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AIR MINISTRY

METEOROLOGICAL OFFICE

THE

MARINE OBSERVER'S HANDBOOK

FIFTH EDITION

FOR USE FROM 1st MAY, 1930

Issued by the Authority of the Meteorological Committee

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MARINE OBSERVER'S HANDBOOK.

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LIST OF ILLUSTRATIONS.

THE MARINE OBSERVER'S HANDBOOK.

CHAPTER I.

GENERAL DESCRIPTION OF MARINE METEOROLOGICAL WORK.

This book is primarily intended for the guidance and instruction of the British Corps of Voluntary Marine Observers in carrying out work for the Marine Division of the Meteorological Office, London.

The methods of observation advocated may, however, be applied generally at sea with advantage.

The Meteorological Office was instituted in the year 1854 as a department of the Board of Trade for the purpose of collecting from British ships trustworthy observations for the study of weather 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 for 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 developed 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 International Convention on Safety of Life at Sea, 1929, contains an agreement whereby the governments of the countries party to the Convention undertake to encourage the collection of meteorological data by ships at sea, and to arrange for their examination, dissemination, and exchange in a manner most suitable to aid navigation.

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 currents 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 speed of his vessel with greater economy. The constitution of the office has 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 British ships whose captains have undertaken regular voluntary marine meteorological work 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 for the time being.

Regular observing ships are so disposed as to best provide a network of observations over all oceans. The looseness of the organization is its strength, for under present day conditions of keen competition and commercial rivalry, transfers of officers from ship to ship and transfer of ships to different trades are frequent.

The work of the Corps of Voluntary Marine Observers and regular observing fleet is specialized, and may be summarised as follows:—

(1) The regular recording and return of accurate meteorological observations for statistics and research.

(2) The regular broadcasting of accurate meteorological observations by wireless telegraphy by "**Selected Ships**" for the general purposes of meteorology and navigation afloat and ashore.

(3) The carrying out of experimental work, testing new instruments, making special observations and investigations and generally leading by example in the practical application of marine meteorology to navigation by making weather charts and so on.

This work provides the necessary information for the general service of marine meteorology in the Merchant Navy, and all at sea may benefit therefrom.

In accordance with a resolution of the International Meteorological Conference which met in Copenhagen in 1929, a number of British regular observing ships, proportionate to the British total of the world's tonnage, are detailed as "**Selected Ships**" to broadcast to all ships and report by W/T to specified meteorological centres. The names of these ships are specially indicated monthly in THE MARINE OBSERVER.

A requisite number of ships keep the Meteorological Log and for these purposes 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 thermometers with protectors and a screen, two hydrometers, and in some cases a rain gauge and a barograph may be added to the equipment.

For Routine Wireless Weather reporting, "Selected Ships" may be lent all or any of the following instruments, as found necessary.—One barometer, three ordinary thermometers with protectors and a screen, and a barograph.

A number of packet steamers on cross channel services are supplied with two ordinary thermometers, protectors, and a screen, for the purpose of making special meteorological observations at mid-channel positions on their homeward run, and reporting to the Meteorological Office by telegram.

All other regular observing ships on the list use the ship's instruments only. The port meteorological officers and agents compare these with standards and provide information as to their errors, and generally encourage the proper use and care of meteorological instruments whether the property of the ship or of the Meteorological Office.

Time.

As in navigation the question of time is of great importance in marine meteorology. For the purpose of keeping a general record of meteorological observations in the Meteorological Log for establishing climatological averages and so forth, ship's time is used; either apparent time at ship, or zone time when at sea and local standard times when in port or coasting; and the observations are made at the usual times of the relief of the officer of the watch, viz., midnight, 4 a.m., 8 a.m., noon, 4 p.m., and 8 p.m.

For the purpose of synoptic marine meteorology, and wireless weather signals, Greenwich Mean Time is used, because for these purposes synchronization is of great importance, and therefore the entries in the Meteorological Record of Synchronized Observations are made according to universal Greenwich Mean Times for observation, which are 00, 06, 12 and 18 hours. In hours of darkness these observations are not usually recorded in ships which only have one officer in the watch.

Descriptions of the Various Forms for Observational Work at Sea.

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, Form 915, kept according to ship's time.—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 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, twice daily, synchronized weather observations.

These logs are kept with official tested instruments only, for the purpose of providing standard data. They form the backbone of the work.

Ships keeping the meteorological log are termed for convenience M.L. ships.

Meteorological Record of Synchronized Observations, Form 911, kept according to G.M.T.—Form 911 is ruled as far as possible to accord with the meteorological log, but modified for convenience in coding the observations in the International Ship's Wireless Weather Telegraphy Code. Space is also provided for additional remarks, and for observations of set and drift of current.

Ships keeping Forms 911 are termed for convenience Form ships.

Register for "Selected Ships" Coded Wireless Meteorological Reports, Form 138.—(For use with Meteorological Log, Form 915, and Ships' Meteorological Record, Form 911, synchronised weather observations).—These are supplied to "Selected Ships" only. They are ruled in accordance with the key to the International Ships' Wireless Weather Telegraphy Code, and they contain instructions for coding messages.

Code Card, Form 138A.—A varnished card with the code tables of the International Ships' Wireless Weather Telegraphy Code, together with the schedule for communication, supplied to "Selected Ships" only. (The decode is published yearly in the January MARINE OBSERVER).

Original Note Book, Form 916.—Ruled for eight months exactly similar to the meteorological log (a rough log).

Form 139.—Message form for use between bridge and wireless operator. Supplied to "Selected Ships" only.

Form 912.—Ice Report, supplied to all regular observing ships in trades where ice may be expected.

Form 905.—Report on Cyclones, supplied to any ship as desired.

Form 684.—Special observations of Sea and Swell.

Form 955.—Drift Bottle Paper.

Form 914.—Observations from light ships and coast guard stations in the British Isles.

Form 854.—Form for interception of British Weather Shipping Bulletin.

Form 913.—Blue post card for comparing barometers with standards by post, supplied to all regular observing ships.

Various outline charts for use in making weather charts at sea in all parts of the world are supplied to " Selected Ships " only.

The Return of Meteorological Logs, Records, etc.

The meteorological log Form 915 should be returned on completion, or whether completed or not, at intervals of not more than six months, through the port meteorological officer or agent, accompanied by Form 138 in the case of " Selected Ships ".

The meteorological record Form 911, accompanied by Form 138 in the case of " Selected Ships," should be posted to the address thereon (Meteorological Office, London) at the end of each voyage.

Samples of weather charts, and photographs or sketches, with a view to publication in THE MARINE OBSERVER, should as far as possible be attached to the meteorological log or record covering the period.

The blue post card should be completed and returned at the end of each voyage, or oftener if desirable.

Port Meteorological Officers and Merchant Navy Agents.

To maintain as far as possible regular personal touch with the Corps of Voluntary Marine Observers, and to regulate the supply of loaned instruments to regular observing ships and generally to advise shipping and seamen, the Meteorological Office has branch offices at the London docks and at Liverpool, with a master mariner, specially qualified in marine meteorology, in charge; and at a number of ports in the British Isles, and in the more distant parts of the British Empire, agencies are established, the agents also being master mariners especially interested in the work.

The addresses of these gentlemen are given monthly on the reverse side of the Ice Chart in THE MARINE OBSERVER.

Marine observers are requested to consult the port meteorological officers and agents, and to acquaint them with their requirements. They will visit regular observing ships, supply, inspect, maintain or withdraw instruments, and provide any necessary forms and information for carrying out the work.

Each agency is allotted a certain number of places for regular observing ships in the Fleet List; but no matter what agency port a ship is based upon, all agencies will give special attention to the requirements of any ship on the list.

The Use made of the Data collected.

A committee appointed to consider certain questions relating to the Meteorological Department of the Board of Trade after the death of Admiral FITZROY in 1866 (under whom the Department was instituted) recommended " that knowledge which is obtained through the medium of the observation of sailors, and what is capable of being utilized for their benefit should be so utilized as soon as possible, and that they should feel a confidence that it is so utilized ".

This recommendation, made over sixty years ago, holds good to-day and, therefore, interesting remarks and information are extracted from the logs and records on receipt, and published under the heading of " The Marine Observer's Log " in THE MARINE OBSERVER, usually a year after the occurrence, most of these items being of seasonal interest.

The observations recorded in meteorological logs are extracted and used for many purposes, including the compilation of ocean meteorological charts.

The observations recorded in the meteorological record of synchronized observations, Form 911, are used for the construction of synoptic charts and very largely for answering enquiries as to the state of the weather at the time of shipping casualties.

All observations are available by mutual arrangement for exchange with colonial and foreign meteorological services, and are, therefore, made according to agreement reached through the International Commission for Marine Meteorology.

Upon the receipt of meteorological logs and Forms 911, they are examined and classified according to the value of the observations contained therein and the evidence given of the practical application of the work to navigation. A certain percentage of the best logs and records are classed " Excellent ". Logs and records not reaching this standard, which is set by marine observers themselves, but being of sufficient accuracy and value to comply with requirements are classed " Very Good ". Logs and forms which are good, but which do not comply in all respects with requirements, are classed " Good ", while those which are found upon examination not to meet requirements are " not classed ".

The Hollerith System of Data Extraction.

The method adopted for the extraction and compilation of observations from meteorological logs which have reached the standard of " Very Good " and above, is the Hollerith System. This system is one in which figures can be represented on a card, by holes punched by machine in corresponding positions on the card. Consequently, before the observations can be punched on cards, it is necessary to code them into figures. One card is punched for each 4-hourly set of observations and a specimen of a coded log and the corresponding punched card is reproduced in PLATE I.

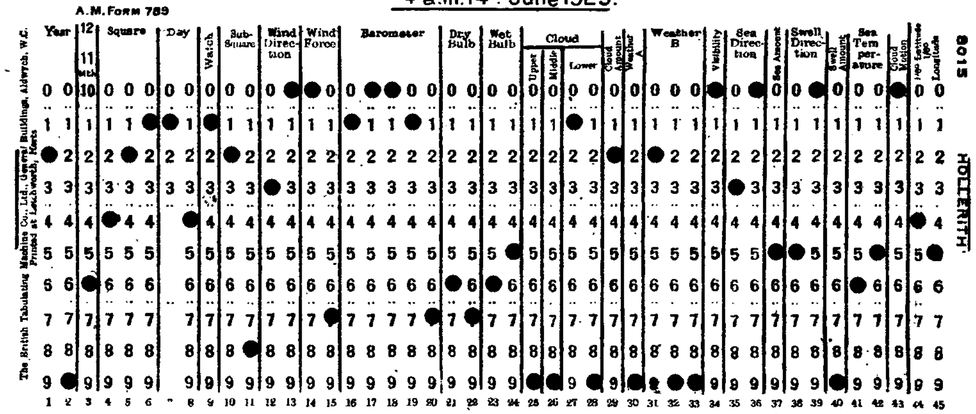
PLATE I. **SPECIMEN OF CODED LOG.*** *To face p. 10*

Meteorological Log kept on board S.S. Cambridge   Captain R. Williams, from Auckland to Balboa.

	DATE. Year 1929 Month VI Day. Civil Time.	Hour, Ship's Time.	Latitude. Observed.	Latitude. Dead Reckoning.	Longitude. Observed.	Longitude. Dead Reckoning.	Current when determined at short intervals.	Course and Distance. Each four hours. True Course.	Distance by Revs.	Wind at the time of observation. Direction. TRUE. (Nearest point)	Force 0 to 12.	Barometer.* No. A2174. Height of Cistern above Sea 46 ft. Uncorrected Reading. Mb.	Att. Therm. Absolute Scale.	True Atmospheric Pressure at Sea Level. The barometer reading corrected for Temperature, Height, Gravity. Marine Observer's Handbook, 6th Edition.	Thermometers. Dry Bulb. No. 28417	Wet Bulb. No. 28415
			The DR. position is desired every watch in addition to those at Noon. When short interval currents are logged, the Observed and DR positions from and to, with times, should also be given.													
421	14	1	2		8					30	07			10017	67	65
	14	4		32 44		138 59		067½°	45·0	NNW	7	1002·7	294	1001·7	67·0	65·0
421		2	2		8					30	08			10032	69	66
		8		32 28		138 01		067½°	51·0	NNW	8	1004·4	294	1003·2	68·5	66·0
421		3	2		7					30	08	29·71		10053	70	67
		NOON	32 11s.	32 10s.	137 05w.	137 18w.		067½°	51·0	NNW	8	1006·7	296	1005·3	70·2	67·0
		4	Current in last hours		°	mls.										

Hour, Ship's Time.	Clouds at time of observation. The direction from which the clouds are moving should be noted when determinable. Names. Upper & Middle.	Lower.	Prop. of Sky Clouded 0 to 10.	Weather at time of observation. According to Beaufort Notation.	Visibility or Fog Intensity.	Sea Surface. Waves. Direction from TRUE.	Amt. 0–9 by Douglas Scale.	Swell. Direction from TRUE.	Amt. 0–9 by Douglas Scale.	Temp. by No. [illegible]	Spec. Grav. by No. [illegible]	Time of Remark.	Remarks. Here give Remarks as to phenomena which cannot be indicated in the other columns, with the times of their occurrence; especially the times of Changes in Direction and Force of Wind, as well as the Direction, Veering or Backing Force and Duration of Squalls: Ice and Derelicts should be reported on Form 912. Also note the hour at which the Ship arrives in or leaves Port. (See "Marine Observer's Handbook" for further particulars.)	Rainfall by Gauge. mm.
	99	19	2	9299	0	30	5	50	9	65	045			
4		St. cu.	2	bq		NNW	5	Confd.	9	65·0				
	69	13	9	9999	0	30	5	50	9	66	020			
8	Ci.st./Ci.cu.	St.cu/Cu NNW 3	9	o		NNW	5	Confd.	9	66·0				
	99	39	5	9999	0	30	5	30	7	67	010			
NOON		Cu NNW 1	5	bc		NNW	5	NNW	7	67·5	26·0			
4														

SPECIMEN OF CORRESPONDING PUNCHED CARD.
4 a.m. 14th June 1929.



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The punched cards are dealt with by two machines: (1) The Hollerith Electrical Sorter, (2) The Hollerith Electric Tabulating and Printing Machine. In the sorting machine, each column of the card can be sorted into numerical sequence and this machine is used for the sorting and grouping of cards, e.g., the grouping of observations to provide the data for the construction of wind roses, etc. By running the cards through the electrical tabulating and printing machine, any selected number of columns can be totalled and the number of cards going through the machine counted. In addition, this machine is fitted with a printing attachment, which, if required, prints the figures corresponding to the holes punched on each individual card, so that it is possible to list the whole of the observations as well as obtain totals.

The observations on cards are assembled and stowed in geographical areas of 10° of latitude by 10° of longitude, each " 10° Square " being numbered in accordance with Marsden's Chart. Two Marsden Charts are published each year in the June number of THE MARINE OBSERVER, with " Work of the Year ", one showing the number of observations in each " 10° Square ", punched on to cards during the current year and the other, the total number of observations in each " 10° Square " extracted since 1920, in order that all concerned may be aware of the progress that is being made in utilizing the observations returned in meteorological logs and to indicate the data available for research and exchange.

The Marsden " 10° Square " is sub-divided into a hundred " 1° Squares ", and provision is made on the card for punching the position of the ship at the time of observation to within 10 minutes of latitude and longitude.

The three main advantages of this system are: accuracy, the ease and saving in computation when sufficient punched cards are available, and the facilities that the printing of observations offers for international exchange of data.

Already it has been possible to carry out several investigations which have produced valuable information for the benefit of seamen. Using this system, tables of corrections for the diurnal range of the barometer have been computed for the North and South Tropics. These provide information which is usetul for comparing the barometer with normals so that the exact departure from normal can be ascertained, thus providing means for judging whether there is likelihood of a tropical revolving storm. Wind roses, with the frequency of fog occurring with each wind direction, for all months of the year for the south-west approaches to the British Isles and the approaches to Table Bay, Cape of Good Hope, have also been constructed from calculations made by this system, which are useful when making a landfall in these regions. These have been published in THE MARINE OBSERVER.

Since these machines can only deal with figures, the remarks of special phenomena are indexed, 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 greater than it was in the old system. Observers are, therefore, requested to use every care to facilitate the computers' work in this respect.

The Marine Observer.

Acknowledgment, Recognition, and Return for Voluntary Work at Sea.

THE MARINE OBSERVER is issued monthly to every observing ship in the Fleet List which is published at the end of each number. With this list is published a monthly acknowledgment of all returns received from regular observing ships since the previous issue.

This review of the Marine Division of the Meteorological Office in co-operation with voluntary marine observers contains articles and information of interest and practical use at sea. In it are given weather signals, wireless and visual, useful to shipping in all parts of the world, and advice to marine observers for the conduct of the work.

A number of pages entitled "The Marine Observer's Log" are reserved for extracts from meteorological logs and Forms 911, together with the experiences of marine observers. This is a special feature of the magazine and with it many beautiful illustrations by seamen are published.

Yearly, in the June number, a report entitled "Work of the Year" is published, with a list of the names of the captains and principal observing officers, with the names of their ships, to whom the Meteorological Committee have made excellent awards in special recognition of very fine work. These awards usually take the form of a handsomely bound volume of THE MARINE OBSERVER, inscribed with the name of the recipient.

Ocean meteorological charts are also supplied to regular observing ships.

Particulars desired from Intending Marine Observers.

Commanders and officers who wish to have the names of their ships placed on the list of regular observing ships, or commanders on transfer from one ship to another who wish to continue will greatly assist by furnishing the following particulars to the agents at the ports, or at ports where agencies do not exist, to the Marine Superintendent, Meteorological Office, London :—

Name of ship.
Steam, motor or rig.
Port of registry.
Gross tonnage.
Description of barometer carried.
Readings of barometer for comparison.
Nature of W/T installation.
Name of captain.
No. of B. of T. certificate.
Owners.
Address.
Name of officer detailed as principal observer.

When a commander on transfer wishes to take the place of his ship in the Fleet List to his new command, he should in sending notification state whether his relief wishes to carry on or not.

It should be understood that this service is entirely voluntary and is for the specific purpose of aiding and improving navigation, and for the advancement of meteorological science.

It should be understood that the commanders of ships who volunteer to do this work and are placed on the list, undertake to advise the Marine Superintendent or the appropriate agent when they are transferred to another ship, or if they are for any reason unable to carry out the work and make returns regularly.

They undertake that if their ship is detailed as a " Selected Ship," circumstances permitting, they will make two coded wireless weather reports daily of observations, taken at the prescribed times, to all ships and such stations as are specified.

General Application of Marine Meteorology to Safe Navigation.

Though it is only possible for the Marine Division of the Meteorological Office to undertake the supervision of the voluntary work of 500 regular observing ships, every endeavour is made to encourage the general application of marine meteorology as an aid to navigation throughout the Merchant Navy.

