INSTRUCTIONS

TO

OBSERVERS OF THE INDIA METEOROLOGICAL DEPARTMENT.

BY

J. ELIOT, M.A., F.R.S., F.R. MET. SOC., C.I.E.,

METEOROLOGICAL REPORTER TO THE GOVERNMENT OF INDIA AND DIRECTOR-GENERAL OF INDIAN OBSERVATORIES.

SECOND EDITION.

Printed for the use of the Meteorological Department by authority of the Government of India.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA
1902.

CALCUTTA:
GOVERNMENT OF INDIA CENTRAL PRINTING OFFICE,
8, HASTINGS STREET.

CONTENTS.

INSTRUCTIONS

TO

OBSERVERS OF THE INDIA METEOROLOGICAL DEPARTMENT

INTRODUCTION.

1. The present book of instructions for meteorological observers in India is intended to supersede the Indian Meteorologist's Vade Mecum which is no longer in print. Since the publication of that work a large number of changes have been made in the methods of taking and recording observations in India, which have made it necessary to prepare a new book of Instructions for observers.

2. Meteorological observers in India now merely take the readings of certain meteorological instruments and forward by telegram or by post on suitable forms the statements of these recorded readings or observations to the Meteorological Office. The reduction and preparation of the data for subsequent use and discussion is done in one or other of the Meteorological Offices in India. Hence this pamphlet of "Instructions to observers" is confined to a description of the various instruments in use at the meteorological observatories in India, the precautions to be taken to maintain them in good order, the methods to be used to restore them to good order when it is possible for the observer to do it, and the proper methods of reading the instruments and of taking and recording the observations. No explanations are given as to how the readings are corrected and reduced for inclusion in the Daily Weather Reports and other publications of the Department. It is simply and solely a book of instructions to enable Indian observers to take and record the observations of the meteorological instruments entrusted to their care satisfactorily and correctly.

3. Requirements for systematic accurate observation at Indian observatories.—In order that satisfactory and trustworthy observations for any place should be obtained, it is necessary that a set of accurate meteorological instruments should be in use, that they should be exposed under proper conditions, and that they should be in the charge of an observer who takes due care of them and reads them

B.

carefully and exactly at the appointed hours, and records the observations in the appointed manner.

4. **Supply of accurate instruments.**—Every effort is made by the Imperial Meteorological Office, Calcutta, to obtain thoroughly reliable instruments. All instruments are carefully examined and tested at the Alipore Observatory attached to the Imperial Meteorological Office before they are issued to observatories. Whenever an observatory is inspected, the instruments are thoroughly examined by the inspecting officer, and comparative readings are taken in order to test whether the instruments continue to be in good order, and if not, they are condemned and replaced by new instruments, either at the time or shortly afterwards.

5. **Requirements for proper exposure of instruments at Indian meteorological observatories.**—The various instruments used in Indian observatories require different exposures. It is, for example, very desirable that barometers should not be exposed to large or sudden changes of temperature, and they are hence usually placed in rooms which are kept closed so far as possible. The thermometers are, on the other hand, used to obtain the temperature of the air out in the open, but not exposed to the sun's rays, and are hence placed in a shed open at the sides, but covered with a thick thatched roof, whilst the raingauges are placed out in the open, and the instruments for recording the direction and force of the wind are erected on the most elevated exposed position that is available.

The complete space requirements of an observatory are hence :—

1st.—A large or moderate-sized room in which the barometer may be permanently located.

2nd.—A large open space not far from the barometer room, in which the shed for housing the thermometers may be erected, and in which the raingauge may be suitably placed, at a distance from all buildings, trees, etc.

3rd.—A flat roof or tower for the reception of the wind vane and anemometer. Where these are wanting, it is usually necessary to erect a wooden staging.

6. **Chief objects for which meteorological observations are recorded in India.**—Meteorological observations are recorded for a variety of reasons and with a number of objects in view. One of the most important objects is to collect data from which to determine the climatic conditions of the place and the district in which it is situated, and of which it is believed to be representative. By the climatic conditions are meant the prevailing or mean air pressure conditions, the mean or normal temperature and humidity conditions, the diurnal monthly and annual variations of temperature and humidity, the mean winds, the normal quantity of rainfall of the year, and also month by

month and day by day. When the average or (as they are usually termed) the normal conditions have been determined for any period, it is then possible to compare the actual conditions that prevailed during any season or part of a season with the conditions that previous observations have shown to prevail usually at that period, and to utilize the comparison between the actual and the normal in explaining the health or sanitary conditions of the period, the unusual prevalence of certain diseases, the condition of the crops, etc., etc.

Meteorological observations in India are also used largely for the purpose of giving warnings of the approach of cyclonic storms, floods, etc.

It may, however, be accepted that the most important use which is made of the observations at any observatory in India is the determination of the normal meteorological or climatic conditions of the district in which the observatory is situated and which it is believed to represent.

In order to determine the normal meteorological conditions of a place, accurate observations for a period of at least ten years are necessary in India. When observations for ten years or upwards have been taken at an observatory, and the means or normal values have been deduced or determined by methods employed in all meteorological offices, they form a standard serving useful purposes. They serve as a test of the probable accuracy of future observations at the same place. They are utilized as a standard to ascertain the peculiar features of the weather at any time, as estimated by the observations of the meteorological instruments in use. They also enbale the climatic conditions of one place to be compared critically with those of other places, and may be employed to throw light upon any peculiar features in the health of the population or the abnormal prevalence of diseases, epidemic or otherwise, in the district of which it is representative. The collected series of observations and the means derived from them for any station are hence of very great value.

7. **Conditions necessary to obtain a prolonged series of accurate observations at stations in India.**—It is, however, evident that if we wish to obtain an accurate and satisfactory estimate by means of a few years' meteorological observations, the observation should be taken under similar or identical conditions throughout the whole period. This requires that the following conditions should be fulfilled :—

1st.—That the instruments used for observation should be always in good order, and if it be necessary for any reason to change an instrument, one of similar kind and quality should be substituted.

2nd.—That the conditions of exposure of the instruments should be unchanged throughout the whole period.

3rd.—That the observer should always take the observations, as far as possible, with the same degree of accuracy and care and at the appointed hours.

The second and third conditions are mainly under the control of the Superintendents and Observers of the meteorological observatories, and the first under that of the Meteorological Reporters who are usually able to judge from the observations submitted whether the instruments are in good order or not.

8. **Change of site of observatories especially objectionable.**—The second of these conditions is the one which is on the whole the most difficult to secure in India. Observatories are usually established in an open place near some Government building, as for example, a hospital, dispensary, post office, etc. The site for the shed is, as a rule, selected by an officer of the Department, and care is taken to choose a spot well away from trees, buildings, etc., and that is not watered by irrigation, and is believed to be representative, as far as possible, of the open country in the neighbourhood of the station. Sooner or later, young trees are planted near the shed by some energetic official. When they grow up, they shade and shut the observatory more or less completely from the prevailing winds. Sometimes the ground round the shed is laid out into flowerbeds, etc., and the ground freely irrigated from some neighbouring well, etc. That such changes are not infrequent is shown by the fact, that in one province alone in which there are only eleven observatories which have been established and working satisfactorily for upwards of ten years, the conditions of at least three have been altered to a very considerable extent in this way. One is apparently damper than it used to be, the second is hotter, and with a smaller daily range of temperature, and at the third, the observations have been eccentric and useless, as the comparison with the means of previous observations at that station frequently shows, for example, that when it is hotter than usual at all other places in the neighbourhood it is apparently cooler at that station. Unfortunately the Meteorological Department can do little more than protest against such changes of conditions.

It is hence evident that a change of site of an observatory from one part of a station to another will often alter very considerably the conditions of exposure. It will be sufficient to give only one example :—The observatory at Lahore was formerly located in the Mayo Hospital, but it was found necessary to remove it. It was established in an open area at the same level near the Jail where the conditions, so far as could be judged by eye inspection, were almost identical. The following gives the actual mean temperature at the two places as determined by two years' comparative observations taken in the years 1885 and 1886 :—

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1st Site .	58°·7	62°·3	76°·2	87°·3	91°·6	99°·6	93°·4	92°·9	94°·1	86°·7	76°·4	64°·8
2nd Site .	58·3	63·3	76·1	87·4	91·2	98·9	92·9	92·3	94·1	86·9	76·4	64·6
Difference	+0·4	—1·0	+0·1	—0·1	+0·4	+0·7	+0·5	+0·6	0	—0·2	0	+0·2

A similar comparison of the maximum and minimum temperature shows still larger differences than the preceding, as is established by the data of the following tables :—

		Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean Maximum.	1st Site . .	64°·1	68°·4	81°·5	92°·8	96°·5	104°·8	97°·8	97°·9	99°·7	93°·3	84°·0	72°·0
	2nd Site . .	63·7	68·1	81·0	92·9	95·9	104·1	97·8	97·6	99·5	93·4	83·7	71·5
	Difference . .	+0·4	+0·3	+0·5	−0·1	+0·6	+0·7	0	+0·3	+0·2	−0·1	+0·3	+0·5
Mean Minimum.	1st Site . .	45·5	44·2	57·2	65·8	71·1	79·9	80·6	80·0	75·2	63·0	51·1	45·2
	2nd Site . .	43·6	41·7	55·2	62·9	69·1	78·3	79·8	79·4	73·3	60·8	48·4	42·9
	Difference . .	+1·9	+2·5	+2·0	+2·9	+2·0	+1·6	+0·8	+0·6	+1·9	+2·2	+2·7	+2·3

Hence, even under the most favourable conditions, a change of site of an observatory at a station will probably introduce a change in the observed temperature readings, averaging sometimes as much as 2° or 3°, and this change may sometimes be positive, and sometimes negative. And as the differences between the actual mean monthly temperatures and the normal means of stations in India are in three months out of four not greater than two degrees, it is evident that a mere change of site of an observatory, might alter the temperature observations to such an extent, as to conceal the real variations of the temperature of the period from the normal, and hence, (if the effect of the change of site be not carefully ascertained and allowed for in the observations) a comparison of these observations with the normals derived from the observations at the old site would be useless (or, still worse, misleading) for any scientific purpose, such as, for instance, tracing the relations between weather and disease.

It is almost self-evident that a thermometer exposed in a closed room in India would give a very different temperature from one exposed in the verandah of the same house, or from another placed under a grass covered shed amongst trees, or from another placed under a grass covered shed in the open to which the winds had ready and free access, and yet each of these might be termed the temperature, at that instant, at the place of observation. It is not necessary to give any proof of this, as any one can test it for himself.

It is hence absolutely necessary if the observations are to be not only accurate, but of value for scientific purposes, that they should, so far as possible, be taken under standard and similar conditions everywhere in India, and the Meteorological Department has laid down standard conditions, and endeavours, so far as possible, to adopt them at all observatories, and to secure, so far as possible, their continuance.

9. **Conditions that should be fulfilled in the selection of a site for an observatory at a station.**—It follows from the preceding remarks :—

1st.—That when it has been decided to establish an observatory at a station, the site for the observatory should be selected with the greatest care. The most important requisite is, that it should be a permanent site, one that will not in the future be required for any other purpose, and be utilized for that purpose by some other Government Department.

2nd.—That the site, on which the shed for the thermometers is to be erected, should be a large and fairly open plot of ground, at least 30 yards in diameter, so that the shed may be at least 50 feet from any large trees or buildings, and the prevailing winds may have free access to the shed.

3rd.—That the space set apart for the observatory should be maintained, so far as possible, in the same state, no shrubs or trees being planted within the area, nor changes made in the cultivation of the ground immediately surrounding the shed and within an area 30 yards in diameter, more especially such as require a large amount of additional irrigation.

4th.—That the observatory should, if possible, be continued at this site. The longer an observatory has been maintained in a given site, the more valuable are the accumulated observations as they furnish more trustworthy and accurate means or normal values of the elements of meteorological observation, and hence the greater the objection to a removal from a site, the conditions of which have been exactly ascertained, to another one, the conditions of which are known only to the extent that they differ from the preceding by unknown small or moderate amounts varying with the season and other conditions.

5th.—That, in order that a change of site may be effected in such a way as to enable the previous observations to be fully utilized for future comparison, it is necessary, comparative observations should be taken at the two sites for at least two years, in order to determine the differences in the temperature, humidity and rainfall conditions of the two sites, or exposures, etc. When this has been done, it is then possible to apply corrections to the observations (and their means) at the old site, and thus adapt them to represent the conditions at the new site.

10. **Thermometer sheds.**—The preceding remarks have stated the conditions that should be observed in selecting a site for an observatory. It has been pointed out that it is also necessary to have the instruments exposed under similar conditions. Hence the sheds in which the thermometers are exposed should be constructed on the same plan at all stations. This principle has not been fully carried out for various reasons. At meteorological stations in the Madras Presidency, the sheds are all of the pattern introduced upwards of 38 years ago by the late Mr. Pogson, Government Astronomer. Where new sheds of this pattern are required, they are made at Madras under arrangements carried out by the Meteorological Reporter to the Government of Madras. It is hence not necessary to give any plans or details of these sheds. Over the remainder of India, the sheds are constructed according to the pattern introduced by the late Mr. Blanford into Bengal many years ago. As it is frequently necessary that these sheds should be constructed under local supervision, the following information is given for the guidance of the Superintendents or other local authorities, when called upon to furnish plans and estimates for the construction of such sheds:—

The Bengal pattern shed consists of a framework twenty feet long and sixteen feet wide, well thatched above and open all round. It should be erected in an open grassy place, at a distance of not less than 50 feet from any wall or other radiating surface, the ridge pole pointing north and south. It has a small opening above, to allow of the escape of heated air. This opening, however, should be small, and may be advantageously replaced by a section of a large bamboo, to serve as a ventilating pipe, inserted through the thatch immediately beyond the ridge pole. The cage containing the thermometers is affixed to the southern pole, and faces to the north. The eaves should be between five feet and five feet six inches above the ground.

Full and complete plans and estimates for sheds of this pattern were kindly worked out by Mr. Mackenzie, District Engineer, when he arranged for the erection of a shed at Mainpuri. The plans are given in the accompanying Plates I and II.

The statement of the quantities and of the probable cost of the shed which, it may be noted, is of a stronger and neater pattern than the great majority of sheds hitherto erected on this pattern in Northern India, is given on the plan (Plate II).

The cost of erecting a strong and neat shed of this pattern in any part of Northern and Central India should hence not exceed Rs. 160.

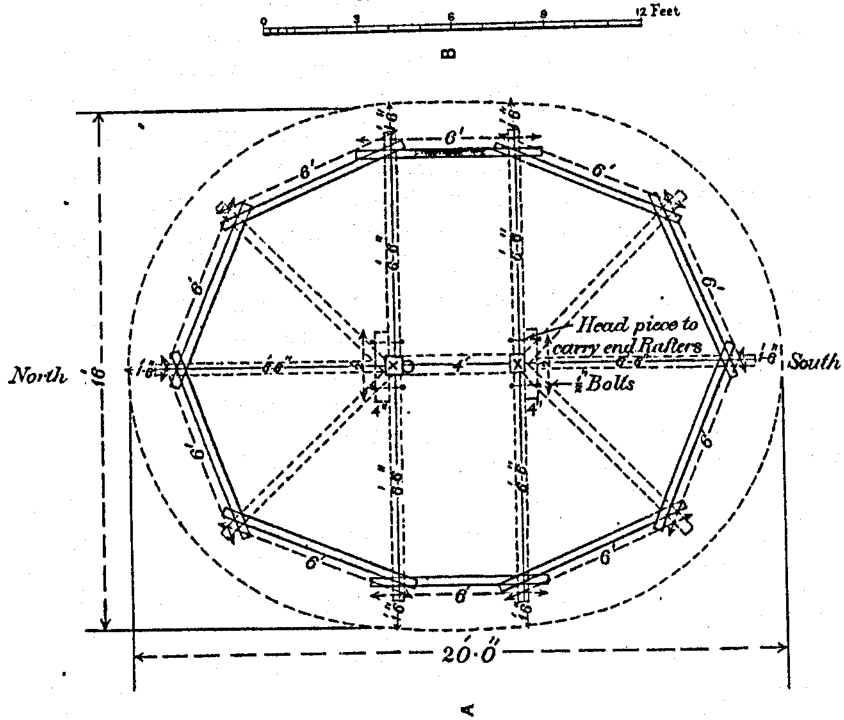
11. **Objections to verandahs and stands.**—Other modes of exposing thermometers are—suspending them against a wall or on an open stand in the verandah of a house, or in a small box with louvre sides supported on four legs. All these are open to serious objection. The walls of a house absorb a large quantity of heat during the daytime and give it out again during the night, while the circulation of air in a verandah is necessarily less free than in an open shed. The result is, that a thermometer thus exposed, shows a temperature too low in the daytime, and too high at night. In 1866 and 1867, Dr. J. C. Bow, at Chunar, instituted a comparison between the temperatures shown by thermometers exposed in a verandah and under a thatched shed, and in 1866 found that, while in the former position the mean daily range was 12° only, in the latter it was 24°; and in 1867, 11° in the former and 23° in the latter. Thus half or more than half of the daily range was lost in the verandah by the want of free exposure. The means for the month and the year were nearly the same in the two cases, but while, on an average, the extreme day temperature, as determined from the verandah observations, was 6° too low, that of the night was too high by the same amount.

