when the trace shows that the extreme was of very short duration the sluggishness referred to above may cause a considerable difference between the reading of the standard and that of the recorder.

The same remarks with regard to the time of setting apply to the thermograph as to the barograph, *q.v.*

Hydrometer.

This instrument is employed for determining the specific gravity of liquids. The hydrometer used at sea is constructed of glass. If made of brass, the corrosive action of salt water soon renders the instrument erroneous in its indications. The form of the instrument in common use is shown in the engraving (Fig. 7). It consists of a glass tube and a float, with a bulb at the end partly filled with mercury or small shot, to act as ballast and to make the instrument float steadily in a vertical position.

From the neck of the bulb the glass expands into an oval or cylindrical shape, to give the instrument sufficient volume for flotation; above this it is tapered off to a narrow upright stem closed at the top, attached to which is a scale. The divisions on the scale read downwards, so as to measure the length of the stem which stands



FIG. 7.

above the surface of any fluid in which the hydrometer is floated. The denser the fluid, or the greater its specific gravity, the higher will the instrument rise; the rarer the fluid, or the smaller its specific gravity, the lower it will sink.

The indications depend upon the well-known principle, that any floating body displaces a quantity of the fluid which sustains it, equal to the weight of the floating body itself. According therefore as the specific gravities of fluids differ from each other, so will the quantities of the fluids displaced by any floating body, or the depth of its immersion, vary, when it is floated successively in each.

The true specific gravity of a sample of sea-water is the ratio of its weight to the weight of an equal volume of pure water at a standard temperature, namely, 277a (4°C. , or $39\cdot2^{\circ}\text{F.}$).

A hydrometer will show the zero of its scale, when it floats in distilled water at that temperature or in any sample of water or other liquid of the same specific gravity. If the specific gravity, or the density of water be increased, as it is by the presence of salts in solution, the hydrometer will rise; if on the contrary the density or specific gravity be diminished as by a sufficient rise of temperature, the hydrometer would carry the zero of its scale under water.

The scale of the hydrometer now being issued by the Meteorological Office is graduated from 15 to 35, that is to say, for use in water the specific gravity of which lies between 1·015 and 1·035, which is the range of sea water in almost all parts of the globe, though it may float above this range in parts of the Suez Canal, where the water is extremely salt.

The instrument is used on board ship to show the relative density of different parts of the ocean. On the north-western side of the North Atlantic, in the regions of Doldrums, Bay of Bengal, and Black Sea, and in the vicinity of the mouth of a large river, the hydrometer will sink much deeper owing to the comparative freshness of the water. This instrument is of great value for ascertaining the change of draught of a ship proceeding to sea from a river, or *vice versa*.

The specific gravity of the sea should be taken in the same water as the sea surface temperature. The hydrometer should be slightly spun in the centre of the bucket; when it has lost all up and down motion, and before the turning motion has entirely ceased the scale is read.

It has been defined that specific gravity of a sample of sea water is the ratio of its weight to an equal volume of pure water at 277a. Since the volume of water changes with its temperature, it is clear that a correction must be made for temperature, but as glass also changes its volume with changes of temperature, this correction for hydrometers will be modified by this factor. In order to make this correction small the scale on Meteorological Office hydrometers is so arranged that, if the temperature is 288a (59°F.), there is no correction.

Since the density of sea water depends on its salinity, a more accurate method of determining the specific

gravity of a sample is by obtaining its salinity from chemical analysis and then converting this salinity determination into specific gravity by means of a table prepared for this purpose. For this purpose samples are collected by a few selected ships on certain routes for the Board of Agriculture and Fisheries, and the chemical analysis is made by the Government chemist.

The hydrometer needs most careful handling to obtain the best results. It is an instrument of which the weight is very nicely balanced and which will, therefore, be made inaccurate by any foreign matter which adheres to it. The hydrometer should be washed occasionally in distilled water and care must be taken that it is always scrupulously clean, all dust smears or greasiness being got rid of by wiping with a clean, soft cloth before and after use. When the ship is in a seaway, it is necessary that the bucket should be hung up and allowed to swing.

Parallax is very likely to occur in reading this instrument and must be watched for. It will be noticed that the surface of the water will be curved up round the stem of the instrument by capillarity. The point of the scale to be observed is that point which is on a level with the surface of the water, not the highest point to which it is drawn up around the stem. Care should be taken to read the instrument just before the spin has died down and when all up and down motion has ceased.

The Rain Gauge.

A rain gauge, suitably fitted for use in steamships, is lent to a number of marine observers.

The instrument, Fig. 8, which is a 5-in. gauge of the Snowdon pattern, consists of a cylindrical funnel (*f*) having a rim 4 in. deep, to the edge of which a stout brass ring (*r*) is firmly fixed; a vertical cylinder, with closed

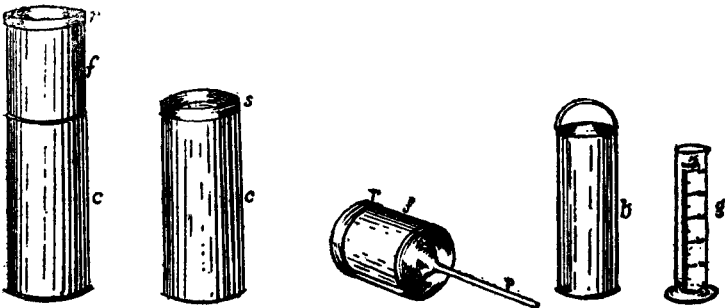


FIG. 8.

base (*c*), and shoulder (*s*), upon which the lower edge of the funnel-cylinder rests when in position; and a can (*b*), which rests on the bottom of the lower cylinder.

Precipitation is directed from the funnel to the can by means of a pipe (*p*) attached to the former, reaching almost to the bottom of the latter. The brass ring, the inside measurement of which is exactly 5 in. in diameter, is bevelled on the outside so as to form a knife edge upon which no rain can rest.

The rim of the cylinder being 4 in. deep, the loss of precipitation by splashing is prevented and its collection when in form of snow facilitated.

With the exception of the ring the instrument is made entirely of copper.

The rain collected is measured by pouring it into a measuring glass which is graduated to indicate either millimetres or hundredths of an inch.

The measuring glass (*g*) will hold ten millimetres or two-fifths of an inch of rainfall, an amount which corresponds with 4.54 oz. when collected in the gauge (5 in.) described.

The quantity of precipitation collected by a rain gauge depends to some extent upon its exposure; in order, therefore, that the gauge may be free, when in action, from the sheltering effects of deck houses, skylights, deck furniture, etc., provision is made for hoisting it to a suitable height above the deck, where, under all but exceptional conditions of wind and sea, it will also be exempt from spray.

The special arrangements for doing this are similar to those used for hoisting an oil masthead light.

The instrument is attached to an iron frame, Fig. 9 *a*, by two bands (*bb*) which encircle the cylinder, two tubes (*tt*) forming the sides of the frame.

A two-pronged fork of bar iron (*pp*) has an eye (*e*) formed in the bend of the bar, for use in securing an iron halyard block or gin (*g*) to the fork and the fork to the stay.

In Fig. 9 *b*, the rain gauge is shown attached to its frame.

When the frame is hoisted close up to the stay, the rim of the gauge will be above it; thus the instrument will have a free exposure (Fig. 9 *c*).

Should the gauge require steadying when it is in position the guys should be set up rather nearer the ship's side.

It will be noticed that the precipitation in the measuring glass of the rain gauge has not a flat surface

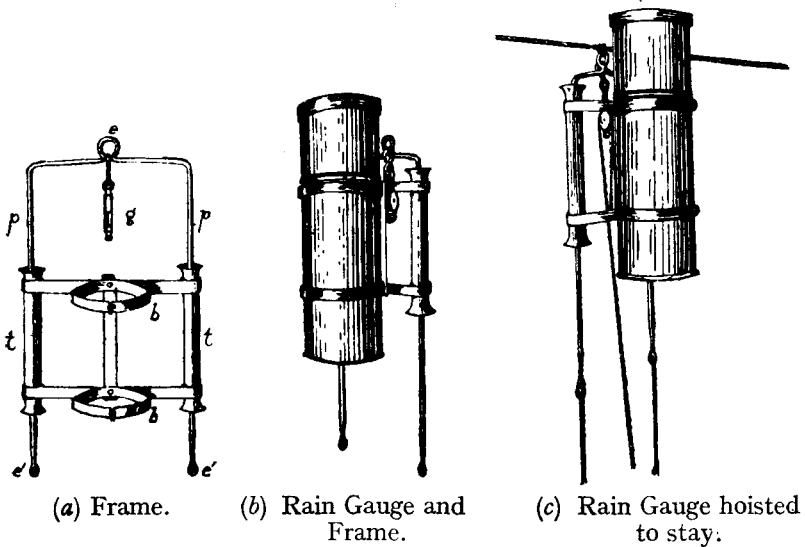


FIG. 9.

but is drawn up at the sides. The scale reading corresponding to the lowest point should be given as the amount of precipitation.

When snow is collected in the rain gauge, it may be melted out by slightly warming the gauge before a fire. An alternative method which is quicker and is useful if snow is falling at the hour of observation is to measure accurately a quantity of hot water, pour it into the gauge to melt the snow, then measure out the total amount of water in the gauge; the result, less the quantity of hot water, will be the amount of precipitation.

It should be remembered that dew and fog are apt to leave precipitation; this should be measured and recorded.

PART II.—NON-INSTRUMENTAL OBSERVATIONS.

CHAPTER IV.

WIND AND SEA OBSERVATIONS.

There are certain observations which at present cannot be measured by mechanical means, at any rate at sea. The landsman has the advantage of the sailor in that with the aid of a self-recording anemometer he can obtain a continuous and accurate record of the wind both in direction and force; with a nephoscope he can determine the motion of a cloud; such instruments are not practicable at sea owing to the unsteadiness of the ship. Reliance, therefore, has to be placed on eye observations.

Wind Direction.

The direction of the wind is given by the point of the compass from which the wind blows. For meteorological purposes, the *true* direction is required. If the direction is recorded by the use of cardinal points, endeavour should be made to judge the wind to the nearest point, since for the scientific comparison of the wind observed with the forces which cause it, it is essential that this accuracy should be maintained.

Veering and Backing.

One point needs attention with regard to the change of direction, which is described as “veering” and “backing,” caused by cyclonic and anticyclonic systems drifting over any place.

There is said to have been some uncertainty in former years as to the meaning of the words as applied to the changes in the direction of the wind in the Southern Hemisphere, though seamen spoke of the wind as changing in direction in southern latitudes with the sun, and against the sun in northern latitudes. At the International Conference of Directors of Meteorological Institutes and Observatories, held at Innsbruck in 1905, a question was raised in this connection. The Conference having ascertained the rule in use at the British Meteorological Office agreed that the same should be recommended

for general adoption by passing the following resolution :—
“ That Meteorologists in the Southern Hemisphere, as in the Northern Hemisphere, are requested—without regard to other weather phenomena—to employ the term ‘ backing ’ whether at an observing station or on board ship, exclusively to denote a change in direction against the hands of a watch, *i.e.*, W-S-E-N : and the term ‘ veering ’ for changes in the opposite direction, with the hands of a watch, *i.e.*, W-N-E-S.”

Wind Force.

Wind force is expressed numerically on a scale from 0 to 12. This scale, with a statement explanatory of the respective wind conditions to which the numbers refer, was originally suggested by Captain, afterwards Admiral Sir Francis Beaufort, in the year 1808, for use on board ships of the British Royal Navy. Although more especially applicable to the full-rigged frigate of that date, the scale soon came into general use, not only in the Royal Navy, but also in the Mercantile Marine. Since Admiral Beaufort’s time, however, so many changes had taken place in the build, rig, and tonnage, of sea-going vessels, that in 1874 Beaufort’s scale was adapted to the full rigged ship of that *period*, with double topsails; and in 1926 the International Meteorological Committee re-affirmed this scale.

The specification of the Beaufort numbers is as follows :—

The Beaufort's Wind Scale.

Meteorological Wind Scale.				The Seaman's Wind Scale.			Beaufort Number. International.
Determined at coast stations for a height of 33 ft. above sea level.				Beaufort's description of Wind. International.	Deep Sea Criterion, 1874. International.	Coastal Criterion.	
Beaufort Number. International.	Limits of Velocity nautical miles per hour. knots.	Average Velocity nautical miles per hour. knots.	Equivalent pressure in pounds upon a circular disc of one square foot.				5	6	7	8
1	2	3	4				
0	Less than 1	0	0	Calm	Just sufficient to give steerage way* -	Sufficient to give good steerage way to fishing smacks with the "wind free."†	0
1	1 to 3	2	.01	Light air			1
2	4 to 6	5	.08	Light breeze			2
3	7 to 10	9	.28	Gentle breeze			3
4	11 to 16	14	.67	Moderate breeze	4		
					1 to 2 knots	Fishing smacks with topsails and light canvas "full and by," make up to 2 knots.	
					3 to 4 knots	Smacks begin to heel over slightly under topsails and light canvas make up to 3 knots "full and by."	
					5 to 6 knots	Good working breeze. Smacks heel over considerably on a wind under all sail.	

5	17 to 21	19	1·31	Fresh breeze	That to which she could just carry in chase, full and by—	Royals, &c.	Smacks shorten sail	5
6	22 to 27	24	2·3	Strong breeze		Topgallant sails.	Smacks double-reef gaff mainsails.	6
7	28 to 33	30	3·6	Moderate gale		Topalls, jib, &c.	Smacks remain in harbour and those at sea lie to.	7
8	34 to 40	37	5·4	Fresh gale		Reefed upper topsails and courses.	Smacks take shelter if possible.	8
9	41 to 47	44	7·7	Strong gale		Lower topsails and courses.	—	9
10	48 to 55	52	10·5	Whole gale		That with which she could scarcely bear lower maintopsail and reefed foresail.	—	10
11	56 to 65	60	14·0	Storm		That which would reduce her to storm stay-sails.	—	11
12	Above 65	—	Above 17·0	Hurricane		That which no canvas could withstand	—	12

For the purpose of showing the forces of winds by wind roses on Meteorological Charts, winds are grouped as follows :—

Scale Numbers.

-	Calm.
-	Light winds.
-	Moderate winds.
-	Gales.

The scale numbers are attributed to the wind force at the time of observation by judgment of the observer. For the purposes of the Meteorologist, forces of 8 to 10 only are gales.

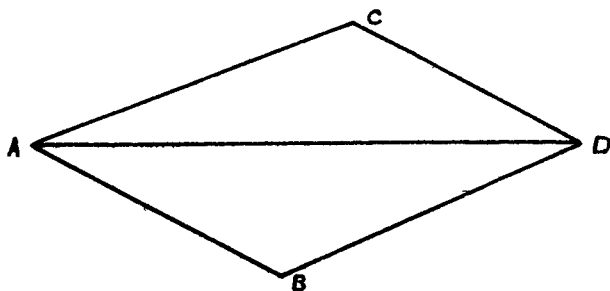
The Gale Warning Signal in the British Isles is hoisted for winds which may reach force 8 or above. For this purpose force 7 is not considered.

In a steamer the force of the wind may be judged by an experienced observer by the appearance of the sea, remembering that polar winds create more sea than equatorial winds, rain has a smoothing effect, and tides or currents influence the sea surface differently when there is a weather or lee tide or current.

* A full-rigged ship of 1874.

* Cutter or Yawl rigged average sized sailing trawler, loaded, with clean bottom.

To determine both the velocity and direction of the wind it is found by seamen that the appearance of the surface of the water is of the utmost help. It is not possible to explain in words the criteria for determining the various Beaufort forces; by a glance at the waves, but seamen in sailing ships by long practice have learnt to estimate the wind thus with extreme accuracy. The only method of learning thus to read the sea is practice with the aid of one who is an accurate judge of wind. To measure the true wind in a ship under way is a different matter. When the wind is dead aft in a steamer, and of the same velocity as the ship's speed, there is apparent calm on board the ship. In a calm a ship steaming 10 knots will have an apparent head wind velocity of 10 knots, but as soon as the wind blows from any direction out of the fore and aft line the problem becomes complicated. For instance, if the ship is travelling along the line AB with speed 15 knots, and the wind appears to be coming from the direction DA with velocity 29 knots (Beaufort scale 7), the true direction of the wind is along CA, and its velocity will be 18 knots. This is most simply got by drawing a figure as below, making BA proportional to 15 and DA proportional to 29 and then measuring DB, which is equal to CA, where ABDC is a parallelogram.



Working it out by trigonometry it is obtained by the formula $BD^2 = AB^2 + AD^2 - 2 AB, AD \cos BAD$ and so the angles from the rule of sines.

If a hand anemometer is used with judgment and skill, the velocity of the true wind may be found either graphically or by computation with traverse tables by the formula above, but the observer who has not this instrument may obtain far better estimates by looking at the sea than at the smoke from the funnel.

Sea Disturbance.

The following scale has been adopted for estimating Sea Disturbance :—

<i>Scale.</i>	<i>Description.</i>	<i>Height of Waves, Crest to Trough.</i>
0	Calm	0
1 } 2 }	Smooth Sea	{ less than 1 ft. 1 to 2 ft.
3	Slight Sea	2 „ 3 „
4	Moderate Sea	3 „ 5 „
5	Rather Rough Sea	5 „ 8 „
6	Rough Sea	8 „ 12 „
7	High Sea... ..	12 „ 20 „
8	Very High Sea	20 „ 40 „
9	Precipitous Sea	40 ft. and above.

Swell should be denoted by the following characteristics suggested by a commission appointed by the International Maritime Meteorological Conference that met at Paris in 1919.

Swell Characteristics.

No Swell.	Rough Swell.
Slight Swell.	Heavy Swell.
Moderate Swell.	Very Heavy Swell.
Rather Rough Swell.	Abnormal Swell.

These characteristics for swell should be recorded and not a scale of numbers. Direction of sea disturbance and swell should be observed and recorded. If the swell should present a confused appearance, the word “confused” should be recorded in the direction column, together with the chief direction or directions, thus “Confused NE and SE,” or “Confused SW.”

Revision of Scales of Sea and Swell Disturbance.

It will be noticed that the scale for sea disturbance only takes into account the height of the wave, while the characteristics for swell are even more indefinite.

The Marine Superintendent a few years ago issued a circular to the Captains of log keeping and W/T reporting ships, inviting opinions and suggestions as to these scales.

Many interesting and useful replies were received from Captains, but that forwarded by Captain H. P. Douglas, C.M.G., R.N., H.M.S. *Mutine*, now Hydrographer of the Navy, appears to be the most practicable suggestion as it provides a scale both for logging the observations and making coded W/T reports, and is attractive to seamen.

This scale, with slight modification to meet the views of Meteorologists and with Captain Douglas' approval, has been circulated (with further alteration of arrangement) by the International Hydrographic Bureau to all the great maritime nations, inviting their opinions on its suitability for ultimate adoption as an international scale.

Favourable replies have been received, but as the matter is still under International consideration, we cannot make any change in the scales for observation.

However, there is no doubt that the Douglas scale would be more useful if average lengths could be allotted to the different descriptions of swell.

It is therefore hoped that within the next few years, sufficient observations of the length, period and height of swell will be forthcoming, to enable dimensions, corresponding to these short descriptions, to be given for guidance in routine observation for both log and W/T reports. Marine observers are therefore asked to obtain these measurements in order that this nautical scale may be completed with the aid of nautical experience.

Douglas Sea and Swell Scale.

SEA.	SWELL.									
	No swell. 0	Low.		Moderate.			Heavy.			Confused. 9
		Short or Ave age. 1	Long. 2	Short. 3	Average. 4	Long. 5	Short. 6	Average. 7	Long. 8	
0 Calm ...	00	01	02	03	04	05	06	07	08	09
1 Smooth ...	10	11	12	13	14	15	16	17	18	19
2 Slight ...	20	21	22	23	24	25	26	27	28	29
3 Moderate ...	30	31	32	33	34	35	36	27	38	39
4 Rough ...	40	41	42	43	44	45	46	47	48	49
5 Very Rough	50	51	52	53	54	55	56	57	58	59
*6 High ...	60	61	62	63	64	65	66	67	68	69
*7 Very High ...	70	71	72	73	74	75	76	77	78	79
*8 Precipitous ...	80	81	82	83	84	85	86	87	88	89
†9 Confused ...	90	91	92	93	94	95	96	97	98	99

NOTE.—In this scale a new departure has been introduced in that length of swell and height of swell are, from the point of view of observations, considered separately and then combined together for coding.

A *Short Swell* means a Swell where the length or distance between each successive top of swell is small.

A *Long Swell* means a Swell where the length or distance is large.