Experience has proved that over collection of regular written returns from shipping is detrimental to efficiency and that this work is better left to a fixed number of ships whose commanders and officers are specially interested and have the necessary facilities.

The owners of any ship not entitled to receive literature in return for specialized voluntary meteorological work at sea, can purchase the same published information as is supplied to regular observing ships, from H.M. Stationery Office ; and all ships can receive free of charge information by wireless issued in Weather Shipping Bulletins, as well as the reports from " Selected Ships."

For information and guidance of seamen in this connexion a book entitled WIRELESS AND WEATHER AN AID TO NAVIGATION has been published ; and a pamphlet entitled " Decode for use with the International Code for Wireless Weather Messages from Ships," may be purchased of H.M. Stationery Office, or any bookseller, price 3*d*.

CHAPTER II.

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 port meteorological officers or agents, and are delivered by hand to ships. The barometer will be found in its specially designed box.

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. 17.

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 position 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 unauthorized 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 minimize 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 from sunny decks, deck houses, etc. The thermometer screen should be removed 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 be aimed at, is 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. When not in use it may be stowed as most convenient.

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 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 new standard marine mercurial barometers lent by the Meteorological Office are now provided with a case so fitted that it may conveniently be used in dock or harbour as a means of lock-up, without removing the barometer from its sea position. Figure 1 shows the case, with suspension arm socket secured within it and barometer in sea position. The case should be firmly secured to the bulkhead. The socket is screwed to the bottom of the case, and a clip "A" is provided to hold the barometer in its stowed position when in port. A hook should be fitted to secure the lid open while at sea.

The Barograph, when used on board ship, should be placed on a suitably cushioned bed or 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.

The Louvred Screen for the thermometers is of two types, known as the Portable (large) and the Modified (small). Both are louvred on all four sides and may be exposed in sun or shade, preferably slung from an awning spar or ridge rope, so as to have an unimpeded circulation of air flowing through them. It is desirable 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 36, and, therefore, the position may require to be changed with shifts of wind and/or alterations of course.

The two thermometers in their protectors (see page 36) 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.

Instruments should be returned by hand from ships to the appropriate port meteorological officer or agent.

When this is not possible, as for example at ports where there are no agents, before barometers are sent by train, application should be made to the Marine Superintendent in London, for advice and instructions.

To face page 16.

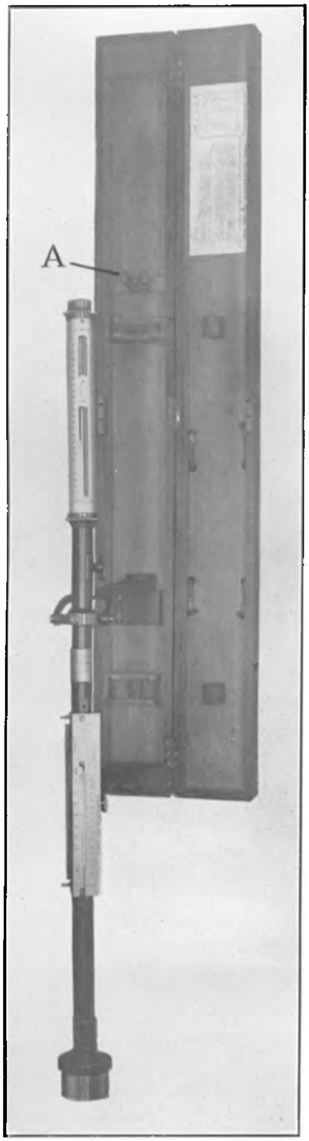


FIG. 1.

How to Pack Instruments for Return to the Meteorological Office.

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 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 labelled " 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 passenger train 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 cistern should be unscrewed, the mercury poured out, and the cistern then replaced after making certain that there is no mercury left in the instrument. The loose mercury should be placed in a strong glass or stone bottle, securely corked and packed carefully inside the box. These precautions are particularly necessary when the barometer is fitted with a Gold correction slide.

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. In this case a " Dooly ", which is a specially designed crate, with long handles, in which to pack the barometer will be sent ; instructions for packing being contained therein.

CHAPTER III.

THE BAROMETER.

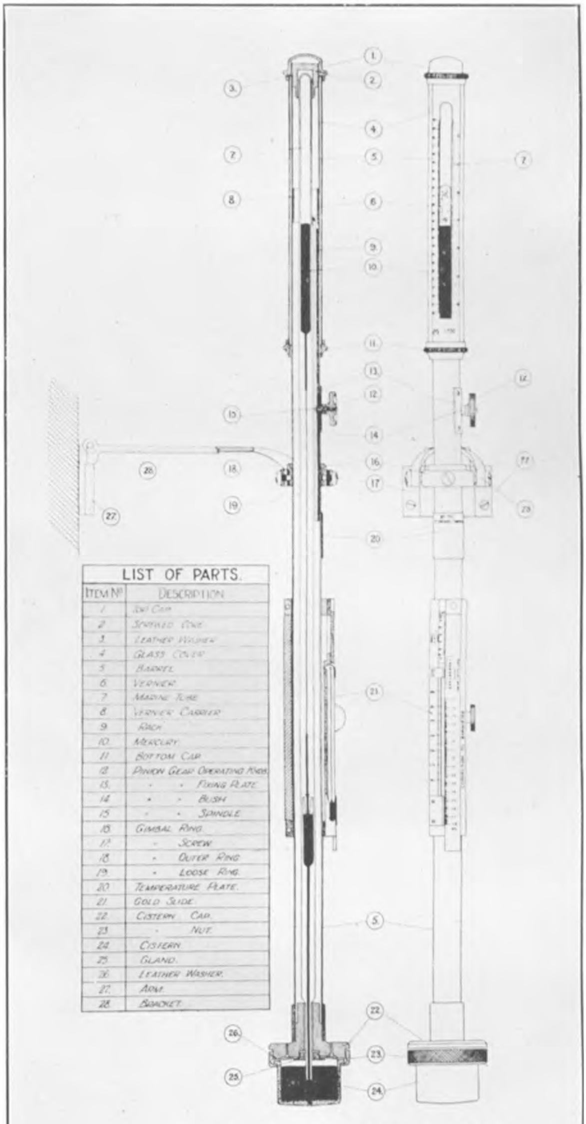
The barometer is an instrument with which to measure the weight or pressure of the atmosphere. Two kinds are in use for observations at sea, the mercury and the aneroid.

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 pressure, 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 admits access to the superincumbent air ; and a washer of leather permits of the atmosphere exerting pressure, but prevents 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.

Standardisation of the Parts of the Marine Barometer.

It has been recognized for some time that marine mercurial barometers could be more efficiently and economically maintained if they were all of one pattern with interchangeable parts. The barometers at present in use have the same general form and all have passed the schedule of tests at the National Physical Laboratory so that the necessary standard of accuracy has been ensured. The makers were, however, allowed a considerable amount of latitude in matters of detail with the result that accessories such as glass covers to scale and vernier, attached thermometers, gimbal fittings and suspension arms were of many patterns. It has, therefore, been necessary for agents and observers, however far away from London, to return the whole barometer to the Meteorological Office in the case of a breakage or replacement.

To face page 19.



STANDARD PATTERN MARINE BAROMETER
With Gold Slide for effecting corrections.

FIG. 2.

The Instruments Division of the Meteorological Office was therefore asked to draw up specifications for a standardized marine barometer. This was done and a number of the instruments have subsequently been made and tested with very satisfactory results. An illustration of this new standard pattern marine barometer is given in Figure 2.

The important points in the new instrument are not seen from the outside, the only striking difference from the older patterns being in the cistern, which is not black but is made of bright stainless steel. In the following brief account, therefore, the main features are explained.

The Barometer Tube.—This is made of English lead glass and is built up of several parts as shown in Figure 2. At the top is the part seen when reading the barometer, a plain cylinder the bore of which is ·315 of an inch. Below this, in order, follow a tube of bore ·063 of an inch, a length of fine capillary tubing, the air-trap, another length of ·063 inch tubing and, lastly, the dipping tube which extends into the cistern. Generally speaking the wider the bore of the upper part of the tube the better, but it cannot be made very wide as the cistern would have to be very large to contain the mercury when the barometer is reading low. The bore of ·315 of an inch, which is appreciably larger than in some of the old patterns, has been chosen as a convenient size, which also gives a good curvature to the upper surface of the mercury, hence rendering the instrument easy to read.

The fine capillary tube is for the purpose of reducing the amount of "pumping." In some old barometers the tube was merely pinched or constricted at a point. It is unfortunately impossible to reduce "pumping" without making the barometer sluggish, and therefore a marine barometer always indicates pressure changes a little later than they actually occur. This delay is called the "lagging time." For all practical purposes it may be assumed that a reading with one of the new barometers gives the accurate value of the pressure 4·5 minutes before the time of reading. These instruments have been constructed so that the "falling time" is exactly the same as the "lagging time." The "falling time" is found by inclining the tube until the mercury fills the top of the tube, bringing it back to the vertical, and then timing the fall of the mercury between two definite points on the tube. These points were chosen shortly after the introduction of the marine barometer in 1854 and were 1·5 and 0·5 inches above the undisturbed level of the mercury. In the new barometers the points are nearly the same; expressed in millibars they are 50 mb. and 18 mb. above the undisturbed reading. The old specification for marine barometers stated that the falling time must lie between 3 minutes and 6 minutes. In those instruments which had capillary tubes the lagging time was roughly equal to the falling time, the relationship not being as exact as in the new barometers.

The dipping tube which enters the cistern has an external diameter of ·236 of an inch; the open end is located exactly at the centre of the cistern, this position being the best for the prevention of accidental admission of air.

The Cistern.—As is well known it is very important to keep the mercury of a barometer as clean as possible, otherwise the index error of the instrument will be altered, with a resulting error in the corrected reading. Stainless steel has been used for the cisterns of the new instruments as it has been found by experiment that it keeps the mercury cleaner. The new cistern is also larger than the old, thus giving the following advantages:—

(*a*) A lessened risk of getting air into the tube in transport, since the tube dips more deeply into the mercury.

(*b*) The scale is easier to read since the divisions are further apart (or as it is called, a more open scale).

(*c*) The corrections are more uniform over the whole range of fluctuation of the mercury.

There is only one disadvantage in the use of a large cistern, namely the increase in weight due to the additional quantity of mercury. In the new instruments this increase is nearly compensated by making the walls of the cistern much thinner so that there is little noticeable increase in total weight.

The Brass Case and Accessories.—Apart from the tube and cistern, the marine barometer consists of a brass outer case, at the top of which the scale or scales are engraved, and which also carries the glass shade, the vernier and its actuating screw, the gimbal ring and attached thermometer. Little need be said about these except that the best available designs have been adopted and the dimensions standardized. The gimbal ring is brazed to the tube for security, since it has to carry the entire weight of the barometer. Theory and experiment both indicate that the point of suspension of the barometer should be as high up the case as possible and the gimbal ring is, therefore, attached as near as may be to the pinion which actuates the vernier. A high point of support tends to reduce the error due to oscillation of the barometer when the ship is rolling or pitching.

The arm on which the barometer is supported when in use has been strengthened by the introduction of a ridge, giving it a **T** section. Its dimensions and those of the socket screwed to the bulkhead have, of course, been standardized.

The Measurement of Barometric Pressure in Pressure Units.

Until some years ago it was the general 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 ·01 of an inch is barely accurate enough for scientific work, whereas to read to ·001 of an inch is not practicable, at any rate at sea. On the millibar scale, however, ·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 29·53 in., or 750·1 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 Merchant Navy, which are issued by the Meteorological Office, are normally graduated in millibars, and can be read to tenths. Some barometers in use have, in addition, an inch scale which can be read by vernier to half hundredths of an inch.

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.

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*a* to 305*a* and is entered in the appropriate column of the original note-book or record.

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

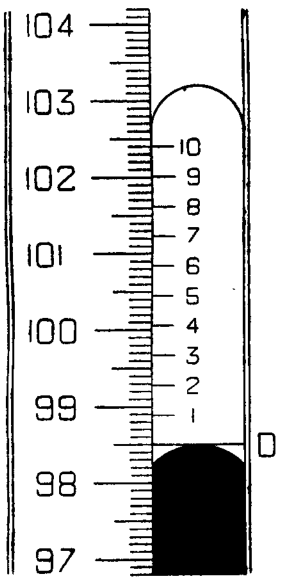


FIG. 3.

READING THE SCALE.

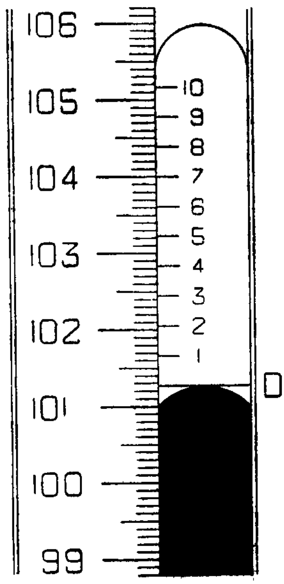


FIG. 4.

it assists the eye. Figures 3 and 4 illustrate this. If the 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 Figure 5. The vernier is read in just the same way as that of a sextant. The reading will be speedily mastered by examining Figures 3 and 4, that of Figure 3 being 985·0 millibars and that of Figure 4 being 1012·7 millibars.

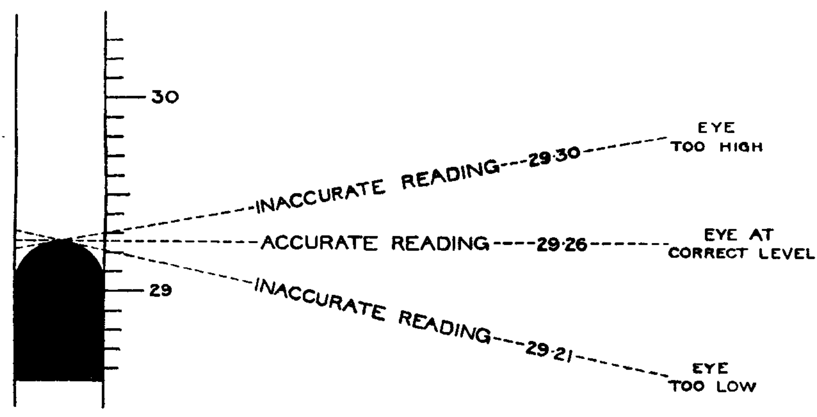


FIG. 5.

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 and the references to temperature in the following instructions are to the readings on that scale.

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 at 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 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 pages 98 to 103. They are used as follows:—

The height of the cistern above sea-level having been determined, the table on pages 98 and 99 is used and the value of the *fiducial temperature* for the latitude of the ship is made out by adding or subtracting the figures given in that table to the *standard temperature.*

Having determined the adjusted fiducial temperature for the latitude, the table on pages 100 to 103 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 1,000 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.

Standard temperature of barometer..	..		285·0a
Ship's latitude, 32° 39′ } Height of barometer above sea level, 42 ft. }	Correction from Table I ..	+	2·4a
Adjusted fiducial temperature	.. ..		287·4a
Attached thermometer reading	.. ..		293·0a
From Table II—*Correction* ..	.. ..	−	1·0 mb.
Observed barometric reading	.. ..		1016·9 mb.
Correction as above	.. ..	−	1·0 mb.
Corrected barometric reading	.. ..		1015·9 mb.

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

Marine mercurial barometers issued by the Meteorological Office are fitted with a Gold Slide (so named after the inventor, Lieutenant Colonel E. GOLD, D.S.O.) which was devised to facilitate the correction of barometer readings for temperature, height and gravity, without reference to the Tables.

The Slide, Mark IV, consists of a thermometer mounted alongside a scale marked " Correction to Barometer," the latter being movable by rack and pinion. At the top of the slide are two scales, one marked " Latitude " and the other marked " Height above Water Line." The whole is clamped to the barometer by means of screws.

The latitude scale is engraved on a strip of metal, which is adjusted alongside an " Index Scale," to allow for the index error of the instrument. *This necessary adjustment is made in the Meteorological Office before the barometer is issued,* and the latitude scale should therefore not be moved.

To use the apparatus, move the slide up or down so that the height of the barometer above the water line, indicated by the scale, coincides with the latitude of the ship on the latitude scale. The correction to be applied to the barometer reading is then read off in line with the top of the mercury column in the thermometer.

To check that the slide is correctly adjusted when the instrument is first placed in position, set the height scale so that zero for height coincides with 45° on the latitude scale. Then read 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.

There are a number of older pattern (Mark III) scales in use, in which the " Index " scale is omitted ; but these scales are also adjusted for index error of the instrument before issue.

Care of Gold Slides.—The scales, which are silvered, may be kept clean by using a soft cloth to remove any dust or dirt. Metal polish should never be applied.

A very little clock-oil may occasionally be used for lubrication.

If the rack and pinion become very stiff a responsible officer may overhaul as follows.

Remove the slide from the barometer and place it face downward. A small brass block securing the pinion in position will then be seen. Remove this by taking out the four screws. Wipe the pinion and its bearing with a soft rag to remove dirt and old oil ; apply a little fresh clock oil. Now remove the four small screws, two at each end of the rack. The slider can then be taken out. Wipe off all dirt and old oil from the rack and bearing surfaces. Put a drop of fresh clock oil on the rack and on the back of the slider. Reassemble, taking care to see that the pinion is properly engaged in the rack before tightening the screws. The slider should then move up and down quite smoothly.

The screws which secure the " latitude " scale should not be touched during this operation. Before replacing the slide on the barometer it is desirable to check the adjustment by the methods previously described.

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

Although the pressure unit (the millibar) has been adopted for official use 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 (page 22). 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 ·005 in. The divisions on the fixed scale are each ·050 in. It is not usual, however, to record the height of the barometer at sea to thousands of an inch ; readings to hundredths are sufficiently accurate in temperate latitudes, but within the tropics an accuracy of half-hundredths should be used.

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

Example.—In latitude 51° N., barometer reads 30·240 at a height of 36 ft. above sea-level. The attached thermometer reads 58° F., and the index error is + ·005.

		Inches.
Uncorrected reading		30·240
Index error correction	+	·005
		30·245
Temperature correction for 58° F. (Table III) ..	—	·080
		30·165
Height correction for 36 ft. at air temperature of 58° F. (Table IV)	+	·039
		30·204
Gravity correction in latitude 51° N. (Table V)	+	·016
		30·220

Conversion of Millibars to Inches.

A table for the conversion of barometer readings in Millibars to Inches, or vice versa, is given in Table VI.

It must be clearly understood that in barometers graduated in both the Millibar and Inch Scales, the *uncorrected* readings taken at the same time will differ. The reason for this is that the millibar graduation is constructed to give the true atmospheric pressure at its standard temperature of about 285°A (*54°F.*) at sea level in Latitude 45° ; whereas the inch scale is graduated to give true atmospheric pressure at a temperature of *28·6°F.* at sea level in latitude 45°.

It will thus be seen that the correction for temperature is different for each scale, and it is only when both readings have been fully corrected that they will agree.