It is sometimes necessary to remove the thermometers from a shed during repairs or partial reconstruction. It may then be desirable to suspend the thermometers in the least objectionable position so that observations may continue to be recorded during the repairs. In such cases if there be a north verandah available, the instruments should be placed in it. They should be placed in the centre of the verandah, and not against the wall, and hence some simple method of suspending the thermometer cage, so as to give a fairly free exposure on all sides, should be arranged for. If this cannot be done, the observations of temperature should be discontinued during the repairs.

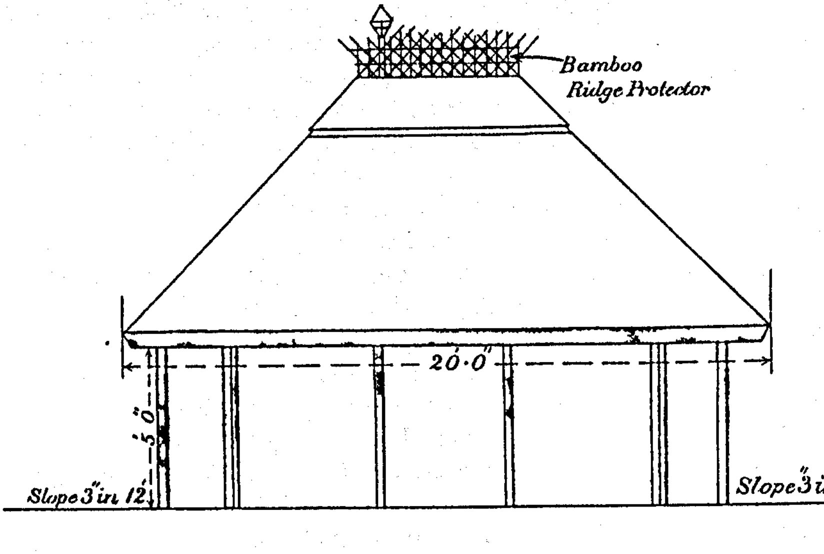
12. **Repairs to observatory sheds, etc.**—It has been pointed out (Sections 7 and 8) that, in order to obtain accurate and satisfactory observations, the conditions of exposure of the instruments

OBSERVATORY

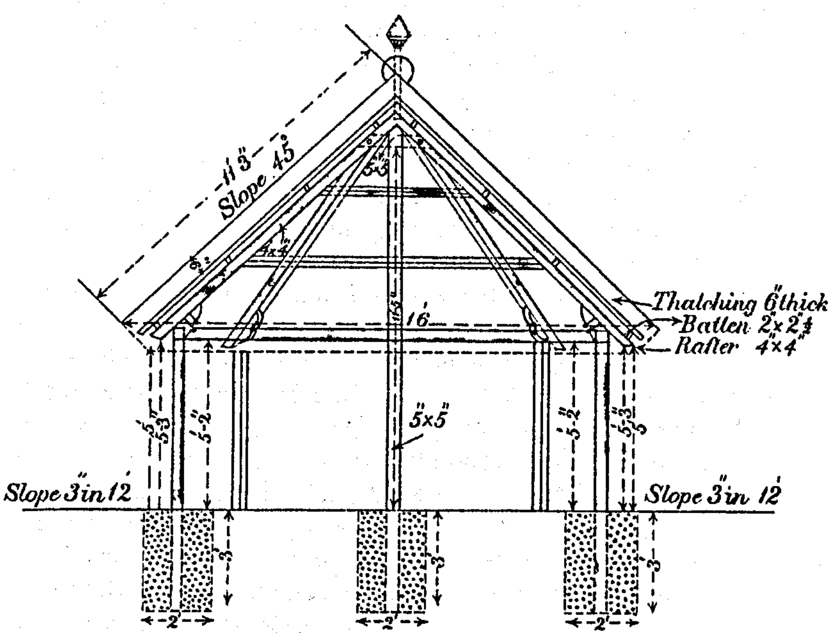
Scale 1 Inch = 6 Feet.



ELEVATION.



Met. 404 Wr. India.—Aug. 09.—1,100.



STATEMENT OF QUANTITIES AND COST.

		Estimated Cost.
		Rs.
Concrete	144 C. ft.	14
Wood work	407 C. ft.	102
Bamboo frames	348 S. ft.	10
Thatching 6"	396 S. ft.	24
Sundry job in dressing Floor, Nails and Spikes, Ridging Bamboo guard and Ventilator about		13
	Total Rs. -	163

N. B.—Where "Bullas" and "Bullies" can be had cheaper than Scantlings, they should be used for the whole of wood work.

should remain, so far as possible, unchanged in every respect. For this reason alone it is necessary that observatories should, so far as possible, be kept in the same state of good repair. It is also desirable for another reason. Experience shows that if an observatory shed be kept in good condition, the cost of the petty repairs necessary to maintain it in that state is comparatively trifling, whereas if neglected for a year or two, it will almost certainly fall into bad repair, and it will probably be necessary, after two or three years' neglect, to renew the whole or the greater part of the shed at a considerable cost. It is therefore not only essential for accurate observations but most economical that sheds should be kept in a state of constant good repair, and hence as soon as any petty repairs are required they should be executed without delay.

It is one of the recognized duties of Observers to look carefully after the condition of their observatory sheds and other buildings, and to call the attention of their Superintendents to any defect, in order that the necessary action may be at once taken to carry out the repairs required.

The following is the procedure to be adopted when repairs or partial reconstruction of a meteorological observatory is considered to be necessary by the Superintendent[1]:—

(1) If an observatory requires repairs, the Superintendent should report the fact to the officer controlling the observatories of the province in which the observatory in question is situated, when he will be informed what action it is necessary to take.

(2) The Superintendent of the observatory should, if so directed by the controlling officer, obtain estimates from one or more local contractors, and forward each estimate *in duplicate* to that officer.

(3) The controlling Meteorological Office should send the estimates without delay to the Imperial Meteorological Office at Calcutta with any necessary remarks or suggestions that appear desirable for the information of that office.

(4) The Imperial Meteorological Office, after making any necessary enquiries, either direct from the Superintendent of the observatory concerned or the controlling Meteorological Office, will return the approved estimate duly sanctioned to the Superintendent of the observatory through the controlling Meteorological Office.

(5) On receipt of the sanctioned estimate, the Superintendent should get the work done with as little delay as possible by the contractor whose estimate has been approved, and when the work has been completed in accordance with the estimate, and to his full

[1] In March, 1896, the Indian Meteorological observatories were transferred to the charge of the Public Works Department, with the exception of Secunderabad, Veraval, Deesa, Quetta, Chaman, and the Extra-Indian observatories. To observatories under the Public Works Department only sections (1) and (8) apply.

satisfaction, a bill signed by the contractor, and countersigned by the Superintendent, giving details of materials used and of cost, and enclosing the sanctioned estimate and a completion certificate signed by the Superintendent, should be sent direct to the Imperial Meteorological Office at Calcutta, whence the amount of the bill will be remitted direct to the Superintendent by means of a money order.

(6) The sanctioned estimate should innocase be exceeded without the previous consent and sanction of the Imperial Meteorological Office.

(7) Superintendents of observatories are requested to carefully note that repairs to observatories should, on no account, be commenced without sanction from the Imperial Meteorological Office (with which alone rests the payment for all repairs to observatories), obtained through the Provincial Reporter.

(8) Superintendents should also see that the observers look after the proper preservation of the sheds, and that when repairs are required, the fact should be notified without delay to the Controlling Officer.

13. **Classification of observatories.**—The observatories of the India Meteorological Department are classified as follows:—

First class.—Observatories at which continuous records are obtained by means of self-registering instruments.

Second class.—Observatories at which observations are recorded three times daily, *viz.*, at 8 A.M., 10 A.M. and 4 P.M.

Third class (*a*).—Observatories where observations are recorded at 8 A.M. only for transmission by telegraph[1] to Simla, Calcutta, Bombay or Madras.

(*b*).—Observatories where observations are recorded at 10 and 16 hours only.

Fourth class.—Observatories where observations of only temperature, wind direction and rainfall are recorded.

14. **Instruments supplied to Indian observatories.**—The following gives a list of the instruments[2] supplied to second and third class observatories arranged according to their exposure:—

1st.—In office room.

(1) Barometer.

2nd.—In observatory shed.

(2) Dry bulb thermometer.
(3) Wet bulb "
(4) Maximum "
(5) Dry minimum thermometer.
(6) Wet " "

[1] A few observatories send observations by post only.

[2] Barographs, thermographs and anemographs have been supplied to certain second and third class observatories.

3rd.—Outside shed.

(7) Raingauge.

4th.—On roof of some building, or on staging.

(8) Wind vane.

(9) Anemometer.

In order that meteorological observations may be of value, it is not merely necessary that accurate instruments and suitable buildings should be provided. The most important requisite is, that observers should know how to read all the instruments entrusted to them accurately, and that they should take the observations carefully and correctly, at the appointed times, and record them in the manner laid down in the following instructions.

Observers should understand that it is a deception, a fraud, to put on permanent record the temperature at say 3-30 P.M., as the temperature at 4 P.M., and yet it is to be feared that many observers are careless in regard to taking observations exactly at the appointed hours. Again several cases have come to light during recent years of observers having delegated a large part of their work to a subordinate, or even to a messenger orpeon, paying them a small portion of their meteorological allowance. It is hardly necessary to state that any observer who delegates his work by a private arrangement and without obtaining the sanction of his Superintendent and the local Meteorological Reporter is acting dishonestly. It is of course desirable that at every station there should be some one who has been taught by the observer, qualified to take up the work of recording the observations in case of the illness, etc., of the observer. Such an arrangement is, however, quite different from that of delegating a large part of the duties to a messenger or peon for an allowance of say two rupees per mensem.

Honesty is hence a *sine quâ non.* But neither honesty nor zeal will suffice without knowledge, and it is the object of the following instructions to enable observers to read their instruments correctly, and to keep them in proper order. Explanations are given so far as is possible in a book of instructions, in order that observers may understand the reasons of the rules and methods laid down in the instructions, in the hope that this will assist observers to take the observations intelligently and not blindly and by rote.

15. Books on Meteorology.—For those who are interested in this subject as a science and who wish to study it, the following elementary works are recommended:—

R. H. Scott's Elementary Meteorology; Abercrombie's Weather; Buchan's Handy Book of Meteorology; Davis's Elementary Meteorology; and Waldo's Modern Meteorology.

BAROMETER.

16. **Description of Instrument.**—The barometer (Fig. 1) is an instrument devised to measure the pressure of the atmosphere at the place and time of observation. It consists of a vessel, usually of cylindrical shape, partially filled with mercury in which is inverted a glass tube about 36 inches in length closed at the top and open below, and which before being inverted was entirely filled with mercury. It is proved in treatises on hydrostatics that the air pressure on the surface of the cistern can support in the tube a column of mercury which presses on its base with a force equal to that of the air on the same area of cistern surface. An air column resting on any surface at about the level of the sea presses equally with a column of mercury of the same section and about 30 inches high on an average. Hence if a tube less than 30 inches in length is filled with mercury and is plunged into the mercury contained in the cistern at a place at or near the sea-level it will remain filled with mercury. But if longer (and a barometer tube is always longer than 30 inches), the top of the mercury in the tube will fall to about that height above the level of the mercury in the cistern and leave a vacuum in the upper part of the tube, usually known as the Torricellian vacuum. If the pressure of the air on the mercury of the cistern increases, the column of mercury in the tube increases in length, and if the pressure of the air decreases, the column of mercury in the tube decreases proportionately in the tube. Hence the length of the mercury column (from the surface of the mercury in the cistern to the top of the mercury in the tube) is a measure of the pressure of the air on the mercury in the cistern or of the air immediately surrounding the barometer cistern.

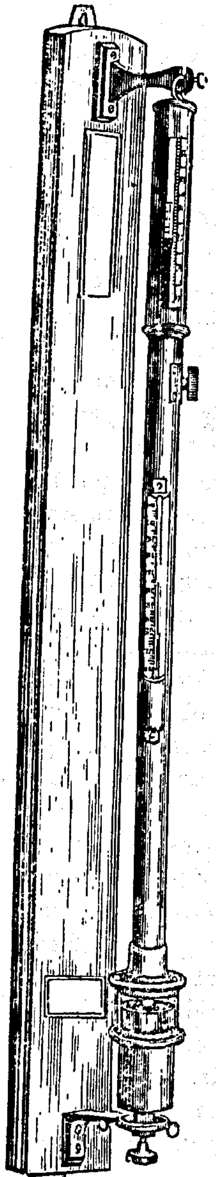


Fig. 1.—Fortin Barometer.

A scale hence forms a part of the barometer to enable the length of the variable column of mercury in the tube to be measured readily and exactly.

The essential parts of a barometer are :—

(1) A cistern of mercury.

(2) A tube of about 36 inches in length containing the column of mercury.

(3) A scale.

In addition to these essential parts there are certain arrangements for enabling the length of the mercurial column to be measured as exactly as possible, and usually within one or two thousandths of an inch of the correct value. These are :—

(1) Certain arrangements in the cistern.

(2) The addition of a vernier to the scale.

(3) An attached thermometer.

These additions are described fully below.

17. **The Cistern.**—The cistern is a completely closed cylindrical vessel. Externally the lower portion is of brass and the upper portion of glass in order to enable the surface of the mercury in the cistern to be seen. It is closed above and below by brass plates. Through the lower plate passes a screw, the object of which is explained below; and through the upper plate passes the tube of the barometer containing the mercury column which measures the air pressure. The lower portion of the cistern is bound to the upper by means of three screws shown in the diagram (Fig. 1) given under section 16 and also again in the figure given with section 21 (Fig. 3). The cistern is, when in proper order, mercury-tight but not air-tight. The external air in fact communicates with the internal air between the glass portion and the upper brass plate sufficiently rapidly to enable the air inside to follow fully and quickly the changes of pressure of the air immediately surrounding the cistern.

18. **The scale and zero point.**—The scale of the barometer from which the readings are made is divided into inches, tenths and twentieths of an inch, and numbers are attached so as to enable the scale divisions to be read at once. As the fluctuation of the barometer at the same place only extends over a few inches, the scale is not graduated down to the zero point. In the barometers supplied to the stations in the plains of India, they are graduated from 31 inches to 25 inches, and in those used at the hill stations, they are graduated down to 20, 15 or 10 inches, according to the height of the station.

The zero point of the scale, that is, the point from which the measurements on the scale are made, is the point of a small ivory pin or stud which projects downward from the top or upper brass plate of the cistern. It is at once seen by looking through the upper cylindrical glass portion of the cistern.