A *Low Swell* means a Swell where the height between the lowest and highest part of the swell is small.

A *Heavy Swell* means a Swell where the height is great.

* These are considered to represent seas which occur with a swell or in the open ocean, for instance the highest sea recorded in sheltered waters would be 5, or under exceptional circumstances (*e.g.*, a hurricane) 6 or 7 might be used. The idea of the roughness would be conveyed by the force of the wind.

† Occasioned by current, tide, sudden shift of wind, and not necessarily strong wind.

Methods of Observing Waves.

Systematic measured observations of ocean waves are much wanted and the following notes are given for the guidance of marine observers.

The observations required are set out in the form given below :—

S.S. Captain
Observer
From To.....
Date.....

Time of Observation.....
Latitude.....
Longitude
True Course.....
Speed in Knots.....
If hove to, True Direction of Ship's Head.....
Wind at time of observation—True Direction.....
Force by Beaufort Scale.....

Depth of Water in Fathoms (Approx.).....
Element observed, Sea or Swell?Very important.
Height of Waves in Feet.....
Length of Waves in Feet.....
Period, True.....seconds.
Velocity, True.....
True Direction from which the waves come.....

General State of Sea—True Direction.....
Amount of Disturbance by Scale
General State of Swell—True Direction.....
Amount of Disturbance.....

Remarks (including methods of measurement adopted, degree of reliability, number of waves actually measured, variability of dimensions, etc.).....
.....
.....
.....

Note.—Only *actual measured observations* should be entered.

On board a moving ship, the measurement of the dimensions of waves frequently presents serious difficulty. The sea is often in a very confused state, owing to the crossing of waves from different directions and the combination of different series of waves travelling in similar directions; and it is almost hopeless to attempt any measurement in these cases. Only those seas in which well-defined ridges of water follow one another with some approach to uniformity should be selected for measurement.

Estimates, particularly those of wavelengths, are of little value for the purposes of investigation, for unless special precautions are taken, or the circumstances are specially favourable, even the practised eye of the seaman may be completely deceived in judging the distance between two wave crests as viewed from on board ship. The error is least when the height of eye above the waves is large, but even then, the estimates of independent observers may differ considerably.

Height.—No really accurate means of measuring height has yet been introduced. The most usual method is for the observer to climb the rigging or otherwise place himself at a height above the deck, sufficient for his eye to be just in line with the advancing wave crest and the horizon, when the ship is in the hollow. The height of eye above the ship's water line would then be the height of the oncoming wave. The nearer the observer is to an amidships position the less chance will there be of the measurement being vitiated by pitching. If the ship rolls heavily he should allow for this as accurately as possible by judging the amount of heel, or endeavour to make his observation at the moment when the ship is upright in the hollow. Exaggeration of estimates of wave heights is mostly attributable to the error caused by pitching and rolling. See Fig. 10. When the ship is rolling (b) the observer O has to take up a *higher* position to get a line on the horizon than when she is upright (a).

While the above method is, with reasonable care, sufficiently accurate for large waves, the observer may not be able to take up a position low enough for the observation of the smaller waves, especially in modern liners; and the heights of these may often only be roughly estimated.

Another source of error may arise from the fact that the length of the ship will perhaps considerably exceed that of the wave, and not permit her to lie completely in the trough. In this case the ship may be buoyed up on two waves, and the height of the oncoming crest will consequently be underestimated.

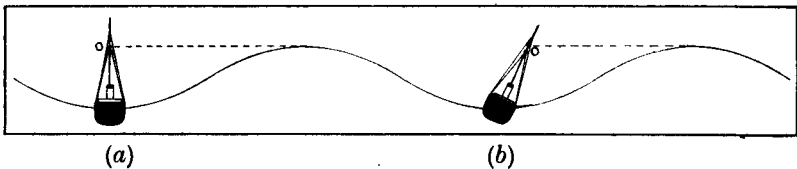


FIG. 10.

Length, Period and Velocity.—It is evident that the simplest conditions for observing the lengths and periods of waves are when the ship is stem on to the waves, and is stationary. The true period and true speed of the waves can then be obtained by direct observation, and the length calculated. The following simple and effective methods of determining length, period and velocity of waves are those advocated by Captain J. F. Ruthven in his book "Take Care of the Ship."

Imagine a fore and aft base line (AB) say 400 ft. long, at each end of which a pair of battens is erected, parallel to the wave crests (and at right angles to the ship's keel) to be used as sights.

Observers at both stations note, by watches previously compared, the instant when a wave crest crosses their line of sight; they also note how long an interval elapses before the next wave crosses their

observation station. Comparing their records, they determine the time, say 8 seconds, occupied by the waves in traversing the length

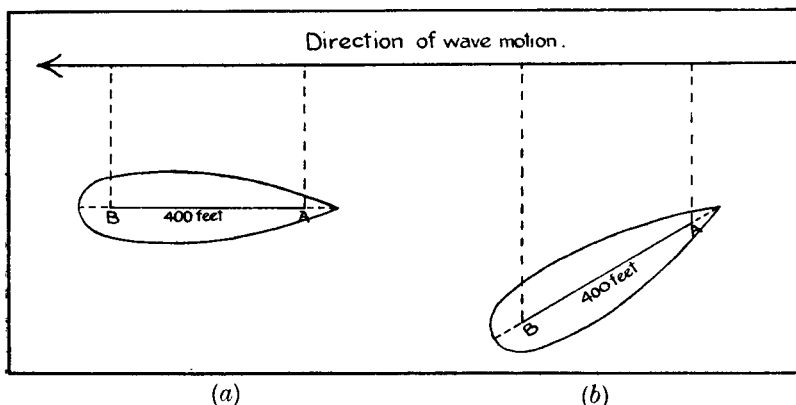


FIG. 11.

AB, while the interval between successive waves is say 10 seconds; the *speed* of the waves is obviously then 50 ft. per second, and as they pass the observation points at 10-second intervals, this is the period and gives a wave *length* of $50 \times 10 = 500$ ft.

If the ship's keel makes an angle with the waves as in (b) we can still use the same base line, and train our battens parallel with the wave crests. The new or virtual base for our calculations will be the perpendicular distance between AB which will vary with the angle of the ship's fore and aft line and is obtained by multiplying the base AB, 400 ft., by the cosine of the angle between ship's keel and wave direction; or with Traverse Table, distance between sights as *distance*, angle between wave direction and ship's course as *course*, then *D. Lat.* = distance travelled by wave crest.

When the ship is steaming, allowance has to be made for the ship's direction and speed in relation to that of the waves, and the following imaginary examples are worked out as simply as possible without the use of algebraic formulæ, for the guidance of observers.

(1) Suppose the ship steaming head to sea, when she will meet the waves sooner than when at rest. Let the time occupied by the wave travelling along the base line of 400 ft. be 6.2 seconds (called the *speed interval*), and that between the passage of successive wave crests (called the *length interval*) be 7.7 seconds. The speed of the ship is 15 ft. per second.

In the first interval, the ship will have travelled $15 \times 6.2 = 93$ ft. and the *speed* of the wave will therefore be

$$\frac{400 - 93}{6.2} = 50 \text{ ft. per second.}$$

Now as the wave is travelling 50 ft. per second, and the ship 15 ft. per second, they will be approaching one another at the rate of 65 ft. per second, and in the length interval, 7.7 seconds, will cover $65 \times 7.7 = 500$ ft. which is the length of the wave. The *true period* is *length* divided by *speed* = $500 \div 50 = 10$ seconds.

(2) Suppose the ship to be travelling in *same direction* as waves. at a speed of 30 ft. per second. Let the *speed interval*, i.e., time occupied by wave traversing the base line, be 20 seconds, whilst the

length interval was 25 seconds. In the first-named interval the ship would have travelled $30 \times 20 = 600$ ft., and the wave speed would therefore be $\frac{600 + 400}{20} = 50$ ft. per second.

As the wave is travelling 20 ft. per second faster than the ship, this multiplied by the length interval, 25 seconds, will be the length of the wave = 500 ft.

The period is, of course, the same as before.

(3) Suppose the ship steaming at 15 ft. per second *against the waves*, but making an angle of 26° with their direction.

$$\begin{aligned} \text{The virtual base} &= 400 \text{ ft.} \times \cos. 26^\circ \\ &= 400 \text{ ft.} \times .9 = 360 \text{ ft.} \end{aligned}$$

$$\begin{aligned} \text{Component of ship's speed} \\ \text{(at right angle), towards} \\ \text{the wave} &= 15 \times \cos. 26^\circ = 15 \times .9 = 13.5 \text{ ft.} \end{aligned}$$

The observed *speed interval* was 5.67 seconds and *length interval* 7.9 seconds.

During the speed interval the ship will have travelled to meet the wave $13.5 \times 5.67 = 77$ ft., and the speed of the wave will therefore be $\frac{360 - 77}{5.67} = 50$ ft. per second.

As the wave is travelling 50 ft. per second and the ship is approaching it at 13.5 ft. per second, they will be closing at 63.5 ft. per second, which when multiplied by the length interval, 7.9 gives 500 ft. as the length of the wave.

(4) The last example is that of the ship *steaming with the waves* at 30 ft. per second but at an angle of 18° with their direction.

$$\begin{aligned} \text{In this case the virtual base will be} \\ 400 \text{ ft.} \times \cos. 18^\circ &= 400 \times .95 = 380 \text{ ft.} \\ \text{Component of ship's speed away from} \\ \text{the wave} &= 30 \times \cos. 18^\circ = 30 \times .95 = 28.5 \text{ ft.} \end{aligned}$$

The observed *speed* and *length* intervals were respectively 17.8 and 23.2 seconds. During the speed interval, the ship will run away from the wave $28.5 \times 17.8 = 507$ ft. This has to be added to the virtual base to get the distance the wave travels in that period, viz., $507 + 380 \div 17.8$, which gives the wave speed of 50 ft. per second.

The wave is travelling at 50 ft. per second, that is 21.5 ft. per second ($50 - 28.5$) faster than the ship; this multiplied by the length interval, 23.2 gives the length of the wave, viz., $21.5 \times 23.2 = 500$ ft.

Another easy method of measuring wavelengths is to tow astern a buoy or other mark, paying out sufficient line so that when a wave crest passes the stern, the buoy is on the crest of the next wave. The length of line run out gives the apparent wavelength; if waves and ship are travelling in the same or opposite direction, apparent length = true length; if ship's course makes an angle (B) with wave's course, the true length is simply obtained thus:—

$$\text{True length} = \text{Apparent length} \times \cos. B.$$

CHAPTER V.

CLOUD AND WEATHER.

Clouds.

Cloud observations may be considered under three headings :—

- (1) Amount.
- (2) Form.
- (3) Direction and Velocity of Motion.

Amount of Cloud.

The proportion of the sky covered by cloud should be indicated on a numerical scale running from 0, cloudless, to 10, completely overcast; in other words, we are required to estimate the number of tenths of the area of the sky which would be covered by the cloud present supposing them moved up to each other so as to form a continuous sheet. The numbers given are to refer solely to the amount of the sky covered and not to the density, height or other quality of the cloud.

In estimating, the observer will do well to sub-divide the sky mentally into quadrants by means of diameters at right angles to each other. An estimate (on the scale 0–10) is then formed for each quadrant separately, and the figure finally entered in the register is the mean of the four numbers so obtained.

The direction of the dividing diameters should be selected to give convenient sub-divisions of the prevailing cloud canopy.

Fog must be regarded as a cloud at sea surface level, and 10 must accordingly be entered for the amount of cloud on days when the sea lies under its pall. Some uncertainty arises in the case of mists, or when the sky is obscured by a very thin haze. Supposing that more definite cloud forms are entirely absent, the observer is occasionally confronted by the problem whether he should enter the amount of cloud as 0 or 10. In all such cases appropriate notes should be made in the “remarks” column of the register.

Cloud Forms.

Luke Howard, whose classification of cloud forms is the basis of the system now in use, distinguished three principal cloud forms, viz. :—

- (1) Cirrus cloud (of fibrous or feathery appearance, mares' tails).
- (2) Cumulus cloud (having rounded top).
- (3) Stratus cloud (arranged in horizontal sheets or layers).

Many forms intermediate between these primary types are found to occur, and these are specified by compounding the names of the primary types. As the observation of cloud forms became more common, it was found desirable to increase the number of types and to agree on definitions for them. The following classification of clouds into 10 main types has been adopted.

Upper Clouds.

(1) **Cirrus (Ci).**—Delicate clouds of fibrous texture, taking the form of feathers, generally of a white colour. At times the cloudlets are detached, at others they are joined up into continuous masses. Occasionally cirrus clouds are arranged in belts which cross a portion of the sky in "great circles" and, by an effect of perspective, converge towards one point or two opposite points of the horizon. (Cirro-stratus and Cirro-cumulus often contribute to the formation of these belts.)

(2) **Cirro-Stratus (Ci-St).**—A thin, whitish sheet, at times completely covering the sky and only giving it a milky appearance (it is then sometimes called cirro-nebula), or at others, presenting more or less distinctly, a formation like a tangled web. This sheet often produces halos around the sun or moon.

N.B.—The title strato-cirrus is suppressed as giving rise to confusion.

(3) **Cirro-Cumulus (Ci-Cu).**—Small globular masses or white flakes without shadows, or having very slight shadows, arranged in groups and often in lines. (French, *Moulon*, German *Schäfchenwolken*.)

N.B.—The title cumulo-cirrus is suppressed as giving rise to confusion.

(4) **Alto-Cumulus (A-Cu).**—Largish globular masses, white or greyish, partially shaded, arranged in groups or lines, and often so closely packed that their edges appear confused. The detached masses are generally larger and more compact (changing to strato-cumulus) at the centre of the group; at the margin they form into finer flakes (changing to cirro-cumulus). They often spread themselves out in lines in one or two directions.

(5) **Alto-Stratus (A-St).**—A thick sheet of a grey or bluish colour showing a brilliant patch in the neighbourhood of the sun or moon,

and which, without causing halos, may give rise to coronæ. This form goes through all changes similar to those shown by cirro-stratus, but by measurements made at Upsala its altitude is one-half less.

Lower Clouds.

(6) **Strato-Cumulus (St-Cu).**—Large globular masses or rolls of dark cloud, frequently covering the whole sky, especially in winter and occasionally giving it a wavy appearance. The layer of strato-cumulus is not, as a rule, very thick and patches of blue sky are often visible through the intervening spaces. All sorts of transitions between this form and the alto-cumulus are noticeable. It may be distinguished from nimbus by its globular or rolled appearance.

(7) **Nimbus (Nb).**—A thick layer of dark clouds, without shape or form and with ragged edges from which steady rain or snow usually falls. Through the openings in these clouds an upper layer of cirro-stratus or alto-stratus may almost invariably be seen. If the layer of nimbus separates up into shreds, or if small, loose clouds are visible floating at a low level, underneath a large nimbus, they may be described as *fracto-nimbus* ("Scud," of sailors).

(8) **Cumulus (Cu.) (Wool-pack or Cauliflower Cloud).**—Thick cloud, of which the upper surface is usually dome-shaped and exhibits protuberances while the base is horizontal. These clouds appear to be formed by a diurnal ascensional movement which is almost always noticeable. When the cloud is opposite the sun, the surfaces facing the observer have a greater brilliance than the margins of the protuberances. When the light falls aslant, these clouds show deep shadows. When on the contrary they are on the same side as the sun, they appear dark with bright edges. Occasionally the upper surface of cumulus cloud, though mammalated, is not dome-shaped. This form is characteristic of areas of high pressure.

The true cumulus has clear superior and inferior limits. It is often broken up in strong winds and the detached portions undergo continual changes. These may be distinguished by the name *fracto-cumulus*.

(9) **Cumulus-Nimbus (Cu-Nb).**—The Thunder Cloud : Shower Cloud. —Heavy masses of cloud rising in the form of mountains or turrets or anvils generally having a sheet or screen of fibrous appearance above (false cirrus), and underneath, a mass of cloud similar to "nimbus." From the base there usually fall local showers of rain or of snow (occasionally of hail or soft hail). Sometimes the upper edges have the compact form of cumulus, forming into massive peaks round which the delicate *false cirrus* floats, and sometimes the edges themselves separate into a fringe of filaments similar to that of the cirrus cloud. This last form is particularly common in spring showers. The front of thunder clouds of wide extent frequently presents the form of a large bow spread over a large portion of the sky which is uniformly brighter in colour.

(10) **Stratus (St).**—A uniform layer of cloud which resembles a fog but does not rest on the ground. The complete absence of details of structure distinguishes stratus from other more compact forms of clouds. If the cloud layer is broken up into irregular shreds by wind or by mountains, it may be distinguished by the name *fracto-stratus*.

In view of the almost infinite diversity which cloud phenomena present, the observer must not expect to

be able to assign without hesitation all clouds to one or other of the types described. If he is unable to classify the clouds seen, he should note the facts in the Log. If abbreviations be used for the names of the cloud types those given above should be employed.

The attention of observers is directed to the Cloud Plate accompanying this book, which is intended to be put up in a conspicuous and handy place in the chart house.

The type of cloud will usually give some indication of its approximate height.

Cloud Motion.

The direction of motion of clouds should always be stated as the direction from which the cloud is coming. It is best observed by sighting the cloud against a fixed point. At sea such fixed points are difficult to find; but at night time and when the cloud canopy is broken, stars near the zenith form very suitable fixed points. It should be remembered that the motion of a cloud near the horizon will be distorted by the effect of perspective. This effect will decrease as the zenith is approached. Clouds should not, therefore, be observed for motion that are at a greater zenith distance than 30° , unless no observation near the zenith is possible. Investigations of cloud observations made in recent years appear to indicate that Marine Observers make very good estimates by this means.

The speeds of clouds cannot be measured accurately at sea, but the following qualitative scale of velocities should be used:—0 to denote stationary, 1 to denote slow movement, 2 moderate and 3 fast. The method of recording cloud motion that should be adopted is to place the direction of motion underneath the relevant cloud type and a figure of the above scale to denote its velocity; thus $\overset{\text{Ci}}{\text{NW}} 2$ means Cirrus Cloud moving from north-west at moderate speed, While A-Cu.0 denotes that Alto-Cumulus is stationary.

Several different cloud forms will frequently be present simultaneously. In such cases the direction of motion of each type should be observed and noted in the Log, though the motion of the upper and middle clouds is of the greatest importance. As far as possible each layer should be observed separately, and its appropriate direction and velocity entered. It is often

very difficult to observe the motion of upper cloud without comparing it with the lower. This should never be done. The motion recorded must be the absolute motion of the cloud, not its motion relative to another moving object.

Attention is also directed to the following details :—

Undulated Clouds.—It often happens that the clouds show regular striae, parallel and equidistant, like waves on the surface of water. This is mostly the case with the cirro-cumulus, strato-cumulus (roll cumulus), etc. It is important to know the direction of these striae. When two distinct systems are apparent, as is often seen in clouds separated into globular masses by striae in two directions, the directions of these two systems should be noted. As far as possible, these observations should be taken of striae near the zenith so as to avoid errors caused by perspective.

The Point of Radiation of the Upper Clouds.—These clouds often take the form of narrow parallel lines, which by reason of perspective appear to issue from a given point on the horizon. The “point of radiation” is the name given to the point where these belts or their prolongations meet the horizon. This point on the horizon should be indicated in the same manner as the direction of the wind, N., N.N.E., etc.

Weather.

The state of the weather is recorded in letters of the Beaufort Notation, which are as follows :—

Letters to indicate the State of the Weather.

b = blue sky whether with clear or hazy atmosphere.	p = passing showers.
c = cloudy (<i>i.e.</i> , detached opening clouds).	q = squalls.
d = drizzle or fine rain.	r = rain.
e = wet air without rain falling.	rs = sleet, <i>i.e.</i> , rain and snow together.
f = fog.	s = snow.
fe = wet fog.	t = thunder.
g = gloomy.	tl = thunderstorm.
h = hail.	u = ugly, threatening sky.
kq = line squall.	v = unusual visibility.
l = lightning.	w = dew.
m = mist.	z = dust haze; the turbid atmosphere of dry weather.
o = overcast sky (<i>i.e.</i> , the whole sky covered with one impervious cloud).	

The letters **b**, **c**, **o**, **g** and **u** are used to describe the general appearance of the sky.

The use of the letters **g** and **u** is sufficiently clear from the definitions given above. The following remarks apply to the use of the letters **b**, **c** and **o**.

In order to provide for occasions when there are only small quantities of cloud present, **b** should be used to denote less than a quarter of the sky clouded; and **c** should be used when more than three-quarters of the sky is covered. Proportions of cloud and blue sky between the above are denoted by using both the letters **b** and **c**.