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 original notebook, 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.

A case recently occurred (in 1929) where a ship in the Eastern North Atlantic reported the barometer 10 millibars lower than it really was. Due to this, it was supposed that a secondary had formed to the west of Ireland, and gale warnings were issued for the north west coasts of the British Isles. Thus the forecasting was thrown out through an error in the " tens."

Parallax has been mentioned on page 23 ; 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.

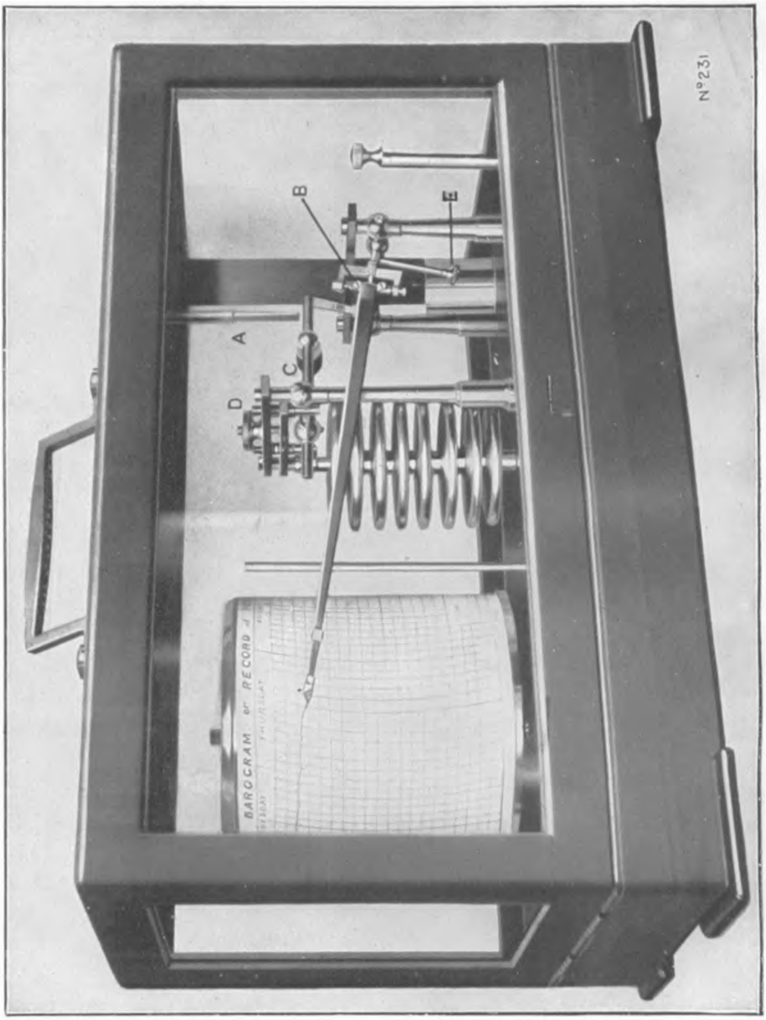
It is found that the effect of having the door of the charthouse, in which the barometer is situated, open or closed, is to alter the height of the mercury column. This is especially true in strong winds. The doors should, therefore, be closed while the barometer is being read, if there is much wind.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

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



THE BAROGRAPH.

(*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 :—

Highest Reading.		*Lowest Reading.*
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.

The Aneroid Barometer.

This instrument is not lent to regular observing ships ; but there are so many in use at sea that a short description will be useful.

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 record as a guide to persons consulting the data.

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 by the Meteorological Office is a combined result, and makes allowance for both height and index error.

The Barograph.

A portable barograph (Plate II), 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 useful for obtaining a continuous record of barometric pressure. 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 to the association of these minor fluctuations of pressure disclosed by the barogram, 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 connexion 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 barograph should be kept to Greenwich Mean Time throughout the voyage. Time marks should be made each day at noon, ship's time, 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.

Barographs require constant attention and care.

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 good clock oil, care being taken to remove excess of oil.

The most 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 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.

Change of Barometer or Barometric Tendency.

The change or tendency of the barometer has always been of first significance to seamen in the indications of this instrument.

Since the synoptic method came into use with wireless telegraphy communication at sea, observation of absolute atmospheric pressure has become more necessary for providing information of pressure distribution. When this is known, the change or tendency of the barometer is of still greater importance.

In all well-ordered ships the barometer is logged at the end of each watch, and sometimes every 2 hours. Therefore it is generally possible to ascertain the exact change or tendency of the barometer.

To find the change of the barometer, it is not necessary to correct the readings, as is done to find the absolute pressure.

For the purpose of reporting the change or tendency of the barometer in code by wireless, Table VII, page 108, adapted from the International Ships' Weather Telegraphy Code should be used.

To find and record the tendency of the barometer with this table, take the difference and the interval between recorded readings ; if the interval is not exactly 2, 3 or 4 hours, interpolate between the values given in Table VII. When possible, an interval of exactly 3 hours should be used.

To estimate the true tendency of the barometer at any position in a ship under way, it is necessary to allow for course and speed, and, therefore, in reporting tendency the course and speed made during the interval of observation should be reported.

Change or Tendency of the Barometer by Barograph.

By means of the barograph it is possible to report exactly what the changes have been.

Table VIII, page 108, is adapted from the International Ships' Weather Telegraphy Code. This gives what is called the " Characteristic " of the changes of the barometer during the last three hours.

Figure 6 illustrates each of the characteristics given in this Table, and from Table IX, page 109, the amount of the change, rise or fall, otherwise known as the Tendency may be given, by comparing the level of the pen at the time of observation with its level as indicated on the trace, three hours previously.

When this method is used for reporting by " Selected Ships " the barogram with trace should be attached to the meteorological record of synchronized observations, when it is returned to the Meteorological Office, London.

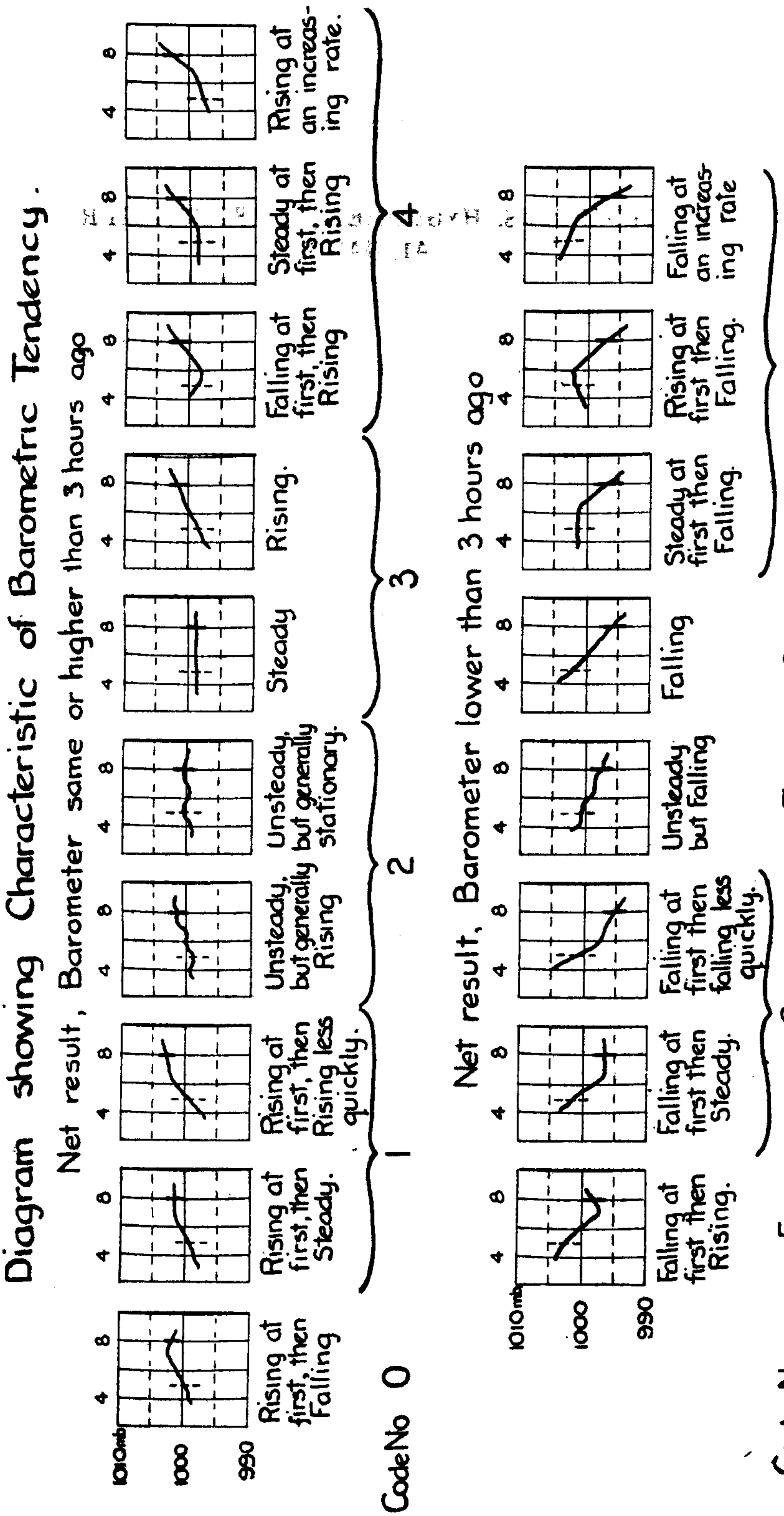


Diagram showing Characteristic of Barometric Tendency.
Net result, Barometer same or higher than 3 hours ago
1010mb
1000
990
4
8
Rising at first, then Falling
Rising at first, then Steady.
Rising at first, then Rising less quickly.
Unsteady, but generally Rising
Unsteady, but generally stationary.
Steady
Rising.
Falling at first, then Rising
Steady at first, then Rising
Rising at an increasing rate.
Code No 0
1
2
3
4
Net result, Barometer lower than 3 hours ago
Falling at first then Rising.
Falling at first then Steady.
Falling at first then falling less quickly.
Unsteady but Falling
Falling
Steady at first then Falling.
Rising at first then Falling.
Falling at an increasing rate
Code No
5
6
7
8
9

FIG. 6.

CHAPTER IV.

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. 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°.

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 X 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 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

* 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.

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 louvres, so as to let in the air freely.

The annexed photograph (Plate III) 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 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 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.

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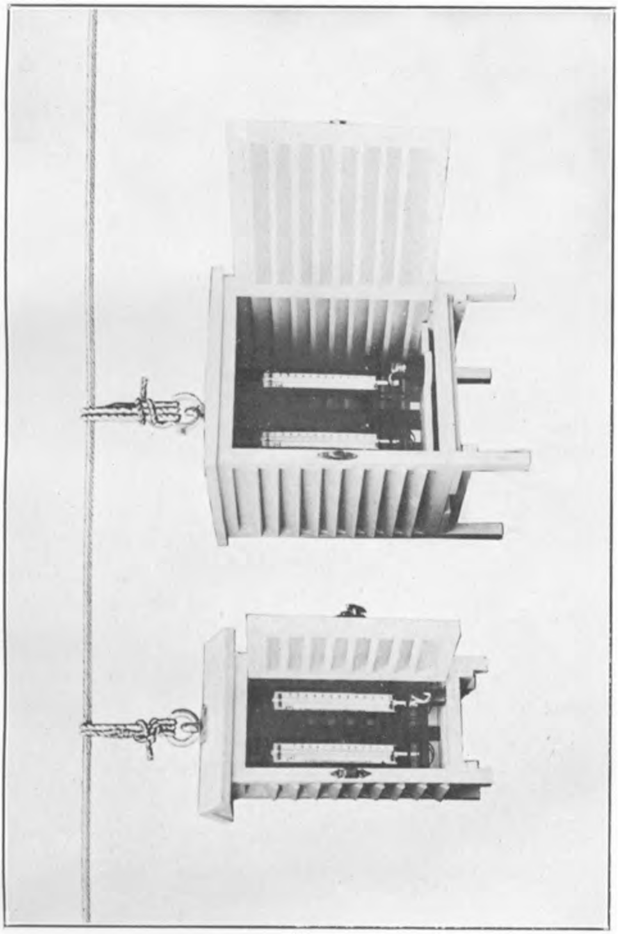
* To secure the strands to the thermometer, take a round turn with the strands middled on the bight and pass the ends through the bight forming a round turn and cow hitch.

METEOROLOGICAL OFFICE.

SHIP'S THERMOMETER SCREENS.



Modified, with Thermometer Protectors.

Portable, with Thermometer Protectors.

The glass, or other small holder of water should be as far as possible from the dry thermometer, as in Plate III. 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 (page 36) 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 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 under a weather cloth.

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.

For the purpose of ascertaining the humidity and dew point, Tables XI and XII may be used. In each table a line is ruled to call attention to the fact that above the line evaporation is going on from a water surface but below the line it is going on from an ice surface. Owing to this, interpolation cannot be made between figures on different sides of this line.

Air and Sea Thermometer Protectors.

In order to minimize the breakage of thermometers mahogany protectors are now supplied as illustrated in Figure 7. 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.

Sea Surface Temperature.

An ordinary thermometer fitted with a sea thermometer protector is used for surface temperature observation.

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.

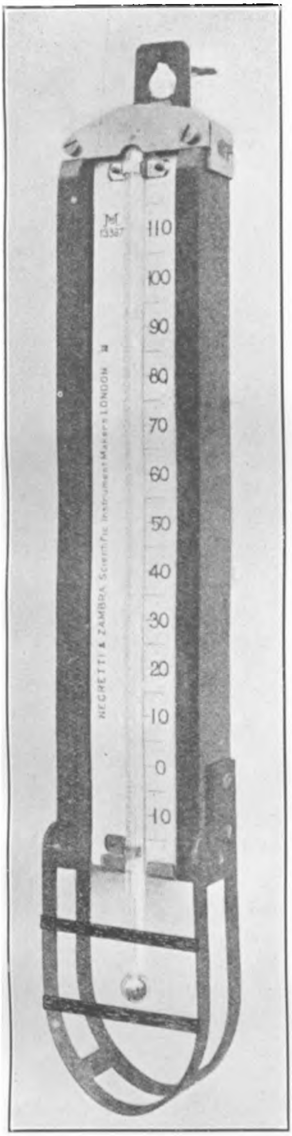
Reading Thermometers.

To avoid errors due to *parallax* (*vide* page 23) the observer's eye must be at precisely the same height as the top of the mercury column of the thermometer.

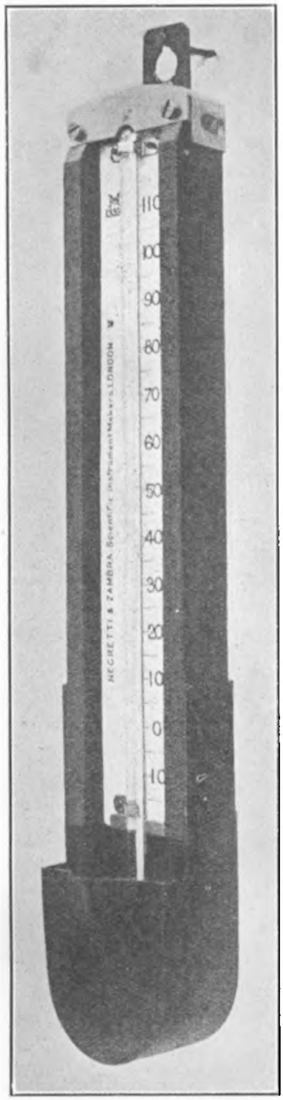
In order to obtain satisfactory results from the observations of the dry and wet-bulb thermometers, the values must be known with accuracy; hence the observer should, when reading these instruments, estimate fractions of a degree to the nearest *tenth*.

To face page 38.

MAHOGANY PROTECTORS FOR THERMOMETERS.



AIR PROTECTOR.



SEA PROTECTOR.

FIG. 7.

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.

This instrument is not lent by the Meteorological Office to regular observing ships, but as they are occasionally carried in some ships, a few remarks will be useful.

A self-recording thermometer, or thermograph, may be used 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, to be an aid in foretelling changes in weather conditions.

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.

Thermographs for meteorological use should be exposed on deck, preferably in a louvred 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.

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

The Sea Thermograph.

This instrument has not yet been adopted by the London Meteorological Office.

A thermograph for reading the sea temperature at the depth of the ships' main inlet has, however, been used with success by the Canadian Meteorological Service. This instrument is attached to the main inlet in the engine room, and keeps a continuous record of the temperature of the sea through which the ship steams. It, therefore, may prove of considerable value in the investigation of ocean currents, oceanographical research, and the climatology of the sea.

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 Figure 8. It consists of a glass tube and a float, with a bulb at the end partly filled with small shot, to act as ballast and to make the instrument float

FIG. 8.

FIG. 9.

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 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 height of an equal volume of pure water at standard temperature, namely, 277A (4 C., or 39·2 °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 specific gravity of the sea should be entered in the meteorological log when at sea at noon daily.

The Hydrometer in Port.

During the last year or two, requests have been received for information of the specific gravity of water at loading ports abroad and we have not been able to provide it.

Some years ago consideration was given as to whether the hydrometer should retain its place in the instrumental equipment of the meteorological log keeping ships. It was retained because it was pointed out that though observations of the specific gravity of sea water had been taken all over the oceans for many years, this instrument was useful to the master and officers of ships to determine the specific gravity at loading berths so that they could make the correct allowance for change of draught.

The recording of hydrometer observations at sea has continued satisfactorily and no doubt many ships supplied with this instrument observe the specific gravity for the purpose of the ship's draught in port but they do not enter the observations taken in port in the meteorological log.

In view of the need for information of the specific gravity of water in harbours and ports in all parts of the world, marine observers are asked when in port, to observe and record once daily the specific gravity of the water. These observations may be conveniently entered at the end of the log. The date, time, port and berth should be given, also the state of the tide, together with information of freshets or other conditions which may temporarily affect the density of the water.

In order to facilitate these observations in ports where the specific gravity may fall below 15 it is proposed to replace the original pattern which was capable of measuring the specific gravity from 1000 to 1040, as in Figure 9.

Reading the Hydrometer.

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.

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.

Correction of Readings.

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 specially detailed ships on certain routes for the Board of Agriculture and Fisheries, and the chemical analysis is made by the Government chemist. This is referred to in Chapter VIII.

To face page 43.