19. **Verticality.**—It has been stated above that the pressure of the atmosphere on the mercury surface of the cistern is measured by the height of the top of the mercury column in the tube above the mercury surface in the cistern. It is hence clear that the distance between the surface of the mercury in the cistern and that of the top of the column should be measured exactly on a vertical line. The barometer tube and scale should therefore be perfectly vertical, in order that the height or distance to be measured may be properly measured. If a barometer be not vertical, the length of the column as read on the scale attached to it, will be invariably greater than the vertical height, and the actual measurements will be larger than they ought to be, and be more or less erroneous according to the amount that the barometer deviates from the vertical.

As barometers are usually placed in position by officers of the Department during visits of inspection, and due precautions taken to ensure that they are in such cases suspended properly and vertically, observers should on no account interfere with the suspension of the barometer, unless they first obtain permission from the Local Meteorological Reporter or the Imperial Meteorological Office at Calcutta, when full instructions will be given in each case to the observers to enable them to make the desired or necessary changes of suspension properly.

20. **Surface of the mercury in the tube.**—An examination of the top of the mercury in any barometer tube will at once show that its surface is not flat but rounded. This is due to the fact of the mercury being confined in a tube of comparatively small section, and is a special result of what is termed "Capillary action."

The surface of the column of mercury in all barometer tubes is hence not flat, as might at first be expected from what is known of the free surface of water in large vessels, tanks, etc., but rounded or convex, and it is hence necessary to state what is regarded as the top of the column. The top of the column is the highest point of the curved or rounded surface. It is not, as is too often assumed by careless observers and by persons unacquainted with the proper use of the instrument, the line which bounds the contact of the mercury with the glass, and which is appreciably lower than the real top or summit of the column. The following (Fig. 2) is a magnified sketch of the appearance of the top of the column:—

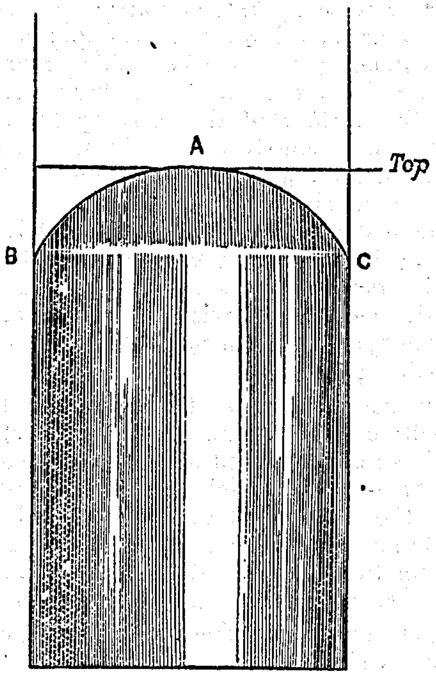


Fig. 2.—Top of Mercury column of Barometer.

BAC is the rounded top. A is the highest point, top or summit. BC is the line of contact of the mercury surface with the glass. *The length of the column is hence the measure from the zero point to the highest point or summit of the rounded surface marked A in the diagram.*

The exact measurement of the height of this point (A) above the level of the mercury in the cistern is effected by means of the "Vernier" which is described in section 22.

21. **Adjustment of the mercury surface in the cistern to the zero point of the scale.**—The pressure of the air at any place is in a state of continual change, and hence the length of the column of mercury in a barometer tube is also continually changing, at one time increasing and at another time decreasing. As the quantity of mercury in the barometer is constant, it is evident that when the column in the tube lengthens, it can only do so by a portion of the mercury in the cistern passing into the tube, and hence at the same time the level of the mercury in the cistern must sink. Similarly, if the length of the column of mercury in the tube diminishes, a portion of the mercury previously in the tube must pass out into the cistern and hence raise the level of the mercury surface. Hence not only is the length of the column continually changing but also the level of the surface in the cistern, at one time rising above the ivory point and at another time falling below it.

It has been explained above that the measure of the pressure is the height or distance in a vertical line from the mercury surface in the cistern to the top of the mercury column, and that the measurement is made by a scale, the zero or starting point of which is the point of the ivory stud passing down from the upper brass plate or top of the cistern. It is hence essential when taking a reading or observation of the barometer that the point of the ivory needle should coincide exactly with the surface of the mercury in the cistern, and that there should be some contrivance to bring them together or move the needle out of the liquid when it is immersed in it, so as to make the point of the needle coincide exactly with the surface of the mercury. This is done in the barometers usually supplied to Indian observatories by keeping the point of the needle fixed and adjusting the level of the mercury surface so as to touch it exactly. This method of adjustment was devised by Fortin, and all barometers in which it is employed are termed "Fortin barometers" or "barometers on Fortin's principle."

Barometers constructed on this principle have the bottom of the cistern (within the outside brass cylinder) formed of a bag of leather. A screw provided with a milled head projects from the bottom of the brass casing which encloses the cistern and in which it works. At the upper end of this is a small wooden piece which presses upon the bottom of the bag. As the screw is turned round, it either lifts up the bottom of the bag or allows it to fall down, and hence alters the height of the mercury surface in the cistern.

The external and internal construction of the cistern of a standard barometer is shown below.

Fig. 3 is a sketch of the exterior.

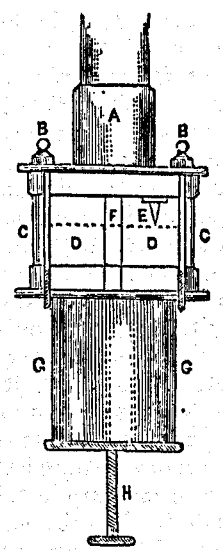


Fig. 3.—Exterior of cistern of Fortin barometer.

CC is the glass portion of the cylinder, and GG the lower portion made of brass. BB are the heads of two of the screws which bind the glass portion of the cistern to the lower portion. A is the brass casing enclosing the barometer tube, the lower portion F of which is shown dipping into the mercury in the cistern. DD is the mercury the surface of which is represented by the dotted horizontal line. E is the ivory stud, the end or point of which is the zero of the scale. H is the screw by turning which the surface DD of the mercury in the cistern can be made to coincide exactly with the ivory point.

Fig. 4 exhibits the internal arrangements.

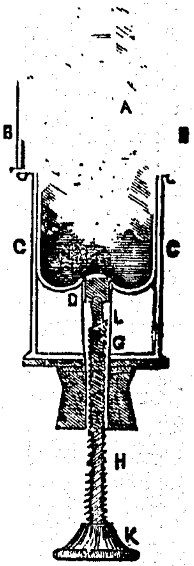


Fig. 4.—Interior of cistern of Fortin barometer.

A is the ivory stud, BB is the glass portion of the outer cistern and CC the lower or brass portion. D is the leather bag firmly attached to the cylinder by suitable arrangements. The lower part of D is raised or lowered by the wooden piece L which forms the upper portion of the screw KHG.

In order to adjust the mercury surface in the cistern, first lower it by turning the screw until the surface is well below the stud. Then raise it again very slowly until it just touches the point of the stud, without being pressed down at the point of contact. If the surface of the mercury is bright the position of contact may be judged very accurately, by watching the apparent approach of the point and its reflection in the mercury, until they meet. If the point appears to press down upon the mercury surface and to form a little cup-like hollow, the latter is too high and must be lowered.

If the stud have a chisel edge, the adjustment may be determined by so screening the cistern at the side, that the ivory stud is well shaded; and keeping the eye on the level of the mercury surface a piece of paper or other white surface behind. A streak of light is then seen below the stud until the instant that contact is made, when it at once disappears. The degree of accuracy with which the adjustment may be made very much depends on the skilful arrangement of the light.

22. **The Vernier.**—In order to enable the height of the mercury column to be measured very accurately, a small moveable scale of peculiar construction called a "Vernier" (Fig. 5), from the name of its inventor, is attached to the instrument.

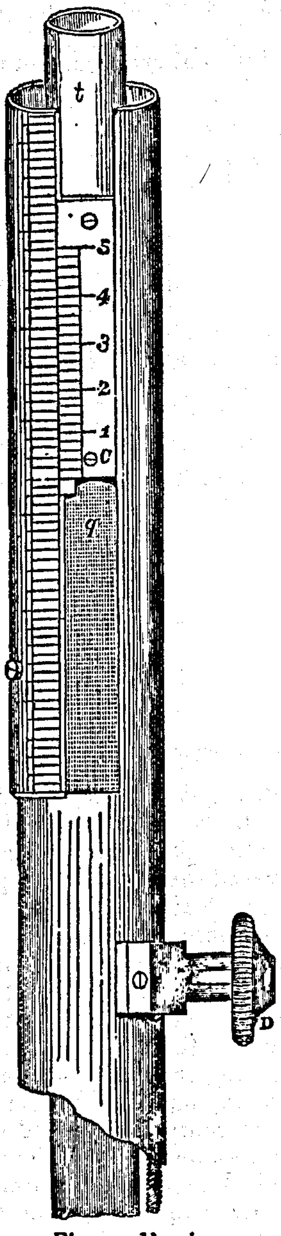


Fig. 5.—Vernier.

In observatory barometers the fixed scale is divided into equal parts, the smallest divisions being half-tenths of an inch in length (or ·05 inch). There are twenty-five divisions on the vernier or moveable scale which are together exactly equal to twenty-four divisions or spaces on the barometer large fixed scale. Hence each of the divisions on the vernier scale is shorter than a division of the fixed or large scale by $\frac{1}{25}$th part of its length. As the length of the fixed scale divisions is $\frac{1}{20}$th of an inch, or ·05 inch, the vernier scale divisions are each shorter than ·05 inch by $\frac{1}{500}$th of an inch or ·002 inch.

Now, if the vernier and fixed scales of any observatory barometer be examined, it will be seen that if the first mark of the vernier coincide (or is in the same straight line) with the first mark of the fixed scale, the last mark will also coincide, but no other, and if the first mark of the vernier do not coincide with an adjacent mark on the fixed scale, it will be seen on running the eye up the two scales that the marks come nearer and nearer together, and that before the end of the vernier scale is reached, two marks, one on each scale, will be in the same line, and if the eye runs further up the scale, the marks again separate.

A consideration of the previous remarks will show that when the first mark or zero line on the vernier is not in a straight line with a division on the fixed scale, its distance from the nearest lower division on the fixed scale is measured by the number of steps or divisions on the vernier scale up to the division which is on the same straight line as a division on the fixed line. For, as each succeeding division of the vernier scale is nearer to each succeeding division of the fixed scale from the foot or zero of the vernier scale, by the fixed amount ·002 stated above, it is evident that the measurement of the difference will be at once made by reckoning each division of the vernier scale as equal to ·002 inch.

The values of the graduations of the scale divisions of the fixed scale and vernier scales of observatory barometers are as follows:—

On the barometer scale AB (Fig. 6).—The interval between a long line and the next long line corresponds to and measures a distance of a tenth, or ·100, of an inch.

The interval between a short line of the scale and either of the nearest long lines measures a distance of a twentieth or ·050 of an inch.

On the vernier scale CD (Fig. 6).—The interval between two long lines measures a length of the mercury column equal to one-hundredth or ·010 of an inch.

The interval between any two consecutive distances measures a length of the mercury column equal to one five-hundredth, or ·002, of an inch.

The following (Fig. 6) shows the appearance of the fixed a
vernier scales side by side in an observatory barometer :—

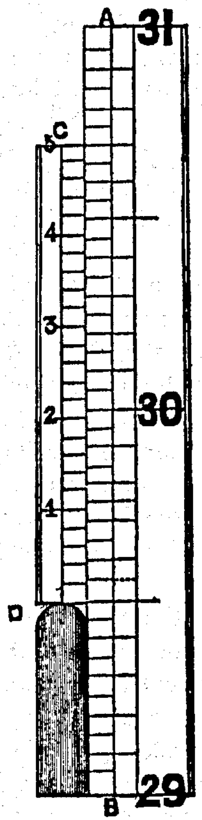


Fig. 6.

Fig. 6 shows the numbers that are usually given on the
scales to facilitate the calculation of the measurement. On the fix
scale every inch or twentieth division is marked, and on the verni
scale every fifth division (representing hundredths of an inch) a
counting the first as zero, these divisions are numbered 1, 2, 3,
and 5.

One of the first things an observer learning to read the bar
meter has to acquire is the habit of filling up mentally the value
each of the divisions, giving it its proper measure for its position
the scale.

The height of the mercury column is always estimated to tho
sandths of an inch or to three places of decimal figures; as f
example, 29·968 inches.

In the fixed scale the distance between two consecutive divisions is $\frac{1}{20}$th of an inch or ·050 inch. Hence, commencing with the division marked 29 inches, or 29·000 inches, all that has to be done is to add ·050 inch for each succeeding division. Thus the exact value of each scale division on the fixeds cale between the 29 and 30 inch divisions is given below (Fig. 7) :—

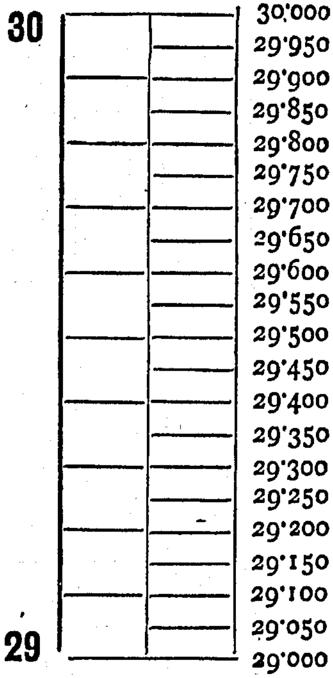


Fig. 7.

Each inch of the scale could be filled up in a similar manner.

A moderate amount of practice should enable any observer not merely to fill up mentally the numbering of the scale divisions in this manner, but also to write down the value of any scale division in its complete form (*i.e.*, to three places of decimals).

In the case of the vernier, the distance between any two consecutive divisions represents two-thousandths of an inch or ·002 inch. Hence, counting the edge or bottom line of the vernier[1] as the begin-

[1] At the bottom of the vernier of some barometers on the right or left hand side according to the side of the fixed scale, there is a projecting piece of metal like a tooth. This is frequently about a twentieth of an inch in length, and sometimes even more, and it is attached to the vernier to enable the zero line to be clearly seen. Great care must, however, be taken after setting the vernier so that its zero line corresponds with the top of the mercury column (see section 23) that the reading is also made from the zero line and not from the bottom of the tooth. Careless observers have been frequently known to read their barometers about a twentieth of an inch too low by reading from the bottom of the tooth and not from the actual zero line.

ning or zero line, all that has to be done is to add on ·002 inch for each succeeding division. The following (Fig. 8) shows the divisions of a vernier with the numbers actually given on that scale to aid in assigning their correct values, and their values properly stated in decimal figures in thousandths of an inch on the right hand side of the diagram of the vernier scale below:—

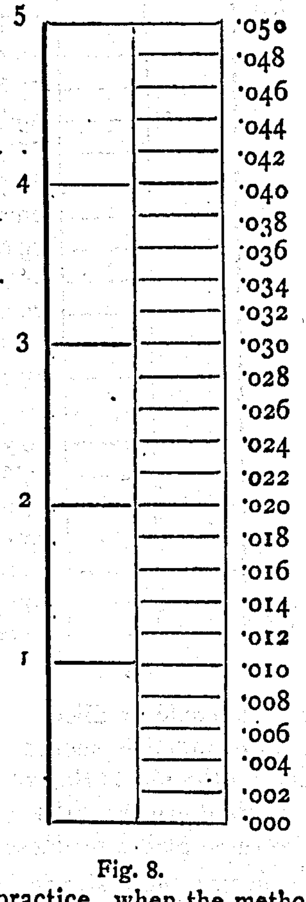


Fig. 8.

A small amount of practice, when the method of progression of the numbers has been observed, will enable the learner to write down the value of any scale division.