The amount of sky covered by cloud to the nearest tenth part of the whole sky is indicated in the Meteorological Log in a column specially provided for that purpose as described at the beginning of this chapter.

Precipitation.—A distinction is drawn on the Beaufort Notation between steady rainfall (**r**), light drizzle (**d**), and passing showers (**p**). The indication of passing showers is useful, and the time of commencement and ending of heavy showers should always be noted. The letter **e** has been added to the Beaufort system to indicate a state in which the air deposits water copiously on exposed surfaces without "rain" falling.

Unless otherwise stated, it is assumed that the letter **p** refers to showers of rain. Snow or hail showers may be noted thus : **sp**, **hp**; showers of mixed hail and rain thus **rhp**.

Visibility and Fog.—Fog, **f**; Mist **m**; Haze, **z**;—these three words are used to indicate a deterioration of the transparency of the lower layers of the atmosphere caused by solid or liquid particles, and in ordinary literature the choice of the particular term employed is almost at the discretion of the writer.

Mist and *fog* both refer properly to surface cloud; when either is experienced there will be little or no difference between the readings of the dry bulb and wet bulb thermometers. A slight fog is sometimes called a haze, but the use of the word haze should be restricted to the obscurity due to smoke, dust or other cause, when the air is dry and there is considerable difference between the dry bulb and wet bulb readings.

Endeavours have been made to draw a distinction between *mist* as a cloud on the surface which wets objects exposed to it, and *fog* as being one in which objects remain dry. The distinction is, however, not a practical

one, having regard to the established usage of travellers on land and sea. Fog seems always to imply hindrance to shipping, and thus the word may be used to denote the obscurity of the atmosphere regarded not from the point of view of the meteorologist, but from that of the navigator.

When the obscurity does not interfere with navigation it may be identified as mist, and thus mist may be regarded in a sense, as slight fog, and fog as thick mist.

Wet Fog.—A fog in which water is deposited copiously on exposed surfaces should be noted by means of the letters **fe**.

Fog and Visibility Scale.

(Specification for use at Sea.)

0	Dense fog.	Objects not visible at 50 yards.
1	Thick fog.	„ „ 1 cable.
2	Fog.	„ „ 2 cables.
3	Moderate fog.	„ „ $\frac{1}{2}$ mile.
4	Mist or haze, or very poor visibility.	„ „ 1 mile.
5	Poor visibility.	„ „ 2 miles.
6	Moderate visibility.	„ „ 5 „
7	Good visibility.	„ „ 10 „
8	Very good visibility.	„ „ 30 „
9	Excellent visibility.	Objects visible more than 30 miles.*

The estimation of the state of the atmosphere in regard to visibility is an easier matter for a fixed station on shore than it is at sea, because on shore a series of objects A, B, C, etc., at known distances from the point of observation can be chosen, and the observer can decide which of the selected objects he can see, and knowing that they are there, those which he cannot see. At sea, so long as he is near land, an observer may see an object at a distance which he can estimate or calculate, and he may know from the chart the distance of other objects which he cannot see, but in the open ocean the only object available is an occasional ship within range of vision.

The distance can in that case be estimated by the lapse of time and run, since she was passed; or perhaps judged by previous experience of the appearance at a distance but the circumstances in which two such vessels would be available, one just gone out of sight and the other visible at a known and suitable distance, are so

* If the visibility is exceptionally good, the letter **v** should be entered in the weather column.

few so that the assignment of visibility by measurement in the proposed scale is only rarely possible.

In a long steamer the lowest numbers of the scale 0 and 1, can be determined by the length of the ship.

2 and 3 indicate conditions of fog or obscurity of the atmosphere when visibility goes beyond the length of the ship, but is not sufficient for speed, on account of traffic.

4 and 5 indicate conditions when visibility is sufficient to proceed at speed concerning traffic, but when coastal navigation may be difficult.

If there is any obscurity or abnormal refraction the visible horizon may be very misleading as a means of judging distance, particularly when the height of eye is great as in the case of an observer on the bridge of a large liner.

CHAPTER VI.

OPTICAL ATMOSPHERIC PHENOMENA.

The following instructions for observing optical atmospheric phenomena are translated, from the instruction drawn up by the late Professor J. M. Pernter and incorporated in the Handbook issued by the Austrian Meteorological Department. They received the approval of the International Conference of Directors of Meteorological Institutions which met at Innsbruck in 1905.

There are a large number of optical phenomena which not only arrest the attention of observers on account of their beauty, but also are more or less closely connected with the weather; they are of importance for both reasons, and observers are recommended to note them carefully.

Halo.

Solar Halo; Lunar Halo.—Many different kinds of halo have been observed (*see* Fig. 12*). The most common is the halo of 22° —a large ring, CIBG, round the sun or moon, having a radius of very nearly 22° (of a great circle). When of no great intensity the ring appears white, but when it is more strongly developed we may easily recognise the fact that the edge nearest the sun is red—very pure red—and that orange, yellow, and, under very favourable circumstances,

* Fig. 12 is a representation of the so-called Danzig phenomenon, as seen, drawn, and described by the well-known astronomer Hevel. The date of the observation is shown at the head of the figure. This figure is a facsimile of the original in Hevel's Publication (*see* Hellmann, "Neudrucke, Meteorologische Optik," p. 57).

green, follow on, as we go outwards. The latter colour is always rather faint and whitish, and the blue is almost always so faint that it is not recognised as blue. Violet is never recognisable. The ring thus appears white on its outer edge.

A ring of about twice the radius, halo of 46° , Fig. 12, VXYZ, occurs more rarely. Its luminosity is much less than that of the halo of 22° ; the arrangement of the colours, if visible, is the same.

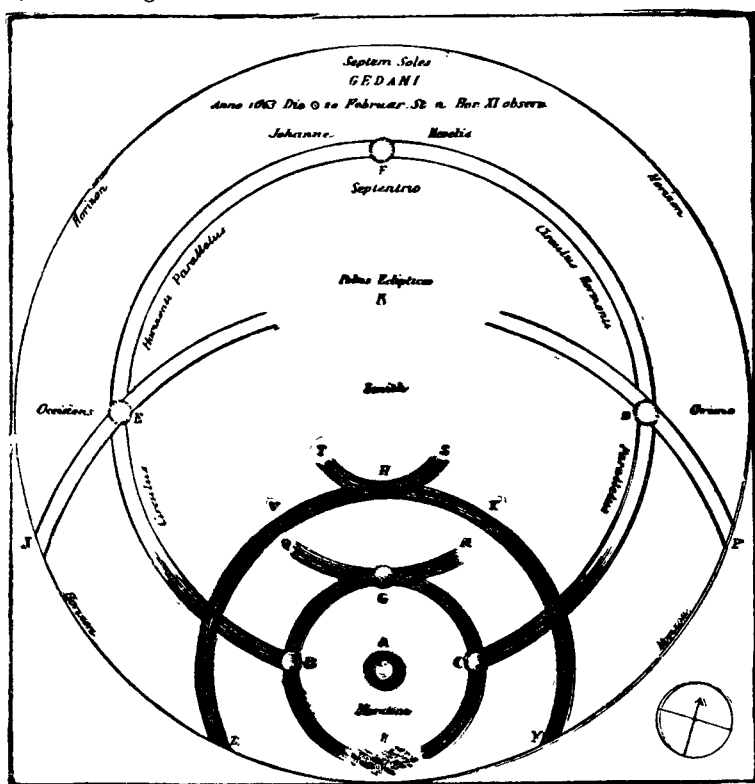


FIG. 12.

Occasionally a colourless white ring, which passes through the sun parallel to the horizon, may be recognised. This is called the horizontal circle or mock sun ring. The latter name has been given to it because the mock suns described below lie on or near it. It is represented in the figure by the circle CDFEB, in which the portion BC, which passes through the sun, is omitted. This is frequently the case, but there are many cases on record in which the portion passing through the sun was distinctly visible.

A fourth ring is exceedingly rare; it is white, and has a radius of about 90° ; it is known as the halo of 90° . In the diagram two portions of it, NE and DP, are visible; if produced they would pass through K. It is obvious that this halo can never be seen in its entirety in our latitudes, for this would require the sun to be in the zenith.

It should be mentioned that the rings are frequently incomplete in the cases of the three first-mentioned halos also; at times only small portions of them can be seen.

There are a number of other halo phenomena which, from their method of formation, can only be seen as arcs. Among these are the so-called *arcs of contact*, of which two are shown in the figure. Both of them are arcs of upper contact, RGQ belonging to the halo of 22° , THS to that of 46° . Arcs of lower contact may occur in connexion with both these rings, but they are very rare. The arcs of upper contact appear with their convex sides turned towards the sun, as shown in the figure. Contact arcs appear occasionally at the sides of the halos of 22° and 46° , but they are as rare as the arcs of lower contact. The arcs of upper contact are very luminous at the points of contact, which have occasionally been described as "mock suns." The colour effects are often brilliant, red being turned towards the sun, *i.e.*, on the convex edge of the halo. The coloration of the arc of upper contact of the halo of 46° is frequently exceedingly brilliant. The ends of the arc of upper contact of the halo of 22° are frequently bent downwards.

A large number of other rings and arcs have been observed on rare occasions, and are generally described as "irregular"; observers who are fortunate enough to see such irregular bows are requested to sketch and describe them carefully, and, if possible, to **measure their angular distance from the sun**.

Of all halo phenomena, mock suns (*parhelia*) and mock moons (*paraselenæ*) are probably the most admired. These terms are used to describe luminous, or even brilliant, images of the sun which are seen most frequently at or near the intersection of the halo of 22° with the white mock sun ring (B and C, Fig. 12). Very rarely mock suns are seen at or near the intersection of this ring with the halo of 46° . The mock suns of this halo are always very faint, and their colouring is indistinct; mock suns belonging to the halo of 22° are, on the other hand, both frequent and very luminous, and their colours are brilliant. Red is on the side nearest the sun, with yellow, green, and blue following in order. Blue is generally indistinct, and violet is usually too faint to be distinguished. As a rule a long and pointed white tail, occasionally attaining a length of 20° , extends from the mock suns along the mock sun ring (*see* Fig. 12).

The mock suns of the ring of 90° (D and E, Fig. 12) have been observed on a few occasions only since Hevel's day.

Not infrequently mock suns are seen without any of the rings being observed.

A white brilliant image of the sun is occasionally observed immediately opposite to it, *i.e.*, 180° away from the luminary along the mock sun ring. This is known as the counter sun. Mock counter suns, at about 60° along the mock sun ring from the counter sun, have been repeatedly observed, and their distances from the sun have been measured.

Other mock suns, besides those which have been mentioned, are occasionally seen. Observers are requested to sketch and describe carefully what they see, should they happen to observe one of these. If possible they should determine its position by measurement.

Other very beautiful halo phenomena are afforded by *sun pillars*, which are most easily observed at sunrise or sunset. These frequently extend about 20° above the sun and generally end in a point. At sunset they may be entirely red, but as a rule they are of a blinding white and show a marked glittering. If the sun is high in the heavens, white bands may appear vertically above and below him, but these

are not very brilliant and often they are very short. Occasionally these white columns appear simultaneously with a portion of the white mock sun ring, and so form another very remarkable phenomenon, viz., the cross (Fig. 13).

Frequently parts only of the rings and arcs are visible, having apparently no connexion with one another, thus lending a very peculiar appearance to the sky; not infrequently these arcs intersect obliquely, which increases the strangeness of the appearance.

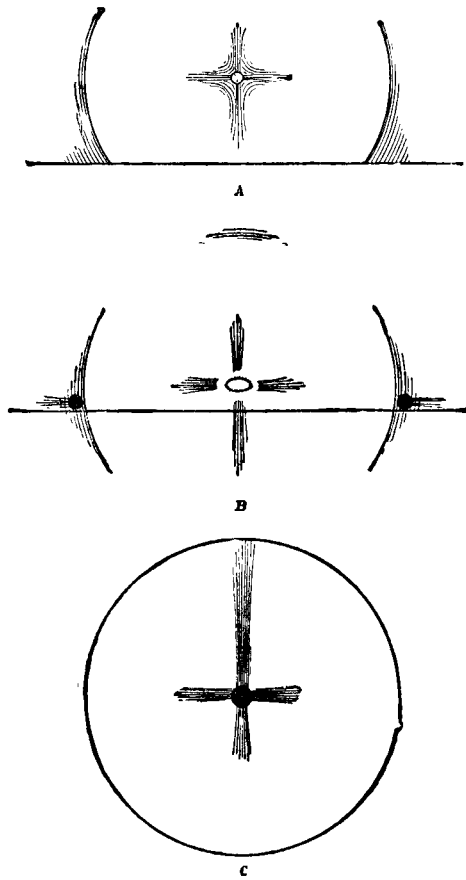


FIG. 13.

Many other halo phenomena are known to occur, but the space which can be devoted to the subject in a book of instructions to observers is limited, and they cannot all be described here. All halo phenomena should be sketched and described, and, if possible, photographed.

Halos only occur in presence of cirrus clouds or of light ice fog; they are produced by refraction and reflection of the rays of the sun or moon by ice crystals. The sun has been assumed as the source of light in all the phenomena described. This has been done solely for the sake of brevity; precisely similar though rather less brilliant appearances may be produced by moonlight.

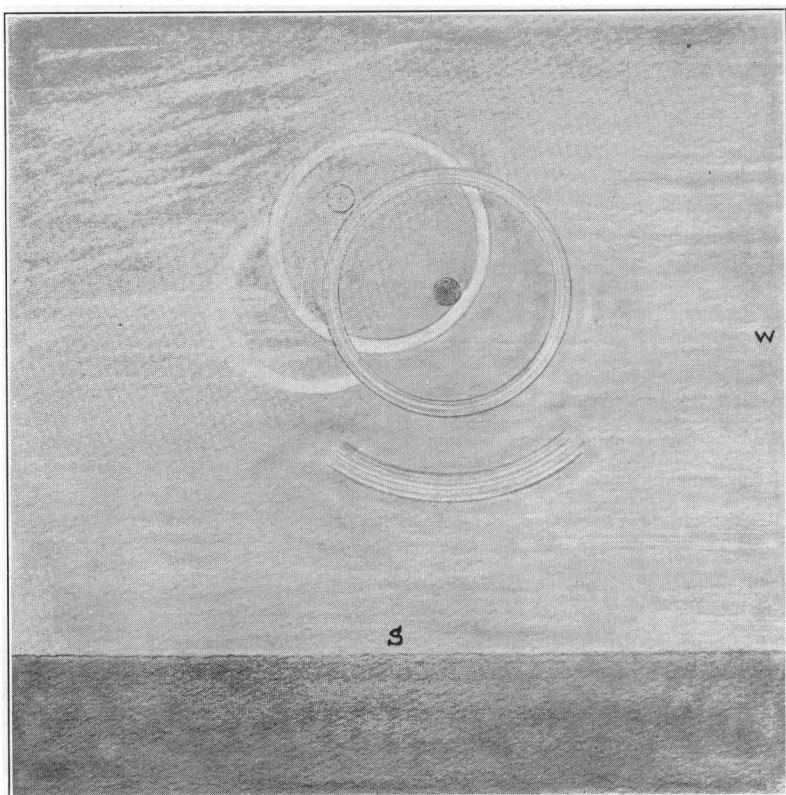


FIG. 14.

SOLAR HALO.**Caribbean Sea.**

Witnessed from S.S. *Tainui*, Captain W. HARTMAN, Southampton to Colon, Observer Mr. P. S. HORWOOD, 3rd Officer.

" March 6th, 1925. Position at Noon: Latitude $13^{\circ} 09' N.$, Longitude $75^{\circ} 07' W.$ At 11.45 a.m. a halo, showing the colours of the spectrum, formed around the sun with a radius of $21\frac{1}{2}^{\circ}$, the breadth of the spectrum subtending an angle of $\frac{3}{4}^{\circ}$. Shortly afterwards an arc of a second halo appeared to the southward, this arc being concentric with and similar to the first, while a third complete halo and an arc of a fourth were observed. Neither of these two latter showed the spectrum, nor were they concentric one with the other or the sun.

"The greatest brilliancy was attained at 12.15 p.m. when the whole presented an interesting and unusual sight. By 12.40 p.m. it had disappeared completely."

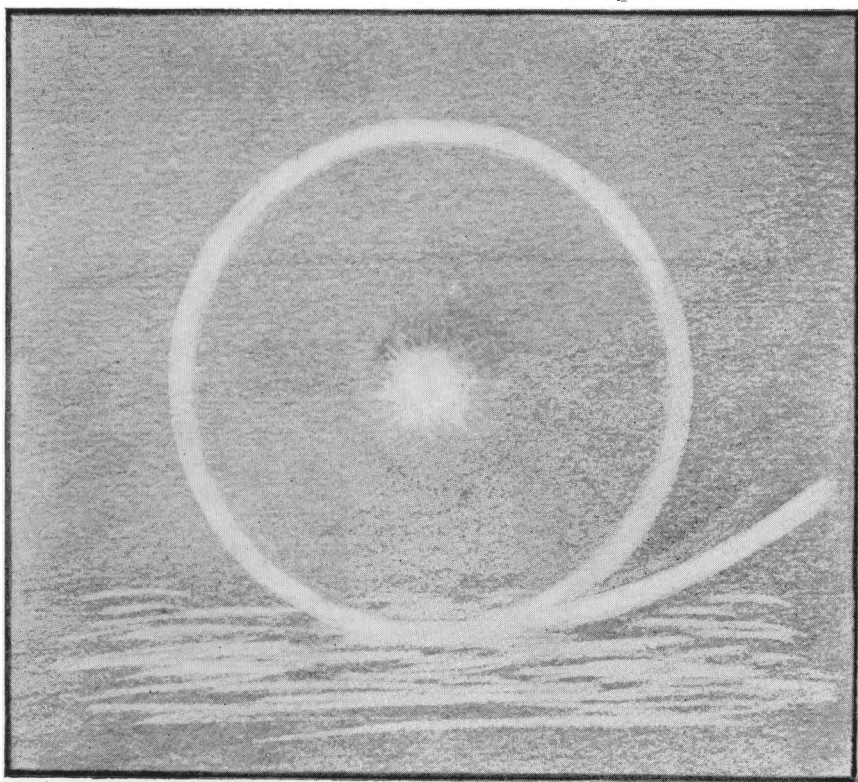


FIG. 15.

LUNAR HALO.

Witnessed from S.S. *Port Hunter*, Captain S. C. COTTELL, London to Australia, Observer, Mr. C. R. TOWNSEND, 3rd Officer.

"The above sketch represents the Lunar Halo and arc of contact as observed on the night of February 28th, 1923, in Latitude $16^{\circ} 16' S.$, Longitude $89^{\circ} 43' E.$ (approx.). The complete circle was $22\frac{1}{3}^{\circ}$ radius and showed as a plain white ring, as also did the arc which was only visible for a very short period. The point of contact, although of greater luminosity, was indistinct on account of cirrus clouds covering that position of the circle."

Coronæ. Solar Corona; Lunar Corona. Coronæ are seen most frequently round the moon. As their diameter is generally considerably smaller than that of the halo of 22° they are very near the luminary and can thus only be seen around the sun under favourable circumstances. No doubt they occur round the sun as frequently as round the moon; they may be observed by making use of a reflector or of a smoked glass to reduce the intensity of the light.

Coronæ are very different from halos. The latter are produced by refraction, whereas the former are diffraction phenomena. The positions and orders of the colours serve to distinguish the two sets of phenomena. Coronæ invariably show a brownish red inner ring, which, together with the bluish-white inner field between the ring and the luminary, forms the so-called *aureole*. Frequently—indeed, very frequently—the aureole alone is visible. The brownish red ring is characteristically different from the red ring of a halo; the former is distinctly brownish, especially when the aureole alone is visible, and of considerable width, whereas the latter is beautifully red and much narrower. If other colours are distinguishable, they follow the brownish red of the aureole in the order from violet to red, whereas the red in a halo is followed by orange, yellow and green. The order of the colours is thus reversed.

The size of the diameter of the ring is not an infallible criterion for distinguishing between halos and coronæ, for a corona may be quite as big as a halo. Bishop's ring* has furnished a well-known example of such a corona. The criteria which the observer should apply to distinguish the two sets of phenomena are not the diameters of the rings, but the sequence of colour and the presence of the brown-red of the aureole.

As coronæ are diffraction phenomena they occasionally show the sequence of colour two or three or even four times over. This can never be the case with a halo. Observers are requested to note carefully the colours which they can identify and also the order in which they follow one another from the inside to the outside of the ring.