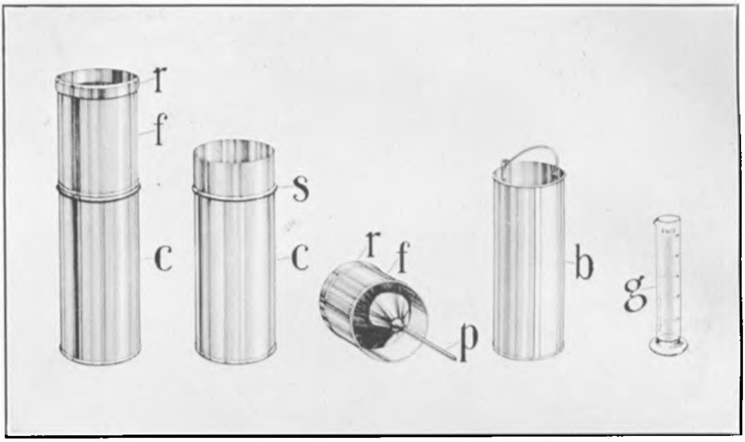
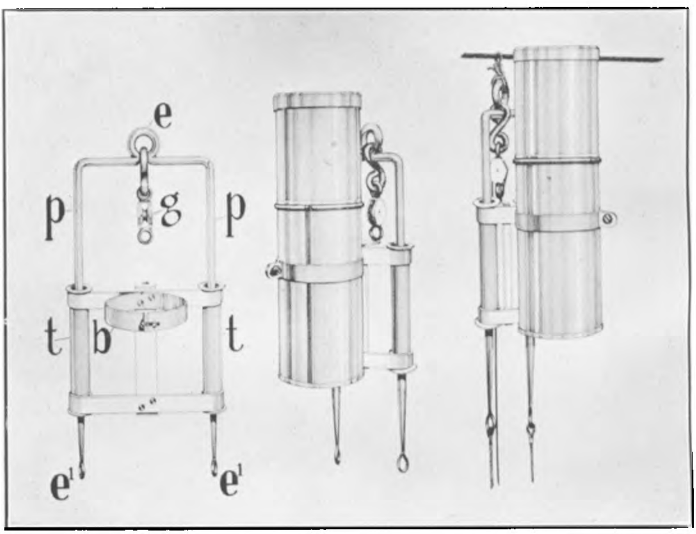


Fig. 10.



(*a*) Frame. (*b*) Rain Gauge and Frame. (*c*) Rain Gauge hoisted to stay.

Fig. 11.

The Rain Gauge.

The captains of a few regular observing ships in different trades who are willing to undertake these special observations in addition to the other voluntary work may be lent these instruments on special application. They are not supplied as part of the usual equipment of M.L. ships.

The instrument, Figure 10, 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 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 millimetres.

The measuring glass (*g*) will hold ten millimetres 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 free 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, Figure 11*a*, by a band (*b*) which encircles 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 Figure 11*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 (Figure 11*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 but is drawn up at the sides. In reading, the bottom of the meniscus or curved surface of the water, should be accepted as the true height of its column ; and in order to avoid errors arising from parallax, care should be taken to hold the measuring glass so as to bring the meniscus on a level with the eyes.

When spraying has occurred since the previous observation, the water collected should be tasted, and if found to be brackish a remark to that effect should be noted.

The measuring glass must be kept scrupulously clean.

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.

The rain gauge should be lowered to the deck at 8 a.m. each day, whatever weather conditions may have prevailed during the previous twenty-four hours.

The water collected in the can provided for the purpose should be carefully poured into the graduated measuring glass, and the amount measured entered in the meteorological log. In the event of the can overflowing, the overflow should be measured and included in this amount.

CHAPTER V.

WIND, SEA, AND SWELL OBSERVATIONS.

There are certain observations which at present cannot be measured by mechanical means 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 generally practicable at sea owing to the unsteadiness of the ship. Reliance, therefore, has to be placed on eye observations.

Wind.

The direction of the wind is observed by compass. The *true* direction from which the wind blows is required to the nearest point.

The direction and force of the wind is estimated by watching the sea surface and the use of the Beaufort Scale and Mariner's Compass.

Veering and Backing

At the International Meteorological Conference held at Innsbruck in 1905, it was recommended :—

> " 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 devised by Captain, afterwards Admiral Sir FRANCIS BEAUFORT, in the year 1808, for use on board ships of the British Royal Navy. Although 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 Merchant Navy. 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 :—

Beaufort Wind Scale.

Beaufort Number. International.	Meteorological Wind Scale. Determined at coast stations for a height of 33 ft. above sea level. 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.	The Seaman's Wind Scale. Beaufort's description of Wind. International.	Deep Sea Criterion, 1874. International.	Coastal Criterion.	Beaufort Number. International.
1	2	3	4	5	6	7	8
0	Less than 1	0	0	**Calm**	——	——	**0**
1	1 to 3	2	·01	**Light air**	**Just sufficient to give steerage way***	Sufficient to give good steerage way to fishing smacks with the "wind free."†	**1**
2	4 to 6	5	·08	**Light breeze**	**That in which a well-conditioned man-of-war, with all sail set, and clean full, would go in smooth water from— 1 to 2 knots**	Fishing smacks with topsails and light canvas "full and by" make up to 2 knots.	**2**
3	7 to 10	9	·28	**Gentle breeze**	**3 to 4 knots**	Smacks begin to heel over slightly under topsails and light canvas make up to 3 knots "full and by."	**3**
4	11 to 16	14	·67	**Moderate breeze**	**5 to 6 knots**	Good working breeze. Smacks heel over considerably on a wind under all sail.	**4**

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**	**That to which she could just carry in chase, full and by—**	**Topsails, 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.

0	Calm.
1 to 3	Light winds.
4 to 7	Moderate winds.
8 and above	Gales.

The scale numbers are attributed to the wind force at the time of observation by judgment of the observer.

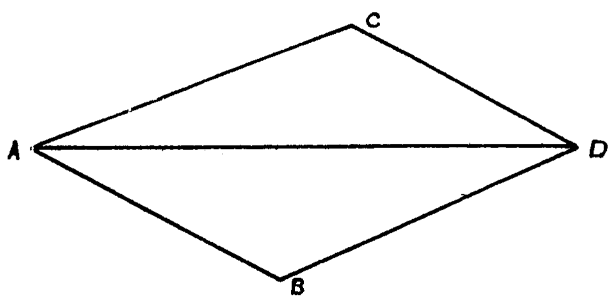
The Gale Warning Signal in the British Isles is hoisted for winds which may reach force 8 or above. For this purpose force 7 is not considered a gale.

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 great help. It is not possible to explain in words the criteria for determining the various Beaufort forces by watching 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 difficult 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 of 10 knots velocity, 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 simply obtained 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. The observer who has not this instrument had far better estimate by looking at the sea than at the smoke from the funnel.

Sea and Swell.

For the purpose of recording or reporting the state of the sea and swell, the Douglas sea and swell scale given below is used.

In 1921 a circular was sent to the Captains of regular observing ships, asking for their views upon the existing scales and notations for logging weather, wind and sea.

The concensus of opinion obtained was that the Beaufort notation of weather, and the Beaufort scale of wind force were satisfactory ; but that the existing scales for recording sea and swell could be improved.

A number of scales drawn up by marine observers were received, of which the most suitable was that devised by Captain H. P. Douglas, C.M.G., R.N., of H.M. Surveying Ship, *Mutine,* now Hydrographer of the Navy.

This scale was circulated by the International Hydrographic Bureau to all its States members, and at the meeting of the International Meteorological Conference, held at Copenhagen in 1929, it was recommended for international use.

Douglas Sea and Swell Scale.

SEA.	SWELL.									
		Low.		Moderate.			Heavy.			
	No swell. 0	Short or Average. 1	Long. 2	Short. 3	Average. 4	Long. 5	Short. 6	Average. 7	Long. 8	Confused. 9
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	37	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

The combined scale above is very convenient for observing both sea and swell. But careful distinction should be made between the two whenever possible ; sea being the waves caused by wind at the place and time of observation, while swells are waves due to past wind or wind at a distance.

The Scales may be used separately as below :—

State of Sea.

Scale Number.	*Description.*
0	Calm
1	Smooth
2	Slight
3	Moderate
4	Rough
5	Very rough
6	High
7	Very high
8	Precipitous
9	Confused

Swell.

Scale Number.	*Description.*
0	No swell.
1	Low swell, short or average length.
2	Low swell, long.
3	Moderate swell, short.
4	Moderate swell, average length.
5	Moderate swell, long.
6	Heavy swell, short.
7	Heavy swell, average length.
8	Heavy swell, long.
9	Confused swell.

It will be noted that no dimensions are given with the Douglas scale. To be of value such dimensions should be based on averages obtained from many measured observations.

These are being collected, but up to the present few have been received ; and marine observers are urged to systematically measure waves, and record the measurements whenever possible. For this purpose, Form 684 is supplied, a copy of which is given below.

When making these measurements of sea and swell, marine observers should name the sea or swell by the term used in the Douglas scale, according to their own judgment, so that average dimensions may be computed from these observations, and attached to the terms by the result of this combined experience.

METEOROLOGICAL OFFICE—AIR MINISTRY.

SPECIAL OBSERVATIONS OF SEA AND SWELL.

Marine Observers are invited to make measurements of sea and swell, under varying conditions, upon the lines suggested, which follow overleaf. The observations are as follows :—

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.

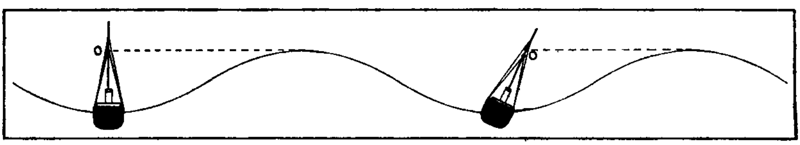
It is requested that this form, when completed, be forwarded to the Meteorological Office with the next meteorological log or record.

Methods of Measuring Waves.

On board a moving ship, the measurement of the dimensions of waves frequently presents 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.—The most usual method for measuring the height of waves is for the observer to climb the rigging or otherwise place himself at a height 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* Figure 12. 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*).



(*a*) (*b*)

FIG. 12.

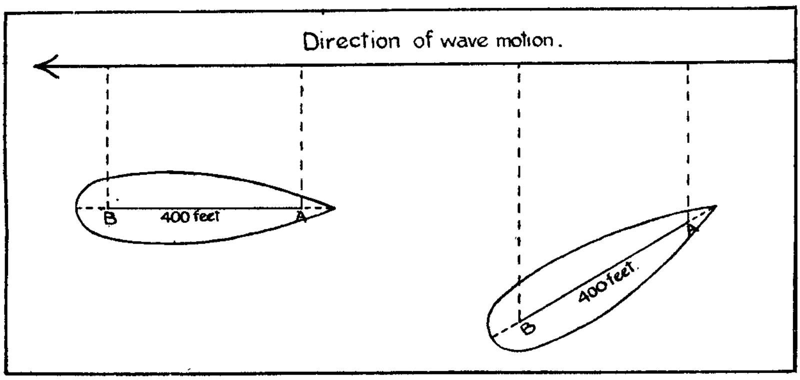
Another source of error may arise from the fact that the length of the ship will perhaps considerably exceed that of the wave, and not permit her to lie completely in the trough. In this case the ship may be buoyed up on two waves, and the height of the oncoming crest will consequently be underestimated.

The above method is suitable for large waves, but 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 be estimated.

Length, Period and Velocity.—It is evident that the simplest conditions or 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 (*see* Figure 13) 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 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.



(*a*) (*b*)

FIG. 13.

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, 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 × 6·2 = 93 ft. and the *speed* of the wave will therefore be

$$\frac{400 - 93}{6{\cdot}2} = 50 \text{ ft. per second.}$$

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 × 7·7 = 500 ft. which is the length of the wave. The *true period* is *length* divided by *speed* = 500 ÷ 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 × 20 = 600 ft., and the wave speed would therefore be

$$\frac{600 + 400}{20} = 50 \text{ ft. per second.}$$

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.

The *virtual base* = 400 ft. × Cos. 26° = 400 ft. × ·9 =	360 ft.
Component of ship's speed (at right angle), *towards the wave* = 15 × Cos. 26° = 15 × ·9 =	13·5 ft.

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 × 5·67 = 77 ft., and the speed of the wave will therefore be $\frac{360 - 77}{5{\cdot}67}$ = 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.

In this case the virtual base will be 400 ft. × Cos. 18° = 400 × ·95 =	380 ft.
Component of ship's speed *away from the wave* = 30 × Cos. 18° = 30 × ·95 =	28·5 ft.

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 × 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 ÷ 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 × 23·2 = 500 ft.

Another method of measuring wavelengths and one which will be preferred by many, 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 :—

True length = Apparent length × Cos. B.

CHAPTER VI.

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 log or record 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.

When the upper sky, medium sky, or lower sky is invisible, either through darkness, fog or dust storm or other surface phenomenon, the cloud form should be indicated by a hyphen (-) or a solidus (/) or by the sign x. The same entry should be made for the middle or upper sky in cases where this is invisible by reason of the obstruction of a *complete* lower layer of cloud. A blank column would imply no observations made. In all such cases appropriate notes should be made in the " remarks " column of the log or record.

Cloud Forms.

Luke Howard, whose classification of cloud forms at the beginning of the XIXth century 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).

Lower Clouds.

(6) **Strato-Cumulus (St-Cu).**—Large globular masses or rolls of dark cloud, frequently covering the whole sky. 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 Alto-Cumulus are noticeable. It may be distinguished from Nimbus by its globular or rolled appearance.

(7) **Nimbus (Nb).**—A very low layer of ragged cloud generally associated with rain or snow.

Through the gaps between these clouds a layer of Alto-Stratus is nearly always visible.

If the layer of Nimbus is broken into small fragments they may be distinguished by the name of Fracto-Nimbus (Fr-Nb) (" 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 an ascensional movement of air. 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.

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 (Fr-Cu).

(9) **Cumulo-Nimbus (Cu-Nb).**—Shower Cloud, sometimes accompanied by thunder. Heavy masses of cloud rising in the form of mountains or turrets or anvils, generally having a sheet or screen of fibrous appearance above (Anvil 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, and sometimes the edges themselves separate into a fringe of filaments similar to that of Cirrus cloud. The front of thunder clouds of wide extent frequently presents the form of a large low arch above a region of brighter sky.

(10) **Stratus (St).**—A uniform layer of very low cloud which resembles a fog but does not rest on the ground. If the cloud layer is broken up into irregular shreds, it may be distinguished by the name Fracto-Stratus.

In view of the 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. Many skies consist of intricate agglomerations of different types of cloud.

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 internationally. The correct abbreviations of the names are also given.

Upper Clouds.

(1) **Cirrus (Ci).**—Detached clouds of delicate appearance, fibrous (thread like) structure, without true shadows, generally white in colour.

Cirrus clouds take the most varied shapes such as isolated tufts, thin filaments pencilled on a blue sky, branched filaments in feathery form, curved filaments ending in tufts, etc. Often they are arranged in bands which traverse part of the sky as arcs of great circles and which by perspective effect converge towards two opposite points on the horizon. (Often Cirro-Stratus and Cirro-Cumulus participate in the formation of these bands).

(2) **Cirro-Cumulus (Ci-Cu).**—Small globular masses or white flakes without shadows, or having very slight shadows, arranged in groups and often in lines. Mackerel sky.

(3) **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.

Middle Clouds.

(4) **Alto-Cumulus (A-Cu).**—Largish globular masses, white or greyish, partially shaded, arranged in groups or parallel lines, and often so closely packed that their edges appear confused. The detached masses are generally larger and more compact (resembling Strato-Cumulus) at the centre of the group ; at the margin they form into finer flakes (resembling Cirro-Cumulus).

Alto-Cumulus Castellatus is a distinct variety of this type in which some of a group of A-Cu. clouds are extended vertically upwards in heads or little towers.

(5) **Alto-Stratus (A-St).**—A veil of a colour more or less grey. Sometimes the veil is translucid resembling a thick layer of Cirro-Stratus and through it the sun or the moon can be seen dimly gleaming as though through ground glass. This form exhibits all stages of transition between Alto-Stratus and Cirro-Stratus.

At other times it forms a thick layer of dark grey hue, indistinct or fibrous or, more rarely, wavy.

All continuous rain or snow falls from Alto-Stratus though in these cases a layer of Nimbus usually obscures the Alto-Stratus.

Sub-divisions of some of the main types given above are recognised. The observer should be careful not to use the names "Strato-Cirrus," "Cumulo-Cirrus" and "Cumulo-Stratus" which are now obsolete. 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 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 $\frac{\text{Ci}}{\text{NW}}2$ 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 "lower" clouds and "upper and middle" clouds should be separately observed and entered in the Log. 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. When all is said and done the movement of upper cloud is by far the most useful observation.

Attention is also directed to the following details :—

Undulated Clouds.—It oftens happens that the clouds show regular striae, parallel and equidistant, like waves on the surface of water. This is mostly the case with 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. The bearing of this point on the horizon should be indicated to the nearest point of the Compass, True .—

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

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** chould 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**.

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 word haze should be used for 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.

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

Visibility.

The letter **v** of the Beaufort scale denotes an abnormal clearness and transparency of the atmosphere. This letter should be used to indicate conditions of visibility which may or may not occur when the highest number of the scale given below indicates the distance at which objects may be seen.

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.	,,	,,	,,	½ mile.
4	Mist or haze, or very poor visibility.	,,	,,	,,	1 ,,
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.			

At a shore station the measurement of visibility is a comparatively simple matter by the observation of objects at fixed distances at sea it may often be difficult or impossible.

When coasting and when fixes can be obtained, the distance of points when first sighted or last seen may be measured from the chart.

In the open sea, when ships meeting are sighted, visibility may be calculated if the time is taken when first and last seen, if the speed of the other ship is known.

In a long vessel the lowest numbers of the scale, 0 and 1, can be determined by direct measurement. 2 and 3 indicate conditions of obscurity such that visibility extends beyond the length of the ship, but is not sufficient to proceed at speed on account of traffic. Accurate estimation of 2 and 3 may often be impossible. 4 and 5 indicate conditions when it may be possible to proceed at speed as regards traffic, but when coastal navigation by visual bearings may be difficult. The use of the horizon to estimate 6 or 7 is not to be relied on ; cases have occurred where such attempted measurements are believed to have attributed to stranding. 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.

The state of the atmosphere known as unusual or exceptional visibility is generally recognisable by seamen. At such time it is so clear that stars may be seen to rise and set at night with the naked eye and the pole topmast of a steamer hull down may be seen on the horizon by day.

CHAPTER VII.

OPTICAL AND GENERAL PHENOMENA.

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. A number of other meteorological and general phenomena of interest are also included in the present chapter.

The descriptions of halo and coronal phenomena are based upon 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.

Halo Phenomena.

In the following description of halo phenomena it has been assumed that the sun is the source of light. This has been done solely for brevity; precisely similar though rather less brilliant appearances may be produced by moonlight. Halos only occur in presence of cirrus clouds or light ice fog; they are produced by refraction and reflection of the rays of the sun or moon by the ice crystals composing the cloud.