23. **Setting the vernier.**—The vernier scale is usually engraved on a piece of metallic tube which is moved up and down by means of a pinion and rack worked by a screw (*vide* Figs. 1 and 5). In taking a reading, the lower edge of this tube must be made to coincide accurately with the top of the mercurial column as shown in the annexed woodcut, and this requires that *the top of the column shall be exactly on the same level as the eye of the observer* (see Fig. 9). In this

position, on looking through the tube, the lower edges of the vernier which slide in front and behind will coincide. Hence in order to set the vernier properly, raise it a little above the top of the column, get both edges in a line with the eye, and then lower it slowly till these edges form a tangent to the topmost outline of the column, no part of it being covered and light being seen on both sides of the curved surface.

As a final caution it may be mentioned that if the barometer is so suspended that the top of the column is above the eye of the observer or if the eye is above this level, so that the front and back edges of the vernier cannot be made to coincide, the reading will invariably be too high. This is owing to parallax, and is illustrated by the accompanying figure (Fig. 9).

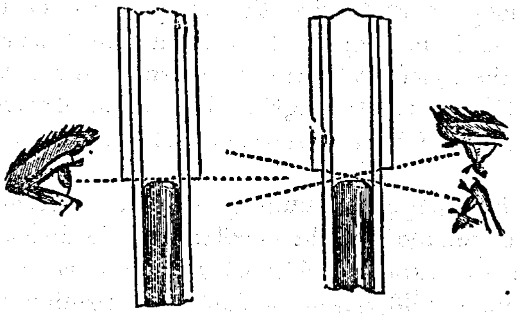


Fig. 9.—Effects of Parallax.

The vernier *appears* to be set when its lower edge forms an apparent tangent to the meniscus (*i.e.*, the rounded part of the column of mercury shown in Fig. 2, page 15, between A and the line BC) of the mercury surface. If the eye be too low, the hinder edge of the vernier slide will appear to do this before the vernier is lowered to the same level; if the eye is above the top of the column, the front edge will do so. But the front and back edges of the vernier will coincide with each other, and with the mercury surface, only when all three are on the same level. Before taking the reading, the setting of the vernier must, therefore, always be verified by moving the eye up and down, to ascertain, firstly, that in no position of the eye is light seen between the highest part of the surface and the edge of the vernier; secondly, that there is one position in which the vernier conceals no part of the mercury meniscus, but only touches it.

24. **Attached thermometer.**—It has been explained above how the pressure of the air is measured by the length of the mercury column in the tube of the barometer. As however mercury, like other liquids, increases in volume when it is heated, it is evident that the column might be altered in length by heating it or cooling it in any way, even if no change were taking place in the pressure of the air. As the length of the mercury column can be altered in two independent ways, *viz.*, by a change of the temperature of the mercury of the barometer itself, or by an alteration of the pressure of the external air, and it is the effect of the second change alone which is desired to be known, the barometer must either be always kept at the same

temperature (which is not possible at Indian observatories) or the effect of the first change, that of the temperature of the mercury must be ascertained and allowed for. It is hence necessary to ascertain the temperature of the mercury in the barometer, in order to allow for the effect of changes of temperature in altering the length of the mercury column. This is arranged for in observatory barometers by attaching a thermometer to the tube of the barometer. As the use of this attached thermometer is to give the temperature of the barometer with which it is in contact, it should not be touched, breathed upon, etc.,by the observer. Also as it is small and hence liable to be affected by the immediate neighbourhood of the observer, it should be invariably read before the observation of the barometer itself is made.

25. **Reading the barometer (examples).**—If the preceding explanations have been understood and the numbering of the divisions on the fixed and vernier scales (in full decimal notation) has been practised and learnt, there should be no difficulty in reading the height of the mercury column by means of the two scales in any case.

In order to take a reading the lower edges of the vernier are adjusted so as to be in the same level with the highest point of the mercury column. The lowest or zero line of the vernier scale is either exactly in the same line as a division of the fixed scale or it is not. If it is in the same line, the number of the division on the fixed scale, given to three decimal places, is the reading or height of the barometer.

If the lowest or zero line of the vernier scale is not in a straight line with a division of the fixed scale, proceed as follows. First, note the division on the fixed scale next below the lowest or zero line or edge of the vernier and write down its proper number as a division of the scale to three places of decimals, as for example 29·650. Care should be taken that the zero line of the vernier is selected for reading and not the bottom of the tongue of the vernier (see footnote on page 21). Then pass the eye up the vernier scale, beginning from the lowest division, until it comes to that division of the vernier scale which is exactly in a straight line with a division on the fixed scale and note down the number to three places of decimals that represents the measure of that division of the vernier scale, as for example ·038. Add this to the previous amount noted, and it will give the length of the mercury column or the height of the barometer. The addition worked out in full would be as follows:—

Reading on fixed scale	29·650
Reading on vernier scale	·038
Complete reading	29·688

It sometimes happens that no division of the vernier scale is in an exact line with a division on the fixed scale. In such a case the division which is nearest to the one on the fixed scale should be selected.

The following diagram (Fig. 10) gives the illustration of the above case. On page 20 another illustration of a vernier reading (Fig. 6) is given, and in that case the reading is 29·500 inches.

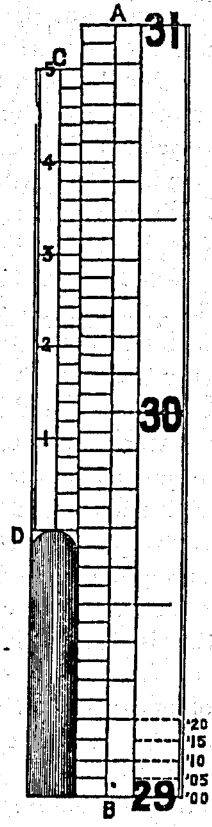


Fig. 10.

26. Kew Principle Barometers.—In the foregoing sections, 16 to 25 inclusive, instructions are given as to the construction and method of setting and reading barometers constructed on what is called the "Fortin's" principle. At a few of the Indian observatories, barometers have been supplied, the construction of which differs in some respects from the Fortin instruments. Under section 21 it has been shown that with any rise and fall of the mercury in the tube of a barometer there is a corresponding fall or rise of the mercury surface in the cistern of the Fortin barometer. In that form of barometer, by means of the arrangement described in section 21, the mercury surface in the cistern is raised or lowered mechanically until it is always exactly at the zero point as indicated by the ivory pointer, and hence the exact height of the barometer can always be ascertained by reading off the scale of inches provided. In the "Kew Principle" Barometers this end is attained in another way. It will be noticed that if the mercury column in a barometer is rising, the surface of the mercury in the cistern will fall. And as the area of the surface of mercury in the cistern is very much larger than the area of the column of mercury in the barometer tube, the fall in the cistern will be much smaller than the rise in the column in the tube. As an example, suppose the column of mercury as measured on the tube had risen one inch and the surface of mercury in the cistern had fallen 0·05 inch, it is evident there will have been a real or total rise of $1+0{\cdot}05=1{\cdot}05$ inches. It is clear that if instead of graduating the fixed scale of the barometer in *true* inches it is graduated so that one *true* inch of the tube is marked as 1·05 inches, then the reading of the barometer will be correct in the case in point. Hence it follows that by knowing the area of the tube and the area of the cistern it is possible to prepare a scale for every barometer which by the single reading of the top of the mercury column, and without reference to the surface of the mercury in the cistern, will tell the exact height of the column of mercury in the tube above the mercury in the cistern. In such barometers the graduation on the fixed scale are not true inches, but the scale will vary in different instruments. In these instruments, as there is no necessity for observing the position of the surface of the mercury in the cistern, no glass cistern at all is provided, and the cistern is made of iron.

In the Kew Principle (K. P.) barometer therefore only the reading of the top of the column in the tube has to be made as shown in sections 22 and 23, and the procedure described in section 21 has to be omitted.

It should hence be noted that the instructions below in section 27, paras. 3 and 7, and section 28, para. 3, only refer to Fortin's principle barometers and cannot be applied to Kew principle barometers.

27. Method of taking an observation of the barometer.—The following gives the various steps in taking a complete observation of the barometer :—

1st.—Read the attached thermometer to the nearest degree.

2nd.—Tap the barometer slightly with the finger in order to free the mercury from the sides of the tube at the top of the column.

3rd.—By means of the adjusting screw at the bottom of the cistern, adjust the level of the mercury surface in the cistern by turning (if necessary) the screw till the ivory stud or point is quite free from the mercury. Then turn the screw slowly in the opposite direction until the surface exactly touches the stud or point. When the mercury surface is quite clean and bright, the proper adjustment is most easily made by causing the ivory point to exactly touch its reflected image in the mercury below. When the mercury is covered with a thin film, it is best to determine the contact by lowering the point in the mercury until a slight dimple is formed, and then slightly moving the screw until the dimple is about to disappear.

4th.—Adjust the vernier by raising it till it is well above the top of the column, and then lowering it till the back and front edges coincide exactly and are in a line with the highest point of the curved surface of the mercury column in the tube and without covering any part of it. This adjustment will *not* cut off the light at the sides of the convex surface.

5th.—Read the height of the mercury column by means of the barometer and vernier scales, and write it down in the note-book.

6th.—Verify it by re-setting the vernier and taking another reading of the instrument.

7th.—After the reading has been taken, recorded and verified, the mercury in the cistern should be lowered until the surface is well below the ivory point. If this be not regularly done, dirt will collect and the mercury will oxidise and appear dull beneath the ivory point. Thus its reflected image will become faint and indistinct.

28. Rules for management of barometers.—The following points in connection with the management of barometers should be borne in mind by observers :—

1st.—A barometer *should be exposed as little as possible to changes of temperature.* The justness of the temperature correction depends upon all parts of the instrument having thesame temperature as that shown by its attached thermometer. But the mercurial column is enclosed in a glass tube, a bad conductor of heat, and this again usually in a metal tube, with a air space between. Consequently, the mercury is slow in acquiring or parting with heat; and it is only by keeping the temperature around as uniform as possible that the required conditions are even approximately fulfilled. *A* *barometer should therefore be kept in a well-enclosed room, and the sun must never shine on it, nor must it be near a fire-place.* Hence observers should take precautions, so far as is possible under the circumstances, in order to prevent large and rapid changes of temperature in the rooms in which the barometers are suspended, as, for example, closing up the rooms when possible during the hottest and coolest parts of the day.

2nd.—It is absolutely necessary, in order that the adjustments necessary for an accurate reading of the barometer may be properly and correctly made, that the instrument should be placed in a *good light*. The source of light should be either on the right or left, and not from the back or from opposite the barometer (which is the worst of all). This is usually secured, so far as is possible, when the barometer is placed in position by an officer of the Department. Observers should however see that purdahs, etc., are not hung up or other changes made which are likely to impair the light for the reading of the barometer.

3rd.—The accurate adjustment of the cistern level, as described in section 21, is sometimes much facilitated if a little screen of paper or cardboard be adjusted to the side of the cistern so as to throw the ivory point into shade, whilst the white surface behind is well illuminated.

4th.—The top of the mercury column should be on a level with the observer's eye when he is taking a reading. Hence, when an observer finds that a barometer is hung too high for him to read the instrument as directed above, he should obtain a wooden stand of suitable elevation.

5th.—The barometer should be kept clean, and the exposed parts should hence be wiped occasionally (with a damp cloth) if necessary.

6th.—A barometer should never be removed from the place it has habitually occupied without first obtaining the permission of the controlling Meteorological Office, unless such removal is absolutely unavoidable and urgent, *e.g.*, in case of a fire in an adjoining building, etc. When the controlling Meteorological Office permits or directs the removal of a barometer it will give full instructions as to the method of effecting the removal. These should be strictly carried out, otherwise it is very probable air may enter the tube of the barometer during the removal, and the instrument hence become unfitted for further use.

29. **Tests of condition.**—A good barometer, if taken proper care of, is not at all liable to go out of order, and, as a rule, it is not necessary for the superintendents or observers at observatories in India to examine their barometers and test whether they are in good order. They are always carefully examined when observatories are inspected. It is, however, desirable that the superintendents and observers should be acquainted with the most important and simplest tests for ascertaining whether barometers are in good working condition or not, in order that if the observations are believed to be doubtful, they may be able to ascertain whether it is due to the instrument being out of order. When a barometer is in good order, if slowly inclined till the mercury touches the top of the tube, it gives a sharp click at the moment of contact. If it fails to do this, there is air above the column. The surface of the mercury against the tube should be bright and there should be no visible air-specks. A dull surface shows that there is probably a film of air adhering to the glass. Air is, however, injurious, only when it reaches the Torricellian vacuum above the column.

Sometimes little drops of mercury form by condensation on the inner surface of the tube in the Torricellian vacuum. They do not affect the reading, and are of no importance in the case of a barometer on Fortin's principle, but they vitiate the readings of an instrument constructed on the Kew principle.

If a barometer on the Fortin's principle is found to have leaked a little at the cistern, it does not affect the reading, so long as sufficient mercury remains to admit of the mercury level being adjusted to the fiducial point, that is, to the level of the ivory pin. If it continues to leak, it should be dismounted, the mercury in the cistern screwed up as described at the end of section 31, and put aside in an inverted position, until it can be sent for repair. *But any leakage whatever in a barometer to which a capacity correction is applied, or one on the Kew principle, introduces a permanent error, which affects all its readings.*

As it is sometimes necessary to send barometers to distant stations and to call for the return of barometers for comparison at the Alipore Observatory and re-determination of their errors, the two following sections give hints as to the method to be adopted for suspending barometers and for taking them down and packing them for despatch to the Imperial Meteorological Office, Calcutta. Barometers are, it should be noted, very delicate instruments, and are extremely liable to be broken in transit or to be rendered unfit for use by the admission of air into the tube, and it is hence desirable that the instructions in the following sections should be carefully noted, and followed as exactly and carefully as possible, whenever a barometer is removed from one position to another at an observatory, or is sent back to the Imperial Meteorological Office at Calcutta.

30. **Suspending a Barometer.**—The barometer is suspended to a hook projecting from the upper end of the backboard; and the lower extremity kept in place by three adjustable screws, passing through a ring, near the lower end.

First, drive a nail into the wall at a height of about 5 feet 6 inches. Suspend the backboard on this, and then hang the barometer on the hook provided for the purpose. Lower the mercury in the cistern, till the cistern level is about adjusted to the fiducial point, and then make a mark on the backboard, corresponding to the top of the mercury column. Having done this, screw up the cistern screw, remove the barometer, invert it carefully, and replace it in its case. Then dismount the backboard.

Next, having selected the place for the instrument in accordance with the directions of the foregoing section, drive a strong nail or spike into the wall at such a height that when the backboard is suspended on it, the mark already made on the backboard may be *about half an inch below the level of the observer's eye.* Suspend the backboard, and set it as nearly vertical as can be judged by eye.

Then, after unscrewing the three clipping screws in the ring that receives the cistern end of the barometer, suspend the barometer to its hook, having already inserted the lower end into the ring below. While still hanging freely, move the lower end of the board to right or left, or, if necessary (when the wall is not vertical), either end outwards from the wall *until the lower extremity of the barometer hangs freely in the middle of the ring.* In this position, fix the lower end of the backboard by a small nail driven through the eye provided for the purpose at its base; or, failing this, by a nail on each side of the board. Then screw up the three clipping screws till they clip the freely suspended barometer and retain it in the same position. Lower the cistern level as before. Adjust the light as described in a preceding section (Section 28, para. 2).

N.B.—A barometer is more easily set for reading when fixed and not swinging, but *before fixing it, it must be allowed to take a vertical position by swinging freely;* and when fixed, its verticality must be tested by a plumb-line held, first in front of the instrument, and then at one side.