In a foggy atmosphere (especially on mountains) an observer, standing with his back to the sun, will sometimes see a coloured ring of light round the shadow cast upon the fog by his own head. This appearance has been variously called "glory," "Ulloa's ring," "Brocken spectre," etc.

Green and red patches are occasionally seen in cirrus clouds, at a great distance from the sun or moon. They have no apparent connexion with coronæ and may even occur when no corona is visible. Frequently a number of these patches may be seen along a line passing through the sun. This phenomenon is known as "irisation." The most important point to note is the (angular) distance between the sun (or moon) and the patches showing irisation.

Rainbow.—The erroneous assumption that all rainbows show the same sequence of colours and have the same radius has caused the careful study of this phenomenon to be much neglected. It has been shown that the colours of a rainbow as well as their extent and the position of the greatest luminosity are very variable and depend on the size of the drops producing the bow. It is very desirable that greater attention be given again to this subject. If we note (1) the

* In the year following the eruption of Krakatoa (1883) and again in 1903 after the eruption of Mount Pelée, a brownish red ring of over 20° diameter was frequently seen with a clear sky. It was proved to be an unusually large corona.

sequence of colours seen in the primary bow commencing with the red; (2) the colour which shows the maximum luminosity, and (3) which colour band is the widest, we can in most cases calculate the size of the drop producing the bow. This can be done with greater certainty if the observer also pays attention to the supernumerary bows which frequently appear on the inner side of the primary bow and (1) notes the sequence of colours in them, and (2) states whether the bows are continuous with the primary bow and with one another.

Observation should also be made of the secondary bow which appears outside the primary bow at a distance of about 12° from it. This bow is of less importance, if the primary bow is visible.

Coloration of the Sky.—A cloudless sky appears to be blue, but it may show all possible gradations between a deep blue and a whitish-blue shade. It is desirable to note the gradations of colour according to the scheme; deep blue, light blue, and pale blue. Such observations give information regarding the purity of the air, and may also be used as indications of coming weather.

The most beautiful colours are seen at dusk. When the sky is cloudless, the colour and form of the first "purple light" is worth attention. It is approximately parabolic in shape and appears at a considerable elevation above the point where the sun disappeared soon after sunset.* It varies in colour between pink and violet. Observers are also invited to note the colouring of the western sky and the appearance of the "second purple light" which develops after the disappearance of the first. The time of disappearance of the second light is also of importance. If "Alpenglühén" and "after glow" are associated with the sunset, the phenomena should be noted.

The coloration of the clouds at sunset is often very beautiful and very striking, and is therefore frequently noted, although the phenomena observed when the sky is clear are more important.

Mirage.—The phenomenon termed mirage is caused by the refraction and reflection of light rays through layers of air of different densities. It should be recorded whether the image is inverted or not; whether there are two or more images. When mirage appears it should be noticed if it has any connection with sudden variations in temperature.

Aurora.—Auroral displays are often seen in higher latitudes. For the guidance of those who are interested to observe them in detail the following notes are given and information on these lines will be most welcome to the Meteorological Office.

The precise way in which Aurora comes to exist is still a matter of dispute, but it is now almost universally believed to be an electrical phenomenon. Auroral light is supposed to be the visual effect accompanying the passage of electrical discharges of some kind through the earth's atmosphere. Auroral forms are difficult to classify owing to their great variety and the rapid changes they go through.

* All these remarks apply also to sunrise but in the reverse order.

The chief types are :—

- (1) Arcs of a more or less regular shape.
- (2) Bands or ribbons.
- (3) Rays or streaks.
- (4) Floating curtains or draperies, often with folds.
- (5) Corona.
- (6) Patches or isolated cloud-shaped masses.
- (7) Diffused light.

Arcs present themselves in many forms. The simplest consists of an approximately circular segment of uniform or nearly uniform light, whose lower ends may extend like those of a rainbow right down to the horizon. An arc may, however, be made up of brighter and less bright narrow concentric arcs in juxtaposition; or it may consist of an innumerable number of short rays side by side, their lengths being in some cases approximately parallel to one another, in other cases radial, or nearly so, to the arc which they form. The arc is often elliptical or irregular in form, and there may be several arcs of different shapes visible simultaneously. In regular-shaped arcs the summit, or highest point above the horizon, is usually not far out of the observers' magnetic meridian—*i.e.*, the vertical plane in which the compass needle lies—the arc being directed roughly magnetic east and west. It is, however, not at all uncommon for the summit to be considerably out of the magnetic meridian, and in high latitudes the summit has been observed in almost every possible magnetic azimuth. The observer in noting the azimuth of the summit should always specify whether his directions are astronomical or magnetic. In measuring the altitude of the summit he should take the lower or concave edge of the arc, as this is usually much the better defined. It is not unusual for arcs to be in visible motion, rising from the horizon towards the zenith or receding from it; and it may be impossible to do more than note approximately the greatest and least altitudes attained.

When an arc extends right down to the horizon it is worth recording the number of degrees between the ends measured along the horizon. The sky immediately under the concave border of an arc often appears dark. It is somewhat doubtful whether this is merely an effect of contrast. The existence or non-existence of this "dark segment" should be noted, and if it exists care should be taken to state whether stars can be seen through it.

Bands and Ribbons are of innumerable shapes. They may be nearly straight, as if broken portions of an arc, or may assume the most complicated and serpentine of forms. They may appear more or less homogeneous, or may be visibly composed of rays. There seems a general tendency for the length of a band to be perpendicular to the magnetic meridian, but the shapes are so various that it is difficult to define the position with accuracy.

Rays often occur in close juxtaposition, the combination going to form an arc or a band. But they also occur separately. They often extend from the upper or convex border of an arc towards the zenith. The apparent length of rays often alters very rapidly. The ray seems suddenly to dart towards the zenith and retire from it. This characteristic has led to the description of auroral phenomena as "merry dancers." What exactly happens it is impossible to say. Assuming aurora to be an electrical phenomenon, the total length of

a particular line of electrical discharge may suddenly alter, or the length may remain unchanged, but the intensity of the current may suddenly increase so much as to render visible a portion of the discharge route previously invisible. In some cases rays group themselves into a sort of fan-shaped appearance. Sometimes there is a single large fan, made up of rays which may point towards a common centre, or may be more or less parallel; in other cases there may be several apparently independent fan-shaped bundles of rays.

Auroral Draperies or Curtains are one of the most impressive forms, but are seldom seen except in fairly high latitudes. The drapery may appear single or multiple, and the lower border may be nearly straight or very sinuous. These draperies seem often in rapid motion, and observers in high latitudes have described the appearance seen as they approach and pass overhead. When directly overhead they are said to narrow to a streak, just as a vertical sheet of light would seem to do as one passed immediately under it.

Corona, when fully developed, is, perhaps, the finest form of all. As the name denotes, it is a more or less regular display of light forming a crown disposed about a centre. An imaginary line drawn from the apparent centre to the observer's eye is usually nearly parallel to the direction of the dipping magnetic needle. The immediate centre of the corona is ordinarily comparatively dark. Next to the darker centre is commonly bright illumination, which may appear fairly homogeneous or be obviously composed of rays. Further from the centre the ray structure is usually dominant. In some cases there is little general illumination, and the rays appear comparatively isolated from one another.

Patches of Aurora often resemble the higher clouds, and it is sometimes doubtful whether the observer is looking at a really aurora or merely illuminated cloud. Observers have asserted that what has been seen as cirrus before sunset, or in early twilight, has later been seen as a patch of aurora, and that what has appeared as a patch of aurora in the early morning has been seen as cirrus after dawn. It is thus desirable that observers should keep an eye on cloud forms at times of aurora, and make notes of any phenomena likely to throw light on the alleged connection between aurora and cirrus.

Diffused Auroral Light sometimes fills the whole or a large part of the sky, the illumination, though usually brighter in some parts than others, showing no distinct outlines.

Colour.—The dominant colour in auroral light is white, with a yellow tint. When faint, aurora usually appears a nearly pure white, with increasing brightness there is a tendency to yellow. Sometimes in bright aurora, especially when rays are dominant and there is much apparent motion, there is a great deal of red. Under these circumstances it is not unusual to see green as well. The red is usually strongest towards the horizon, the green towards the zenith. Thus a ray may seem to have its lower end red and its upper green; or a corona may seem green towards the centre and red below. It has been asserted that in some instances at least the green is a contrast colour, and is no longer seen when the observer excludes the light from the distinctly red parts of the aurora. Other colours are occasionally seen, including even violet.

Spectroscopic examination of auroral light shows that the brighter part is made up of rays of definite wave length. The identification with the spectra of known gases is, however, still a disputed question. Accurate measurements of the wave lengths of auroral light are of considerable interest, but they are difficult to make, even by trained physicists, owing to the comparative faintness of the light and the rapid changes usually in progress.

Intensity and Visibility of Auroral Light.—The intensity varies within wide limits. An aurora may be so faint as to be visible only to the keenest eyesight, and there may be electric discharges which would be visible as aurora to beings endowed with keener eyesight than man. In Arctic regions aurora is said to be sometimes so bright that it compares with full moon light as the electric light does with gas light. The estimate made of the brightness is often largely dependent on whether the moon is visible or not. It is thus important, when recording any estimate of brightness to describe the circumstances under which the observation was made. On moonless nights a statement that print of definite size can be read at a specified distance by a normal-sighted eye is probably the simplest way in which information can be conveyed.

Even the brightest aurora becomes invisible when the sun rises, and in fact aurora is seldom seen until the sun is at least 5° below the horizon. It is thus difficult to be certain as to the hour of the day at which are best developed the electric currents whose tracks are seen as aurora after sunset. But aurora, as an optical phenomenon, has been found at most stations in the northern hemisphere, where careful observations have been made—with the possible exception of some in Greenland and Northern Canada—to have its greatest development from one to three hours before midnight. In the antarctic several observers have found auroral display to be most numerous in the early morning. In some cases aurora has been visible during the same 24 hours over a large part of one, if not both, hemispheres; but in such a case the brilliancy of the display at any particular place seems largely dependent on the local time.

Variations throughout the Year.—A complication arises from the action of sunlight. In high latitudes it is never dark in summer, and then aurora is invisible. Near the equator the length of the day is comparatively independent of the season, but aurora is a very rare occurrence in latitudes much under 40° . In most of Northern Europe, and in North America between 40° and 60° N. latitude, aurora is most frequent near the equinoxes. In higher latitudes the maxima of frequency near the equinoxes seem to disappear, being replaced by a single maximum of frequency near mid-winter. It is doubtful whether there is a real difference according to the latitude in the season of greatest frequency of the electrical phenomena to which aurora is due, or whether the apparent difference is not simply a matter of the different conditions of visibility.

Local Frequency of Aurora.—In the northern hemisphere the frequency increases as we go northwards from the tropics until a latitude is reached which depends on the meridian along which we travel. Our information for very high latitudes is limited, but it is believed that a maximum is reached, after which the frequency of aurora falls off as we go still further north. The latitude of maximum frequency is believed to vary from about 55° N. in longitude 60° W.

to fully 75° N. in longitude 90° E. Aurora is at least five times as often visible in the North of Scotland as in the South of England. In Europe in latitude 40° N. on the average under one aurora is seen per annum; in North America, in the same latitude ten times as many are visible.

At places to the south of the zone of maximum frequency aurora is usually seen in the north, but in very high northern latitudes it is usually seen in the south. In intermediate latitudes aurora is seen sometimes in the north, sometimes in the south. It is thus desirable to make it quite clear from which horizon the altitude of auroral arc is measured.

Information respecting aurora in the southern hemisphere is much less copious than in the case of the northern hemisphere. Very fine displays of aurora have occasionally been seen in Australasia and on passages across the Southern Ocean, and a good many have been seen by members of some of the Antarctic exploratory expeditions, but it is generally believed that aurora is more common in the northern hemisphere than in the southern.

Variation from Year to Year.—Aurora is much more often seen in some years than others. There seems to be a fairly well marked 11-year period, coincident, or nearly so, with the sun-spot period. There seems no doubt that in temperate latitudes aurora are very decidedly more numerous in years of many than in years of few sun-spots. In Greenland and some other Arctic regions the connexion between sun-spot and aurora frequency appears, however, to be different from that ordinarily observed elsewhere.

Connexion with Magnetic Storms.—A big auroral display in Great Britain or similar latitudes is always, or nearly always, accompanied by a big magnetic storm and large earth currents. The magnets at observatories are disturbed from their normal positions, and sometimes kept in nearly constant oscillation, whilst telegraph wires are traversed by large currents, which sometimes seriously interfere with the dispatch of messages for several hours on end. It is thus desirable during bright auroral displays to keep an eye on the compass, and to remember that deviations larger than 1° from the normal position are sometimes experienced during magnetic storms, even in the south of England. The amplitude of displacement of the compass needle during magnetic storms increases as we go north or approach the magnetic pole. Displacements of 4° or 5° , or even more, from the normal have been recorded in North America.

While, however, in moderate latitudes auroral displays are nearly always accompanied by a more than ordinarily disturbed state of the compass needle, this connexion is by no means so nearly invariable in higher latitudes, where aurora and magnetic disturbances are both much more common. Several observers have reported that in Arctic regions aurora frequently occurs without any special magnetic disturbance, and that there is no very clear connexion between the two phenomena unless the apparent movements of the aurora are exceptionally large and rapid, or the changes of brightness unusually great.

When auroral draperies are observed in motion, it is especially desirable to watch the compass needle, as several Danish observers in Greenland have observed motions on such occasions which are strongly suggestive of the passage of electric currents in a vertical direction in the space occupied by the drapery.

Height of Aurora.—Of recent years many measurements of height have been made in Norway, the earliest by Prof. Störmer, who devised satisfactory means of photographing aurora. Simultaneous photographs are taken as in rangefinding, from two ends of a measured base, usually from 15 to 25 kilometres long, but sometimes a good deal longer. The observers at the two ends are connected by telephone and arrange to direct their cameras at certain stars, which appear in the photographs. The positions of the aurora relative to the stars in the two photographs show a greater or less shift according to the auroral height, which can thus be calculated. Some of the earlier photographs gave a height under 50 kilometres, but doubt is now thrown on these, as the more recent measurements put the lowest edge of the aurora at from 90 to 120 kilometres, the most common heights for it being from 100 to 110 kilometres. For the highest auroral level much more variable results are obtained. Heights exceeding 250 kilometres are sometimes found.

The Norwegian results throw much doubt on the claims that several observers have made that they have seen aurora at much lower levels between themselves and mountains. No one should refrain from publishing an observational result merely because it runs counter to the theoretical views of his contemporaries, but he ought to be prepared for active criticism.

Sound.—If aurora never descends below 80 kilometres the presumption is strongly against the accuracy of observers who say that they have heard aurora produce a sound resembling the discharge of electricity from points, which has waxed and waned simultaneously with the fluctuations of luminosity. But the assertion that aurora has been audible has repeatedly been made by observers of some reputation in the Arctic. Thus it is desirable that any report of such an occurrence should not be rejected without investigation.

The Zodiacal Light.

The Zodiacal Light is a soft faint light, usually white, which may be seen in the tropics on any clear night, rising cone shaped above the western horizon after sunset, and above the eastern horizon before sunrise; except when the moon is past her first quarter and has not waned to her last, when it is masked by the light from the satellite. Even in latitudes of the temperate zones it is visible after twilight, when the sky is sufficiently clear, on winter or spring evenings or just before daybreak in the summer or autumn. It cannot be seen on summer or autumn evenings in temperate latitudes of either hemisphere because it extends from the sun, and lies approximately in the plane of the ecliptic. Therefore the course of the latter, in north temperate latitudes being in the south-west, and in south temperate latitudes in the north-west, is, during these seasons, so near the horizon that the light is extinguished by the thickness of the atmosphere through which, in order to be visible, it would have to

pass. Near the Equator, when weather conditions are favourable, the Light may be seen equally well in all months of the year, as the ecliptic in Equatorial regions is always well above the horizon.

Various explanations have been offered to account for the Zodiacal Light, not one of which is wholly convincing, and the results of observations of its spectrum have been conflicting. Some astronomers have expressed the opinion that it is caused by a sort of lens-shaped luminous appendage surrounding the sun, consisting, probably, of incandescent gas extending beyond the Earth's orbit, nearly in the plane of the ecliptic. More recent observations of the phenomenon have led to the belief that it is due to the reflection of solar light from a swarm of bodies, minute and possibly meteoric, which revolve about the sun, the attenuated edge of which extends beyond the orbit of our planet.

The nature of the matter from which the Zodiacal Light emanates has not in fact been discovered, and so little is known in other respects in regard to it that careful observations in suitable latitudes would be useful. By those who desire to contribute information in this connexion a keen watch should be kept between sunset and sunrise for the appearance of the Light, especially when in tropical latitudes; and the time and extent of its visibility noted.

It is confined for the most part within the limits of the Zodiac; and those who are familiar with the principal stars and the constellations should have no difficulty in describing, when seen, the place it occupies from time to time in the heavens: its breadth, extent and path; also its degree of brilliance, taking the light of the Milky Way, in definite positions, or that of well known nebulae as criteria.

Associated with the Zodiacal Light is another phenomenon which has puzzled astronomers, to which has been applied the term *Gegenschein*, from a German word the meaning of which may be expressed in English as *counter-glow*.

It is a faint light which is seen in the sky after sunset exactly opposite the sun when that luminary is considerably below the horizon. It varies in distinctness but is, as a rule, so faint that even the light of the Milky Way suffices to drown it. When observed, its exact altitude should be measured and noted, the ship's

position stated, also the apparent time at ship, as well as the mean time at Greenwich.

Meteors or Shooting Stars.

During the night watches the seaman has many opportunities for obtaining useful observations of meteors or as they are commonly called *shooting stars*. He can probably recall having seen in the sky at times one of these visitors to our atmosphere so bright that it has illumined the whole heavens.

By those who watch for their appearance several meteors may, as a rule, be seen on a clear night in the course of an hour. Usually they occur singly, but occasionally they are seen in swarms and the display on such occasions is impressive. Less frequently the passage of a meteor is followed by a report similar to that accompanying the discharge of ordnance; and more rarely the aerolite is seen to fall to the earth.

Aerolites, as these meteoric visitors to our earth are called, have been subjected to crucial examination by chemists and mineralogists, and have been found to contain no new chemical element; but the combination of the elements of which they are composed differs from any known on earth, so that they must have their origin outside the earth.

The so-called *shooting star* is merely an incandescent aerolite.

Observations of ordinary meteors are of scientific value, as well as those that form part of the meteoric showers that occur at certain periods. The most remarkable of these recur in November and are called *Leonids*, because their *radiant point* is in the constellation of *Leo*. The radiant point is that position in the heavens at which the meteors of a shower would be found to meet if their apparent paths were drawn on a celestial globe and continued backwards. It is the radiant point of the meteors that an observer should endeavour to ascertain; but, failing that, he might trace their paths among the stars by the luminous streaks they leave in their wake.

Professor Adams, the famous mathematician and astronomer, found by an elaborate calculation that the November meteoric showers are due to the earth's encounter with a swarm of particles which follow Tempel's comet in its orbit. This comet was first seen, as a faint telescopic object, by an astronomer named Tempel, at Marseilles in December, 1865.

The *Perseids*, which derive their name from the constellation *Perseus*, in which their radiant point is situated, belong to another well known meteoric shower, and may be looked for in August.

The number of radiants which has actually been observed is very considerable, and a complete list is given in the Fourteenth Report of the Meteors Section of the British Astronomical Association (1923, price 2s.).

The points which should be observed in the case of all meteors are the following :—

1. The point of appearance and the point of disappearance among the stars.
2. The duration of the flight.
3. Magnitude of the meteor relative to the stars and planets.
4. Any notable colour or colour changes.
5. Whether seen through gaps in cloud or not.

In addition to these, any peculiarities observed should be noted.

Observations taken by observers at widely separated points make it possible to compute the height of appearance and disappearance of the meteors. The data so obtained have been employed to discuss the temperature of the very attenuated atmosphere at great heights above the earth's surface, and any addition to the amount of information available will be welcomed by those interested in the subject.

Comets.

Observations of Comets, to be of any value, should include angular distances, measured with a sextant, between the comet and at least two but preferably three stars of the first or second magnitude; the respective names of which should, of course, be stated. The position of the ship at the time of observation, referred to the Greenwich meridian, should also be entered.

Corposants or St. Elmo's Fires.