Many different kinds of halo have been observed. Figure 14 is a reproduction of a drawing made by the astronomer Hevel on February 20th, 1663, when many of the different kinds of halo phenomena described below were seen at the same time. The most common halo is the halo of 22°, a large ring CIBG, round the sun. This angular dimension, together with those given below, refers to the radius of the halo measured along a great circle. Ordinarily this halo is white, but when developed in greater intensity the edge near the sun is a very pure red with orange and yellow in succession outwards. In very favourable circumstances green and blue are seen, both faint and whitish, particularly the blue which is rarely recognisable. The halo thus appears white on its outer edge.

The halo of radius 46° VXYZ (Figure 14) occurs more rarely and is much fainter than that of 22°; the colour sequence if visible is the same.

The halo of radius 90° is exceedingly rare and is seen only as a faint white ring of the approximate radius given. In the diagram two portions of it, NE and DP, are visible. This halo can never be seen complete unless the sun is in the zenith.

Occasionally a colourless ring passing through the sun parallel to the horizon may be seen. This is the *horizontal circle* or *mock sun ring*, shown in the figure as CDFEB, the portion BC passing through the sun being omitted. This portion is frequently missing though it has been often seen.

All the halo phenomena so far described may be seen as incomplete rings or arcs on occasion, but there are a number of other phenomena which, from their method of formation can only be seen as arcs. Among these are the *arcs of contact* and the

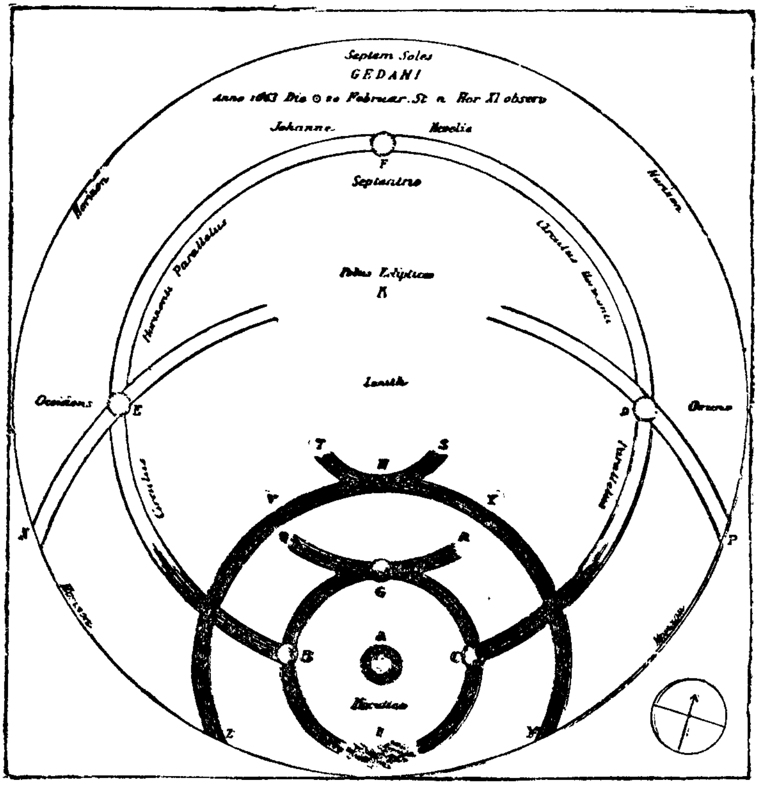
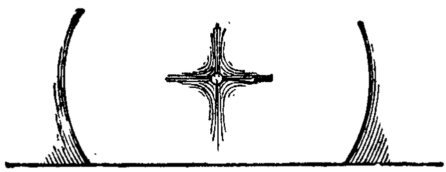


Fig. 14.

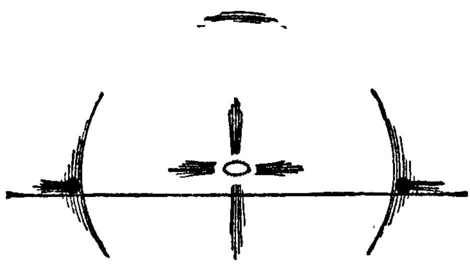
circumzenithal arc. In Figure 14 RGQ is the upper arc of contact to the halo of 22° while THS is the circumzenithal arc which is observed either in contact with, or nearly in contact with, the halo of 46°. In both cases the arcs have their convex sides turned towards the sun and are very luminous at the points of contact so that these have sometimes been described as " mock suns." The colour effects are often brilliant, especially in the case of the circumzenithal arc, which as its name implies is centred at the zenith. In both cases red is nearest to the sun. Arcs of lower contact may occur in connexion with the halos of

22° and 46°, but these are very rare. In Figure 17 a portion of the arc of lower contact to the lunar halo of 22° is shown. Contact arcs appear occasionally at the sides of the same two halos, but are as rare as those of lower contact.

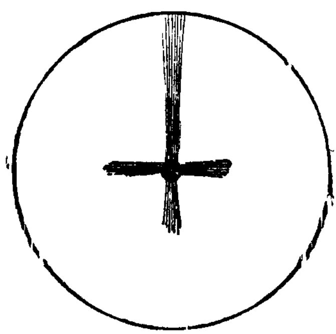
Of all halo phenomena, *mock suns* (*parhelia*) and *mock moons* (*paraselenæ*) are probably the most admired. These terms are used to describe luminous, or even brilliant, images of the sun which are seen most frequently at or near the intersection of the halo of 22° with the white mock sun ring (B and C, Figure 14). Very rarely mock suns are seen at or near the intersection of this



A



B



C

FIG. 15.

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* Figure 14).

The mock suns of the ring of 90° (D and E, Figure 14) 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 very beautiful halo phenomena are afforded by *sun pillars,* which are most easily observed about 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,* three varieties of which are shown in Figure 15.

A large number of other halo phenomena, complete halos, arcs, elliptical halos, mock suns in unusual situations, etc., are known to occur, having been observed more or less rarely ; these are classified as "irregular" halo phenomena. A fine example of such an irregular phenomenon is shown in Figure 16. Owing to the limited space available it is not possible to describe them more fully here. The mose essential feature of any observation is the measurement of the angular dimensions of the radius, i.e. the angular distance from the sun. Without this the observation of a rare form of halo is of little value. The halo of 22° is too commonly observed both round the sun and moon to be of particular interest unless some unusual feature is observed, such as the colours being exceptionally bright. Observers fortunate enough to observe a complex halo system or any interesting halo feature are asked to sketch and describe what they see, with the angular measurements appended. 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. It is possible to photograph halos giving a suitably short exposure such as would best show the details of the clouds.

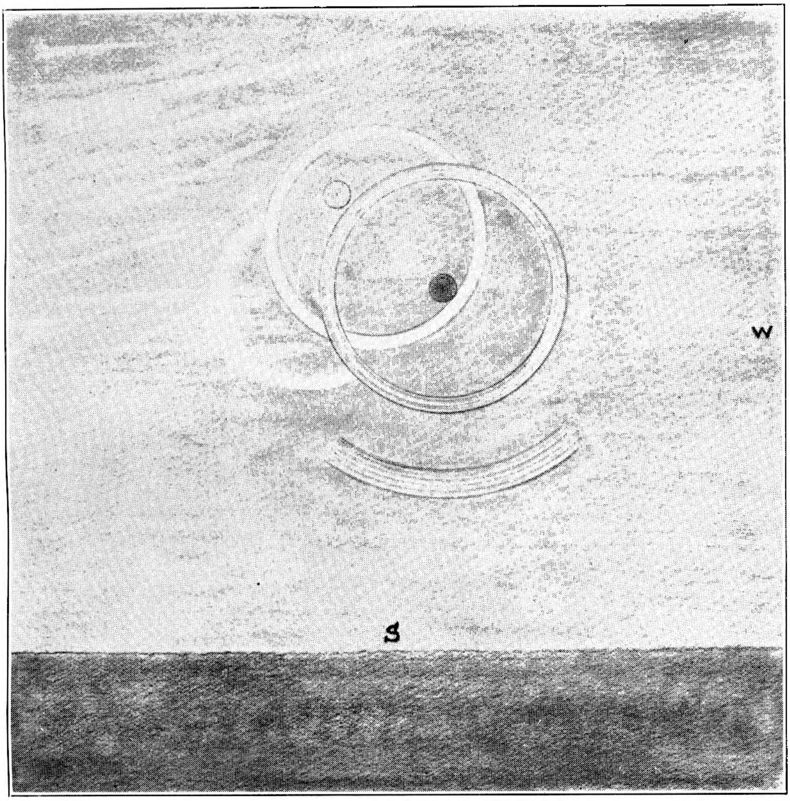


FIG. 16.

SOLAR HALOS.

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° 09′ N., Longitude 75° 07′ W. At 11.45 a.m. a halo, showing the colours of the spectrum, formed around the sun with a radius of $21\frac{1}{2}$°. the breadth of the spectrum subtending an angle of $\frac{3}{4}$°. 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."

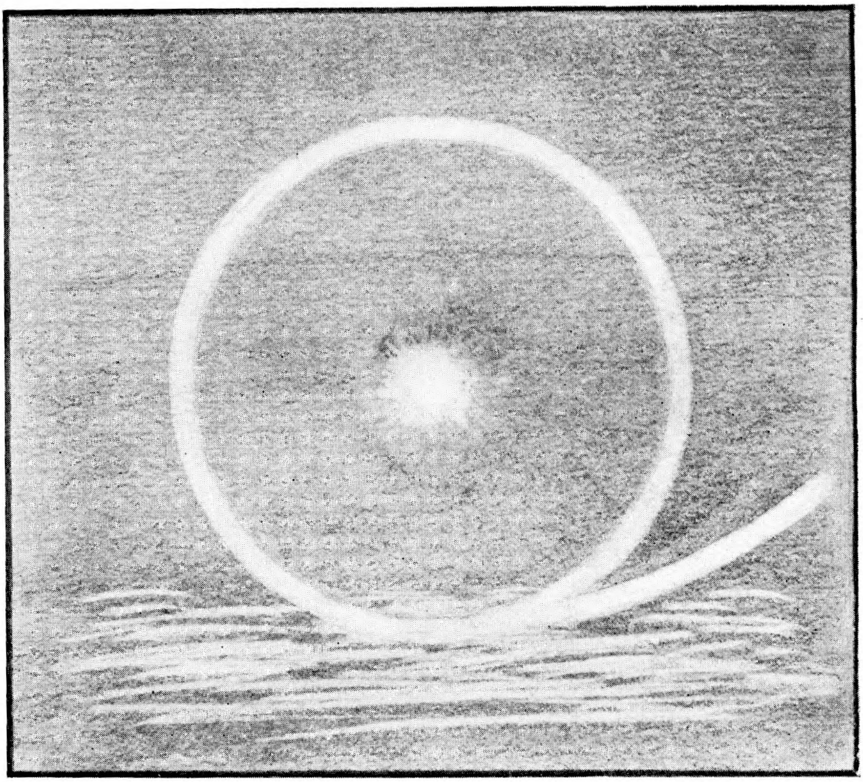


Fig. 17.

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° 16′ S., Longitude 89° 43′ E. (approx.). The complete circle was 22½° 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.

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.

Coronae are of entirely different formation 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*. 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 in exceptional circumstances be quite as big as a halo. 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 and received the name of Bishop's Ring. 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 coloured rings of light round the shadow cast upon the fog by his own head. The whole phenomenon is called the " Brocken spectre," and the coloured rings are usually known as a " Glory." A large outer ring, known as " Ulloa's Ring," which is really a white rainbow, is sometimes seen at the same time. The shadow of the observer on fog may sometimes be seen with a source of artificial light behind the observer.

Iridescent Clouds.

Green and red patches are occasionally seen in cirrus and other 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.

Rainbows.

The normal appearance of a bright well-developed rainbow is as follows. The chief or primary bow shows the sequence of colours, violet, blue, green, yellow, orange and red, the red being on the outside or top of the bow. Closely inside this bow are one or two supernumerary bows with the colours in the same order, the first inner bow being much fainter than the primary bow and the second fainter still. In cases of exceptionally brilliant rainbows more than two supernumerary bows may be seen. Outside the primary bow and entirely detached from it is the secondary rainbow in which the colours appear in the reverse order, red inside and violet at the top or outside. The primary bow is formed by means of one internal reflection in each raindrop, the secondary bow by two such reflections. In very exceptional cases more than one secondary bow has been seen. The sun, the observer's eye and the centre of the circle of which the primary rainbow forms an arc are always in a straight line, so that the azimuth of the highest part of the bow is 180° from the sun's azimuth. The normal radius of the arc of red light of the primary rainbow is 42°, of the violet arc 40¼°, in the secondary bow the radii are :—for red light 51° and for violet light 54°, all the values given being approximate ones. Hence it follows that the normal breadth of the primary bow is about 1¾° and that of the secondary bow about 3°. It also follows that with the sun at an altitude of 42° the uppermost point of the primary bow is on the horizon and hence no primary bow can be formed if the sun's altitude exceeds 42°. Consequently rainbows are mainly morning and evening phenomena ; nearer mid-day if seen at all the arc of the bow is shorter and the altitude small. It is most commonly observed during fog.

Lunar rainbows are formed in precisely the same circumstances as solar ones, but are considerably rarer having regard to the comparatively short periods that a bright moon is above the horizon. In favourable circumstances a lunar rainbow is so much fainter than a solar one that colour is difficult to distinguish and the normal appearance of a lunar rainbow is whitish. In exceptional cases, however, the same sequence of colours may be observed as in a solar rainbow. On rare occasions white rainbows are formed by the sun ; for this to occur the raindrops composing the cloud must be very small and the observer must be near the cloud. Such a rainbow is called a " fog-bow " or " Ulloa's Ring " and may form a complete circle.

An observer interested in rainbows should note that the colours, the angular extent of the colours and the position of the greatest luminosity in the bow are variable and depend on the size of the water drops producing the bow. If it be desired to make observations of value on these differences the following points should be noted in the primary bow (1) The sequence of colours (2) the colour which shows the maximum luminosity (3) which colour band is the widest. He should also note the sequence of colours in the supernumerary bows and whether these bows are continuous with the primary bow and with each other. Observation of the secondary bow is of less importance.

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. The gradations of colour according to the scheme—deep blue, light blue, and pale blue—may be noted. 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. At sunrise these phenomena occur in reverse order. The time of disappearance of the second light is also of importance. If " after glows " and other colorations 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 of greater meteorological interest.

Duration of Twilight.

Twilight lasts until the sun is 18° below the horizon so that in tropical latitudes when the sun sets perpendicularly or nearly so, the duration of twilight is shortest. At the pole there is about a couple of months twilight between the long summer day and the long winter night. The following table gives the duration of twilight for various latitudes.

Latitude N.	January 1st.	April 1st.	July 1st.	October 1st.
0°	1 hr. 16 min.	1 hr. 10 min.	1 hr. 16 min.	1 hr. 10 min.
20°	1 hr. 20 min.	1 hr. 15 min.	1 hr. 25 min.	1 hr. 14 min.
40°	1 hr. 39 min.	1 hr. 34 min.	2 hr. 4 min.	1 hr. 32 min.
60°	2 hr. 48 min.	2 hr. 41 min.	—	2 hr. 25 min.
Latitude S.	July 1st.	October 1st.	January 1st.	April 1st.

In midsummer, latitude 60°, twilight lasts all night, the sun never being 18° below the horizon.

Mirage.

The phenomenon termed mirage is caused by the refraction of light rays through layers of air of different densities. In some cases the rays are totally reflected from a stratum of air. Mirage takes a number of forms ; images of an object may appear when the object is quite invisible or one or more images may be seen in addition to the visible object. Great distortion of the image may occur on occasion.

Mirage at sea or in coastal waters is usually the result of a layer of warm air, often of no great height, lying in contact with cooler water. These are the same conditions that give the type of sea-fog usually experienced. Hence mirage is often associated with sea-fog, being seen either just before or just after the fog or in the clear spaces between fog-banks.

In the layer of warm air over the sea, temperature increases with height, the air in contact with the sea being cooled thereby. A ray of light coming from an object at low altitude, such as a distant ship, is therefore so bent by refraction as to appear to come from a higher altitude. Hence the object appears enlarged vertically. In the same way objects which are actually below the horizon may be rendered visible, with or without much enlargement. The distortion and raising of the sun or moon at rising or setting are examples of this kind of mirage, usually known by the term " abnormal refraction." Another term for this kind of mirage is " looming." In this connexion the definition of " to loom," given by Admiral Smyth in " The Sailor's Word-Book " (1867), is of interest :—" An indistinct enlarged appearance of any distant object in light fogs, as the coast, ships, etc. ; ' that land looms high,' ' that ship looms large.' The effect of refraction."

Other varieties of mirage can be shown to be due to the same cause. The layer of cool air near the sea may extend high enough to produce the opposite effect, namely the " stooping " or vertical contraction of objects. Other forms include the inverted image of a ship or other object just above it, and an erect image may also be seen over the inverted one. Inverted images are seen when the rays of light coming from the bottoms of the objects take greater curvatures than those coming from the tops of the objects.

Land mirage is of a different type, being produced by a layer of very warm air near the ground. This is often seen in desert regions and over hot surfaces, such as roads, in temperate latitudes. An inverted image of the object appears as if in conjunction with water. Mirage of this type may be seen on coasts on hot days as a strip of white light at the bottom of cliffs, islands, etc., causing them to appear cut off from the sea in front. This mirage is really a reflection of the sky.

In observations of mirage the relative temperatures of air and sea should always be noted.

Green Ray.

When the sun sets under favourable conditions the last portion of the upper part of the disc momentarily becomes a brilliant bluish-green as it disappears. This coloration may be observed either with or without optical assistance. Favourable conditions are—sun bright at time of setting and setting taking place at the sea horizon or behind distant land showing an uninterrupted edge. Sometimes also a " green flash " of light shoots upwards from the setting sun. Similar phenomena are observed at the appearance of the upper limb at sunrise; they are attributed to the unequal refraction of light of different colours.

The green ray has occasionally been observed in connexion with other bodies, such as at the setting of the bright planet *Venus*.

Propagation of Sound and Weather Conditions.

The propagation of the air-waves which are received by the human ear as sound is a very complex matter and is liable on occasion to irregularities. These irregularities affect only the audibility of sound, not its pitch. Sound waves are reflected or refracted when they encounter strata or patches of air where there is a change of wind speed, temperature or humidity. If the observer and the source of sound are within a continuous stratum of fog, audibility is greater than normal, but if not, the presence of fog in patches may render sound inaudible even at short distances.

Marine observers are requested to log whenever possible the maximum distance at which sound signals or noises are heard at sea, also vagaries and peculiarities of the propagation of sound through the atmosphere at sea.

Every opportunity should be taken to ascertain the position at which the sound was made and to fix the position of the ship hearing the sound, also when sound is apparently cut off, the positions at which this takes place and where the sound is reheard. The method and details of obtaining fixes and measurements should be given.

In cases of ships' sound signals the relative bearings and distance is sufficient, provided that the Latitude and Longitude of the observing ships are given. In all cases time and date is essential.