31. **Packing and carriage of barometers.**—A barometer must

always be packed and carried in an inverted position, that is, *cistern upwards* (or else horizontal). The safest mode of packing is to construct a *dooly* of bamboo, of the form shown in the annexed figure (Fig. 11) and to lash the barometer to it in the proper position, and well surrounded by straw. The whole may then be covered with canvas or gunny cloth, leaving a hole for the insertion of a bamboo beneath the forks, by which it is to be carried by two *coolies* in the manner of an ordinary *dooly*. Such a package may be sent safely by rail or ship, provided ordinary care be used in placing and moving it. If a barometer is on the Fortin's principle, before inverting it to pack it, the cistern screw should be turned till a small air space only (about as large as the bowl of an egg spoon or half an inch of the tube) is left and hence sufficient to allow of the expansion of the mercury due to any change of temperature that may occur during transit.

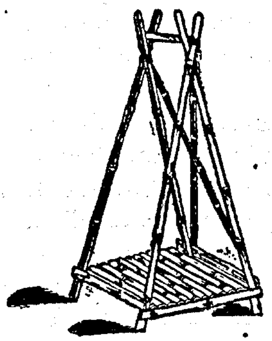


Fig. 11.—*Dooly* for carrying barometers.

32. **Barometer cage.**—As the barometers at many observatories in India are hung in rooms at hospitals or other public buildings or offices frequented by large numbers of people, it is necessary to provide some protection for them so as to prevent their being examined by people ignorant of their construction. It is hence usual to place the minside a cage securely attached to the wall, within which the barometer is placed, and to keep the door of the cage locked, except at the time of observation.

The following gives a statement of the most satisfactory method of arranging for the suspension and protection of a barometer.

Two bars of wood, about 18 inches long by 6 inches broad and 1½ inches thick, should be fastened horizontally to the wall. The upper one should be at an elevation of about 5½ feet and the lower at an elevation of about 2 feet. They should be exactly horizontal, and their faces should be in the same vertical plane as tested by a plumb line, and the lower bar should be exactly underneath the upper bar in every respect as in Fig. 1 of Plate III.

They should be very securely fastened to the wall so that the leverage of the barometer upon the bars may not loosen the upper one at all. The cage, which is shown in Fig. 2, Plate III, should then be fastened to the wall by driving nails in through the holes in the four iron pieces provided at the top and bottom of the back. The cage is so placed as to enclose the two wooden bars described above. Then the barometer should be secured so as to occupy the right or left half of the space, and when the observatory is inspected the barometer brought by the inspecting officer, in order to test the condition of the observatory barometer, can be attached to the other half of the bars.

The cage hitherto supplied to observatories is of the form and size shown in Fig. 12. These cages have been supplied by the Imperial Meteorological Office to all observatories at which the protection of a cage is considered necessary or desirable for the barometer. This form of cage has the disadvantage of not folding up into a compact space, and is hence unsuited for transport by rail, and a cage, of which the sketch is given in Fig. 2, Plate III, has been devised in order to meet this objection. It can be folded down flat and packed into a small space, and hence be sent more easily and economically to distant stations than the old type of cage. It has the further advantage of opening out in a manner which enables the barometer cistern to be better lighted than the old form of cage. This type of cage will be supplied in future to observatories requiring a protection for their barometer.

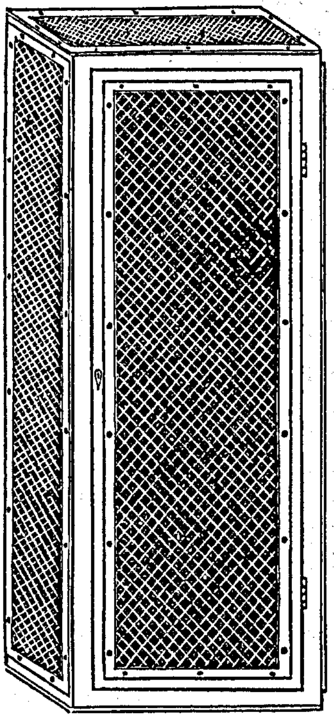
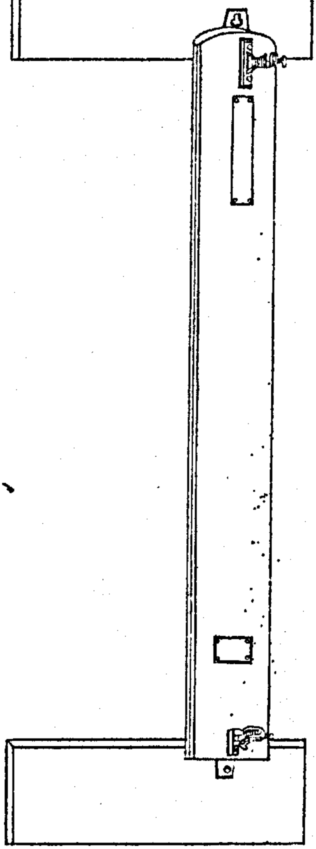


Fig. 12.—Barometer Cage.

33. **Aneroid barometers.**—These barometers, although very compact and handy, are not used at observatories in India. They are liable to sudden changes, and are hence not sufficiently reliable or accurate enough for observational work in India. They are, however, occasionally supplied to distant observatories to which it is hardly possible to forward mercurial barometers without breakage. The following paragraphs give a brief description of the aneroid barometers usually supplied in such cases.

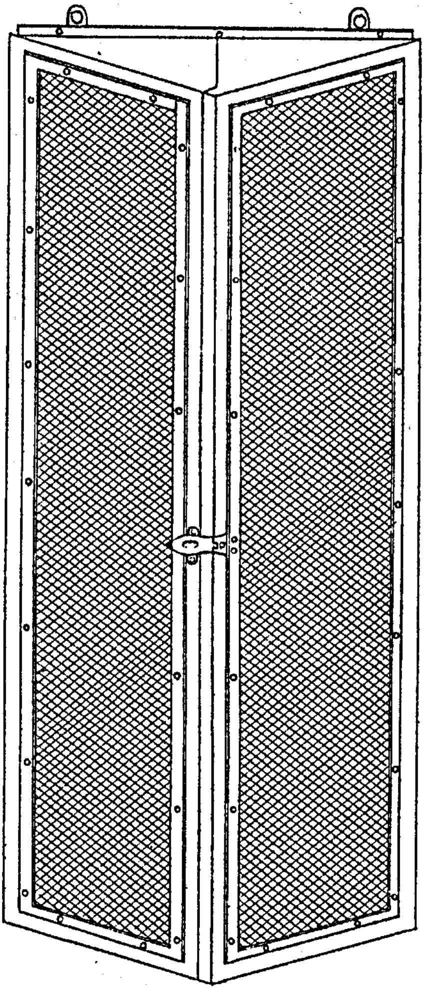
The aneroid barometer in the general form in which it is made consists of a brass cylindrical case about five inches in diameter and two inches deep, faced with a dial graduated and marked in the same manner as an ordinary barometer and upon which the index or pointer shows the atmospheric

Fig. 1.



METHOD OF SUSPENDING BAROMETER.

Fig. 2.



CAGE FOR BAROMETER.

pressure in inches and decimals. Within the case, is placed a flat metal box made of German silver, generally not more than half an inch deep and about two inches or a little more in diameter, from which nearly all the air is exhausted. The top and bottom of this box are corrugated in concentric circles, so as to yield inwardly to external pressure, and return when it is removed. The pressure of the atmosphere continually changes, and with this varying pressure, the top and bottom of the box approach to and recede from each other by a small quantity; but the bottom being fixed to the base, nearly all this motion takes place on the top. The top of the box is elastic, and rises and falls according as the pressure of the air on it lessens or increases. To the eye, these expansions and contractions are not perceptible, so small is the motion. But they are rendered very evident by a delicate mechanical arrangement, communicating with a system of levers; and, by the intervention of a piece of watch-chain and a fine spring passing round the arbour, the index or pointer turns to the right or left, according as the external pressure increases or decreases. Thus, when by increase of pressure the vacuum box is compressed, the mechanism transfers the movement to the index, and it moves to the right; when the vacuum box expands under diminished pressure the motion is reversed, and the index moves to the left. As the index traverses the dial, it shows upon the scale the pressure in inches and decimals of an inch exactly as is done by a mercurial barometer.

The engraving (Fig. 13) represents the mechanism of an aneroid. The outer casing and face of the instrument are removed, but the index hand is left attached to the arbour. A is the corrugated vacuum box which has been exhausted of air through the tube J, and hermetically sealed by soldering. B is a powerful curved spring, resting in gudgeons fixed on the base-plate, and attached to a socket behind, F, in the top of the vacuum box. A lever, C, joined to the stout edge of the spring, is connected, by the bent lever at D, with the chain, E, the other end of which is coiled round, and fastened to the arbour, F. As the box, A, is compressed by the pressure of the atmosphere increasing, the spring, B, is lightened, the lever, C, depressed, and the chain, E, uncoiled from F, which is thereby turned so that the

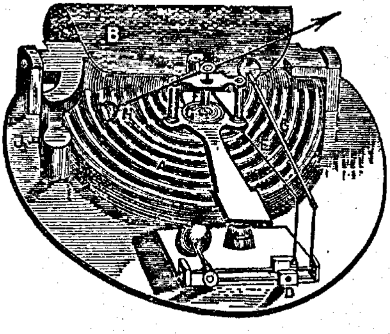


Fig. 13.—Aneroid Barometer.

hand, H, moves to the right. In the meanwhile the spiral spring, G coiled round F, and fixed at one extremity to the framework, and by the other to F, is compressed. When, therefore, the pressure decreases, A and B relax, by virtue of their elasticity; E slackens, G unwinds, turning F, which carries the index hand, H, to the left. Near J is shown an iron pillar, cast as part of the stock of the spring, B. A screw works in this pillar through the bottom of the plate, by means of which the spring, B, may be so adjusted to the box, A, as to set the index, H, to read on the scale in accordance with the indications of a mercurial barometer. In the higher class of aneroid barometers, the lever, C, is formed of a compound bar of brass and steel, so arranged as to perfectly compensate for the effects of extreme variations of temperature.

34. **Directions for using the Aneroid.**—Aneroids are generally suspended with the dial vertical; for if they be placed with the dial horizontal, the indications differ a few hundredths of an inch in the two positions. Therefore, if their indications are to be recorded, the instrument should be read off always in the same position.

35. **Aneroid Barograph.**—This form of aneroid is shown in Fig. 14.

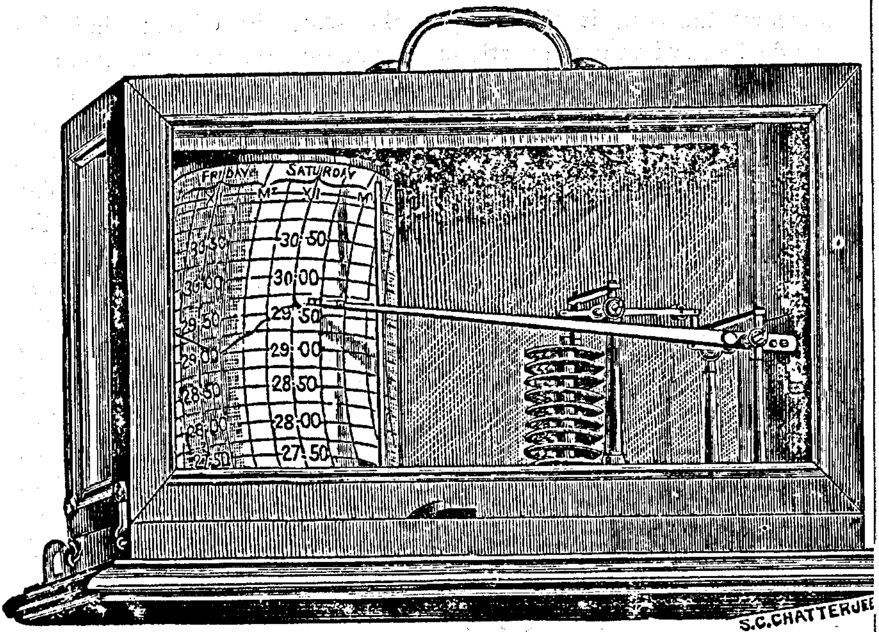


Fig. 14.—Aneroid Barograph.

It differs from the ordinary aneroid in two respects. In the first place, instead of a single vacuum chamber there are several connected together in a vertical series, so that the total movement of the upper surface is the summation of the separate movements of each member of the series. This movement is multiplied by a series of levers as in the ordinary aneroid. The final lever is furnished with a pen at its extremity. The second important feature of this instrument is a moveable cylinder worked by a clock. On this cylinder is fastened a sheet of paper suitably ruled, on which the pen traces out a curve which shows at a glance the changes of pressure during the preceding period. In some of the instruments the cylinders revolve in a week and in others in a day.

36. **Instructions for using the Barograph.**—The following instructions are issued by the maker of the instrument:—

Recording Cylinder.—This is a very compact arrangement. The driving clock is inside the brass cylinder, around which is wrapped the paper on which the record is made. One pinion wheel projects through the end of the cylinder, and engaging with a wheel fixed to the base-plate, the clock turns itself round, and in so doing turns also the paper covering its circumference. The clockwork is carefully (but not hermetically) enclosed; the bottom of the cylinder is closed by a sheet of brass, except that there is a hole just large enough to let the steel axle of the above-mentioned pinion wheel go through. The top is also of brass with two sliding plates, one covering the arbour, for winding, and the other covering the regulator. Proof of the efficacy of these arrangements is afforded by the fact that many of these clocks have been known to run five or more years out of doors and in dirty atmospheres without either oiling or cleaning. It is hardly fair treatment, but the result has been satisfactory. It may be pointed out that Richard's instruments being largely machine-made the parts are interchangeable, and an extra clock (applicable while the other is being cleaned) can be had for a little over £2. Clocks can be had to complete a revolution in any time desired, but those for six hours, twelve hours, twenty-four hours, and a week, are kept in stock.

Attachment of paper.—For most of the instruments special papers have been printed, both with English and metric scales. They are mostly 8 inches by 3 inches, and have merely to be wrapped round the cylinder with their ends placed under a little brass spring.

The pen.—This is a very important feature in the apparatus, and must receive careful treatment. It has much the shape of the lower half of the beak of a bird, and its extremity, like that of a pen, is split. The pen must be kept clean, and this should be done, not by scraping or hard rubbing, but by washing in water with a camel's hair brush. If any particles of hair or fluff are seen near the nib, it may be cleansed by cutting off (not tearing) a small piece of writing paper and drawing it gently through the slit of the nib. The fineness or the coarseness of the trace depends chiefly upon the cleanness of the pen.

The pressure of the pen upon the paper.—In nearly every pattern the pen is slipped on to the end of a long aluminium arm, and near the other end will be seen a brass screw. As a rule, this screw should not be touched, because the instrument is adjusted before despatch; but if, owing to transit, on arrival the pen does not touch the cylinder, or presses hardly upon it, the brass screw should be so turned that the pen just lightly touches the paper, the less the better, provided the ink will flow, because if made to press hardly, friction is produced, and the full delicacy of the instrument is not obtained.

The ink.—This being largely composed of glycerine will not dry up at all readily, and works perfectly in moist climates, but in very wet and foggy ones it absorbs moisture from the air; and if the pen be very full of ink, the additional moisture may make it overflow, and the extra dilution may make the ink pale. In exceptional localities it is therefore well to fill the pen only three quarters full, and if the trace becomes very pale to dry up the pen with a spill of blotting paper, not fluffy, and to fill with fresh ink.

THERMOMETERS.

37. **Use and construction.**—Thermometers are instruments used in meteorological observatories for measuring the temperature of the air, *i.e.*, the intensity of heat or cold.

A thermometer consists of a hollow bulb, spherical or cylindrical in shape and of an attached tube with a fine hollow bore. The instrument is partially filled with some liquid, usually either mercury or alcohol. The liquid fills the bulb and a portion of the tube while the air has been entirely removed from the interior of the thermometer. As the temperature of the substance or matter in contact with the thermometer (in this case, the air) varies, the length of the liquid column in the tube also varies. Either on the tube itself or on an attached piece of porcelain or on both is a scale by means of which the temperature, as indicated by the position of the end of the column of liquid in the tube, is measured.