The electrical phenomenon known as Corposants, or St. Elmo's Fires, frequently seen, not only on the extremities of masts and yards at sea, but also occasionally on the stays and other parts of the ship, appear when atmospheric electricity of low intensity induces electricity on the ship or other object that happens to be under its influence. This induced electricity concentrates at the extremities of structures either at sea or on shore; and becomes visible as a luminous brush discharge. It affords an interesting illustration on a somewhat extensive scale of the elementary principle relating to the power of points in the dissipation of electricity. Seagoers of the several nations have allotted specific designations to these electrical manifestations. English-speaking nations refer to them indiscriminately as *Corposants*, or *St. Elmo's Fires*; in Portuguese they are known as *Corpo Santo*; in Italian, the *Fires of St. Peter and St. Nicholas*; whereas in French and in Spanish, they are the *Fires of St. Elmo*.

Waterspouts and Air Whirls.

These occur more frequently in the tropics than in higher latitudes.

They are accompanied by circular motion of the air, and are formed beneath heavy nimbus cloud.

Observations of these should be made with special attention to the direction of motion of the air, clockwise, or counter-clockwise. The position of the spout or whirl should be given as accurately as possible at frequent intervals. Measurements of diameter and height can be made with a sextant. Special attention should be paid to the height at which the spout meets and breaks. If possible the motion of the water descending and ascending should be recorded. At the same time special observations of the Meteorological instruments should be made to notice if they are affected in any peculiar way by the disturbance.

The introduction of rangefinders in some ships will enable observers to obtain a base from which the dimensions of waterspouts, etc., may be found by sextant angles.

Line Squalls.

The line squall is a squall of wind, accompanied by rain or hail, associated with a sudden drop of temperature and the passing of a long line or arch of dark cloud. This phenomenon is caused by the meeting of warm and cold winds, the most favourable condition for which being the trough of a "V"-shaped depression. In the northern hemisphere the warmer wind being generally from the south-west, the wind direction will veer as a rule, during the passage of the squall (in the southern hemisphere the reverse, using the international sense of the term, will be the case). During the passage of the squall the barometric pressure will rise with great suddenness about 2 mb., and the temperature will fall from 5° to 10° C. or 10° to 20° F. Line squalls are frequently precursors of thunderstorms, and owing to the violent convection and eddying of the atmosphere at the time of meeting of the cold and hot winds are often found to cause waterspouts.

As an instance of these squalls the Pampero of the Argentine and Uruguay may be cited.

CHAPTER VII.

HYDROGRAPHIC OBSERVATIONS.

Current Determination.

In order that observers may supply suitable current data, it seems particularly desirable that they should know for what purpose these observations are required and how they are dealt with.

The currents shown on the charts published by the Hydrographic Department of the Admiralty were generalised from a very large number of observations taken from logs and documents received by the Meteorological Office from ships of the Mercantile Marine and H.M. ships' logs and remark books. The currents along the main ocean routes are being charted in THE MARINE OBSERVER with a view to the revision of Atlases of Current Charts.

On the receipt of meteorological logs current data are checked; all those which appear to be reliable are converted into 24 hour values and entered into data books for the one degree square of the middle position; *i.e.*, the position to the nearest minute of latitude and longitude midway between the two points fixed by observation between which the current is calculated.

When a sufficient number of observations have been collected, these values are generalised and plotted on charts in the form of current arrows and current roses.

Determination of Current by differences between Observed Positions and Dead Reckoning.

It is obvious that the value of a current observation is dependent on the accuracy with which the positions of the ship can be determined. Cross bearings, horizontal angles of well defined and accurately charted terrestrial objects, or good twilight stellar sights are more accurate for this purpose than the determination by sights of the sun near the meridian and prime vertical, especially if the run of the ship between the two observations is long.

The current, if carefully determined between noon and noon is valuable, but the current determined at shorter intervals between *reliable fixes* is more so, being less

subject to error and variation; for the current is not likely often to run in the same direction over a long distance such as that covered by a fast ship in a day's run, particularly when passing near the junctions of ocean currents as off Cape Guardafui, Cape Delgado, the Tail of the Newfoundland Banks, or when crossing the separating line of the Equatorial and Counter Equatorial Currents.

Currents determined at short intervals should be checked with the noon to noon result and all should be entered in their respective columns.

It is desired, when possible, that the speed of the ship through the water should be ascertained by two different methods, as this will increase the accuracy of the estimation of the day's run. It is suggested that for deep ships the revolutions of the propeller should be one of these though the patent logs should be in constant use. The methods adopted should be stated in the log.

By the method of computation of current from the difference between observed and D.R. positions all factors not allowed for in the D.R. are attributed to current. It is, therefore, essential that variation and deviation of the compass should be frequently and carefully determined and allowed for and that leeway and any other possible disturbing factors should be estimated and applied.

If the true courses steered and the distances run through the water with times of alteration of course and speed are given it will facilitate checking.

The Determination of Surface Set and Drift by Bottles, etc.

Another method of determining drift is by setting bottles afloat which are returned to the Meteorological Office, if recovered, with a note of the position of their recovery. A stout sheet of white paper, with the following clearly written upon it, should be placed in a bottle carefully ballasted to float in sea water with not more than a quarter of its volume above the surface, tightly corked and sealed.

" This bottle was thrown overboard from S.S.
in latitude —, longitude —, at — G.M.T. on —
19—.

The finder is requested to post this paper to The Director, Meteorological Office, Air Ministry, London, by whom the cost of postage will be returned.

The finder is also requested at the same time to state the exact position and date at which the bottle was found.

(Signed) Captain S.S. ———.

Drift bottles have been picked up after travelling many thousands of miles.

The drift of a small object like a bottle gives no indication of the current below the surface. There may be currents running beneath the surface in different directions to that of the surface, and it is important that these should be known.

The values for current determined by the difference of observed position and D.R. probably gives set acting on the ship at a depth of half her draught.

To navigators making a land fall the value of the current observation is of the greatest importance, but it often happens that with the additional work of the ship when approaching or leaving port these are not recorded. Current determined between the last celestial fix of the passage and the first reliable terrestrial fix after making the land, is essential; and currents determined between terrestrial fixes when coasting are much desired.

The Determination of Sub-Surface Current.

These observations are seldom possible in ships of the Mercantile Marine, but cable ships when stationary may be in favourable circumstances to make them. Currents below the surface may be measured by a ship at anchor or riding to a cable by means of a current meter, of which instrument many good patterns are made. The Ekman Current Meter has been used with success. This apparatus consists of a form of submarine log and compass with vane combined. When lowered to the required depth the propeller is set in motion by means of a messenger; and can be stopped in the same manner. The velocity is indicated by means of a dial. The direction by compass is shown by a number of shot which roll along the needle and drop off its point into receptacles corresponding to the points of the compass.

In addition to current observations there is much other hydrographic information that, though not used in the Meteorological Office, will be forwarded to the proper quarter if sent to the Director.

Most important of this information is the reporting of the positions of uncharted rocks, shoals, etc. It must be impressed on observers in reporting such information that accurate positions are essential to plot the sounding. The data for its reduction to L.W.O.S. should be sent in, as it is most necessary that all computations should be checked thoroughly. A sounding is useless for charting purposes unless its position can be fixed accurately, but all indications of shoal water which is uncharted should be reported.*

Information should also be sent in on the following points :—

Inaccurately charted positions, additions to foreign harbour works, discrepancies of the character and range of lights from those given in the Admiralty Light Lists, discrepancies of sound signals and submarine sound apparatus.

Tidal observations, submarine tremors, and abnormal sea waves.

Any danger to shipping, as ice, wreckage, derelicts, etc.

* Such information will be forwarded to the Hydrographer of the Navy through the Superintendent for Naval Meteorological Services.

PART III.—METEOROLOGICAL LOGS AND REPORTS.

CHAPTER VIII.

INSTRUCTIONS FOR KEEPING THE ORIGINAL NOTE BOOK AND THE METEOROLOGICAL LOG.

Between pp. 78 and 79 will be found a specimen of a Meteorological Log, and at the beginning of every log is given a specimen page for the guidance of observers. At the bottom of each page the columns will be found numbered from left to right. This arrangement in the Original Note Book is the same.

Inside the cover of the log will be found a space set aside for information as to the position of the instruments, and reliability of observations of currents, and on the fly-leaf is made an entry of the names of the ship and the observers.

It should be remembered that a blank space is better than an uncertain observation.

Columns 1 and 2.—Day and Hour.—The name of the month may be written or its number given in Roman numerals, as shown in the specimen. The day is reckoned in civil time starting at midnight. The hour is intended for apparent time at ship; as this will not always be correct, the amount that the clock is fast or slow of G.M.T. at ship's noon should be entered daily. A note should be made of the number of minutes the clock is put forward or back with the time that the correction is made. Zone time may be used if preferred, but it should be clearly stated.

The log book is ruled for an observation every fourth hour.

Columns 3, 4, 5, 6 and 6a—Latitude, Longitude and Current.—Whenever the ship's position is found, whether at noon or at any other hour, it should be entered in these columns together with the D.R. position for the corresponding hour and a note made of that hour. If cross bearings can be obtained of land the position should be given as Lat. and Long. In column 6a the current as computed should be entered. These current observations are most useful, and attention of observers is particularly drawn to them. Observers are urged to

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the Meteorological Log.*

give remarks to indicate the reliability of the current observations, as no one ashore can decide whether a current observation expresses the true state of affairs or not. The terms "favourable" and "adverse" should not be used, but the actual figures worked out from the D.R. and observed positions. Currents of less than 5 miles per 24 hours are grouped together, but it is most necessary when such currents (or no current) are experienced that they should be recorded. If the observed and D.R. positions are merely entered as identical and the current entry left blank it is impossible for the computer ashore to know whether it represents a true observation or not. For current observations *see* p. 73.

Marine Observers will give great assistance if when the Latitude and Longitude is worked up for 4 a.m., 8 a.m., 4 p.m., 8 p.m. and Midnight, they will enter them, for these positions if not entered, have to be calculated in the Marine Division for the purpose of extraction.

Columns 7 and 8.—True Course and Distance.—These are required for obtaining or checking the Dead Reckoning at the times of the weather observations and to check the current found.

Column 11.—Direction of Wind (*vide* Chapter IV.).—This observation should state the *true* direction of the wind at the hour of observing, not an estimate of the direction during the watch. If, however, a squall is blowing at the time of observation, the direction and force should be given which existed before the squall. It is particularly requested that the direction, force, and duration of squalls with any other important remarks respecting them, such as how the wind changed during the squall, etc., be entered in Column 25. Any sudden change in direction or force of the wind should be noted with the exact time of the occurrence in Column 25.

Column 12.—Force of Wind.—The force of the wind should be estimated according to the Beaufort Scale, pp. 40 and 41.

Columns 13 and 14.—Barometer and attached Thermometer.—The number of the instrument and the height of the cistern (or lower end) above the sea level (at least at the beginning and end of each passage) must be entered at the top of the column; this height is, of course, affected by the ship's draught. Any change in the position of the instrument should be noted in the remarks column. The reading of the ship's barometer should be

Meteorological Log kept on board

3/5 CLAN MALCOLM

DATE.		Latitude.		Longitude.		Current when determined at short intervals.	Course and Distance.	Wind at the time of observation.	Barometer.*		True Atmospheric Pressure at Sea Level (Optional). The barometer reading corrected for temperature, height, gravity (see page 16 in Reeds' Observer's Handbook, 2nd Edition).	Thermometers.				
		Observed.	Dead Reckoning.	Observed.	Dead Reckoning.				No. 1, 4, 2, 2	Height of Column above Sea, 2.5 feet.		Uncorrected Reading.	Alt. Therm. Absolute Scale.	Dry Bulb.	Wet Bulb.	
Year 1925	Month XII							Each four hours.	Direction.	Force 0 to 12.			No.	No.		
Day.	Hour.	The D.R. position is needed daily, in addition to that by Observation, but it should be the result of careful calculation, in order to give any value to the estimation of the current.						True Course.	TRUE (Nearest point)			30.04	30.05			
Civil Time.								Distance by Log.								
20 th	4					N 29° E 19	N 14° E 39	NNE	3	1016.0	299.2	1012.1	77.9	72.7		
	8						N 14° E 39	NE x N	3	1018.0	298.2	1014.1	78.8	74.0		
G.M.T. 0845	NOON	0 29' N 4 12' S N 48 35' E 48 20' E Current in last 24 hours N 45° E 22 miles						N 39° W 13	N 14° E 40	NE x N	3-4	1018.0	298.1	1013.8	80.5	76.0
	4	Position by Skyler obs. 1° 45' N 1° 35' N 48° 48' E 48° 66' E						N 39° W 13	N 18° E 39	NNE	4	1015.7	298.2	1011.5	80.0	74.6
	6:36								N 18° E 32							
	8								N 26° E 7	NNE	3	1017.3	299.8	1013.3	78.0	75.0
	MIDT.							S 27° W 2	N 26° E 40	NE x N	3	1017.1	299.6	1013.2	78.2	75.2
21 st	4	Position by Skyler obs. 3° 21' N 3° 23' N 49° 35' E 49° 36' E							N 26° E 37	NE x N	3	1015.8	299.5	1011.9	78.1	75.0
	8							N 16° W 4	N 26° E 37	NE	3	1018.1	300.0	1014.0	80.0	75.8
G.M.T. 0838	NOON	4 24' N 4 12' S N 50 03' E 50 15' E Current in last 24 hours N 41° N 12 miles						S 62° W 9 1/2	N 26° E 39	NE x N	4	1018.0	300.6	1013.8	81.3	76.8
	4	Position by Skyler obs. 5° 15' N 5° 19' S N 50° 22' E 50° 30' E							N 26° E 38	NE x N	4	1016.9	300.9	1011.6	80.8	76.0
	6:16								N 26° E 35	NE x N	3	1018.1	300.0	1014.1	78.8	75.4
	8							S 80° W 5	N 26° E 37	NE x N	4	1018.0	299.5	1014.1	78.8	74.8
	MIDT.															
22 nd	4	Position by Skyler obs. 6° 04' N 6° 06' N 51° 03' E 51° 11' E							N 26° E 37	NE x N	4-5	1017.2	299.5	1013.4	77.0	73.5
	8							S 63° W 3	N 26° E 27							
									N 30° E 11	NE x N	3	1020.2	300.0	1016.1	80.0	73.2
G.M.T. 0833	NOON	7 51' N 7 58' S N 51 23' E 51 43' E Current in last 24 hours S 69° W 2 miles						S 38° W 9 1/2	N 20° E 39	NNE	5	1019.5	299.8	1015.7	77.5	73.7
	4	Position by Skyler obs. 8° 43' N 8° 50' S N 51° 56' E 51° 40' E							N 15° E 36	NNE	5-4	1017.3	299.1	1013.6	77.6	71.7
	6:16								N 15° E 36	NE x N	4	1019.8	298.4	1016.2	76.4	72.0
	8							S 88° W 13	N 16° E 38	NE x N	4	1018.8	298.6	1015.1	77.0	71.2
	MIDT.															
23 rd	4								N 16° E 38	NE	2	1017.9	298.0	1014.4	76.3	70.8
	5:48	10° 32' N 10° 32' S N 51° 49' E 52° 02' E							N 16° E 12							
	8							N 19° W 6	N 20° W 7							
									N 16° W 22	NE x N	2	1021.2	298.6	1017.6	77.0	70.6
									N 16° W 39							
G.M.T. 0833	NOON	11 36' S N 11 39' N 51 29' E 51 50' S Current in last 24 hours S 83° N 21 miles						N 13° E 2	N 28° W 3	N x E	4	1020.3	299.4	1015.5	78.0	71.3
	1:45	Position by hand fix. 11° 55' S N 11° 51' S N 51° 20' E 51° 19' S						S 72° W 1 1/2	N 28° W 14			(30-06)				
	4:00								N 47° W 6							
	8								N 70° W 3	NE x N	4	1019.3	298.8	1015.3	77.0	74.5
									N 70° W 11							
	8								N 85° W 27	NE	3	1021.4	297.7	1017.0	76.8	70.0
	MIDT.							P.T.O.	N 85° W 36	NE x E	3	1020.2	297.6	1016.8	76.6	69.8
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	

* Please give Readings of the Ship's Barometer, say at Noon, at various times during the voyage noting whether it is mercurial or aneroid. It will give great assistance to the computers at the Meteorological Office if Column 13a is completed. This is optional, and whether 13a is

Captain G. A. Neill from Durbaw to Aden

Hour.	Clouds at time of observation.		Weather at time of observation.	Sea Surface.				Remarks.		Rain-fall by Gauge.	
	The direction from which the clouds are moving should be noted when determinable.			Waves.	Swell.	Spec. Prev. by No.	Time of Remarks.	Here give any important Remarks as to phenomena, with the time of their occurrence, especially the time of Change in Direction and Force of Wind, as well as the Directions, Veering or Backing, Force and Duration of Squalls; the Position of low and of Drifts.			
	Names.	Pop. of Sky Clouded 0 to 10.							Time of Remarks.		Here give any important Remarks as to phenomena, with the time of their occurrence, especially the time of Change in Direction and Force of Wind, as well as the Directions, Veering or Backing, Force and Duration of Squalls; the Position of low and of Drifts.
According to Beaufort Notation.		Direction from 0 to 9.		Direction from 0 to 9.		Spec. Prev. by No.		Time of Remarks.		Here give any important Remarks as to phenomena, with the time of their occurrence, especially the time of Change in Direction and Force of Wind, as well as the Directions, Veering or Backing, Force and Duration of Squalls; the Position of low and of Drifts.	
TRUE.		TRUE.		TRUE.		TRUE.		TRUE.		TRUE.	
Also record when Confused.											
4	NIL.	CU NNE 2	2	b	NNE 3	NE Mod	79.0	4.00	Clocks advanced 2 mins.	Very fine & clear.	Small increasing slightly.
8	a-cu	CU	10	0	NEXN 3	NE Slight	78.6	8.00	Sky almost completely covered with a-cu		
NOON	a-cu	CU NNE 2	8	c	NEXN 3	NNE Slight	79.4 24.5	NOON	Clocks advanced 2 mins.	Cloud amount only Sky clearing in N & East. Sea moderate swell. Clear	
4	a-cu	CU NNE 2	2	b	NNE 4	NNE Mod	78.3	4.00	Clocks advanced 1 min.	Very fine clear weather.	Upper clouds dissipating slowly
8	NIL.	NIL	0	b	NNE 3	NNE Mod	77.9	8.30	Heavy masses. Cu-nb clouds from NNE		
MIDT	NIL	CU-nb N-E-N	1	b	NEXN 3	North Mod	78.3	10.30	Heavy masses. Cu-nb clouds from NE for short period.		
								Midl	Heavy Cu-nb clouds. Remainder of match clear sky.		
4	NIL	CU NEXN 2	2	b	NEXN 3	North Rough	78.1	4.00	Clocks advanced 3 mins.	Small increased steadily during match. Rough at intervals.	Fine & very clear.
8	NIL	CU NE 2	2	b	NE 3	North Mod	79.0	8.00	Small rough at intervals.		
NOON	NIL	CU NEXN 5	5	b	NEXN 3	NNE Rough	79.6 24	NOON	Clocks advanced 1 min.	Sea very clear at intervals. Very fine clear weather.	
4	NIL	CU NEXN 2	4	b	NEXN 3	NNE Rough	79.6	4.00	Passing shower. Clouds advanced 1 min.		
8	NIL	CU NEXN 1	1	b	NEXN 4	NEXN Rough	78.2	8.00	Very fine clear weather.	Occasional rough swell.	
MIDT	NIL	CU NEXN 2	2	b	NEXN 4	Confused Rough	79.0	8.15	Wind freshened		
								Midl	Rough confused swell. Fine & clear.		
4	NIL	CU NE 1	1	b	NEXN 4	Conf'd North N-E	79.0	4.00	Clocks advanced 3 mins.	Slightly squally. Occasional rough swell.	Fine & very clear.
8	NIL	CU NEXN 2	2	b	NEXN 3	North N-E	79.0	8.00	Very fine clear weather.		
NOON	a-cu	CU-nb NE 5	5	b	NNE 4	North N-E	79.9 24.6	NOON	Light shower. Wind freshening.	Clocks advanced 1 min.	
4	a-cu	CU-nb NE 6	6	b	NNE 4	NNE Rough	78.2	4.00	Wind freshening. Small clouds very clear.		
8	NIL	CU-nb NE 2	2	b	NNE 4	NNE Rough	78.2	8.00	Very fine clear weather.	Box pumping -6 mb	
MIDT	a-cu	CU-nb NE 6	6	b	NEXN 4	NE Rough	78.5	11.00	Sharp rain squall.		
4	NIL	CU-nb NE 4	4	b	NE 3	North N-E	78.6	4.00	Wind moderated with passing showers in Eastward during match.		Fine & clear.
8	NIL	CU-nb NE 4	4	b	NEXN 2	North N-E	78.0	8.00	Very fine clear weather.		
NOON	a-cu	CU-nb NE 8	8	c	NEXN 4	NNE Mod	79.0 25	NOON	Wind commenced backing.	Clocks retarded 1 min.	
4	a-cu	CU-nb NE 5	5	b	NEXN 3	NE Mod	77.0	4.00	Occasional passing showers during match. Clear		
8	NIL	CU-nb NE 2	2	b	NEXN 3	NE Mod	76.8	8.00	Clocks retarded 5 mins.		
MIDT	a-cu	CU-nb NE 1	1	b	NEXN 3	NNE Mod	76.2	8.15	Cu-nb clouds overlaid only. Fine & clear.		
								8.30	Res Alula Lt. Ho. South 7		
								11.00	Wind freshened slightly & large quantity of Cu clouds passed over from NE		
								Midl	Wind moderated & cleared to N-E		
								25	Cu-nb in bands on N.W. & S.E. line. Very fine & clear.		

entered once a day for comparison, and a note made in the log of its position in the ship and height above sea level.