When such observations are obtained the following weather observations should also be carefully made and recorded :—

Wind, True Direction and Force.
Weather by the Beaufort notation.
Types and amount of cloud and their apparent direction and velocity.
Temperature of the air, dry and wet bulb.
Temperature of the sea.
Visibility by scale.
General remarks.

Aurora.

Auroral displays are often seen in the higher north or south latitudes, being very rare in latitudes much under 40°. On account of the beauty and the interest of the phenomenon the following notes are given for those who wish to observe them in detail. In all cases azimuths should be given as true bearings. Auroral light is supposed to be the visible manifestation of the passage of electrical discharges, possibly of solar origin, through the earth's atmosphere, but the precise mode of its occurrence is still unknown.

Auroral forms are difficult to classify owing to their great variety and their rapid fluctuations and changes. The usual classification now adopted is :—

(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 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 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. In measuring the altitude of the summit the lower or concave edge of the arc should be taken, 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. They also occur separately, often extending from the upper or convex border of an arc towards the zenith. The apparent length of rays may alter very rapidly, the ray suddenly darting towards the zenith and retiring from it. This characteristic has led to the description of auroral phenomena as " merry dancers." Sometimes rays group themselves into 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 generally 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 what the observer is looking at is 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. In 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.

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 very much brighter than the full moon. 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 in 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 displays 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.

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 the 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.

Monthly and Annual Variation.—In most of Northern Europe, and in North America between latitudes 40° and 60° N., aurora is most frequent near the equinoxes. In higher latitudes these two maxima are replaced by a single one in mid-winter. It is, however, doubtful whether this apparent difference is not partly or wholly due to the different duration of sunlight in varying latitudes. Aurora is much more often seen in some years than others and in temperate latitudes there is a fairly well-marked 11-year periodicity, coincident, or nearly so, with the sun-spot period. In Arctic regions the relation between aurorae and sunspots seems to be different to that of temperate latitudes.

Connexion with Magnetic Storms.—A big auroral display in temperate latitudes is nearly always accompanied by a big magnetic storm and large earth currents. Telegraph wires are sometimes traversed by such large currents that the despatch of messages is interrupted for several hours on end, or even rendered impossible. It is desirable during bright auroral displays to keep an eye on the compass, since deviations from the normal of more than 1° are sometimes experienced during magnetic storms, even in the latitudes of the South of England. When auroral draperies are observed in motion it is especially desirable to watch the compass needle. In high latitudes, where aurora and magnetic disturbances are both more common, there is often no apparent connexion between the two phenomena.

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.

Sound of Aurora.—The audibility of aurora, a sound resembling the discharge of electricity from points, is still in dispute. The great height of aurora in the atmosphere seems to rule out the possibility of audible sound, but observers of repute have frequently stated that they have heard a crackling noise in the presence of aurora.

Zodiacal Light.

This is observed as the extremity of an elongated ellipse of soft whitish light which extends from the sun as centre, appearing above the westerly horizon after sunset or above the easterly horizon before sunrise. The best time for observation is just after the last traces of twilight have disappeared in the evening or just before the first traces appear in the morning, the greatest extent of the Light being then visible. The Light retains its apparent place among the stars as it gradually sets in the evening or rises in the morning. It is sufficiently bright even in temperate latitudes not to be rendered invisible by faint twilight or partial moonlight.

The axis of the Light lies nearly in the plane of the Ecliptic, approximating more closely to the plane of the sun's equator. The whole phenomenon is confined to the zodiacal constellations. In tropical latitudes, where the Ecliptic makes a large angle with the horizon at all times of the year, the Light may be well seen on any clear night or morning in all months. In temperate latitudes the Ecliptic is often inclined at a small angle to the horizon and the Light is then rendered invisible by the additional extent of the atmosphere it has to traverse. In the latitudes of the British Isles it is best seen in the evenings of January to March and in the mornings of September to November ; only about the time of the winter solstice is it possible to observe it on the morning and evening of the same day. In February the Light lies between the constellations of *Pegasus* and *Cetus*, the apex being near the *Pleiades*. Just after dark in the latitude of the British Isles the altitude of the apex of the Light is therefore about 50°, the cone lying obliquely with regard to the horizon. At this season the breadth near the horizon is 25°–30°, the altitude of the part of greatest luminosity being 20°–30°.

The Light is pearly and homogeneous and differs markedly in quality from that of the *Milky Way*, the brightest part of which it may considerably exceed in luminosity. It is more brilliantly and readily seen in the tropics, but it is very conspicuous even in the latitude of the British Isles if observed away from large towns. The nature of the Zodiacal Light is unknown. It is generally believed to be a cosmic phenomenon, due to the reflection of the sun's light from innumerable minute bodies or dust which revolve about the sun, the mass extending outwards somewhat beyond the earth's orbit. The meteorological origin of the Light as the final stages of twilight in the earth's atmosphere is, however, still upheld.

Observers interested in the phenomenon should note whether the brightness varies in successive nights or successive years, comparing it with a specified portion of the *Milky Way*, preferably at the same altitude. The position of the axis and of the edges of the cone with respect to the stars should be given as well as they can be judged and notes made of differences in colour, lack of homogeneity, etc. An appearance of "a cone within a cone" has sometimes been seen.

Associated with the Zodiacal Light are two other appearances. Joining the apices of the cones of the morning and evening Zodiacal Lights is an excessively faint band of Light a few degrees wide lying along or nearly along the Ecliptic. This is called the Zodiacal Band. On the Zodiacal Band, at a point very nearly or exactly 180° from the sun's position in the Ecliptic is a somewhat brighter and larger patch, 10° or more in diameter, known by the German name *Gegenschein* (literally "counterglow," but this term in English is applied to a meteorological phenomenon of twilight). The Zodiacal Band and the *Gegenschein* may be observed in temperate latitudes on the clearest nights, but are somewhat brighter in the tropics. Further observations of these phenomena, in comparison with which the Zodiacal Light is a blaze of light, are much desired, especially from tropical localities. The track and width of the Band and the size, shape and exact position of the *Gegenschein* should be noted, together with variations of brilliancy and any special features seen, but the observation will be found difficult to the keenest eyesight. The *Gegenschein* is usually invisible for the few nights on which it is projected upon the *Milky Way* in its annual journey round the Ecliptic.

An entirely distinct phenomenon to which the name " lunar zodiacal light " has been given is sometimes seen before moonrise or after moonset, after the ordinary lunar twilight begins or before it has gone. A faint yellowish cone of light extends vertically upwards from the horizon above the moon's place. It has no relation to the Ecliptic and is a meteorological phenomenon probably of similar formation to the " first purple light," a rosy-purple glow seen above the sun's place shortly after sunset in a cloudless sky.

Meteors or Shooting Stars.

During the night watches the seaman has many opportunities for obtaining useful observations of meteors. " Meteor " is a general term to include all those small bodies which, travelling through space, encounter the earth's atmosphere and become visible by reason of the state of incandesence produced by the friction of rapid passage through the attenuated air of the upper atmosphere. Millions of these objects enter the atmosphere daily, the vast majority of which are entirely disintegrated and subsequently settle down slowly to the earth's surface in the form of almost impalpable dust. A few, however, whose original bulk is greater, may partially survive the disintegrating effect and reach the earth's surface in solid form. The earth's mass is therefore being constantly but slowly added to. These are called meteorites or aerolites. The ordinary small meteors appearing as luminous streaks in the sky are popularly known as shooting stars, but they have of course no connection with any star, being merely small fragments of matter varying in size from about a pin's head to a pea. Larger objects are known as fireballs. These may appear with the brilliancy of a first magnitude star or of the planets *Jupiter* or *Venus*, or, in the very finest examples, may greatly exceed the full moon in their temporary dazzling brilliancy. Many meteors, on the other hand, are so small and faint that they are invisible without optical aid. Unless actually seen to fall to the earth's surface by the observer he cannot say whether a large fireball reaches the earth as a meteorite or not. Many of the larger fireballs and meteorites are seen to burst and sometimes a detonation is heard. The meteorites which have been picked up rarely exceed a few pounds in weight and may be much less, but there have been some of considerable size.

There is a considerable variation in the speed with which these bodies traverse the earth's atmosphere, this speed being the resultant of the meteor's original speed in space and the earth's velocities of rotation around its axis and revolution in its orbit. The resultant speeds usually lie between 10 and 45 miles per second. The average height above the earth's surface is 75 miles during the time of combustion and 50 miles at the time of disappearance.

The meteorites which have reached the earth's surface have been analysed and about one-third of the known chemical elements of which the earth is composed have been found in them. No new chemical element has been found. The elements are, however, frequently combined to form minerals not known in the earth, so their origin must have taken place outside the earth. Small crude diamonds have been found. There are three classes of meteorites according to whether they are predominatingly metallic iron, stone, or a mixture of the two.

The appearance of meteors is as varied as their brightness. Some travel fast, others slowly. Some leave streaks or trains of sparks or luminous vapour while others do not. In many cases the train disappears immediately or it may remain visible for seconds or minutes. In extreme cases the duration has exceeded two hours. When the train remains visible for some time, curious changes may be observed in it following the action of the air currents of the high upper air, combined with the fall of the material due to gravity. Most of the larger meteors and fireballs are strongly coloured and the colours may change during the flight. The apparent path taken by the meteor is usually a straight line or arc, but it may assume serpentine or other forms.

Prolonged study of meteors over many years has shown that meteors belong to families or groups. Thus the well-known Perseid meteors which are very plentiful in August, especially from the 10th to the 13th, radiate from a point in the constellation of *Perseus*, after which they are named. In other words the tracks of all Perseids if produced backwards, whatever part of the sky they are actually visible in, meet in a point, showing that they belong to a cluster of small bodies travelling together in space in the same direction. The radiation of the tracks as seen from the earth's surface is merely a matter of perspective. The Leonids form another family which are most frequent about November 13th and radiate from a point in the constellation of *Leo*. From such well-marked groups there is every gradation down to very weak ones giving perhaps a few faint meteors on one or two nights in the year. It is estimated that about 100 radiant points, that is, separate showers, are active on every night of the year. Catalogues of radiant points have been published. The average rate of appearance of meteors is about 7 per hour in the first half of the year and 16 per hour in the second half, but meteors are always more numerous after midnight than before. On the occasion of special showers such as the Perseids or the Leonids the number observed is considerably greater. Occasionally meteors come in swarms as was the case with the Leonids in 1833 and 1866, when the fall was at the rate of many thousands per hour. All the meteors from radiant points which become active on the same night or succession of nights each year belong to the Solar System and move in definite orbits around the sun, and it has been shown that some of them move in the same orbits as certain comets that have been observed so that these meteors form part of the matter or debris of the comet whose orbit they pursue.

It is not possible for the casual observer of meteors to deduce a radiant point except in the case of a bright well-marked shower such as the Perseids. There are, however, two ways in which the marine observer who is interested in these phenomena may make observations of value.

In the case of single bright meteors the following information should be given :—

(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.

If similar information is obtained for the same meteor from at least one observer in another place it is possible to calculate the heights of appearance and disappearance and the speed of the meteor. With regard to (1), the position if possible should be given to the nearest half-degree, but it is often difficult owing to the suddenness of the appearance. Care should be taken not to overestimate the duration of the flight.

The appearance of meteors in unusual numbers on any night, especially if obviously directed from the same point in the heavens, should be put on record. It is not always realised that individual meteors are only seen over small areas of the earth's surface, and it may happen that the conditions are such that the meteor shower is visible only in restricted longitudes.

There is no direct relation between the appearance of meteors and the weather as was formerly believed. The clearer the night the more faint meteors will be seen. The data of meteor heights and speeds 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. The occurrence or non-occurrence of showers on a particular night is often of considerable astronomical interest.

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, should also be entered. An estimate of the brightness of the head of the comet, in comparison with a star or planet, should also be made.

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, but are not uncommon in the Mediterranean.

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.

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 information regarding any marked movements of the meteorological instruments during the occurrence.

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 which is a special type of nimbus or of cumulo-nimbus. 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 temperate latitudes. In the northern hemisphere the warmer wind being generally from the south-west, the wind direction will veer during the passage of the squall. In the southern hemisphere the wind will normally back. During the passage of the squall the barometric pressure will rise with great suddenness about 2 mb., and the temperature will fall from 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 VIII.

ICE, OCEAN CURRENTS, HYDROGRAPHIC, AND OTHER OBSERVATIONS.

Ice.

The following terms are used to distinguish the different kinds and conditions of ice.

Slush or Sludge.—The initial stages in the freezing of sea water when it is of gluey or soupy consistency. The term is also occasionally used for " brash ice " still further broken down.

Pancake Ice.—Small floes of new ice approximately circular and with raised rims.

Hummocking.—The results of pressure upon sea ice.

Hummocky Floes.—Floes composed wholly or partly of re-cemented pressure ice.

The Pack.—The term used to denote the main belt of derived ice which in the Antarctic girdles the continent south of the zone of the " westerlies " and in the Arctic fills the Polar sea and escapes southward from the outlets of the sea (French, " Banquise de derive ").

The term " pack " is used more generally to mean any area of pack ice however small.

Close Pack.—Pack composed of floes mainly in contact.

Open Pack.—The floes for the most part do not touch.

Drift Ice.—Loose very open pack where water predominates over ice.

Brash.—Small fragments and rounded nodules, the wreck of other kinds of ice.

Berg.—A large mass of glacier ice.

Bergy Bits.—Medium sized pieces of glacier ice or of heavy floes or hummocky-pack washed clear of snow (typical bergy bits have been described as about the size of a cottage).

Growlers.—Similar pieces of ice to the above, but so small as barely to show above sea level.

Rotten Ice.—Floes which have become much honey-combed in course of melting, or which appear black through saturation with water (thin sheets of newly formed very thin ice also appear black and may easily be confused with the last type when met in the pack).

Level Ice.—All unhummocked ice, no matter of what age or thickness, which has platy structure and fibrous appearance when broken.

Fast Ice.—Sea ice while remaining fast in the position of growth. True fast ice is only met along coasts where it is attached to the shore or over shoals where it may be held in position by islands or stranded icebergs.

Pack Ice.—Sea ice which has drifted from its original position.

A Floe.—An area of ice other than fast ice whose limits are within sight. Floes up to two feet in thickness may for convenience of description be termed " light floes " ; floes thicker than this " heavy floes."

A Field.—An area of pack ice of such extent that its limits cannot be seen from a ship's masthead.

A Crack.—Any fracture or rift in sea ice.

A Lead or Lane.—A navigable passage through pack ice.

A Pool.—Any enclosed water area in the pack other than a crack or a lead or lane.

Water Sky.—Dark streaks on the sky due to the reflection of water spaces or the open sea in the neighbourhood of large areas of sea ice.

Ice Blink.—The white or yellowish white glare on the sky produced by the reflection of large areas of sea ice. (The antithesis of water sky.)

Ice should usually be recorded on Form 912, which is supplied to all regular observing ships navigating routes where ice may be encountered, and to any other ships which may apply for these forms.

The date, with latitude and longitude of ice seen, with description in accordance with the terms above, together with measurements of its dimensions when possible, and any remarks of interest, should be recorded.

Ocean Currents.

The set and drift of current may be obtained by four methods, by the first of which the largest amount of suitable data can be obtained ; this is the old time method of difference between the Observed and Dead Reckoning positions at the end of a run.

Set and Drift of Current by Difference between D.R. and Observed Positions.—The set and drift obtained between noon and noon by this method is valuable, but over the distance traversed by a fast ship in 24 hours there may be entirely different sets of current.

Stellar navigation is most valuable for current observation, and probably the best observations of current can be obtained on the run between twilight stellar fixes.

If the ship's position is fixed by position lines from, say, 4 star altitudes on opposite bearings with a good horizon at daylight in the morning, a good navigator can usually be confident that his fix is a dead fix, and after a run of, say, 12 hours, if the dead reckoning is accurately kept, by fixing his ship by the same method with evening twilight stars, he can say with confidence that the difference between the last observed position and the D.R. position is the set and drift of current in the interval.

But supposing that having got an exact stellar fix at daylight in the morning he takes the difference of the D.R. from this position, at noon, and the position obtained with the sun's meridian altitude and sun's position line obtained by altitude in the forenoon transferred by D.R. to noon, his second position is really only a running fix and may be in error to the extent of as much as 3 miles. The interval may only be 6 or 7 hours and the error in the last position alone would be accounted as half a knot of current or 12 miles in a day.

What is wanted on every possible opportunity, when the D.R. is considered reliable and sights accurate, is the set and drift over the noon to noon run and the set and drift between morning and evening stars and evening and morning stars ; the two latter provide the information required and the first provides a check.

When coasting the set and drift obtained at suitable intervals between cross-bearings are most desirable, and upon all occasions when the current can be determined with fair reliance, it should be entered in the log. In large deep draught ships of high speed the revolution of the propellers, if careful allowance for slip is made, will probably give the best indication of distance run through the water ; but where possible, and particularly in small slow ships, the patent log should be used also as a check.

Leeway is a matter of judgment, and if sound, with well adjusted compasses, careful allowance for deviation and variation, and good steering, it will be safe to assume that the course steered is made through the water.

The Dutchman's Log.—When at anchor or lying to a cable, a float with a drogue will give an accurate indication of the set and drift of current.

Drift Bottles and Derelicts.

The Total Set and Drift over great distances may be obtained by means of drift bottles, for which purpose Form 955 is provided. It should be remembereed that a bottle or floating object released from a certain position at sea, and picked up some time afterwards at some place on a distant coast, may have travelled by a devious route, and may have come ashore some time before it was found. The only indication given is that it has travelled at a rate not less than the total direct distance between the two points, divided by the number of days between release and finding.

Drift bottles should be ballasted and paper inserted immediately before release, the cork being sealed with pitch to render it watertight.

The position of all derelicts and floating wreckage, together with a description, should be carefully recorded, particularly noting if waterlogged.

The Current Meter.

The current is the most accurate means of obtaining the direction and velocity of current both at the surface and in the depths, for it measures the rate at which the water passes it in much the same way as the patent log measures the rate at which it is being towed through the water by a ship. The direction is indicated by means of a compass attached to the meter, and thus positive measurements are obtained, but the use of this instrument is only practicable in surveying vessels and other special service ships. A ship should be anchored when she uses it.

Hydrographic Observations.

In order to obviate duplication of work in regular observing ships of the Merchant Navy, and to obviate overlapping of Government Departments, hydrographic and other information may be returned with the Meteorological Log and meteorological record, in manuscript, or entered as Additional Remarks.

Such information will be forwarded to the Hydrographer of the Navy, the Board of Trade, or other appropriate authority.

The most important of these is the reporting of the positions of uncharted or inaccurately charted rocks, shoals, etc. When sending in such information the greatest care should be taken not only to give accurate positions and soundings, but also to provide the necessary data to check bearings, positions, soundings, including the data for the reduction of soundings to L.W.O.S.

Submarine Earthquake Phenomena.