38. **Graduation and scale.**—Thermometers in use in Indian observatories are graduated or marked in such a manner, that if they were plunged into melting ice, the end of the mercury or alcohol thread or column would stand at the mark numbered 32, and if they were placed in the steam of boiling water at sea level and retained long enough to show the temperature of the steam, the end of the column would, in the case of a mercurial thermometer, be opposite to the number 212.[1] The intermediate distance on the scale or tube is divided into 180 equal lengths or parts which are numbered in succession 32, 33, etc., just as the steps of a ladder might be numbered. Each of these divisions is called a degree, and the temperature of melting ice is said to be 32 degrees, and is usually written 32° where the symbol ° denotes degrees.

The scales of all thermometers used in Indian observatories are hence divided into equal lengths in such a manner that 180 of these lengths would be equal to the expansion or change of length of the mercury thread in the instrument, if the bulb were heated from the temperature of freezing to that of boiling water.

In the case of thermometers intended for use at observing stations where the winter cold is very severe, the graduation is continued below the freezing point, and hence at the 32nd division BELOW that of the freezing point, we come down to the division marked 0° and below it the degrees or divisions are marked with the negative sign—(thus—2°). It is, however, only occasionally in the depth of winter

[1] Alcohol thermometers, it should be noted, must not be plunged into steam or even into very hot water, otherwise they will burst. Indeed, alcohol thermometers should never be exposed even to the direct rays of the sun in India, or they may also burst.

at such elevated stations as Leh, Kailang, and Gnatong, that the temperature falls below the zero division.

The scale is engraved on the tube, and for the sake of convenience an additional scale exactly corresponding to that on the tube is usually placed behind it with numbers given at regular intervals. The scales of the thermometers used in Indian observatories are divided into degrees in the manner described above and numbers are attached to every tenth division in order to enable the measurement or number of any division to be read off easily. Every intermediate fifth degree is also marked by a longer line than the ordinary divisions, for the same purpose. By means of the scale the observer can read off the temperature indicated by the column of the thermometer. As the end of the column will usually be between two scale divisions, the observer should read the number of the nearest scale division on the side towards the bulb (*i.e.,* the number of the next lower scale division), and estimate the portion of the column which extends beyond this division in tenths of a degree. Thus, if the number of the next division below the end of the column was 66 and the end of the column was exactly midway between the 66th and 67th divisions, the reading would be $66\frac{1}{2}°$ or $66°{\cdot}5$. A little practice and care on the part of an observer will enable him to read easily and correctly any of the thermometers in use, to a tenth of a degree.

39. **Errors of thermometers.**—No two thermometers will read exactly alike under the same circumstances, just as no two watches will always give the same and correct time. It is hence necessary to have standard thermometers with which to compare ordinary thermometers, to ascertain how far they differ from the standard, so as to allow for these differences or errors. The standard thermometers are kept at the Alipore Observatory, and all thermometers are compared there with the standards before they are issued to observatories, and their errors determined and allowed for by the meteorological offices tabulating the observations for publication in the daily weather and other reports issued by the Department.

40. **Precautions to be observed in reading thermometers.**—It requires some little care to read a thermometer accurately. In order to do so the following points should be carefully attended to:—

1st—The eye must be exactly at the level of the reading or end of the column in the case of the wet and dry bulbs, and in all cases it should be so placed that a line drawn from it to the top of the column would cut the axis of the instrument at right angles. The reason for this precaution is the same as that already given in the case of the barometer (section 23). If the eye is above the reading, however little, the reading will be too high; and *vice versâ.* This is a point, frequently neglected by careless observers.

2nd.—The thermometer must be read quickly, and the face and head must not be very near it; otherwise, it will be affected by the warmth radiated from the body.

3rd.—It must be read to the nearest tenth of a degree by estimation. There is no difficulty in this, and to neglect this rule is a mark of a careless observer.

4th.—Spirit thermometers are read to the lowest part of the concave surface of the column, and mercurial thermometers to the top of the convexity.

41. **Varieties of thermometers.**—Several kinds of thermometers are used at observatories in India for the work of meteorological observation. The following gives the names of the kinds of thermometers in use and the object of their employment: —

(1) The standard or dry bulb thermometer.	For taking the temperature of air at the moment of observation.
(2) Maximum thermometer ...	For registering the highest temperature attained in the day or other period.
(3) Minimum thermometer ...	For registering the lowest temperature during the night or early morning.

In addition to these the following thermometers are in use at the great majority of stations to enable the humidity (*i.e.*, the dryness or dampness) of the air to be estimated:—

(4) Wet bulb thermometer ...	By means of which the humidity of the air at the instant of observation is ascertained.
(5) Wet minimum thermometer ...	By means of which the humidity at the coolest time of the night is ascertained.

42. **Exposure of thermometers.**—It is evident that as thermometers in meteorological observatories are used to measure the temperature of the air in the open, it is necessary that they should be so exposed that the air may have free and ready access to them. If they were placed in the open without any protection, they would evidently be heated by the sun or be cooled by falling rain, hail, etc. It is hence necessary that whilst they must be freely exposed to the moving air, they should be protected from the rays of the sun, etc. In Indian meteorological observatories they are placed in the centre of a large shed, open at the sides and covered with a thick thatching of straw. This shed has been fully described in section 10. The instruments are placed for purposes of protection from animals, mischievous boys, etc., in a cage figured below (Fig. 15) which is supplied to all observatories. The cage containing the thermometers is affixed to the southern central pole of the shed and facing the north. It is situated at such a height that the bulbs of the wet and dry bulb

thermometers are from 4 feet to 4 feet 6 inches above the level of the

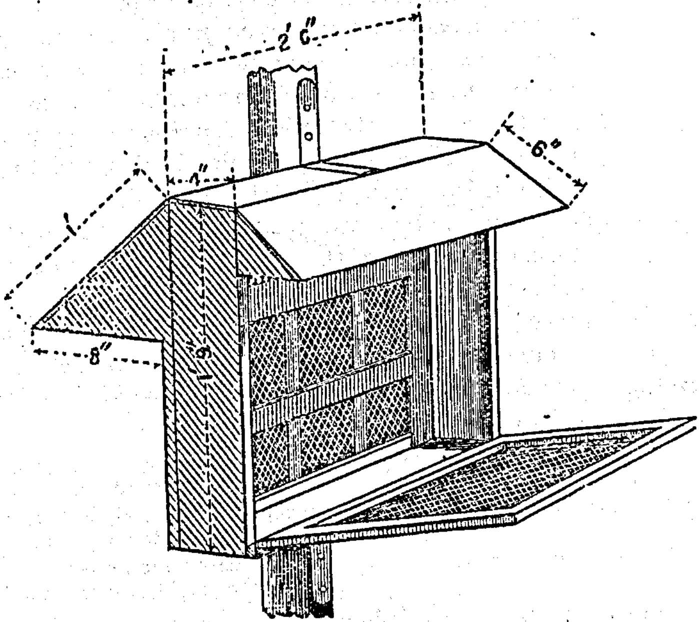


Fig. 15.—Thermometer Cage.

floor of the observatory shed. The best arrangement of the instruments in the cage is shown in the following sketch (Fig. 16) :—

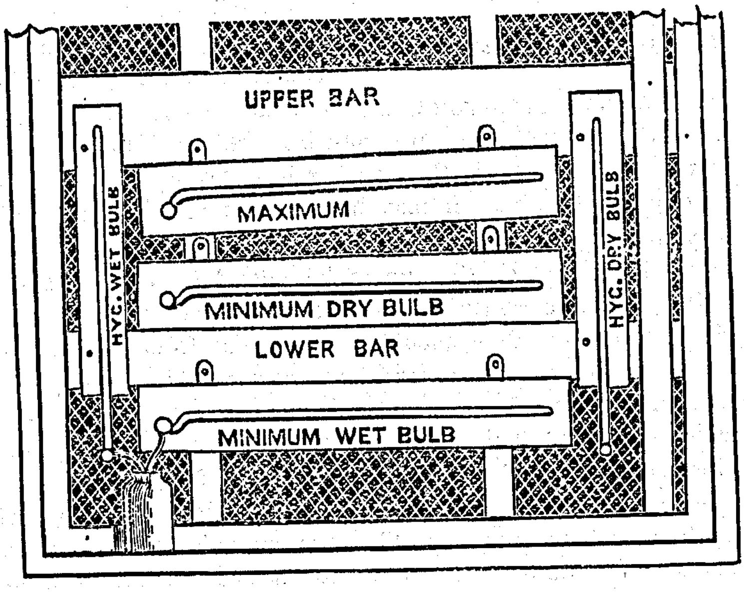


Fig. 16.—Arrangement of Thermometers in Cage.

43. **Precautions to be observed in the suspension of thermometers :—**

1st.—The dry and wet bulbs should be erected in a truly vertical position.

2nd.—The dry and wet minimum thermometers should be truly horizontal.[1]

3rd.—The maximum thermometer should be nearly horizontal with its bulb or left end about a quarter of an inch lower than the tube or right end of the instrument.

4th.—The thermometers should be fixed and suspended in the cage so that they shall not shake during the prevalence of strong winds. This precaution is necessary in order to secure the correct registration of the maximum and minimum temperature during strong winds or stormy weather.

44. **Dry bulb or standard thermometers.**—Standard or dry bulb thermometers (Fig. 17) are used to measure the temperature of the air surrounding the thermometer at the instant of observation. The liquid employed in this class of instrument is invariably mercury. The scale is very carefully graduated. This thermometer is less liable to go out of order than any of the other thermometers, and is hence also used as the standard of reference for these thermometers.

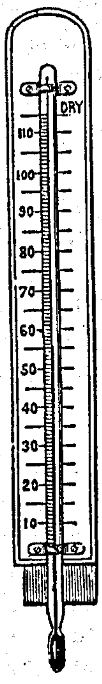


Fig. 17.—Dry Bulb Thermometer.

45. **Maximum thermometers.**—Maximum thermometers are used at observatories to record the highest temperature of the air during the day or any given period. Various contrivances have been devised to effect this object, and hence there are several kinds of instruments of this class The instruments employed by the India Meteorological Department for this purpose are either Negretti and Zambra's maximum thermometers, or Phillip's maximum thermometers (maker Casella).

[1] If the bulb end of minimum thermometers is even only *very slightly* higher than the further end, it will be found a fruitful cause of the separation of small drops of spirit in the upper part of the tube. If such drops frequently accumulate in the upper end of the tube, they may usually be stopped by lowering the bulb end of the thermometer, say, by an eighth of an inch until this tendency ceases.

46. Negretti and Zambra's maximum thermometer.—In an instrument of this class (Fig. 18) the column marks its own maximum. The tube is bent at a short distance above the bulb, and hence

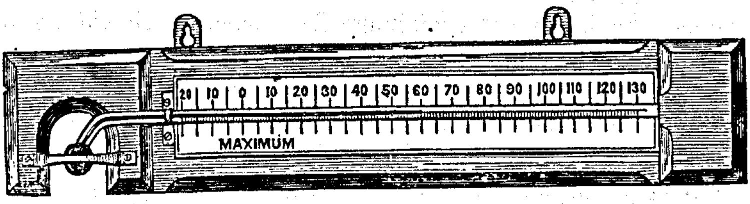


Fig. 18.—Negretti and Zambra's Maximum Thermometer.

consists of two portions nearly at right angles. There is also a slight constriction in the small tube at the bend. The resistance of the constriction is not sufficient to prevent the mercury passing outwards from the bulb along the tube when the temperature is increasing, as the forces acting on the fluid and producing expansion are much more powerful than the resistance offered by the constriction. On the other hand, when the temperature of the air is falling and the bulb cooling, the constriction opposes the return of the mercury in the capillary tube, and the forces of cohesion of the liquid are not sufficiently powerful to overcome the resistance of the constriction. Hence the column breaks at the constriction, and the portion of the column beyond the constriction remains in the same position without change, and hence by its length indicates the temperature when it was highest.

47. How to re-set Negretti and Zambra's maximum thermometer.—As the column after having reached its highest point does not retreat of itself even when temperature is falling, it becomes necessary to *set* the instrument at the beginning of each period for which the maximum temperature is required. Thus, if the highest temperature in the 24 hours succeeding 8 A.M. is desired, the instrument must be *set* at 8 A.M.

It is evident that the instrument will be properly adjusted or *set* when the column in the tube is made continuous, so that it can record any increase of temperature above that at the commencement of the 24 hours or other period of which the maximum temperature is desired. It may be pointed out that except when the temperature is rising there will usually be a break in the mercurial column of this kind of instrument.

The instrument is set by lifting it from its supports and holding it vertically in the hand with the bulb end lowest and shaking it gently, or, if necessary, tapping the lower end of the wooden support of the instrument on the palm of the other hand, until sufficient mercury has run past the constriction to make the column continuous from the bulb upwards. It should then be replaced in its supports, being held throughout the operation with the bulb end lower than the rest of the instrument, so that the column may not break at the constriction during the replacement of the instrument in its position for use.

When the instrument is placed in position, it should, if properly set and returned to its supports, read nearly the same as the dry bulb. Observers remembering this fact can at once, by comparing the maximum and dry bulb, ascertain for themselves whether they have *set* their maximum thermometers properly.

48. **Phillip's maximum thermometer.**—(Fig. 19.)—This instrument is in use at a small number of observatories in India. It is constructed with a small bubble of air introduced into the column about 1½ inches from the end. The upper portion of the column (1½ inches in length) is hence separated from the main portion and is pushed on by the latter when it expands. When, however, the main column contracts with decreasing temperature, the upper portion separated by the air bubble remains unchanged in position in that part of the tube to which it advanced when temperature was increasing, and hence the end of this small column furthest from the bulb registers the highest temperature.

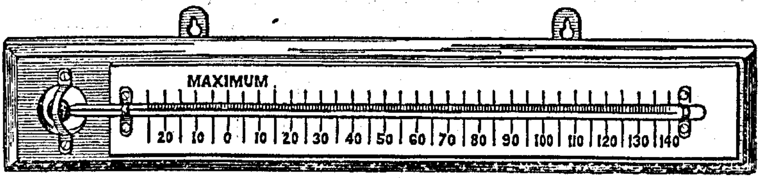


Fig. 19.—Phillip's Maximum Thermometer.

49. **Precautions.**—In the case of this thermometer it should be placed nearly horizontal, and with the upper end about a quarter of an inch higher than the lower or bulb end. When the stem is placed exactly horizontal, it is found that the air bubble sometimes pushes the upper or registering column half a degree or upwards beyond the proper position, and hence increases the reading to that extent, thus introducing an error of small but unknown amount.

This instrument is liable to get out of order by the air bubble working back down the tube and finally passing into the bulb as frequently happens when this thermometer is exposed to a low temperature; when this occurs the instrument becomes an ordinary non-registering thermometer. Hence any observer having an instrument of this class should note carefully if the air bubble remains in its proper position or not, and if it does not do so, as soon as it approaches the bulb end of the tube he should report the fact to the Calcutta Meteorological Office, in order that he may be provided with another instrument.

50. **To re-set the instrument.**—Detach the instrument from its suspension at the bulb end and gently lower the instrument towards the vertical until the detached column has moved down and *nearly* touches the lower column. Then raise the bulb end and fix again to its suspension, taking care that the detached or registering column does not move away from the other portion during the operation of refixing the instrument.

51. **The minimum thermometer.**—Minimum thermometers are used to register the lowest temperature to which the air is cooled during the night or any given period. The liquid employed in the construction of these thermometers is alcohol, and for distinctness is frequently coloured red. The tube is sometimes bent near the bulb as in Fig. 20, but in the majority of instruments in use in India the minimum thermometer is a straight tube with a spherical or cylindrical bulb. Immersed in the spirit column is a very light and delicate glass rod (in appearance like a small pin with a head at each end).