Attention should be paid to Chapter II., p. 14, where are enumerated the precautions necessary in reading the barometer.

It should be remembered that the barometer reading is as important in fine weather as in bad.

When two scales are engraved on the barometer, viz., millibars and inches, *the millibar scale should invariably be read for the purpose of the meteorological log.*

Column 13a.—True Atmospheric Pressure at Sea Level is computed from Columns 13 and 14. It is of very great assistance to the computers of the Meteorological Office if this column is filled in at sea and will greatly facilitate extraction.

Columns 15 and 16.—Dry and Wet Bulb Thermometers.—The numbers of the thermometers should be entered at the top of the columns, and any change made in the instruments should be noted. The thermometers should be read to a tenth of a degree in order that the difference between dry and wet bulb may be accurately obtained. Reference should be made to Chapter III., p. 27.

Column 17—Clouds.—This column is divided into two sub-columns headed "upper" and "lower." The entries in these should conform to Chapter V., pp. 50 and 51, and should be clearly differentiated.

It should be noted that a convenient way of making it clear that two types of clouds are represented and not one compound type is to place a stroke between them; thus St/Cu means that both Stratus and Cumulus are present, but St-Cu means Strato-Cumulus is seen.

Direction of cloud motion should be recorded according to the instructions on p. 52.

Column 18—Amount of Cloud.—The amount of cloud is given on the scale described on p. 49.

Column 19—Weather (*vide* p. 53).—The weather reported should be that of the time of observation only, not that of the preceding four hours. Fog, rain, snow, and hail, with the hours of commencing and stopping, should be entered in the remarks column, the letters **f, r, s, h, p, w, &c.**, being only put in column 19 if actually occurring at the time of observation.

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the Meteorological Log.*

Further facts regarding weather that cannot be expressed by the Beaufort Notation should be also entered in the remarks column, and do not forget that there is ample space for additional remarks at the end of the log.

Column 19a—Fog Intensity and Visibility.—The appropriate figure should be entered in this column from the table on p. 55.

Columns 20 and 20a—Direction of Sea and Swell.—The *true* direction should be given from which sea and swell are coming.

Column 21—Sea Disturbance.—This is given according to the table on p. 43.

Column 21a—Swell Disturbance.—This is given according to the "description" on p. 43. If no swell is present it is necessary that this should be stated and that the space should not be merely left blank, which implies a doubtful observation.

Columns 22 and 23—Surface Temperature and Specific Gravity.—The numbers of the instruments used for these observations should be given at the heads of these columns. Attention should be paid to the instructions in Chapter III., pp. 30 and 34.

The sea water temperature should be taken immediately before the specific gravity, when that observation is made. As a rule, the sea surface temperature should be taken every four hours, while the specific gravity is only necessary once a day at noon. Observations, however, should be made more frequently, when in the neighbourhood of current rips, on each side of lines of foam, &c. In these cases specific gravity observations may reveal remarkable changes in salinity.

Column 24—Time of Remarks.—The hour of entering or leaving port and the exact time of remarks on weather, changes of wind, etc., are most important. The time of altering of the ship's clock should always be noted daily.

Column 25—Remarks.—This column should contain any important facts which cannot be recorded in other columns, even though they may not at first sight appear to be related to Meteorology.

The following are a few of many items that can be recorded.

Any state of weather that is unusual.

The appearance of any of the optical phenomena mentioned in Chapter VI. If possible, a short account

of these should also be given at the end of the log with more details than is possible in the remarks column.

Waterspouts; but if details can be obtained it is better to record these in the space provided at the end of the log.

The temperature of rain just fallen, and that of the air by the dry bulb at the same time.

Red fog, dust, submarine earthquakes.

Tide and current rips, discoloured or luminous parts of the sea.

Magnetic disturbances.

Peculiar clouds. Line squalls.

The time, distance, and bearing of a few headlands is also of use in the remarks column.

Many other items will occur to the seaman which will be worthy of record. The only thing that should be guarded against is the habit of repeating what has already been said in previous columns, which only confuses the important items of the remarks with a mass of material which is already expressed in a more convenient form.

Column 25a—Raingauge.—The rainfall in the gauge should be measured every four hours. The water is poured out into the measuring glass, and the height of the water is read and recorded. The contents of the measuring glass are then poured back into the gauge except at 12 noon. The effect of this method is to give the rainfall that has occurred at each observation since the previous noon. The rainfall recorded at noon being for a complete 24 hours.

Additional Remarks.—At the end of the log will be found pages devoted to Additional Remarks and wireless weather messages made to "All Ships."

These additional remarks should be accounts of any phenomena that can be observed in detail such as tropical revolving storms, optical phenomena, descriptions of local winds such as Pamperos. Notes on abnormal currents and interesting experiences in navigation and seamanship in relation to Marine Meteorology will be specially welcome.

In low latitudes air-whirls are sometimes met with which are revealed by violent commotion in the lower clouds. Detailed descriptions of these are much needed together with notice of any marked movements of the meteorological instruments during the occurrence.

Hydrographic notes given on the lines detailed in Chapter VII. will be forwarded to the proper quarters.

Notes on Magnetism, Biology, or any other scientific subject will be welcome, and every effort will be made to forward them to the correct authority.

Illustrations.—The photographing, or otherwise illustrating, of phenomena would be a most excellent record to be preserved, especially when explained fully with remarks.

It is hoped that many more pictures will be obtained in the future, a selection of which are published in THE MARINE OBSERVER, and due regard should be had to reproduction in that Journal.

Weather charts made at sea should be attached to the inside of the back of the log.

Hints for Keeping the Ship's Meteorological Report, Form 911.

The form is ruled up with vertical columns which are numbered at the foot.

Columns 1 and 2.—Month and day need no comment.

Column 3.—The time of observation should be ship's time at 8 a.m. and 8 p.m., against which should be noted A.T.S. or local standard whichever is being kept. The difference from G.M.T. should be stated in the Remarks column.

Columns 4 and 5.—The Latitude and Longitude of the position at which the observations are made should be entered with the care and accuracy used in the ship's own log book.

Columns 6 and 7.—Wind direction and force (*vide* Chapter IV.). These should be entered *true*, the direction and force being estimated from the appearance of the sea surface and the direction being given in points.

Columns 8 and 9.—Barometer and attached thermometer (*vide* Chapter II.). Always enter the uncorrected reading of the barometer whether column 10 is completed or not. The reading of the attached thermometer is only necessary if the barometer is mercurial.

Column 10.—The index correction to ship's barometers is supplied by the Meteorological Office to those ships which forward a blue postcard (Form 913). It is given in two forms for aneroid barometers and mercurial barometers.

For an aneroid the reduction to sea level is combined with the index correction in that case the True Atmo-

spheric pressure is given by adding or subtracting this combined correction from the pressure as read.

For a mercurial barometer the correction is given for index only, the True Atmospheric pressure is then obtained by following the procedure given in Chapter II.

Column 11.—Enter the temperature of the air as measured by a thermometer unaffected by the sun's direct rays, spray, rain, or artificial heat (*vide* Chapter III).

Column 12.—The method to be adopted for obtaining sea surface temperature is given in Chapter III.

Columns 13, 14 and 15.—The Column for cloud type is sub-divided under two headings, "Upper" and "Lower." The entries in these should conform to Chapter V., pp. 50 and 51, and be clearly differentiated.

It should be noted that a convenient way of making it clear that two types of clouds are represented and not one compound type is to place a stroke between them; thus St/Cu means that both Stratus and Cumulus are present, but St-Cu means Strato-Cumulus is seen.

Direction of cloud motion should be recorded according to the instructions on p. 52.

The amount of cloud is given on the scale described on p. 49.

Column 16.—The Beaufort notation of weather is given on p. 53.

Column 17.—The Visibility Scale is given on p. 55.

Columns 18 and 20.—The *true* direction should be given from which Sea and Swell are coming.

Columns 19 and 21.—The scale of Sea disturbance and the description for swell are given on p. 43.

Column 22.—In the remarks column should be entered any feature of the weather which is not adequately described in the preceding columns, especially the time of commencement and ending of fog, rain, etc. Also visibility when making landfall. The time and distance off salient points of land should be entered.

Columns for the recording of ocean current observations are also included. These columns will be self-explanatory to the navigator.

Space is also provided for records of W/T reports made to "All Ships" and also for additional remarks, which should be used for describing unusual phenomena in detail and specially interesting experiences. These should be illustrated by means of sketches or photographs when possible and regard should be had to their being reproduced in THE MARINE OBSERVER.

TABLE I.

THE ADJUSTMENT OF FIDUCIAL TEMPERATURE

Latitude N. or S.	Height in Feet of Barometer								
	0	5	10	15	20	25	30	35	40
°	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>
0	-15.2	-14.2	-13.1	-12.1	-11.0	-10.0	-8.9	-7.8	-6.8
2	15.1	14.1	13.0	12.0	10.9	9.9	8.8	7.7	6.7
4	15.0	14.0	12.9	11.8	10.8	9.8	8.7	7.6	6.5
6	14.8	13.8	12.7	11.7	10.6	9.6	8.5	7.4	6.4
8	14.6	13.6	12.5	11.5	10.4	9.4	8.3	7.2	6.2
10	14.2	13.2	12.1	11.1	10.0	9.0	7.9	6.8	5.8
12	13.8	12.8	11.7	10.7	9.6	8.6	7.5	6.4	5.4
14	13.4	12.4	11.3	10.3	9.2	8.2	7.1	6.0	5.0
16	12.8	11.8	10.7	9.7	8.6	7.6	6.5	5.4	4.4
18	12.3	11.3	10.2	9.2	8.1	7.1	6.0	4.9	3.9
20	11.6	10.6	9.5	8.5	7.4	6.4	5.3	4.2	3.2
22	10.9	9.9	8.8	7.8	6.7	5.7	4.6	3.5	2.5
24	10.1	9.1	8.0	7.0	5.9	4.9	3.8	2.7	1.7
26	9.3	8.3	7.2	6.2	5.1	4.1	3.0	1.9	0.9
28	8.5	7.5	6.4	5.4	4.3	3.3	2.2	1.1	-0.1
30	7.6	6.6	5.5	4.5	3.4	2.4	1.3	-0.2	+0.8
32	6.6	5.6	4.5	3.5	2.4	1.4	-0.3	+0.8	1.8
34	5.7	4.7	3.6	2.6	1.5	-0.5	+0.6	1.7	2.7
36	4.7	3.7	2.6	1.6	-0.5	+0.5	1.6	2.7	3.7
38	3.7	2.7	1.6	-0.6	+0.5	1.5	2.6	3.7	4.7
40	2.6	1.6	-0.5	+0.5	1.6	2.6	3.7	4.8	5.8
42	1.6	-0.6	+0.5	1.5	2.6	3.6	4.7	5.8	6.8
44	-0.5	+0.5	1.6	2.6	3.7	4.7	5.8	6.9	7.9
46	+0.5	1.5	2.6	3.6	4.7	5.7	6.8	7.9	8.9
48	1.6	2.6	3.7	4.7	5.8	6.8	7.9	9.0	10.0
50	2.6	3.6	4.7	5.7	6.8	7.8	8.9	10.0	11.0
52	3.7	4.7	5.8	6.8	7.9	8.9	10.0	11.1	12.1
54	4.7	5.7	6.8	7.8	8.9	9.9	11.0	12.1	13.1
56	5.7	6.7	7.8	8.8	9.9	10.9	12.0	13.1	14.1
58	6.6	7.6	8.7	9.7	10.8	11.8	12.9	14.0	15.0
60	+7.6	+8.6	+9.7	+10.7	+11.8	+12.8	+13.9	+15.0	+16.0

Based on a Temperature of 290a.

TABLE I.

FOR LATITUDE AND HEIGHT ABOVE SEA LEVEL.

Cistern above Sea Level.								Latitude N. or S.
45	50	55	60	65	70	75	80	
<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>	°
-5.7	-4.7	-3.6	-2.6	-1.5	-0.5	+0.6	+1.6	0
5.6	4.6	3.5	2.5	1.4	0.4	0.7	1.7	2
5.5	4.5	3.4	2.4	1.3	0.3	0.8	1.8	4
5.3	4.3	3.2	2.2	1.1	-0.1	1.0	2.0	6
5.1	4.1	3.0	2.0	0.9	+0.1	1.2	2.2	8
4.7	3.7	2.6	1.6	0.5	0.5	1.6	2.6	10
4.3	3.3	2.2	1.2	-0.1	0.9	2.0	3.0	12
3.9	2.9	1.8	0.8	+0.3	1.3	2.4	3.4	14
3.3	2.3	1.2	-0.2	0.9	1.9	3.0	4.0	16
2.8	1.8	-0.7	+0.3	1.4	2.4	3.5	4.5	18
2.1	1.1	0.0	1.0	2.1	3.1	4.2	5.2	20
1.4	-0.4	+0.7	1.7	2.8	3.6	4.9	5.9	22
-0.6	+0.4	1.5	2.5	3.6	4.6	5.7	6.7	24
+0.2	1.2	2.3	3.3	4.4	5.4	6.5	7.5	26
1.0	2.0	3.1	4.1	5.2	6.2	7.3	8.3	28
1.9	2.9	4.0	5.0	6.1	7.1	8.2	9.2	30
2.9	3.9	5.0	6.0	7.1	8.1	9.2	10.2	32
3.8	4.8	5.9	6.9	8.0	9.0	10.1	11.1	34
4.8	5.8	6.9	7.9	9.0	10.0	11.1	12.1	36
5.8	6.8	7.9	8.9	10.0	11.0	12.1	13.1	38
6.9	7.9	9.0	10.0	11.1	12.1	13.2	14.2	40
7.9	8.9	10.0	11.0	12.1	13.1	14.2	15.2	42
9.0	10.0	11.1	12.1	13.2	14.2	15.3	16.3	44
10.0	11.0	12.1	13.1	14.2	15.2	16.3	17.3	46
11.1	12.1	13.2	14.2	15.3	16.3	17.4	18.4	48
12.1	13.1	14.2	15.2	16.3	17.3	18.4	19.4	50
13.2	14.2	15.3	16.3	17.4	18.4	19.5	20.5	52
14.2	15.2	16.3	17.3	18.4	19.4	20.5	21.5	54
15.2	16.2	17.3	18.3	19.4	20.4	21.5	22.5	56
16.1	17.1	18.2	19.2	20.3	21.3	22.4	23.4	58
+17.1	+18.1	+19.2	+20.2	+21.3	+22.3	+23.4	+24.4	60

and Barometer height of 1000 mb.

TABLE II.
CORRECTION OF BAROMETER FOR DIFFERENCE
ADJUSTED FIDUCIAL

Attached Thermometer.	271	272	273	274	275	276	277	278	279	280	Attached Thermometer.
a.	mb	mb	mb	mb	mb	mb	mb	mb	mb	mb	a.
271	0.0	+0.2	+0.3	+0.5	+0.7	+0.9	+1.0	+1.2	+1.4	+1.5	271
272	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	272
273	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	273
274	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	274
275	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	275
276	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	276
277	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	277
278	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	278
279	1.4	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	279
280	1.5	1.4	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	280
281	1.7	1.5	1.4	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	281
282	1.9	1.7	1.5	1.4	1.2	1.0	0.9	0.7	0.5	0.3	282
283	2.0	1.9	1.7	1.5	1.4	1.2	1.0	0.9	0.7	0.5	283
284	2.2	2.0	1.9	1.7	1.5	1.4	1.2	1.0	0.9	0.7	284
285	2.4	2.2	2.0	1.9	1.7	1.5	1.4	1.2	1.0	0.9	285
286	2.6	2.4	2.2	2.0	1.9	1.7	1.5	1.4	1.2	1.0	286
287	2.7	2.6	2.4	2.2	2.0	1.9	1.7	1.5	1.4	1.2	287
288	2.9	2.7	2.6	2.4	2.2	2.0	1.9	1.7	1.5	1.4	288
289	3.1	2.9	2.7	2.6	2.4	2.2	2.0	1.9	1.7	1.6	289
290	3.2	3.1	2.9	2.7	2.6	2.4	2.2	2.0	1.9	1.7	290
291	3.4	3.2	3.1	2.9	2.7	2.6	2.4	2.2	2.0	1.9	291
292	3.6	3.4	3.2	3.1	2.9	2.7	2.6	2.4	2.2	2.0	292
293	3.8	3.6	3.4	3.2	3.1	2.9	2.7	2.6	2.4	2.2	293
294	3.9	3.8	3.6	3.4	3.2	3.1	2.9	2.7	2.6	2.4	294
295	4.1	3.9	3.8	3.6	3.4	3.2	3.1	2.9	2.7	2.6	295
296	4.3	4.1	3.9	3.8	3.6	3.4	3.2	3.1	2.9	2.7	296
297	4.4	4.3	4.1	3.9	3.8	3.6	3.4	3.2	3.1	2.9	297
298	4.6	4.4	4.3	4.1	3.9	3.8	3.6	3.4	3.2	3.1	298
299	4.8	4.6	4.4	4.3	4.1	3.9	3.8	3.6	3.4	3.2	299
300	5.0	4.8	4.6	4.4	4.3	4.1	3.9	3.8	3.6	3.4	300
301	5.1	5.0	4.8	4.6	4.4	4.3	4.1	3.9	3.8	3.6	301
302	5.3	5.1	5.0	4.8	4.6	4.4	4.3	4.1	3.9	3.8	302
303	5.5	5.3	5.1	5.0	4.8	4.6	4.4	4.3	4.1	3.9	303
304	5.6	5.5	5.3	5.1	5.0	4.8	4.6	4.4	4.3	4.1	304
305	5.8	5.6	5.5	5.3	5.1	5.0	4.8	4.6	4.4	4.3	305
306	6.0	5.8	5.6	5.5	5.3	5.1	5.0	4.8	4.6	4.4	306
307	6.2	6.0	5.8	5.6	5.5	5.3	5.1	5.0	4.8	4.6	307
308	6.3	6.2	6.0	5.8	5.6	5.5	5.3	5.1	5.0	4.8	308
309	6.5	6.3	6.2	6.0	5.8	5.6	5.5	5.3	5.1	5.0	309
310	-6.7	-6.5	-6.3	-6.2	-6.0	-5.8	-5.6	-5.5	-5.3	-5.1	310

NOTE.—This table is based on a Standard Pressure of 1,000 mb. being, "Add one per cent. of the correction for each 10 millibars

TABLE II.—*cont.*

BETWEEN " ATTACHED THERMOMETER " AND TEMPERATURE.