Marine Observers experiencing earthquakes, submarine or otherwise, or their effects, should carefully record their observations, preferably as " Additional Remarks."

Marine Biological Observations.

The recording of sea life is not generally desirable in the meteorological returns of observing ships, but exceptional experiences should be recorded.

By examining with the microscope minute sea animals marine observers may find a profitable and interesting occupation in their leisure. In the days of sailing ships, much was learned about animalculae, and Captain Toynbee, a former Marine Superintendent of the Meteorological Office, when in command of sailing ships, returned in his logs many beautiful drawings of specimens.

Recently the Committee for Aeronautical Research have turned their attention to the speed of porpoises; and reliable observations and evidence of the speed of sea mammals and fishes, if recorded in the logs, may be useful in throwing light on questions of form, propulsion and speed of vessels or aircraft.

Phosphorescence.

The phosphorescence of the sea is one of the most remarkable of natural phenomena and various explanations of it have been attempted in the past. One theory held that seawater absorbed sunlight by day and emitted it by night. In 1749–50, however, a small animalcula giving a blue light was discovered by VIANUELLI and GUIXELLANI in the Mediterranean and subsequent investigation has shown that animal life is the origin of marine phosphorescence. Light production is due to a great variety of organisms, from microscopic ones up to many forms of deep sea fish, and the peculiarity of the light is that it is generated without heat, a process never yet achieved in the laboratory. Light from different organisms has been analysed and the colour is also found to vary through white, silver, green blue and lilac to red. The method of production has been shown to be some form of slow oxidization which is entirely automatic in the lower forms of life, but is in some measure under control in the higher forms. Recent research has shown that while phosphorescence may occur anywhere it is most frequent in the warmer tropical seas and in particular in the Arabian Sea, where it exhibits a definite maximum in August. In the North Alantic Ocean some regions show summer maxima, while others have spring maxima. It also appears that phosphorescence is more frequent in coastal regions than in mid-ocean. One remarkable type of phosphorescence is the diffused " milky sea " which may give light enough to read by and to illuminate clouds. This type has often been reported as exerting a calming effect upon the sea surface. More elaborate phenomena occur which have not yet been satisfactorily explained, such as phosphorescent bands and the great rotating phosphorescent wheels.

Observations for Fishery Research.

Arrangements are made on behalf of the Director of Fisheries Laboratory, Ministry of Agriculture and Fisheries, at Lowestoft, through the Port Meteorological Officers, for the collection of water samples on certain ocean routes, by a limited number of ships.

Special instructions with apparatus are supplied as necessary through the Port Meteological Officers.

General.

While it should be remembered that the purpose of the system of voluntary marine meteorological observation carried out by the corps of voluntary marine observers is for the advancement of marine meteorology as an aid to navigation and to supply other services with reliable meteorological observations, it must be borne in mind that marine meteorology since it was first organized has been enhanced by its close association with other branches of the sciences of the sea. Careful discrimination is necessary in recording observations which are not entirely meteorological, and the captains of ships are asked to have valuable information of natural sea phenomena suitably returned.

CHAPTER IX.

INSTRUCTIONS FOR KEEPING THE ORIGINAL NOTE BOOK, THE METEOROLOGICAL LOG & SHIP'S METEOROLOGICAL RECORD OF SYNCHRONIZED OBSERVATIONS.

As the interest of the Corps of Voluntary Marine Observers increases, so more information is returned to the Marine Division, and there is a tendency to send in supplementary documents to the Meteorological Log and Ship's Meteorological Record Form 911.

The strength of the Marine Division is constant, that is to say, the number of assistants in the Marine Division to handle the data received remains the same whatever the amount. To maintain or increase the output of published information it is therefore necessary to regulate collection. Marine observers will greatly assist the Division, and in so doing help towards publication by making their logs and records when returned as complete as possible.

The meteorological log is for the purpose of giving a complete four-hourly record. The only way such a log can be properly kept at sea is by logging the observations at the relief of the watch, so that the officer of the watch when relieved can devote the necessary time and attention for the entry of these highly accurate and comprehensive observations, which form the backbone of the work and provide standard data for use with the Hollerith system of mechanical computation, and for the purposes of research.

The Original Note Book and the Meteorological Log.

A specimen of a page of the meteorological log is given in PLATE IV, 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 a misleading observation.

Columns 1 and 2.—Day and Hour.—The name of the month may be written or its number given in Roman numerals. The printed hours of observation are ship's time.

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 if so it should be clearly stated.

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

Columns 3, 4, 5, 6 and 7.—Latitude, Longitude and Current.— The position of the ship at noon, both observed and dead reckoning should be entered. If the D.R. position is entered at each observation hour, it will greatly assist.

When obtainable with accuracy, the set and drift from noon to noon should be entered. In Column 7, the set and drift for shorter periods, preferably between twilight and twilight should be entered.

When these short period currents are given, the observed and D.R. positions used, with time, should be entered in Columns 3 to 6.

Columns 8 and 9.—True Course and Distance.—The true course should be entered in the usual way to the nearest degree, also the distance by log or revolutions every four hours, and when course is altered materially.

Columns 10 and 11.—Direction and Force of Wind.—The true direction of the wind to the nearest point, and the force of the wind by Beaufort scale should be entered for the time of observation, the observations being made as indicated in Chapter V.

The time of material changes in direction and force of wind may be noted in the remarks column.

Columns 12 and 13.—Barometer and Attached Thermometer.— Enter the barometer and attached thermometer as read in accordance with advice given in Chapter III.

Column 14.—True Atmospheric Pressure at Sea Level.—Enter the corrected reading of the barometer ; *see* instructions for applying corrections in Chapter III.

Columns 15 and 16.—Dry and Wet Bulb Thermometer.—Enter the readings of the dry and wet bulb thermometers as read to the nearest degree or tenth of a degree.

Column 17.—Clouds.—Enter the types of cloud according to whether they are upper and middle or lower, in their respective columns, also the direction of movement and velocity of the upper cloud, in accordance with instructions given in Chapter VI, and PLATE V.

Column 18.—Amount of Cloud.—Enter the total amount of cloud in accordance with Chapter VI.

Column 19.—Weather.—Enter the weather by Beaufort Notation in accordance with Chapter VI.

Column 20.—Fog Intensity and Visibility.—When measurements of visibility can be obtained, enter the visibility by scale given in Chapter VI.

Columns 21 and 23.—Direction of Sea and Swell.—Enter the direction of the sea in Column 21 and of the swell in Column 23, both to the nearest point, true.

Columns 22 and 24.—Description of Sea and Swell.—Enter the appropriate scale numbers by Douglas sea and swell scale.

Column 25.—Sea Surface Temperature.—Enter the sea surface temperature to the nearest degree or tenth of a degree.

Column 26.—Specific Gravity.—Enter the specific gravity as obtained by hydrometer, Chapter IV, at noon daily. (This observation is required in port when at open berths, but should then be recorded in "Additional Remarks" at the end of the log).

Columns 27 and 28.—Remarks.—Carefully enter the time in Column 27 of occurrences and observations which are not recorded in the previous columns.

These remarks should be as complete as possible, but should not duplicate information given in the other columns.

It is important to note the time of arrival and departure for each port; the time when rain, fog, etc., commence and cease; and any unusual phenomena.

When space does not permit, simply enter "*see* Additional Remarks," and write your remarks carefully in the space provided for that purpose at the end of the meteorological log, with a view to their being published in the MARINE OBSERVER.

Column 29.—Raingauge.—In ships which carry a raingauge, enter the measured amount obtained at 8 a.m. daily.

Generally, remember that in entering up the observations in the meteorological log from the original note book, that space is required above each of your entries in the columns for the purpose of entering the code figures for Hollerith extraction.

Remember that on the last page of the log the principal observing officer is asked to sign it, and the captain to approve it; and that to obtain the "Excellent" classification lies mainly with the observing officers because meteorological logs are only classed "Excellent" which come within a certain percentage of the best returned; consideration being given to the evidence they produce of the application of the work to navigation.

Additional Remarks.—Near the end of the log will be found blank pages headed "Additional Remarks." These pages are provided for the entry of accounts of all matters of interest in marine meteorology, especially those which affect navigation, for which there is not space in the log itself. In writing these

PLATE IV

Meteorological Log kept on board S.S. "Clan Malcolm".

Year 1925 · Month XII

Barometer.* No. 1422 · Height of Cistern above Sea 53 ft.

The D.R. position is desired every watch in addition to those at noon. When short interval currents are logged, the Observed and D.R. positions from and to, with times, should also be given.

DATE: Day. Civil Time.	DATE: Hour, Ship's Time.	Latitude: Observed.	Latitude: Dead Reckoning.	Longitude: Observed.	Longitude: Dead Reckoning.	Current when determined at short intervals.	Course and Distance, each four hours: True Course.	Course and Distance, each four hours: Distance by Log.	Wind at the time of observation: Direction. TRUE. (Nearest point)	Wind: Force 0 to 12.	Barometer: Uncorrected Reading. Mb.	Barometer: Att. Therm. Absolute Scale.	True Atmospheric Pressure at Sea Level. The barometer reading corrected for Temperature, Height, Gravity. Marine Observer's Handbook, 5th Edition.	Thermometers: Dry Bulb. No. 30104	Thermometers: Wet Bulb. No. 30106
20th	4		1 06S		48 01E	29° 19	14°	39	NNE	3	1016·0	299·2	1012·1	77·9	72·7
	8		0 26S		48 10E		14°	39	NE by N	3	1018·0	299·4	1014·1	78·8	74·0
	NOON	0 29N	0 12·5N	48 35E	48 20E		14°	40	NE by N	3-4	1018·0	301·1	1013·8	80·5	75·0
	4	Current in	last 24 hours 1 06N	N 43° E	22 mls. 48 47E	321° 13	18°	39	NNE	4	(29·96) 1015·7	301·2	1011·5	80·0	74·5
	6·36 8	Position by Stellar obs. 1 43N.	1 33N. 1 43N	48 48E.	48 56E. 49 00E.		18° 26°	32 7	NNE	3	1017·3	299·8	1013·3	78·0	75·0
	MIDT.		2 19N.		49 18E.	207 2	26°	40	NE by N	3	1017·1	299·6	1013·2	78·2	75·2
21st.	4		2 52N.		49 34E.		26°	37	NE by N	3	1015·8	299·5	1011·9	78·1	75·0
	5·30 8	Position by Stellar obs. 3. 21N	3. 23N. 3. 25N.	49 35E.	49 36E. 49 50E.		26°	37	NE	3	1018·1	301·0	1014·0	80·0	75·8
	NOON	4 24N	4 12·5N	50 03E.	50 13E.	344° 4	26°	39	NE by N	4	1018·0	301·6	1013·8	81·3	76·8
	4	Current in	last 24 hours 4 56N.	N 41° W	15 mls. 50 20E.	242° 9½	26°	38	NE by N	4	(29·96) 1015·9	301·9	1011·6	80·8	76·0
	6·16 8	Position by Stellar obs. 5 15N.	5 19·5N. 5 30N	50 22E.	50 30·5E. 50 36E.		26°	35	NE by N	3	1018·1	300·0	1014·1	78·8	75·4
	MIDT.		6 03N.		50 53E.	260° 8	26°	37	NE by N	4	1018·0	299·5	1014·1	78·8	74·5
22nd	4		6 36N.		51 10E.		26°	37	NE by N	4-5	1017·2	299·5	1013·4	77·0	73·5
	5·36 8	Position by Stellar obs. 6 54N.	6 55·5N. 7 10N.	51 03E	51 11·5E. 51 27E.		26° 20°	27 11	NE by N	3	1020·2	301·0	1016·1	80·0	73·2
	NOON	7 51N	7 58·5N	51 23E.	51 43E.	243° 3	20°	39	NNE	5	1019·5	299·8	1015·7	77·5	73·7
	4	Current in	last 24 hours 8 26N.	S 69° W	21 mls 51 33E.	218° 9½	15°	36	NNE	5-4	(30·04) 1017·3	299·1	1013·6	77·6	71·7
	6·16 8	Position by Stellar obs. 8 43N.	8 50·5N. 9 01N.	51 34E.	51 40E. 51 43E.		15°	36	NE by N	4	1019·8	298·4	1016·2	76·4	72·0
	MIDT.		9 38N.		51 54E.	268° 13	16°	38	NE by N	4	1018·8	298·6	1015·1	77·0	71·8
23rd	4		10 15N.		52 05E.		16°	38	NE	2	1017·9	298·0	1014·4	76·3	70·8
	5·48 8	10 32N	10 32·5N 10 54N.	51 49E.	52 02E. 51 59E.		16° 340° 344°	12 7 22	NE by N	2	1021·2	298·6	1017·6	77·0	70·6
	NOON	11 36·5N	11 39N	51 29E.	51 50·5E.	341° 6	344° 332°	39 3	N by E	4	1020·3	299·8	1016·5	78·0	71·3
	1·45 4	Current in 11 53·5N.	last 24 hours 11 51·5N. 12 01N.	383° W 51 20E.	21 mls. 51 19·5E. 50 56E.	13° 2 252° 1½	332° 313° 290°	14 6 23	NE by N	4	1019·3	298·8	1015·8	77·0	74·5
	5·00 8	Position by Land Fix 12 05N.	12 05·5N. 12 07N.	50 46E.	50 47·5E. 50 18E.		290° 275°	11 27	NE	3	1021·4	297·7	1017·0	75·8	70·0
	MIDT.		12 10N.		49 41E.	P.T.O.	275°	36	NE by E	3	1020·2	297·6	1016·8	75·6	69·8
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

F3118

* Please give Readings of the Ship's Barometer, say at Noon, at various times during the voyage noting whether it is mercurial or aneroid

Between pp. 92 and 93.

Captain *G. A. Neill.* from *Durban* to *Aden.*

Hour, Ship's Time.	Clouds at time of observation. Names. Upper & Middle.	Lower.	Prop. of Sky Clouded 0 to 10.	Weather at time of observation. According to Beaufort Notation.	Visibility or Fog Intensity. Sea scale.	Sea Surface. Waves. Direction from TRUE.	Waves. Amt. 0-9 by Douglas Scale.	Swell. Direction from TRUE.	Swell. Amt. 0-9 by Douglas Scale.	Temp. by No. 30106	Spec. Grav. by No. 946	Time of Remark.	Remarks. Here give Remarks as to phenomena which cannot be indicated in the other columns with the times of their occurrence; especially the times of Changes in Direction and Force of Wind, as well as the Direction, Veering or Backing, Force and Duration of Squalls. Ice and Derelicts should be reported on Form 912. Also note the hour at which the Ship arrives in or leaves Port. (See "Marine Observer's Handbook" for further particulars.)	Rainfall by Gauge. mm.
4	Nil.	Cu/NNE 2	2	b.		NNE	3	NE	4	79.0		 4.00	Clocks advanced 2 minutes. Very fine and clear. Swell increasing slightly	
8	A. Cu.	Cu.	10	o		NEbyN	3	NE	1	78.6		8.00	Sky almost completely covered with A.cu.	
NOON	A. Cu/ENE 1	Cu/NNE 2	8	c		NEbyN	3	NNE	1	79.4	24.5	 NOON	Clocks advanced 2 minutes. Cu cloud amount 1 only. Sky clearing to N+E Occl. mod. swell. Clear	
4	Ci. St. Ci. Cu.	Cu/NNE 2	2	b.		NNE	4	NNE	4	78.3		 4.00	Clocks advanced 1 minute. Very fine clear weather. Upper clouds dispersing slowly.	
8	Nil.	Nil.	0	b.		NNE	3	NNE	4	77.8		5.30 to 7.00 8.00	Heavy masses Cu. nb. clouds from NNE. Very fine and clear.	
MIDT.	Nil.	Cu. Nb./NE by N 1	1	bc		NEbyN	3	N	4	78.3		10.30 Midt.	Heavy masses Cu. nb. clouds from NE. for short period. Heavy Cu.nb. clouds. Remainder of watch clear sky.	
4	Nil.	Cu./NE by N	2	b		NEbyN	3	N	4	78.7		 4.00	Clocks advanced 3 minutes. Swell increased steadily during watch. Rough at intervals. Fine and very clear.	
8	Nil.	Cu./NE 2	2	b		NE	3	N	4	79.0		8.00	Swell rough at intervals	
NOON	Nil.	Cu/NEbyN	5	bc		NEbyN	3	NNE	4	79.8	24	 Noon	Clocks advanced 1 minute. Swell rough at intervals. Very fine clear weather	
4	Nil.	Cu./NEbyN 2	4	bc		NEbyN	3-4	NNE	4	79.8		0.10 4.00	Passing showers. Clocks advanced 1 minute. Very fine clear weather. Occasional rough swell.	
8	Nil.	Cu/NEbyN 2	1	b		NEbyN	4	NNW & NEbyN	9	78.2		8.00	Fine and clear.	
MIDT.	Nil.	Cu/NEbyN 2	2	b		NEbyN	4	-	9	79.0		8.15 Midt.	Wind freshened Rough confused swell. Fine and clear.	
4	Nil.	Cu/NE 1.	1	b		NEbyN	4	N & NE	9	79.0		 4.00	Clocks advanced 3 minutes. Slightly squally. Occasional rough swell. Fine and very clear.	
8	Nil.	Cu/NE by N 1	2	b		NEbyN	3	N & NE	9	79.0		8.00	Fine clear weather.	
NOON	A.Cu/A St./NE	Cu/Cu Nb./NNE	5	bc		NNE	4	N & NE	9	79.9	24.5	10.00 Noon	Slight shower. Wind freshening. Clocks advanced 1 min. Two layers of Cu./Cu.nb. Lower strata moving very rapidly. Distant showers. Dull outlook ahead.	
4	A.Cu/A st./NE 2	Cu/Cu.nb.	6	bc		NNE	4	NNE	6	79.2		1.00 1.30 to 2.30 4.00	Sky completely overcast with St./Cu.nb. clouds. Clocks adv. 1 min. Frequent passing rain squalls. 2.45 Sky clearing from N & NE Wind moderating. Swell short & very steep. Bar. pumping 4 mb. Cu./Cu.nb. clouds to E'wd. only, with rain. Fine and clear.	
8	Nil.	St.Cu/Cu/NE 1	2	b		NNE	4	NNE	7	78.2		8.00	Fine and clear. Bar. pumping .6 mb.	
MIDT.	A. Cu.	Cu/Cu.nb/Nb/NE 2	6	bcq		NEbyN	4	NE	4	78.4		11.00 11.40 Midt.	Sky becoming cloudy. Sharp rain squall. Fine cloudy weather. Clear. Heavy Nb. clouds astern. Squally	
4	Nil.	Cu/Cu.nb./NE	4	bc		NE	3	N & NE	9	78.8		4.00	Wind moderated with passing showers to E'wd during watch. Fine and clear.	
8	Nil.	St.Cu/Cu/NE	4	bc		NEbyN	2	N & NE	9	78.0		8.00	Fine and clear.	
NOON		Cu/Cu Nb/NE	8	c	8	NbyE	4	NNE	4	79.0	25	10.00 Noon	Wind commenced backing. Clocks retarded 1 min. Occasional passing showers during watch. Clear	
4	A. cu./W 1	Cu./Cu.nb./NNE 2	5	bc	8	NEbyN	3	NE	4	77.0		1.45 4.00	Cape Guardafui Lt.Ho. S.43°W. 4. Clocks retarded 6 min. Cu.Nb. clouds overland only. Fine and clear.	
8	Nil	Det. Cu/ENE 2	2	b	8	NE	3	NE	4	76.8		5.00 8.00	Ras Alula Lt Ho. South 7. Fine clear weather.	
MIDT.	Ci. st.	Nil.	1	b	8	NEbyE	3	NNE	4	76.2		8.15 11.00 Midt.	Wind freshened slightly and large quantity of Cu. clouds passing to als from NE Wind moderated + veered to NEbyE. Ci.st. in bands on NNW + SSE line. Very fine + clear	
	17		18	19	20	21	22	23	24	25	26	27	28	29

so that in the event of the Office Barometer being broken the Ship's can be taken into use and its error can be ascertained.

descriptions an endeavour should be made to make the matter as interesting as possible and yet concise, without unnecessary words. Figures, such as instrumental observations, not included in the columns of the log, should be placed as far as possible at the end of the description. Notes on abnormal currents, and interesting experiences in navigation and seamanship in relation to marine meteorology will be specially welcome.