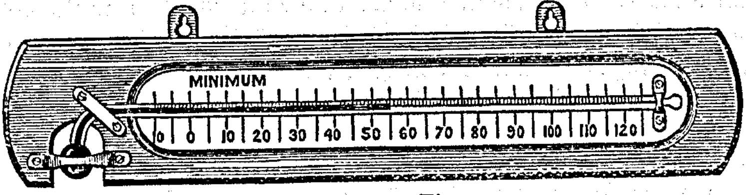


Fig. 20.—Minimum Thermometer.

The end of the spirit column furthest from the bulb acts like a thin elastic skin or membrane, so that when the column contracts as the temperature falls, this skin or membrane (which forms a part of the fluid) pushes against the needle, which then moves along the tube with the membrane and contracting liquid.

On the other hand, when the temperature rises and the spirit column expands, the spirit passes along the index or needle, as it does not entirely fill or block up the tube. Hence the membrane advances and leaves the needle behind, as there is now no longer any sensible force exerted on the needle by the liquid. The end of the needle farthest from the bulb consequently indicates the lowest position to which the end of the column indicating the temperature reaches, and its reading will give the lowest or minimum temperature during the interval which has elapsed since the last previous observation.

52. **How to re-set the minimum thermometer.**—To set the thermometer, detach it from its supports, hold it in a vertical position, *bulb upwards*, and the index will fall slowly till it reaches the

end of the spirit column. It should then be replaced on its supports, care being taken that the needle remains unchanged in its position during this operation.

53. **How to read the minimum thermometer.**—Ascertain by inspection the nearest degree on the scale lower than the end of the index or needle farthest from the bulb, and estimate in tenths of a degree the amount that the end of the index projects beyond that degree. Be careful not to touch the instrument at all during the reading. Then write the reading in degrees and tenths of a degree, as, for example, 63°·4. This will be the lowest temperature which has occurred during the interval since the instrument was last set.

54. **Wet bulb thermometer.—Object of observations of these instruments.**—Every one is familiar with the fact that, in some states of the atmosphere, a piece of wet cloth, hung up in a shady place, will dry quickly; and that sometimes, as in the Upper Provinces in April and May, the air is so dry, that the covers of books and nibs of quill pens curl up and furniture cracks and opens at the joints, owing to the evaporation of the small quantity of moisture that these articles usually contain. On the other hand, during the rains in Bengal and the west coast districts of India and in Lower Burma, etc., it is almost impossible to keep books, clothes, etc., from becoming damp and mouldy. These differences depend on what is termed the humidity of the air,—that is to say, on the quantity of aqueous vapour it contains. When the air contains very little moisture or vapour, it is said to be dry, and when it contains much, it is said to be humid or moist. The observations of the wet bulb thermometers are employed to ascertain and measure exactly the quantity of vapour actually present in it.

55. **Absolute and relative humidity and saturation.**—The quantity of vapour which can exist in a given volume depends on the temperature, and is appreciably the same whether air is present or absent. It is the greater the higher the temperature, but rises very rapidly as the temperature increases. It is rarely that the air contains this maximum quantity, except in cloud or fog, and it is then said to be *saturated*, whatever may be the temperature. If the air is below saturation, the quantity of vapour in it is expressed as a percentage of that required to saturate it at the actual temperature. This percentage is called its *relative humidity*, and it is upon this ratio that what we term its dryness or dampness chiefly depends, for the same quantity of vapour that would saturate the air, or represent 100 per cent. of humidity, at a temperature of 50°, would represent only 30 per cent. of saturation (a very dry atmosphere) at a temperature of 85°.

56. **Principle of the wet bulb thermometer.**—Most persons in India are acquainted with the action of a wetted *tatty* in cooling

the air that passes through it, and also with the common mode of cooling water by surrounding the vessel containing it with a wet cloth or damp straw and hanging it in a shady place, exposed to a hot dry wind; or, what amounts to the same thing, placing the water in a vessel of porous earthenware the outside of which is kept constantly wet by the water soaking through from within. In all these cases, coolness is produced by the evaporation of the water; and the faster the water evaporates, the greater is the cooling effect. Thus it is with the wet bulb of the hygrometer; it is cooled by evaporation, and the temperature falls the lower, the more rapid the evaporation. The dry bulb thermometer shows the actual temperature of the air; and the difference of the readings of the dry and the wet bulb increases with the rate of evaporation, and that again increases with and depends upon the dryness of the air.

Wet bulb thermometers are used to ascertain the hygrometric conditions of the atmosphere, that is, to determine the amount of aqueous vapour there is in the air at the place of observation and to obtain a measure of the dryness or dampness of the air (*i.e.*, of its relative humidity). The readings of this thermometer and of the dry bulb furnish data by means of which these facts can be obtained by an arithmetical calculation. Wet bulb thermometers (Fig. 21) resemble dry bulb thermometers and are ordinary thermometers in every respect, except that they have a piece of muslin tied closely over their bulbs up to the point where the bulb joins on to the tube, and the bulbs are kept constantly wet by a bundle of cotton threads which are loosely tied round the upper part of the bulb and dip into a small bottle of water. The water used should be either rain or distilled water, but if neither can be procured, well-boiled water which has been subsequently cooled should be used. In consequence of the evaporation of the water from the muslin in contact with the bulb, the wet bulb usually reads lower than the dry bulb. The difference in temperature between the two thermometers will be small if there is much moisture in the air, and large if the air is dry.

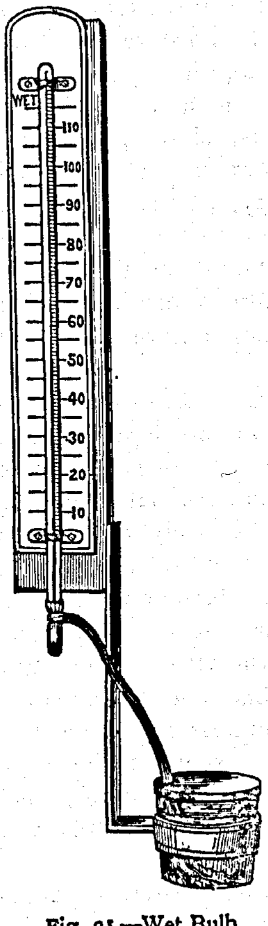


Fig. 21.—Wet Bulb Thermometer.

In the wet bulb thermometer, the accuracy of the results obtained depends entirely on the muslin on the bulb being kept *constantly moist.* If from any cause there should be an insufficient supply of water on the muslin and it becomes even slightly dry, the observations then made will be erroneous and worse than useless, as they will be misleading. Hence the greatest care should be taken to keep the muslin and also the threads properly moist, and this can only be done if the muslin and bundle of threads leading to it are kept *quite clean* and the water bottle kept filled with *clean* water, and the bottle also placed comparatively close to the bulb of the thermometer.

57. **Muslin and wicking for wet bulb thermometers, how applied.**—The bulb of the wet thermometer and at least half an inch of the stem above it should be covered with thin muslin, fastened to the stem just above the bulb.

The muslin must be thoroughly washed in hot water before it is put on the bulb, to remove the starch usually found in it. The muslin is best applied to thermometers with spherical bulbs by placing the finger in the centre of a circular piece of muslin, and by gentle traction on the ends of the threads on the margin, forming a small bag; slip this bag over the bulb and tie securely with thread, taking care that the muslin is firmly and smoothly applied to the bulb.

For cylindrical bulbs, cut the muslin to a rectangular shape, in length about three-quarters of an inch greater than the length of the bulb, and in width a trifle greater than its circumference, so that, when wrapped about, it will cover the bulb completely; overlap the edges only enough to insure perfect covering. After cutting, wet the cover and attach it smoothly and tightly to the bulb, making sure that it is covered completely with one thickness of cloth. While the cloth is wet tie it tightly, both above and below the bulb, with fine thread. Should it be found that the cover has become loose or does not completely cover the bulb, the thread may be wound around the bulb and tied securely.

A roll composed of cotton wicking is made long enough to extend from the bottom of the glass or porcelain receiver containing water to and round the stem of the thermometer just above the bulb and then back again to the glass receiver. The middle of the roll of wicking is passed round the stem of the thermometer just above the bulb after the muslin has been attached to the bulb. The roll of cotton wicking is then tied moderately tightly by a single knot, and the two ends are then placed in the glass receiver filled with water. The wicking will then be in contact with the muslin, and water will freely pass through the wicking and wet the muslin. Under no circumstances should the wicking be allowed to cover the bulb, for there should be nothing touching the bulb but the muslin.

Observers can usually purchase in the nearest *bazar* the muslin and wicking required for their wet bulb, but if not, they will be supplied by the Imperial Meteorological Office, Calcutta, on application.

The muslin on the bulb must always be kept perfectly clean, and must hence be replaced when necessary. A slight coating of any foreign substance on the muslin seriously retards the evaporation and conduction of the water from the bottle.

If the muslin becomes dry, then wet the wicking freely by direct application of a few drops of water.

Keep the glass bottle well supplied with pure distilled water or rain water when the temperature of the air is above the freezing point.

58. **Wet thermometers how read when the temperature is below the freezing point.**—When the temperature of the wet thermometer is below the freezing point, the following method of observation should be adopted:—

Remove the cup of water from its position in the shelter, and keep it full of cold water, as near the temperature of freezing as possible. The wicking need not be removed from the thermometer, but its free end should be passed over the brass support behind the thermometer, leaving the bulb with its muslin cover as before.

At least half an hour before the time for making an observation bring the cup of water underneath the thermometer, and wet the muslin by lifting the cup until the muslin cover is completely immersed, then quickly lower it; the drop which will gather on the bottom of the bulb should be removed by touching it with the edge of the cup. In order to secure a film of ice over the whole bulb, so thick that it will not be wholly evaporated before the time of observation, it may be necessary to repeat the wetting once or twice, especially if there is a high wind.

In case the bulb has already a thin coating of ice left from the preceding observation, the wetting should be wholly omitted. The aim is to have a thin ice film upon the bulb for a sufficient length of time before the observation, to insure that the thermometer has fallen to its lowest point, and is stationary at the time for making the observation.

It may sometimes happen, especially when the air is stagnant and the temperature is near the freezing point, that the water takes more than an hour to freeze, and the mercury remains at the freezing point of water instead of sinking to the temperature of evaporating ice. The freezing in this case may be accelerated by fanning the bulb.

When a thaw occurs, care must be taken that the ice formerly on the bulb has been wholly melted and a water film substituted; at such times the covered bulb and its attached wicking should be immersed in warm water to melt the ice at least an hour before an observation is to be made.

59. **Wet thermometer reading higher than dry.**—If the wet thermometer at any time be found to read higher than the dry, notwithstanding all precautions, examine the latter, wipe it, and make sure that its bulb is perfectly clean and dry, then observe whether the muslin cover of the wet bulb is clean and properly moistened on all sides ; if out of order, a new cover should be put on, and strict attention given to the preceding rules. During very damp or foggy weather it may sometimes happen that the wet thermometer will read slightly higher than the dry. In all cases record the exact reading of the instrument.

60. **Precautions.**—*1st.* The air around the wet bulb must not stagnate according to the theory of the use of this instrument. A gentle current should at all times pass across the bulb; and this conclusion from theory is borne out by observation. In a still atmosphere, as *e.g.*, in a room, the wet bulb gives a reading higher than that supposed by the theory, and the humidity calculated from such an observation is too high. In the thermometer shed the conditions are, in general, those required for good observation; but if the air is quite calm, the wet bulb should be fanned by a hand *punkha* or otherwise before the reading is taken.

2nd.—Distilled water or clean rain-water only should be used for moistening the bulb. River, tank and spring-water contain salts which, on the evaporation of the water, are left encrusting the bulb. They thus form a stony deposit, which destroys the sensitiveness of the instrument. In most parts of India a supply of rain-water is easily procured and stored for use. In Sind and the drier parts of Rajputana and the Punjab, where no other than river or well-water is procurable, a supply of water should be well boiled, and then filtered and allowed to stand before being used; and the bulb of the thermometer must be frequently examined and if a deposit has formed, it should be cleaned by the use of dilute acid and by careful scraping with a *sharp* penknife.

3rd.—A small bottle with a narrow neck is the best form of reservoir. It should be kept always filled with water.

4th.—The bottle should be placed with the neck a little on one side of the thermometer and about half an inch below it.

5th.—The bulb of the thermometer should always be wet. The muslin and thread should be washed at least once a week and be renewed once or twice a month, according as the weather is damp or dry, and dusty. Care should be taken that neither the muslin nor thread is greasy, but that they absorb water freely. If in dry weather the wet and dry bulbs give the same or nearly the same readings, the former is not properly wetted.

6th.—The muslin must be thin and fit closely to the bulb, and must be applied in one thickness only; and the wick that supplies it with water must be sufficiently thick to supply it freely. From 12 to 20 strands of weaver's yarn (or lamp cotton) make a good feeder. A strip of muslin, loosely twisted, is a good substitute for the wick when that cannot be obtained. Before being fitted to the thermometer, both muslin and thread must be well washed with clean water and put on while wet. The muslin, about an inch round (for a small pea bulb), is first made to adhere to the bulb, and secured by a single strand of thread tied immediately above the bulb. The free edges are then trimmed off with a pair of small sharp scissors, and finally the wet wick is passed once round the tube just above the bulb and tied, and the two loose ends (of equal length) loosely twisted together and immersed in the reservoir.

61. **Wet minimum thermometer.**—This instrument is employed to determine the humidity of the air at the time of the day when it is coolest (and usually dampest). This instrument bears the same relation to the dry minimum thermometer that the wet bulb does to the dry bulb. It is in fact an ordinary minimum, the bulb of which is covered with muslin and kept continually damp by means of a roll or string of cotton wicking which passes round the stem of the instrument above the bulb and is immersed in a small glass bottle filled with water.

62. **Precautions.**—The precautions to be observed in the case of the wet minimum thermometers are the same as for the wet bulb.

63. **Deposit of dust on thermometers.**—Thermometers are very liable to be covered with dust in India, more especially in the dry hot weather, when strong winds prevail and the air is laden with dust. The dust should always be removed when observed as any foreign substance reduces the sensitiveness of these instruments. It may be removed by means of a soft camel hair brush without taking down the instruments. In such cases it should be remembered that it is necessary not to disturb or shake the registering thermometers.

64. **To replace etchings on thermometers.**—When a thermometer is frequently wetted or the glass is kept more or less damp by the continued prevalence of damp rainy weather, the marks in the etchings (*i.e.*, the lines showing the divisions) on the thermometer become very indistinct, and hence it becomes difficult to read the instrument accurately. In such cases the observer should report the fact to the Imperial Meteorological Office, Calcutta, and he will be furnished with a small supply of black pigment (*e g.*, printing ink).

To make the divisions of the tube distinct again, rub the black pigment on the tube with the finger when the thermometer is quite dry. Then wipe the tube lightly to remove all the pigment not in the marks or divisions. As a temporary measure the black markings of the divisions can be restored by rubbing the point of a common black lead pencil along the tube which should be previously wiped with a cloth to make it perfectly dry.

65. **Packing of thermometers for transmission by parcel post.**—When it is necessary to return a thermometer to the Meteorological Office, the observer should pack it in the following manner. First wrap the instrument well with sheet cotton and place it in the light wooden box in which the instrument was originally received, or in a similar box. There must be sufficient cotton placed in the box to prevent the thermometers shaking about during transit by post or rail. Place this box in a larger box so that there is a free space of from one to two inches between the two. This space should be carefully packed with saw-dust, cotton wool or soft paper, so that the whole of the inner box (the top, bottom and sides) is enclosed in a layer of about 2 inches of soft material in such a manner that it will not move about inside the outer box. The lid of the outer box should then be screwed down, as the jarring made by driving nails into it might break the instrument.

66. **Instruments received from Post Masters or postmen to be examined.**—When a box, containing a thermometer that has been sent for the use of an observatory, is made over to the observer by the Postal Department, he should, before taking full delivery, open the package and thoroughly examine the instrument and state distinctly on the receipt whether it was received in good condition, or if damaged, the nature of the damage, and also report the state in which he received the instrument without delay to the Meteorological Office from which it was received.