Attached Thermometer.	281	282	283	284	285	286	287	288	289	290	Attached Thermometer.
a.	mb	mb	mb	mb	mb	mb	mb	mb	mb	mb	a.
271	+1.7	+1.9	+2.0	+2.2	+2.4	+2.6	+2.7	+2.9	+3.1	+3.2	271
272	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.7	2.9	3.1	272
273	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.7	2.9	273
274	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.7	274
275	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.6	275
276	0.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	276
277	0.7	0.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	277
278	0.5	0.7	0.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	278
279	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.5	1.7	1.9	279
280	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.5	1.7	280
281	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.5	281
282	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	282
283	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	283
284	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	284
285	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	285
286	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	286
287	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	287
288	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	288
289	1.4	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	289
290	1.5	1.4	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	290
291	1.7	1.5	1.4	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	291
292	1.9	1.7	1.5	1.4	1.2	1.0	0.9	0.7	0.5	0.3	292
293	2.0	1.9	1.7	1.5	1.4	1.2	1.0	0.9	0.7	0.5	293
294	2.2	2.0	1.9	1.7	1.5	1.4	1.2	1.0	0.9	0.7	294
295	2.4	2.2	2.0	1.9	1.7	1.5	1.4	1.2	1.0	0.9	295
296	2.6	2.4	2.2	2.0	1.9	1.7	1.5	1.4	1.2	1.0	296
297	2.7	2.6	2.4	2.2	2.0	1.9	1.7	1.5	1.4	1.2	297
298	2.9	2.7	2.6	2.4	2.2	2.0	1.9	1.7	1.5	1.4	298
299	3.1	2.9	2.7	2.6	2.4	2.2	2.0	1.9	1.7	1.5	299
300	3.2	3.1	2.9	2.7	2.6	2.4	2.2	2.0	1.9	1.7	300
301	3.4	3.2	3.1	2.9	2.7	2.6	2.4	2.2	2.0	1.9	301
302	3.6	3.4	3.2	3.1	2.9	2.7	2.6	2.4	2.2	2.0	302
303	3.8	3.6	3.4	3.2	3.1	2.9	2.7	2.6	2.4	2.2	303
304	3.9	3.8	3.6	3.4	3.2	3.1	2.9	2.7	2.6	2.4	304
305	4.1	3.9	3.8	3.6	3.4	3.2	3.1	2.9	2.7	2.6	305
306	4.3	4.1	3.9	3.8	3.6	3.4	3.2	3.1	2.9	2.7	306
307	4.4	4.3	4.1	3.9	3.8	3.6	3.4	3.2	3.1	2.9	307
308	4.6	4.4	4.3	4.1	3.9	3.8	3.6	3.4	3.2	3.1	308
309	4.8	4.6	4.4	4.3	4.1	3.9	3.8	3.6	3.4	3.2	309
310	-5.0	-4.8	-4.6	-4.4	-4.3	-4.1	-3.9	-3.8	-3.6	-3.4	310

For other pressures an additional correction is necessary, the rule above 1,000, and subtract one per cent. for each 10 millibars below."

TABLE II.—*cont.*
CORRECTION OF BAROMETER FOR DIFFERENCE
ADJUSTED FIDUCIAL

Attached Thermometer.	291	292	293	294	295	296	297	298	299	300	Attached Thermometer.
a.	mb	mb	mb	mb	mb	mb	mb	mb	mb	mb	a.
271	+3.4	+3.6	+3.8	+3.9	+4.1	+4.3	+4.4	+4.6	+4.8	+5.0	271
272	3.2	3.4	3.6	3.8	3.9	4.1	4.3	4.4	4.6	4.8	272
273	3.1	3.2	3.4	3.6	3.8	3.9	4.1	4.3	4.4	4.6	273
274	2.9	3.1	3.2	3.4	3.6	3.8	3.9	4.1	4.3	4.4	274
275	2.7	2.9	3.1	3.2	3.4	3.6	3.8	3.9	4.1	4.3	275
276	2.6	2.7	2.9	3.1	3.2	3.4	3.6	3.8	3.9	4.1	276
277	2.4	2.6	2.7	2.9	3.1	3.2	3.4	3.6	3.8	3.9	277
278	2.2	2.4	2.6	2.7	2.9	3.1	3.2	3.4	3.6	3.8	278
279	2.0	2.2	2.4	2.6	2.7	2.9	3.1	3.2	3.4	3.6	279
280	1.9	2.0	2.2	2.4	2.6	2.7	2.9	3.1	3.2	3.4	280
281	1.7	1.9	2.0	2.2	2.4	2.6	2.7	2.9	3.1	3.2	281
282	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.7	2.9	3.1	282
283	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.7	2.9	283
284	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.7	284
285	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.6	285
286	0.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	286
287	0.7	0.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	287
288	0.5	0.7	0.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	288
289	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.5	1.7	1.9	289
290	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.5	1.7	290
291	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.5	291
292	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	292
293	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	293
294	0.5	0.3	-0.2	0.0	+0.2	0.3	0.6	0.7	0.9	1.0	294
295	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	295
296	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	296
297	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	297
298	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	298
299	1.4	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	299
300	1.5	1.4	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	300
301	1.7	1.5	1.4	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	301
302	1.9	1.7	1.5	1.4	1.2	1.0	0.9	0.7	0.5	0.3	302
303	2.0	1.9	1.7	1.5	1.4	1.2	1.0	0.9	0.7	0.5	303
304	2.2	2.0	1.9	1.7	1.5	1.4	1.2	1.0	0.9	0.7	304
305	2.4	2.2	2.0	1.9	1.7	1.5	1.4	1.2	1.0	0.9	305
306	2.6	2.4	2.2	2.0	1.9	1.7	1.5	1.4	1.2	1.0	306
307	2.7	2.6	2.4	2.2	2.0	1.9	1.7	1.5	1.4	1.2	307
308	2.9	2.7	2.6	2.4	2.2	2.0	1.9	1.7	1.5	1.4	308
309	3.1	2.9	2.7	2.6	2.4	2.2	2.0	1.9	1.7	1.5	309
310	-3.2	-3.1	-2.9	-2.7	-2.6	-2.4	-2.2	-2.0	-1.9	-1.7	310

NOTE.—This table is based on a Standard Pressure of 1,000 mb. being, "Add one per cent. of the correction for each 10 millibars

TABLE II.—*cont.*

BETWEEN " ATTACHED THERMOMETER " AND TEMPERATURE.

Attached Thermometer.	301	302	303	304	305	306	307	308	309	310	Attached Thermometer.
a.	mb	mb	mb	mb	mb	mb	mb	mb	mb	mb	a.
271	+5.1	+5.3	+5.5	+5.6	+5.8	+6.0	+6.2	+6.3	+6.5	+6.7	271
272	5.0	5.1	5.3	5.5	5.6	5.8	6.0	6.2	6.3	6.5	272
273	4.8	5.0	5.1	5.3	5.5	5.6	5.8	6.0	6.2	6.3	273
274	4.6	4.8	5.0	5.1	5.3	5.5	5.6	5.8	6.0	6.2	274
275	4.4	4.6	4.8	5.0	5.1	5.3	5.5	5.6	5.8	6.0	275
276	4.3	4.4	4.6	4.8	5.0	5.1	5.3	5.5	5.6	5.8	276
277	4.1	4.3	4.4	4.6	4.8	5.0	5.1	5.3	5.5	5.6	277
278	3.9	4.1	4.3	4.4	4.6	4.8	5.0	5.1	5.3	5.5	278
279	3.8	3.9	4.1	4.3	4.4	4.6	4.8	5.0	5.1	5.3	279
280	3.6	3.8	3.9	4.1	4.3	4.4	4.6	4.8	5.0	5.1	280
281	3.4	3.6	3.8	3.9	4.1	4.3	4.4	4.6	4.8	5.0	281
282	3.2	3.4	3.6	3.8	3.9	4.1	4.3	4.4	4.6	4.8	282
283	3.1	3.2	3.4	3.6	3.8	3.9	4.1	4.3	4.4	4.6	283
284	2.9	3.1	3.2	3.4	3.6	3.8	3.9	4.1	4.3	4.4	284
285	2.7	2.9	3.1	3.2	3.4	3.6	3.8	3.9	4.1	4.3	285
286	2.6	2.7	2.9	3.1	3.2	3.4	3.6	3.8	3.9	4.1	286
287	2.4	2.6	2.7	2.9	3.1	3.2	3.4	3.6	3.8	3.9	287
288	2.2	2.4	2.6	2.7	2.9	3.1	3.2	3.4	3.6	3.8	288
289	2.0	2.2	2.4	2.6	2.7	2.9	3.1	3.2	3.4	3.6	289
290	1.9	2.0	2.2	2.4	2.6	2.7	2.9	3.1	3.2	3.4	290
291	1.7	1.9	2.0	2.2	2.4	2.6	2.7	2.9	3.1	3.2	291
292	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.7	2.9	3.1	292
293	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.7	2.9	293
294	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.7	294
295	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.6	295
296	0.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	296
297	0.7	0.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	297
298	0.5	0.7	0.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	298
299	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.5	1.7	1.9	299
300	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.5	1.7	300
301	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.5	301
302	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	302
303	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	1.2	303
304	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	1.0	304
305	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	0.9	305
306	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	0.7	306
307	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	0.5	307
308	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	0.3	308
309	1.4	1.2	1.0	0.9	0.7	0.5	0.3	-0.2	0.0	+0.2	309
310	-1.5	-1.4	-1.2	-1.0	-0.9	-0.7	-0.5	-0.3	-0.2	-0.0	310

For other pressures an additional correction is necessary, the rule above 1,000, and subtract one per cent. for each 10 millibars below."

TABLE III.

TABLE of CORRECTIONS to be applied to BAROMETERS with *Brass Scales* extending from the CISTERN to the top of the MERCURIAL COLUMN, to reduce the observation to 32° Fahrenheit.

Temp.	INCHES.											Temp.
	26°0	26°5	27°0	27°5	28°0	28°5	29°0	29°5	30°0	30°5	31°0	
0	+	+	+	+	+	+	+	+	+	+	+	0
1	·068	·069	·070	·072	·073	·074	·076	·077	·078	·080	·081	1
2	·065	·067	·068	·069	·070	·072	·073	·074	·076	·077	·078	2
3	·063	·064	·065	·067	·068	·069	·070	·072	·073	·074	·075	3
4	·061	·062	·063	·064	·065	·066	·068	·069	·070	·071	·072	4
5	·058	·060	·061	·062	·063	·064	·065	·066	·067	·069	·070	5
6	·056	·057	·058	·059	·060	·061	·062	·064	·065	·066	·067	6
7	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	·064	7
8	·051	·052	·053	·054	·055	·056	·057	·058	·059	·060	·061	8
9	·049	·050	·051	·052	·053	·054	·055	·056	·057	·058	·059	9
10	·046	·047	·048	·049	·050	·051	·052	·053	·054	·054	·055	10
11	·044	·045	·046	·046	·047	·048	·049	·050	·051	·052	·053	11
12	·042	·043	·043	·044	·045	·046	·047	·047	·048	·049	·050	12
13	·039	·040	·041	·042	·042	·043	·044	·044	·045	·046	·047	13
14	·037	·038	·038	·039	·040	·040	·041	·042	·043	·043	·044	14
15	·035	·035	·036	·036	·037	·038	·039	·039	·040	·041	·041	15
16	·032	·033	·033	·034	·035	·035	·036	·036	·037	·038	·038	16
17	·030	·030	·031	·031	·032	·033	·033	·034	·034	·035	·036	17
18	·027	·028	·029	·029	·030	·030	·031	·031	·032	·032	·033	18
19	·025	·026	·026	·027	·027	·028	·028	·029	·029	·030	·030	19
20	·023	·023	·024	·024	·025	·025	·025	·026	·026	·027	·027	20
21	·020	·021	·021	·022	·022	·022	·023	·023	·024	·024	·024	21
22	·018	·018	·019	·019	·020	·020	·020	·021	·021	·021	·022	22
23	·016	·016	·016	·017	·017	·017	·017	·018	·018	·018	·019	23
24	·013	·014	·014	·014	·014	·015	·015	·015	·015	·016	·016	24
25	·011	·011	·011	·012	·012	·012	·012	·012	·013	·013	·013	25
26	·009	·009	·009	·009	·009	·009	·010	·010	·010	·010	·010	26
27	·006	·006	·006	·007	·007	·007	·007	·007	·007	·007	·007	27
28	·004	·004	·004	·004	·004	·004	·004	·004	·004	·005	·005	28
29	·001	·002	·002	·002	·002	·002	·002	·002	·002	·002	·002	29
30	—	—	—	—	—	—	—	—	—	—	—	30
31	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	31
32	·003	·003	·003	·003	·003	·004	·004	·004	·004	·004	·004	32
33	·006	·006	·006	·006	·006	·006	·006	·006	·006	·007	·007	33
34	·008	·008	·008	·008	·008	·009	·009	·009	·009	·009	·009	34
35	·010	·011	·011	·011	·011	·011	·012	·012	·012	·012	·012	35
36	·013	·013	·013	·013	·013	·014	·014	·014	·015	·015	·015	36
37	·015	·015	·016	·016	·016	·017	·017	·017	·017	·018	·018	37
38	·017	·018	·018	·018	·019	·019	·019	·020	·020	·020	·021	38
39	·020	·020	·021	·021	·021	·022	·022	·022	·023	·023	·024	39
40	·022	·023	·023	·023	·024	·024	·025	·025	·026	·026	·026	40
41	·024	·025	·025	·026	·026	·027	·027	·028	·028	·029	·029	41
42	·027	·027	·028	·028	·029	·030	·030	·031	·031	·032	·032	42
43	·029	·030	·030	·031	·031	·032	·033	·033	·034	·034	·035	43
44	·032	·032	·033	·033	·034	·035	·035	·036	·036	·037	·038	44
45	·034	·035	·035	·036	·036	·037	·038	·038	·039	·040	·040	45
46	·036	·037	·038	·038	·039	·040	·040	·041	·042	·043	·043	46
47	·039	·039	·040	·041	·042	·042	·043	·044	·045	·045	·046	47
48	·041	·042	·043	·043	·044	·045	·046	·047	·048	·048	·049	48
49	·043	·044	·045	·046	·047	·048	·049	·050	·051	·051	·052	49
50	·046	·047	·048	·049	·050	·051	·052	·053	·054	·054	·055	50
51	·048	·049	·050	·051	·052	·053	·054	·055	·055	·056	·057	51
52	·050	·052	·052	·053	·054	·055	·056	·057	·058	·059	·060	52

NOTE.—The temperature of the “ATTACHED THERMOMETER” should be used when applying these corrections.

TABLE III.—*cont.*

Temp. °	INCHES.											Temp. °
	26·0	26·5	27·0	27·5	28·0	28·5	29·0	29·5	30·0	30·5	31·0	
51	·053	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	51
52	·055	·056	·057	·058	·059	·060	·061	·062	·064	·065	·066	52
53	·057	·059	·060	·061	·062	·063	·064	·065	·066	·067	·068	53
54	·060	·061	·062	·063	·064	·065	·067	·068	·069	·070	·071	54
55	·062	·063	·064	·065	·067	·068	·069	·071	·072	·073	·074	55
56	·064	·066	·067	·068	·069	·070	·072	·073	·074	·076	·077	56
57	·067	·068	·069	·071	·072	·073	·075	·076	·077	·078	·080	57
58	·069	·071	·072	·073	·074	·076	·077	·078	·080	·081	·082	58
59	·072	·073	·074	·076	·077	·078	·080	·081	·083	·084	·085	59
60	·074	·075	·077	·078	·080	·081	·082	·084	·085	·087	·088	60
61	·076	·078	·079	·080	·082	·084	·085	·087	·088	·090	·091	61
62	·079	·080	·082	·083	·085	·086	·088	·089	·091	·092	·094	62
63	·081	·083	·084	·086	·087	·089	·090	·092	·093	·095	·096	63
64	·083	·085	·086	·088	·090	·092	·093	·095	·096	·097	·099	64
65	·086	·088	·089	·091	·092	·094	·095	·097	·099	·101	·102	65
66	·088	·090	·091	·093	·095	·097	·098	·100	·101	·103	·105	66
67	·090	·092	·094	·096	·097	·099	·101	·102	·104	·106	·108	67
68	·093	·095	·096	·098	·100	·102	·103	·105	·107	·109	·110	68
69	·095	·097	·099	·101	·102	·104	·106	·108	·110	·112	·113	69
70	·097	·099	·101	·103	·105	·107	·109	·111	·112	·114	·116	70
71	·100	·102	·103	·105	·107	·109	·111	·113	·115	·117	·119	71
72	·102	·104	·106	·108	·110	·112	·114	·116	·118	·120	·122	72
73	·104	·106	·108	·110	·112	·114	·116	·118	·120	·123	·124	73
74	·107	·109	·111	·113	·115	·117	·119	·121	·123	·125	·127	74
75	·109	·111	·113	·115	·117	·120	·122	·124	·126	·128	·130	75
76	·111	·113	·116	·118	·120	·122	·124	·126	·128	·131	·133	76
77	·114	·116	·118	·120	·122	·125	·127	·129	·131	·134	·136	77
78	·116	·118	·120	·123	·125	·127	·129	·132	·134	·136	·138	78
79	·118	·121	·123	·125	·127	·130	·132	·135	·137	·139	·141	79
80	·121	·123	·125	·128	·130	·132	·135	·137	·140	·142	·144	80
81	·123	·126	·128	·130	·132	·135	·137	·140	·142	·145	·147	81
82	·125	·128	·130	·133	·135	·138	·140	·143	·145	·148	·149	82
83	·128	·131	·133	·136	·138	·140	·142	·145	·147	·150	·152	83
84	·130	·133	·135	·138	·140	·143	·145	·148	·150	·153	·155	84
85	·132	·135	·137	·140	·143	·146	·148	·151	·153	·156	·158	85
86	·135	·138	·140	·143	·145	·148	·150	·153	·155	·159	·161	86
87	·137	·140	·142	·145	·148	·151	·153	·156	·158	·161	·163	87
88	·139	·143	·145	·148	·150	·153	·155	·159	·161	·164	·166	88
89	·142	·145	·147	·150	·153	·156	·158	·161	·164	·167	·169	89
90	·144	·147	·150	·153	·155	·158	·161	·164	·166	·169	·172	90
91	·146	·150	·152	·155	·158	·161	·163	·167	·169	·172	·175	91
92	·149	·152	·154	·158	·160	·163	·166	·169	·172	·175	·177	92
93	·151	·154	·157	·160	·163	·166	·168	·172	·174	·178	·180	93
94	·153	·157	·159	·163	·165	·169	·171	·174	·177	·180	·183	94
95	·156	·159	·162	·165	·168	·171	·174	·177	·180	·183	·186	95
96	·158	·161	·164	·168	·170	·174	·176	·180	·182	·186	·188	96
97	·160	·164	·167	·170	·173	·176	·179	·182	·185	·188	·191	97
98	·163	·166	·169	·172	·175	·179	·181	·185	·188	·191	·194	98
99	·165	·169	·171	·175	·178	·181	·184	·188	·190	·194	·197	99
100	·167	·171	·174	·177	·180	·184	·187	·190	·193	·197	·200	100

TABLE IV.

REDUCTION of BAROMETRIC READINGS to MEAN SEA LEVEL.
READING, 30 inches.

Height in feet.	Temperature of Air. (Dry Bulb in Screen.)										Height in feet.
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	
5	·006	·006	·006	·006	·006	·006	·006	·005	·005	·005	5
10	·012	·012	·012	·011	·011	·011	·011	·010	·010	·010	10
15	·019	·018	·018	·017	·017	·017	·017	·016	·016	·015	15
20	·025	·024	·023	·023	·023	·022	·022	·021	·021	·020	20
25	·031	·030	·029	·029	·029	·028	·027	·027	·026	·026	25
30	·037	·036	·035	·035	·034	·033	·032	·032	·031	·031	30
35	·043	·042	·041	·041	·040	·039	·038	·037	·037	·036	35
40	·049	·048	·047	·046	·045	·044	·043	·042	·042	·041	40
45	·056	·054	·053	·052	·051	·050	·049	·048	·047	·046	45
50	·062	·060	·059	·058	·056	·055	·054	·053	·052	·051	50
55	·066	·066	·065	·064	·062	·061	·060	·059	·057	·056	55
60	·074	·072	·071	·069	·068	·066	·065	·064	·062	·061	60
65	·080	·078	·077	·075	·074	·072	·071	·069	·068	·066	65
70	·086	·084	·083	·081	·079	·077	·076	·074	·073	·071	70
75	·092	·090	·089	·087	·085	·083	·082	·080	·078	·076	75
80	·098	·096	·094	·092	·091	·089	·087	·085	·083	·081	80
85	·105	·102	·100	·098	·097	·095	·093	·090	·089	·087	85
90	·111	·108	·106	·104	·102	·101	·098	·095	·094	·092	90
95	·117	·114	·112	·110	·108	·106	·103	·101	·099	·097	95
100	·123	·120	·118	·115	·113	·111	·108	·106	·104	·101	100

The correction is always ADDITIVE.

TABLE V.

CORRECTIONS for reducing BAROMETRIC READINGS to STANDARD GRAVITY
in LATITUDE 45°.