Accounts of particular winds and storms which can be observed in detail are very valuable. As instances may be given tropical revolving storms, local winds such as Pamperos, squalls showing any remarkable feature, line squalls, and any observed peculiarities of the regular winds such as the Trades and the Monsoons.

Descriptions of any of the phenomena described in Chapter VII are always of interest and may be of real scientific value. This applies not only to the purely meteorological phenomena dealt with in the chapter referred to, but also to the astronomical phenomena and to the miscellaneous ones such as phosphorescence and the propagation of sound over the sea.

Hydrographic notes given on the lines detailed in Chapter VIII 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 appropriate authority.

Information or considered opinions in reply to the Marine Superintendent's circulars or notes of enquiry in THE MARINE OBSERVER may be conveniently written in these pages.

By the nature of their calling marine observers have especial facilities for observing interesting natural phenomena and they are asked to record carefully in clear concise form anything they may see which appears to be unusual, whether it is described in THE MARINE OBSERVER'S HANDBOOK or not. Not only is the interest and usefulness of the marine observer's log, published every month in THE MARINE OBSERVER, thereby enhanced, but also the observations, whether published or not, are stored up for future service as the groundwork of possible investigations. The researches of the future may be directed in ways we cannot yet foresee and the fact that an observation made now appears to be of little direct value either to navigational or meteorological science does not imply that it may not be of value later on.

Illustrations.—Photographs, finished drawings and even careful sketches of phenomena form a most valuable record for preservation, especially with added explanation in the form of remarks. It should be noted that an illustration will often render a long explanation unnecessary. Photographs of interesting cloud formations at sea are always welcome and their value will be increased if the following particulars accompany them :—time, position, barometer, wind, weather, air and sea temperatures and remarks of changes in the appearance of the sky.

It is hoped that many more illustrations will be obtained in the future. A selection of these will be published in THE MARINE OBSERVER. Illustrations other than photographs should be made with due regard to reproduction in THE MARINE OBSERVER. Line drawings should be made in ink, preferably in Indian ink. All drawings should be made on plain white paper, inserted in the log in such a way that they are fixed but readily detachable. The size of any chart or illustration should not, if possible, exceed that of a page of THE MARINE OBSERVER.

Admirable sketches in colour are sometimes received ; these make excellent records, but it is unfortunately not possible to reproduce them in colour in THE MARINE OBSERVER. Sepia or ink washes will reproduce satisfactorily. In the past many of the drawings selected have had to be redrawn in the Marine Division for reproduction.

When photographs are sent in it is requested that they be accompanied by the original negative, which will be returned if desired.

A selection of a few of the best weather charts made during the voyage can be appropriately attached to the fly-leaf of the log.

Synchronized Weather Observations.

After the pages for " Additional Remarks " specially ruled pages are given for entering synchronized observations.

These observations should be recorded at the Universal Greenwich Mean Observation times for weather telegraphy, which are given in Chapter I and on the small chart in the meteorological log itself.

As a complete record, night and day, is kept in the preceding pages of the log, meteorological log ships are not asked to take or enter these synchronized observations at night.

These observations should be recorded exactly at the hours. In " Selected Ships " they should be coded and sent to the wireless operator for transmission at scheduled times.

These pages are similar to the Ships Meteorological Record, Form 911, and therefore *see* detailed instructions below.

The Ships' Meteorological Record, Form 911.

The form is ruled up with vertical columns which are numbered at the foot. The columns for ocean current observations are not numbered.

In " Selected Ships " the observations entered on this Form should be coded immediately on Form 138 ; therefore before commencing this Form 911 it is well to be familiar with the International Ships' Wireless Weather Code which will be found on Form 138, with Tables on Form 138A, and in the January MARINE OBSERVER each year from 1930.

Columns 1, 2, 3 and 4.—Month, Day of Month, Day of Week and Hour.—The name of the month may be written or its number given in Roman numerals. The day of the week should be entered in Column 3 abbreviated. The hours of observation are Greenwich Mean Time, not ships' time, and are printed in Column 4. The Form is ruled for four observations daily, but ships which have not two officers in a watch should not take and record these observations at night.

All " Selected Ships " should record these observations at the Greenwich Mean Times given in the schedule on Form 138A according to wireless watch zones, also given on a chart of the world in the January MARINE OBSERVER each year, from 1930.

Columns 5 and 6.—Latitude and Longitude.—The ship's position at the hour of observation Greenwich Mean Time should be entered here.

Columns 7 and 8.—True Course and Average Speed in Knots during last 3 hours, or for the period for which the change of barometer is recorded.

Columns 9 and 10.—Direction and Force of Wind.—The true direction of the wind to the nearest point, and the force of the wind by Beaufort scale should be entered for the time of observation, the observations being made as indicated in Chapter V.

Columns 11 and 12.—Barometer and Attached Thermometer.—Enter the barometer and attached thermometer as read in accordance with advice given in Chapter III.

Column 13.—True Atmospheric Pressure at Sea Level.—Enter the corrected reading of the barometer; *see* instructions for applying corrections in Chapter III.

Column 14.—Change or Tendency of Barometer.—In ships which have a barograph enter the characteristic and tendency of the barometer by barograph in accordance with the instruction given in Chapter III, by use of Tables VIII and IX, illustrated by Figure 6. When this method is used the barograph traces should be attached when log or record is returned.

In ships which have not a barograph, obtain and enter the change of the barometer from the last recorded reading made not more than 4 hours previously in accordance with Chapter III.

Columns 15 and 16.—Air and Sea Surface Temperatures.—Enter the temperature of the air and sea to the nearest degree Fahrenheit in their respective columns.

Column 17.—Weather at the Time of Observation.—Enter the weather at the time of observation by the Beaufort Notation remembering that this has to be coded by the International Ships' Wireless Telegraphy Code Tables, abridged for British Ships; and therefore that it will be necessary to note such items as the duration of fog, rain, etc., and also in the tropics to compare the barometer readings with normals given on the Ocean Meteorological Charts, so that all signs of tropical revolving storms may be considered in deciding if 18 and 19 of the Present Weather Table should be reported. *This is very important in the interests of safety of life at sea.*

Column 18.—Past Weather.—Enter the predominating feature of the weather by the Beaufort Notation during the last 6 hours ending at the time of observation.

Column 19.—Visibility.—Enter the visibility in accordance with scale given in Chapter VI.

Columns 20 to 24.—Clouds.—Enter the cloud types in Columns 20, 22 and 23, in accordance with Chapter VI and PLATE V (varnished card), being careful to discriminate properly between the layers of cloud visible.

Column 21.—Enter the amount of *lower cloud only*, in tenths.

Column 24.—Enter the *total amount of sky clouded*, in tenths.

Columns 25 and 27.—Direction of Sea and Swell.—Enter the direction of the sea in Column 25 and the swell in Column 27, both to the nearest point, true.

Columns 26 and 28.—Description of Sea and Swell.—Enter the appropriate scale numbers by the Douglas sea and swell scale.

Column 29.—Remarks.—Enter briefly the times of duration of fog, rain, hail, etc., but particularly ice, derelicts, or floating navigational obstructions. *This is very important in the interests of safety of life at sea.*

Ocean Current Observations.—Enter the year and month; the date, time and position *from*; and the date, time and position *to*; the set and the drift in miles, with any remarks necessary.

The set and drift obtained between stellar fixes at twilight during intervals of about 8 to 10 hours are preferable.

Additional Remarks.—*See* instructions for meteorological log on page 92.

Particulars of Instruments should be entered, and the record should be signed by the principal observing officer, and approved by the captain.

APPENDIX.

APPENDIX.

Meteorological Tables.

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
°	a	a	a	a	a	a	a	a	a
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	
a	*a*	*a*	*a*	*a*	*a*	*a*	*a*	°
− 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.	Adjusted Fiducial Temperature.										Attached Thermometer.
	271	272	273	274	275	276	277	278	279	280	
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. For other cent. of the correction for each 10 millibars above 1,000, and subtract one per

TABLE II.—*cont.*

Between "Attached Thermometer" and Temperature.

Attached Thermometer.	Adjusted Fiducial Temperature.										Attached Thermometer.
	281	282	283	284	285	286	287	288	289	290	
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

pressures an additional correction is necessary, the rule being, "Add one per cent. for each 10 millibars below."

TABLE II.—*cont.*

CORRECTION OF BAROMETER FOR DIFFERENCE
ADJUSTED FIDUCIAL

Attached Thermometer.	Adjusted Fiducial Temperature.										Attached Thermometer.
	291	292	293	294	295	296	297	298	299	300	
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. For other cent. of the correction for each 10 millibars above 1,000, and subtract one per

TABLE II.—*cont.*

Between "Attached Thermometer" and Temperature.

Attached Thermometer.	Adjusted Fiducial Temperature.										Attached Thermometer.
	301	302	303	304	305	306	307	308	309	310	
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

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

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

TABLE III—*continued.*

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	·105	·107	·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	·133	·135	·137	·139	·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.) 0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	Height in feet.
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	·068	·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. At 27.	At 30.	Lat. N. or S.	Correction. At 27.	At 30.	Lat. N. or S.	Correction. At 27.	At 30.	Lat. N. or S.	Correction. 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.

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 VII.

CHANGE OF BAROMETER IN LAST 2, 3 OR 4 HOURS.

(Adapted for British Ships.)

(The change in 3 hours should be given if possible.)

	In 2 hours.	In 3 hours.	In 4 hours.	Code Fig.
Barometer steady.—Has not risen or fallen more than	0·3 mb. (·01 in.)	0·5 mb. (·01 in.)	0·7 mb. (·02 in.)	0
Barometer rising slowly.—Has risen	0·7–1·0 mb. (·02–·03 in).	1·0–1·5 mb. (·03–·05 in.)	1·3–2·0 mb. (·04–·06 in.)	1
Barometer rising.—Has risen	1·4–2·4 mb. (·05–·07 in.)	2·0–3·5 mb. (·06–·10 in.)	2·8–4·8 mb. (·08–·14 in.)	2
Barometer rising quickly.—Has risen	2·6–4·0 mb. (·08–·12 in.)	4·0–6·0 mb. (·12–·18 in.)	5·2–8·0 mb. (·15–·24 in.)	3
Barometer rising very rapidly.—Has risen ..	over 4·0 mb. (·12 in.)	over 6·0 mb. (·18 in.)	over 8·0 mb. (·24 in.)	4
Barometer falling slowly.—Has fallen	0·7–1·0 mb. (·02–·03 in.)	1·0–1·5 mb. (·03–·05 in.)	1·3–2·0 mb. (·04–·06 in.)	5
Barometer falling.—Has fallen	1·4–2·4 mb. (·05–·07 in.)	2·0–3·5 mb. (·06–·10 in.)	2·8–4·8 mb. (·08–·14 in.)	6
Barometer falling quickly.—Has fallen	2·6–4·0 mb. (·08–·12 in.)	4·0–6·0 mb. (·12–·18 in.)	5·2–8·0 mb. (·15–·24 in.)	7
Barometer falling very rapidly.—Has fallen ..	over 4·0 mb. (·12 in.)	over 6·0 mb. (·18 in.)	over 8·0 mb. (·24 in.)	8

TABLE VIII.

CHARACTERISTIC OF CHANGES OF THE BAROMETER IN THE LAST 3 HOURS.

(Adapted for British Ships.)

	Description of Changes.	*Code Figure.*
Net result, Barometer same or higher.	Barometer rising at first, then falling by a smaller or like amount..	0
	Barometer rising at first, then steady or rising less quickly	1
	Barometer unsteady; but generally rising or stationary ..	2
	Barometer steady or rising	3
	Barometer falling or steady at first, then rising by the same or larger amount	4
	Barometer rising, at an increasing rate	4
Net result, Barometer lower.	Barometer falling at first, then rising by a smaller amount	5
	Barometer falling at first, then steady or falling less quickly	6
	Barometer unsteady, but falling	7
	Barometer falling	8
	Barometer steady or rising at first, then falling by a larger amount..	9
	Barometer falling, at an increasing rate	9

Note.—These changes can generally only be given by ships which have special barographs on board.

TABLE IX.

AMOUNT OF RISE OR FALL OF THE BAROMETER IN THE LAST 3 HOURS.
(Adapted for British Ships.)

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

TABLE X.

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 XI.

For Finding the Relative Humidity (per cent.).

Dry Bulb.	Depression of Wet Bulb.												
°F.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°
90	100	96	92	88	84	81	77	74	70	67	63	60	57
88	100	96	92	88	84	80	77	73	69	66	63	59	56
86	100	96	92	88	84	80	76	72	69	65	62	58	55
84	100	96	92	87	83	79	76	72	68	64	61	57	54
82	100	96	91	87	83	79	75	71	67	64	60	57	53
80	100	96	91	87	83	79	74	70	66	63	59	55	52
78	100	95	91	86	82	78	74	70	66	62	58	54	50
76	100	95	91	86	82	78	73	69	65	61	57	53	49
74	100	95	90	86	81	77	72	68	64	60	56	52	48
72	100	95	90	85	80	76	71	67	63	58	54	50	46
70	100	95	90	85	80	75	71	66	62	57	53	49	44
68	100	95	90	84	79	75	70	65	60	56	51	47	43
66	100	95	89	84	79	74	69	64	59	54	50	45	41
64	100	94	89	83	78	73	68	63	58	53	48	43	39
62	100	94	88	83	77	72	67	61	56	51	46	41	37
60	100	94	88	82	77	71	65	60	55	50	44	39	34
58	100	94	88	82	76	70	64	59	53	48	42	37	31
56	100	94	87	81	75	69	63	57	51	46	40	35	29
54	100	93	87	80	74	68	61	55	49	43	38	32	26
52	100	93	86	79	73	66	60	54	47	41	35	29	23
50	100	93	86	79	72	65	59	52	45	38	32	26	20
48	100	92	85	77	70	63	56	49	42	36	29	22	16
46	100	92	84	77	69	62	54	47	40	33	26	19	—
44	100	92	84	75	68	60	52	45	37	29	22	—	—
42	100	91	83	74	66	58	50	42	34	26	18	16	—
40	100	91	82	73	65	56	47	39	30	27	—	—	—
38	100	91	81	72	63	54	44	39	31	22	—	—	—
36	100	90	80	70	60	54	44	35	26	18	—	—	—
34	100	90	79	70	60	50	41	31	21	—	—	—	—
32	100	89	79	68	57	47	36	27	17	—	—	—	—
30	100	88	76	65	53	43	33	22	—	—	—	—	—

TABLE XII.

For Finding the Dew Point (°F.).

Dry Bulb.	Depression of Wet Bulb.												
°F.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°
90	90	89	87	86	85	83	82	80	79	77	76	74	73
88	88	87	85	84	83	81	80	78	77	75	74	72	70
86	86	85	83	82	80	79	78	76	75	73	71	70	68
84	84	83	81	80	78	77	75	74	72	71	69	67	66
82	82	81	79	78	76	75	73	72	70	68	67	65	63
80	80	79	77	76	74	73	71	69	68	66	64	62	61
78	78	77	75	74	72	71	69	67	66	64	62	60	58
76	76	75	73	72	70	68	67	65	63	61	60	58	55
74	74	72	71	69	68	66	64	63	61	59	57	55	53
72	72	71	69	67	66	64	62	61	59	57	55	52	50
70	70	69	67	65	63	62	60	58	56	54	52	50	47
68	68	66	65	63	61	60	58	56	54	52	49	47	45
66	66	64	63	61	59	57	56	53	51	49	47	44	42
64	64	62	61	59	57	55	53	51	49	47	44	41	38
62	62	60	59	57	55	53	51	49	46	44	41	38	35
60	60	58	56	55	53	51	48	46	44	41	38	35	32
58	58	56	54	52	50	48	46	43	41	38	35	32	28
56	56	54	52	50	48	46	43	41	38	35	32	29	25
54	54	52	50	48	46	43	41	38	35	32	29	25	20
52	52	50	48	46	43	41	38	36	32	29	25	20	16
50	50	48	46	43	41	39	36	33	29	25	21	16	10
48	48	46	44	41	39	36	33	30	26	22	17	12	4
46	46	44	42	39	36	34	30	27	23	19	13	6	—
44	44	42	39	37	34	31	28	23	19	15	8	—	—
42	42	40	37	34	32	28	25	20	16	9	—	—	—
40	40	38	35	32	29	26	22	17	11	8	—	—	—
38	38	35	33	30	26	22	18	15	10	3	—	—	—
36	36	33	30	27	23	21	16	11	5	—	—	—	—
34	34	31	28	25	22	17	13	7	—	—	—	—	—
32	32	29	26	22	19	14	8	—	—	—	—	—	—
30	30	27	23	20	15	10	4	—	—	—	—	—	—

TABLE XIII.—RAINFALL.

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

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 XIII.—*cont.*—RAINFALL.

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

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.

TABLE XIV.

CONVERSION OF NAUTICAL MILES TO STATUTE MILES AND KILOMETRES.

Nautical Miles.	Statute Miles.	Kilometres.	Nautical Miles.	Statute Miles.	Kilometres.
1	1·2	1·8	20	23·0	37
2	2·3	3·7	30	34·5	56
3	3·5	5·6	40	46·1	74
4	4·6	7·4	50	57·6	92
5	5·8	9·3	60	69·1	111
6	6·9	11·1	70	80·6	130
7	8·1	13·0	80	92·1	148
8	9·2	14·8	90	103·6	167
9	10·4	16·7	100	115·2	185
10	11·5	18·5			

Based on Nautical mile of 6,080 feet.

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