Lat. N. or S.	Correction.		Lat. N. or S.	Correction.		Lat. N. or S.	Correction.		Lat. N. or S.	Correction.	
	At 27.	At 30.		At 27.	At 30.		At 27.	At 30.		At 27.	At 30.
•	ins.	ins.	°	ins.	ins.	°	ins.	ins.	°	ins.	ins.
0	— ·070	— ·078	23	— ·049	— ·054	46	+ ·002	+ ·003	69	+ ·052	+ ·058
1	·070	·078	24	·047	·052	47	·005	·005	70	·054	·060
2	·070	·078	25	·045	·050	48	·007	·008	71	·055	·061
3	·070	·077	26	·043	·048	49	·010	·011	72	·057	·063
4	·069	·077	27	·041	·046	50	·012	·013	73	·058	·064
5	·069	·077	28	·039	·043	51	·015	·016	74	·059	·066
6	·068	·076	29	·037	·041	52	·017	·019	75	·061	·067
7	·068	·075	30	·035	·039	53	·019	·021	76	·062	·069
8	·067	·075	31	·033	·036	54	·022	·024	77	·063	·070
9	·067	·074	32	·031	·034	55	·024	·027	78	·064	·071
10	·066	·073	33	·028	·032	56	·026	·029	79	·065	·072
11	·065	·072	34	·026	·029	57	·028	·032	80	·066	·073
12	·064	·071	35	·024	·027	58	·031	·034	81	·067	·074
13	·063	·070	36	·022	·024	59	·033	·036	82	·067	·075
14	·062	·069	37	·019	·021	60	·035	·039	83	·068	·075
15	·061	·067	38	·017	·019	61	·037	·041	84	·068	·076
16	·059	·066	39	·015	·016	62	·039	·043	85	·069	·077
17	·058	·064	40	·012	·013	63	·041	·046	86	·069	·077
18	·057	·063	41	·010	·011	64	·043	·048	87	·070	·077
19	·055	·061	42	·007	·008	65	·045	·050	88	·070	·078
20	·054	·060	43	·005	·005	66	·047	·052	89	·070	·078
21	·052	·058	44	— ·002	— ·003	67	·049	·054	90	+ ·070	+ ·078
22	— ·050	— ·056	45	± 0	± 0	68	+ ·050	+ ·056			

TABLE VI.

TABLE for the CONVERSION of TEMPERATURE READINGS on the FAHRENHEIT and CENTIGRADE SCALES to the ABSOLUTE SCALE.

Fahr.	Cent.	Abs.	Fahr.	Cent.	Abs.	Fahr.	Cent.	Abs.
0	-17.8	255.2	40	+4.4	277.4	80	+26.7	299.7
1	17.2	55.8	41	5.0	78.0	81	27.2	300.2
2	16.7	56.3	42	5.6	78.6	82	27.8	0.8
3	16.1	56.9	43	6.1	79.1	83	28.3	1.3
4	15.6	57.4	44	6.7	79.7	84	28.9	1.9
5	15.0	58.0	45	7.2	80.2	85	29.4	2.4
6	14.4	58.6	46	7.8	80.8	86	30.0	3.0
7	13.9	59.1	47	8.3	81.3	87	30.6	3.6
8	13.3	59.7	48	8.9	81.9	88	31.1	4.1
9	12.8	260.2	49	9.4	282.4	89	31.7	304.7
10	12.2	260.8	50	10.0	283.0	90	32.2	305.2
11	11.7	61.3	51	10.6	83.6	91	32.8	5.8
12	11.1	61.9	52	11.1	84.1	92	33.3	6.3
13	10.6	62.4	53	11.7	84.7	93	33.9	6.9
14	10.0	63.0	54	12.2	85.2	94	34.4	7.4
15	9.4	63.6	55	12.8	85.8	95	35.0	8.0
16	8.9	64.1	56	13.3	86.3	96	35.6	8.6
17	8.3	64.7	57	13.9	86.9	97	36.1	9.1
18	7.8	65.2	58	14.4	87.4	98	36.7	9.7
19	7.2	265.8	59	15.0	288.0	99	37.2	310.2
20	6.7	266.3	60	15.6	288.6	100	37.8	310.8
21	6.1	66.9	61	16.1	89.1	101	38.3	11.3
22	5.6	67.4	62	16.7	89.7	102	38.9	11.9
23	5.0	68.0	63	17.2	90.2	103	39.4	12.4
24	4.4	68.6	64	17.8	90.8	104	40.0	13.0
25	3.9	69.1	65	18.3	91.3	105	40.6	13.6
26	3.3	69.7	66	18.9	91.9	106	41.1	14.1
27	2.8	70.2	67	19.4	92.4	107	41.7	14.7
28	2.2	70.8	68	20.0	93.0	108	42.2	15.2
29	1.7	271.3	69	20.6	293.6	109	42.8	315.8
30	1.1	271.9	70	21.1	294.1	110	43.3	316.3
31	-0.6	72.4	71	21.7	94.7	111	43.9	16.9
32	±0.0	73.0	72	22.2	95.2	112	44.4	17.4
33	+0.6	73.6	73	22.8	95.8	113	45.0	18.0
34	1.1	74.1	74	23.3	96.3	114	45.6	18.6
35	1.7	74.7	75	23.9	96.9	115	46.1	19.1
36	2.2	75.2	76	24.4	97.4	116	46.7	19.7
37	2.8	75.8	77	25.0	98.0	117	47.2	20.2
38	3.3	76.3	78	25.6	98.6	118	47.8	20.8
39	+3.9	276.9	79	+26.1	299.1	119	+48.3	321.3

TABLE VII.

PRESSURE VALUES.

EQUIVALENTS in MILLIBARS and MILLIMETRES of MERCURY of INCHES of
MERCURY at 32° F. in LATITUDE 45°.

Mercury. Inches.	Milli- bars.	Mercury. Milli- metres.	Mercury. Inches.	Milli- bars.	Mercury. Milli- metres.	Mercury. Inches.	Milli- bars.	Mercury. Milli- metres.
27.02	915	686.3	28.35	960	720.1	29.68	1,005	753.8
27.05	916	687.1	28.38	961	720.8	29.71	1,006	754.6
27.08	917	687.8	28.41	962	721.6	29.74	1,007	755.3
27.11	918	688.6	28.44	963	722.3	29.77	1,008	756.1
27.14	919	689.3	28.47	964	723.1	29.80	1,009	756.8
27.17	920	690.1	28.50	965	723.8	29.83	1,010	757.6
27.20	921	690.8	28.53	966	724.6	29.86	1,011	758.3
27.23	922	691.6	28.56	967	725.3	29.89	1,012	759.1
27.26	923	692.3	28.59	968	726.1	29.92	1,013	759.8
27.29	924	693.1	28.62	969	726.8	29.94	1,014	760.6
27.32	925	693.8	28.65	970	727.6	29.97	1,015	761.3
27.35	926	694.6	28.67	971	728.3	30.00	1,016	762.1
27.38	927	695.3	28.70	972	729.1	30.03	1,017	762.8
27.41	928	696.1	28.73	973	729.8	30.06	1,018	763.6
27.44	929	696.8	28.76	974	730.6	30.09	1,019	764.3
27.46	930	697.6	28.79	975	731.3	30.12	1,020	765.1
27.49	931	698.3	28.82	976	732.1	30.15	1,021	765.8
27.52	932	699.1	28.85	977	732.8	30.18	1,022	766.6
27.55	933	699.8	28.88	978	733.6	30.21	1,023	767.3
27.58	934	700.6	28.91	979	734.3	30.24	1,024	768.1
27.61	935	701.3	28.94	980	735.1	30.27	1,025	768.8
27.64	936	702.1	28.97	981	735.8	30.30	1,026	769.6
27.67	937	702.8	29.00	982	736.6	30.33	1,027	770.3
27.70	938	703.6	29.03	983	737.3	30.36	1,028	771.1
27.73	939	704.3	29.06	984	738.1	30.39	1,029	771.8
27.76	940	705.1	29.09	985	738.8	30.42	1,030	772.6
27.79	941	705.8	29.12	986	739.6	30.45	1,031	773.3
27.82	942	706.6	29.15	987	740.3	30.48	1,032	774.1
27.85	943	707.3	29.18	988	741.1	30.51	1,033	774.8
27.88	944	708.1	29.21	989	741.8	30.53	1,034	775.6
27.91	945	708.8	29.24	990	742.6	30.56	1,035	776.3
27.94	946	709.6	29.26	991	743.3	30.59	1,036	777.1
27.97	947	710.3	29.29	992	744.1	30.62	1,037	777.8
28.00	948	711.1	29.32	993	744.8	30.65	1,038	778.6
28.03	949	711.8	29.35	994	745.6	30.68	1,039	779.3
28.05	950	712.6	29.38	995	746.3	30.71	1,040	780.1
28.08	951	713.3	29.41	996	747.1	30.74	1,041	780.8
28.11	952	714.1	29.44	997	747.8	30.77	1,042	781.6
28.14	953	714.8	29.47	998	748.6	30.80	1,043	782.3
28.17	954	715.6	29.50	999	749.3	30.83	1,044	783.1
28.20	955	716.3	29.53	1,000	750.1	30.86	1,045	783.8
28.23	956	717.1	29.56	1,001	750.8	30.89	1,046	784.6
28.26	957	717.8	29.59	1,002	751.6	30.92	1,047	785.3
28.29	958	718.6	29.62	1,003	752.3	30.95	1,048	786.1
28.32	959	719.3	29.65	1,004	753.1	30.98	1,049	786.8

TABLE VIII.—RAINFALL.

MILLIMETRES (0 TO 50) AND TENTHS TO INCHES, CORRECT TO HUNDREDTHS, ON THE BASIS OF 100 mm. = 3·93701 in.

Tenths	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
mm.	Inches.									
0	·00	·00	·01	·01	·02	·02	·02	·03	·03	·04
1	·04	·04	·05	·05	·06	·06	·06	·07	·07	·07
2	·08	·08	·09	·09	·09	·10	·10	·11	·11	·11
3	·12	·12	·13	·13	·13	·14	·14	·15	·15	·15
4	·16	·16	·17	·17	·17	·18	·18	·19	·19	·19
5	·20	·20	·20	·21	·21	·22	·22	·22	·23	·23
6	·24	·24	·24	·25	·25	·26	·26	·26	·27	·27
7	·28	·28	·28	·29	·29	·30	·30	·30	·31	·31
8	·31	·32	·32	·33	·33	·33	·34	·34	·35	·35
9	·35	·36	·36	·37	·37	·37	·38	·38	·39	·39
10	·39	·40	·40	·41	·41	·41	·42	·42	·43	·43
11	·43	·44	·44	·44	·45	·45	·46	·46	·46	·47
12	·47	·48	·48	·48	·49	·49	·50	·50	·50	·51
13	·51	·52	·52	·52	·53	·53	·54	·54	·54	·55
14	·55	·56	·56	·56	·57	·57	·57	·58	·58	·59
15	·59	·59	·60	·60	·61	·61	·61	·62	·62	·63
16	·63	·63	·64	·64	·65	·65	·65	·66	·66	·67
17	·67	·67	·68	·68	·69	·69	·69	·70	·70	·70
18	·71	·71	·72	·72	·72	·73	·73	·74	·74	·74
19	·75	·75	·76	·76	·76	·77	·77	·78	·78	·78
20	·79	·79	·80	·80	·80	·81	·81	·81	·82	·82
21	·83	·83	·83	·84	·84	·85	·85	·85	·86	·86
22	·87	·87	·87	·88	·88	·89	·89	·89	·90	·90
23	·91	·91	·91	·92	·92	·93	·93	·93	·94	·94
24	·95	·95	·95	·96	·96	·96	·97	·97	·98	·98
25	·98	·99	·99	1·00	1·00	1·00	1·01	1·01	1·02	1·02
26	1·02	1·03	1·03	1·04	1·04	1·04	1·05	1·05	1·06	1·06
27	1·06	1·07	1·07	1·07	1·08	1·08	1·09	1·09	1·09	1·10
28	1·10	1·10	1·11	1·11	1·12	1·12	1·13	1·13	1·13	1·14
29	1·14	1·15	1·15	1·15	1·16	1·16	1·17	1·17	1·17	1·18
30	1·18	1·19	1·19	1·19	1·20	1·20	1·20	1·21	1·21	1·22
31	1·22	1·22	1·23	1·23	1·24	1·24	1·24	1·25	1·25	1·26
32	1·26	1·26	1·27	1·27	1·28	1·28	1·28	1·29	1·29	1·30
33	1·30	1·30	1·31	1·31	1·31	1·32	1·32	1·33	1·33	1·33
34	1·34	1·34	1·35	1·35	1·35	1·36	1·36	1·37	1·37	1·37
35	1·38	1·38	1·39	1·39	1·39	1·40	1·40	1·41	1·41	1·41
36	1·42	1·42	1·43	1·43	1·43	1·44	1·44	1·44	1·45	1·45
37	1·46	1·46	1·46	1·47	1·47	1·48	1·48	1·48	1·49	1·49
38	1·50	1·50	1·50	1·51	1·51	1·52	1·52	1·52	1·53	1·53
39	1·54	1·54	1·54	1·55	1·55	1·56	1·56	1·56	1·57	1·57
40	1·57	1·58	1·58	1·59	1·59	1·59	1·60	1·60	1·61	1·61
41	1·61	1·62	1·62	1·63	1·63	1·63	1·64	1·64	1·65	1·65
42	1·65	1·66	1·66	1·67	1·67	1·67	1·68	1·68	1·69	1·69
43	1·69	1·70	1·70	1·70	1·71	1·71	1·72	1·72	1·72	1·73
44	1·73	1·74	1·74	1·74	1·75	1·75	1·76	1·76	1·76	1·77
45	1·77	1·78	1·78	1·78	1·79	1·79	1·80	1·80	1·80	1·81
46	1·81	1·81	1·82	1·82	1·83	1·83	1·83	1·84	1·84	1·85
47	1·85	1·85	1·86	1·86	1·87	1·87	1·87	1·88	1·88	1·89
48	1·89	1·89	1·90	1·90	1·91	1·91	1·91	1·92	1·92	1·93
49	1·93	1·93	1·94	1·94	1·94	1·95	1·95	1·96	1·96	1·96

The table also serves for converting whole millimetres, from 0 to 500, to inches and tenths.

TABLE VIII.—*cont.*—RAINFALL.

MILLIMETRES (50 TO 100) AND TENTHS TO INCHES, CORRECT TO HUNDREDTHS,
ON THE BASIS OF 100 mm.=3·93701 in.

Tenths	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
mm.	Inches.									
50	1·97	1·97	1·98	1·98	1·98	1·99	1·99	2·00	2·00	2·00
51	2·01	2·01	2·02	2·02	2·02	2·03	2·03	2·04	2·04	2·04
52	2·05	2·05	2·06	2·06	2·06	2·07	2·07	2·07	2·08	2·08
53	2·09	2·09	2·09	2·10	2·10	2·11	2·11	2·11	2·12	2·12
54	2·13	2·13	2·13	2·14	2·14	2·15	2·15	2·15	2·16	2·16
55	2·17	2·17	2·17	2·18	2·18	2·19	2·19	2·19	2·20	2·20
56	2·20	2·21	2·21	2·22	2·22	2·22	2·23	2·23	2·24	2·24
57	2·24	2·25	2·25	2·26	2·26	2·26	2·27	2·27	2·28	2·28
58	2·28	2·29	2·29	2·30	2·30	2·30	2·31	2·31	2·31	2·32
59	2·32	2·33	2·33	2·33	2·34	2·34	2·35	2·35	2·35	2·36
60	2·36	2·37	2·37	2·37	2·38	2·38	2·39	2·39	2·39	2·40
61	2·40	2·41	2·41	2·41	2·42	2·42	2·43	2·43	2·43	2·44
62	2·44	2·44	2·45	2·45	2·46	2·46	2·46	2·47	2·47	2·48
63	2·48	2·48	2·49	2·49	2·50	2·50	2·50	2·51	2·51	2·52
64	2·52	2·52	2·53	2·53	2·54	2·54	2·54	2·55	2·55	2·56
65	2·56	2·56	2·57	2·57	2·57	2·58	2·58	2·59	2·59	2·59
66	2·60	2·60	2·61	2·61	2·61	2·62	2·62	2·63	2·63	2·63
67	2·64	2·64	2·65	2·65	2·65	2·66	2·66	2·67	2·67	2·67
68	2·68	2·68	2·69	2·69	2·69	2·70	2·70	2·70	2·71	2·71
69	2·72	2·72	2·72	2·73	2·73	2·74	2·74	2·74	2·75	2·75
70	2·76	2·76	2·76	2·77	2·77	2·78	2·78	2·78	2·79	2·79
71	2·80	2·80	2·80	2·81	2·81	2·81	2·82	2·82	2·83	2·83
72	2·83	2·84	2·84	2·85	2·85	2·85	2·86	2·86	2·87	2·87
73	2·87	2·88	2·88	2·89	2·89	2·89	2·90	2·90	2·91	2·91
74	2·91	2·92	2·92	2·93	2·93	2·93	2·94	2·94	2·94	2·95
75	2·95	2·96	2·96	2·96	2·97	2·97	2·98	2·98	2·98	2·99
76	2·99	3·00	3·00	3·00	3·01	3·01	3·02	3·02	3·02	3·03
77	3·03	3·04	3·04	3·04	3·05	3·05	3·06	3·06	3·06	3·07
78	3·07	3·07	3·08	3·08	3·09	3·09	3·09	3·10	3·10	3·11
79	3·11	3·11	3·12	3·12	3·13	3·13	3·13	3·14	3·14	3·15
80	3·15	3·15	3·16	3·16	3·17	3·17	3·17	3·18	3·18	3·19
81	3·19	3·19	3·20	3·20	3·20	3·21	3·21	3·22	3·22	3·22
82	3·23	3·23	3·24	3·24	3·24	3·25	3·25	3·26	3·26	3·26
83	3·27	3·27	3·28	3·28	3·28	3·29	3·29	3·30	3·30	3·30
84	3·31	3·31	3·31	3·32	3·32	3·33	3·33	3·33	3·34	3·34
85	3·35	3·35	3·35	3·36	3·36	3·37	3·37	3·37	3·38	3·38
86	3·39	3·39	3·39	3·40	3·40	3·41	3·41	3·41	3·42	3·42
87	3·43	3·43	3·43	3·44	3·44	3·44	3·45	3·45	3·46	3·46
88	3·46	3·47	3·47	3·48	3·48	3·48	3·49	3·49	3·50	3·50
89	3·50	3·51	3·51	3·52	3·52	3·52	3·53	3·53	3·54	3·54
90	3·54	3·55	3·55	3·56	3·56	3·56	3·57	3·57	3·57	3·58
91	3·58	3·59	3·59	3·59	3·60	3·60	3·61	3·61	3·61	3·62
92	3·62	3·63	3·63	3·63	3·64	3·64	3·65	3·65	3·65	3·66
93	3·66	3·67	3·67	3·67	3·68	3·68	3·69	3·69	3·69	3·70
94	3·70	3·70	3·71	3·71	3·72	3·72	3·72	3·73	3·73	3·74
95	3·74	3·74	3·75	3·75	3·76	3·76	3·76	3·77	3·77	3·78
96	3·78	3·78	3·79	3·79	3·80	3·80	3·80	3·81	3·81	3·81
97	3·82	3·82	3·83	3·83	3·83	3·84	3·84	3·85	3·85	3·85
98	3·86	3·86	3·87	3·87	3·87	3·88	3·88	3·89	3·89	3·89
99	3·90	3·90	3·91	3·91	3·91	3·92	3·92	3·93	3·93	3·93

The table also serves for converting whole millimetres, from 500 to 1,000, to inches and tenths.

CONVERSION TABLES—LINEAR.

TABLE IX.

TABLE X.
FOR HEIGHTS.

TABLE XI.
FOR VISIBILITY.

Nauti- cal Miles.	Statute Miles.	Kilo- metres.	Feet.	Metres.	Yds.	Metres.	Yds.	Metres.
1	1·2	1·8	1	0·3	5	5	1,000	914
2	2·3	3·7	2	0·6	10	9	2,000	1,829
3	3·5	5·6	3	0·9	20	18	3,000	2,743
4	4·6	7·4	4	1·2	30	27	4,000	3,658
5	5·8	9·3	5	1·5	40	37	5,000	4,572
6	6·9	11·1	6	1·8	50	46	10,000	9,144
7	8·1	13·0	7	2·1	60	55		
8	9·2	14·8	8	2·4	70	64		
9	10·4	16·7	9	2·7	80	73		
10	11·5	18·5	10	3·1	90	82		
20	23·0	37	20	6·1	100	91		
30	34·5	56	30	9·1	200	183		
40	46·1	74	40	12·2	300	274		
50	57·6	92	50	15·2	400	366		
60	69·1	111	100	30·5	500	457		
70	80·6	148	500	152·4	600	549		
80	92·1	130	1,000	304·8	700	640		
90	103·6	167	10,000	3,048·0	800	732		
100	115·2	185			900	823		

Based on Nautical
mile of 6,080 feet.

Based on figures of the Bureau International des
Poids et Mesures.