67. **Restoration of broken column.**—Spirit thermometers are very liable to derangement in travelling by the separation of the spirit column, which instead of being continuous, becomes distributed in two or three divisions in the upper part of the bore. Sometimes the index is shaken out of the spirit and is found fixed at the upper end of the bore. And occasionally the column of the dry minimum or the wet minimum thermometer in ordinary use breaks up into two or three separate portions. It also frequently happens that the vapour which fills the upper part of the tube is condensed in a drop in its upper part (usually beneath the brass staple that fixes the tube) and the drop enlarges by further condensation, and may in some cases represent a length of several degrees of the spirit column. The method of procedure to be adopted in putting the

instrument in order varies with the nature of the defect, but the following four cases represent practically all the cases likely to occur:—

(*a*) *Some drops of spirit are in the upper part of the tube while the index remains immersed in the column of spirit in the lower part of the tube.*

If the thermometer be provided with a stout and firmly attached scale of wood, porcelain, etc., as is usually the case, grasp it by the upper end, holding the bulb end downwards and taking care not to press on the tube, which might risk breaking it. Then stretch out the arm above the head, keeping the bulb at a distance, and swing the instrument down *rapidly* towards the feet. This movement, repeated a few times, will generally restore the column. In certain cases the small drops of spirit in the upper part of the tube remain obstinately fixed, and even when the process of swinging is carried on rapidly and frequently, it may not effect the desired result. If this method fails, the following may be tried. Immerse the bulb and *the whole of the column of spirit* of the thermometer with the bulb end downwards in a vessel of water which should be as cool as possible. Then place the upper part of thermometer which contains the small drops of spirit in the direct rays of the sun, so that the sun's rays fall full on the drops which have to be removed. Keep the vessel of water and the bulb of the thermometer and the spirit column in the shade by screening them in some way. After the lapse of a quarter or half an hour it will generally be found that the spirit drops have disappeared and the spirit has gone back to the main body of the column. The first method of procedure while causing the detached drops of spirit to pass back into the regular column of spirit will frequently cause the index pin to pass back into the bulb itself, if of the ordinary straight form of instrument shown in Fig. 19 (page 43), or to become jammed in the angle of the bend of thermometer, if of the form shown in Fig. 20 (page 44). Hence a second case arises when—

(*b*) *The index pin is in the bulb or fixed in the angle of the thermometer above the bulb.*

In the case where the bulb and the tube are in the same straight line, all that has to be done is to raise the bulb end until the thermometer is perpendicular, and then gently tap or shake the instrument until the index slides down into the tube. If the thermometer is of the shape shown in Fig. 20, then place the thermometer so that the tube is horizontal with the bulb uppermost and tap the bulb end sharply against the hand, then raise the bulb end and the index will slide forwards in the spirit column. It may be necessary to repeat the operation of tapping several times.

A third case may arise when—

(*c*) *The spirit column is broken up into several fragments by air or other bubbles.*

The procedure to be followed in this case is practically the same as the first process described under (*a*) and hence need not be repeated.

The fourth case only occurs when during transit by post—

(*d*) *The index has been thrown out of the spirit and is fixed in the upper part of the tube, with only a few drops of spirit.*

In this case grasp the *bulb* end of the thermometer in the hand, and proceeding as described in (*a*), transfer the greater portion of the spirit column to the upper end of the tube. Then reversing the instrument, allow the index to fall to the lower end of the transferred column, and finally by repeated swinging re-transfer the spirit, now carrying the index with it, to the bulb end of the tube.

After rectifying the column of a spirit thermometer, it should be left for half an hour in a vertical position, bulb downwards, to allow of the last traces of spirit draining from the upper end of the tube.

68. **Test observations.**—Three of the thermometers in use at meteorological observatories are peculiarly liable to go out of order. These are the maximum, dry minimum and wet minimum thermometers. In some cases they alter or go out of order suddenly, in others there is a gradually increasing change. When these changes occur the instruments no longer show the correct temperature, and if the readings of such instruments be utilised for weather observations, they are necessarily more or less erroneous, according to the nature of the change in the instruments. It is hence necessary that observers should record special observations for the purpose of testing whether their thermometers are in proper order. If these test observations are made according to the following instructions, the Imperial Meteorological Office will be able to detect when any of these instruments is not in a satisfactory condition and will either send another thermometer to replace the unsatisfactory instrument, or give the observer instructions what to do to restore the instrument to its original good condition.

Maximum or minimum thermometers are liable to go out of order in two respects. In the first of these, some change may take place in the column, bulb, etc., by which it no longer records the temperature of the air correctly. For example, a portion of the column of a minimum thermometer may become detached and lodged in the upper portion of the tube. When this has occurred, it is clear that the instrument will always give a lower temperature than it should do, by the amount of the column thus detached; and any observations taken of such an instrument will necessarily be wrong. In the second case, the instruments may indicate the actual temperature correctly, but fail to register properly the highest or lowest temperature. These latter instruments might, hence, be utilised to give the temperature of the air at the time of observation in the same way as the dry bulb does, but are useless, or worse than useless, for registering the maximum or minimum temperature of the previous 24 hours, because they give erroneous observations of the kind for which they are provided.

Errors due to these causes are by no means of infrequent occurrence. For instance, in February 1893, at one observatory the readings of the minimum thermometer were steadily throughout the month about 6° lower than they should have been, and these readings were reported by the observer as correct. At another observatory the readings of the minimum thermometer, registered on five days of the month at 8 A.M. were several degrees higher than the 8 A.M. readings of the dry bulb on the same dates. The maximum or minimum thermometers were in an unsatisfactory state at six stations certainly, and probably at four or five more in that month as shown by the observations. With one exception the observers at these stations did not report any defects in these instruments. The changes giving rise to these erroneous observations were doubtless in some cases such as could not be readily detected by the observer. In others they could have been easily detected, but the observers neglected to examine their instruments carefully to see whether they were in order.

Hence the necessity for frequent test observations, in order that the Imperial Meteorological Office may be able to have a continuous and independent check on the state of the thermometers and be able to ascertain, without frequent references to the observers, whether the thermometers in use continue in good order or not, and may hence, where necessary, recall instruments that are going out of order and cannot be restored to good condition by observers.

In order to test for the first object, *viz.*, whether the instruments are in good condition as ordinary thermometers, so that they might be used to give the actual temperature at the time of observation, observers should make the following test observations daily at 8 A.M. **immediately after they have set the maximum thermometers at second class observatories, and after they have set the maximum and minimum thermometers at third class observatories.**

Take a careful reading of the end of the mercury column of the maximum thermometer, then of the end of the spirit column of the dry minimum, and then of the end of the spirit column of the wet minimum, entering the readings in the proper places in the observation book against the appropriate headings of the "Instrumental *test observations" at the foot of each page. Finally, take a reading of the dry bulb, which will differ slightly from the previous reading of that instrument recorded as part of the ordinary observations at 8 A.M., and enter opposite to the heading "Instrumental test observations" "Actual dry bulb." It will usually differ slightly from the previous reading of the dry bulb (for the 8 A.M. observation), as temperature generally rises rapidly at that time of the day. The observer should be very careful not to touch the bulbs of the instruments or to do anything (such as breathing upon them) which would be likely to affect the readings.*

It is clear that as the maximum thermometer has just been set before taking these test observations, it is then in the same condition as an ordinary thermometer, and hence its reading (if in good order) should be nearly the same as that of the dry bulb. It will rarely be exactly the same if the readings be taken carefully to tenths of a degree, as thermometers differ slightly from each other and do not record exactly the same temperature under the same circumstances. The errors of all the instruments relative to the standard thermometers at Alipore (Calcutta) are determined before they are issued, and hence the Calcutta Office in examining the test observations makes allowance for the known or original differences or errors of the instruments. In the case of the minimum thermometer, when it is in good order, the spirit column remains unbroken, and hence the end of the column always marks the actual temperature of the air at the time, and might (by disregarding the index) be used as an ordinary thermometer. Hence if these observations be taken quickly, the readings of the maximum, minimum, and dry bulb thus taken should differ by very small amounts. The test reading of the wet minimum should nearly agree with that of the wet bulb taken for the ordinary 8 A.M. observations. The differences should, as a rule, not exceed 1°. If they exceed 2°, it is probable the instruments in question are not in good order, and should be carefully examined. If any defect be observed in any one of these instruments, it should either be remedied in accordance with the instructions in section 67, or, if the observer be unable to remedy it, he should notify the fact to the Meteorological Office, Simla, but continue to record the readings at 8 A.M. as heretofore in the ordinary way, and also the test readings, until he receives instructions as to what to do with the instrument.

The following is an example of properly recorded test readings extracted from a register book of 8 hours' observations for February 1893 :—

Instrumental Test Observations.	Actual maximum thermometer	78°·2
	" minimum dry	77°·6
	" " wet	74°·0
	" dry bulb	78°·1

The readings of the maximum, minimum and dry bulb given above, it will be seen, differ very slightly from each other and considerably less than 1°. The 8 A.M. reading of the wet bulb was in this case 73°·3, and less than 1° below the test reading of the wet minimum.

The following is the order respecting these observations which has been issued to second class observers:—

After taking the 8 A.M. observations, and after having set the maximum thermometer, the observer should again read the dry bulb thermometer, the maximum thermometer (as it reads immediately after it has been set), and also the dry minimum and, when there is such an instrument, the wet minimum thermometer. In the case of the two minimum thermometers they are not on this occasion to be read as minimum thermometers are usually read, but the reading of the end of the column of liquid farthest from the bulb must be recorded as if they were ordinary thermometers. These readings should be entered in the space allotted to them in the 8 hour column under the heading of "Instrumental test observations."

The following gives the slightly modified order which is to be followed at third class observatories:—

After taking the 8 A.M. observations, and after having set the maximum and minimum thermometers, the observer should again read the dry bulb thermometer, the maximum thermometer (as it reads immediately after it has been set), and also the dry minimum and, when there is such an instrument, the wet minimum thermometer. In the case of the two minimum thermometers, they are not on this occasion to be read as minimum thermometers are usually read, but the readings of the end of the column of liquid farthest from the bulb must be recorded as if they were ordinary thermometers. These readings should be entered in the space allotted to them in the 8 hour column under the heading of "Instrumental test observations."

The second kind of test observations is required in order to ascertain whether the maximum and minimum thermometers are registering properly, and should be made at all third class observatories, *i.e.*, observatories at which 8 A.M. observations only are recorded.

It is not necessary for second class observers to make test observations of this kind, as the 10 and 16 hours' observations, if taken in accordance with the instructions recently issued, usually show whether the maximum and minimum thermometers register correctly.

The following is the rule laid down in the "Hints to observers," given in the daily note-book of 8 A.M. observations, for these test observations:—

Test the maximum and minimum thermometers once a month *to ascertain if they register properly, according to the instructions issued for that purpose.*

In order to do this observers at third class observatories should, at least once a month, read (but not set) the maximum thermometer shortly before sunset and compare the maximum temperature of that day as thus obtained with the reading as recorded at 8 A.M., next morning, and enter the readings in one of the forms supplied for these test observations. If the two readings differ by less than half a degree, it may be assumed the instrument is registering properly. If the difference is a degree or upwards, a brief note to that effect should be entered in the last page of the monthly register, and the Simla or Calcutta Office will, after going through the observations for that month sent in Form E, decide whether it is advisable to supply a new instrument or not. If the difference be large, or if the air space has vanished and the thermometer fails to register properly, the observer should communicate the fact without delay to the Simla Meteorological Office.

The dry minimum thermometer should, for convenience, be tested on the same day as the maximum thermometer. *The observer should be careful not to set the dry minimum thermometer at 8 A.M. of the day on which he intends to take the test readings, but to leave it exactly as it was before taking the minimum reading.* At about sunset on that day (after taking the test reading of the maximum thermometer) he should read the index and the top of the spirit column of the dry minimum thermometer and record the readings as the test readings on the form supplied for the purpose. He should then set the minimum thermometer, so that it may register the minimum temperature of the night for the next morning's observations. As a general rule the test reading of the index at sunset will agree with the reading previously recorded at 8 A.M. It is however possible, under unusual conditions of the weather, such as a thunderstorm with hail, that the two readings may differ considerably. Hence the observer should also note the character of the weather more especially when the test reading does not agree with the previous 8 A.M. reading.

69. **The wet and dry bulb Thermograph.**—The instrument is shown in Fig. 22. It consists of a case containing a recording cylinder driven by clock work similar to that used in the barograph. Outside the case will be seen two very flat tubes, one curving upwards, the other downwards and each having a small straight rod leading into the recording case. Each curved tube is filled with a liquid, and as it expands with heat the tube becomes straighter, and it will be seen that the rod so acts on the short end of the lever, that as the temperature rises, the pen rises, and as the temperature falls the pen

falls, and thus by an arrangement identical with that already described for the barograph, we get the continuous record for a day or a

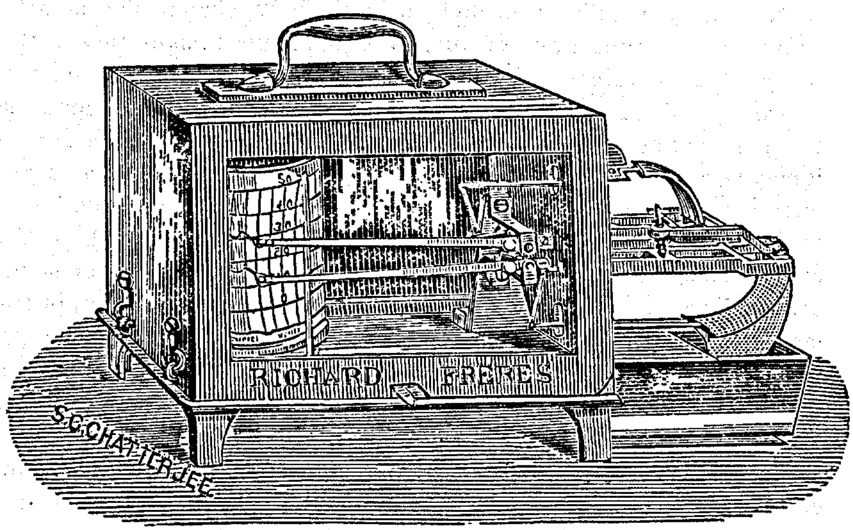


Fig. 22.—Wet and Dry Bulb Thermograph.

week. Both levers write on one cylinder, but the one connected with the lower bulb records a lower temperature, as the lower bulb is sewn up with muslin which is kept wet by dipping into a trough of water. It is usually necessary to put on several folds of the muslin, especially in very dry weather, to insure that the bulb is kept properly wet. When the air is very damp the traces lie very close together, if the levers are set to indicate the true wet bulb and true dry bulb temperatures and the pens are very likely to collide. To avoid this it is usual to set the wet bulb lever to indicate a temperature 10° too low, a difference so large that it cannot lead to mistake; the adjustment is, however, usually made before the instrument is issued and in general the observer should not alter the adjustment (see para. E, General Instructions, p. 60).

70. Directions for setting up and using the Thermograph—The following instructions are issued with the instrument :—

A. *Instructions for setting up the instrument.*—On receiving the instrument, the accessories—*viz.*, key, ink bottle and pen—will be found in a cardboard box. Another box contains the diagram papers. In order to set up the instrument proceed as follows :—

1. Open the case of the instrument.

2. Fit the pen on the style; bring it away from the cylinder by means of the pivoted pin and turn the cylinder to the left, so that the spring binder fixing the paper on the drum is on the *left side of the pen.*

3. Take off the spring binder.

4. Place the key in the opening on the top of the cylinder which is closed by the milled-edged brass button and wind up by turning the key to the left (the other opening, closed by a sliding plate is only used for regulating the escapement and must not be left open). The cylinder should be held firmly with one hand while winding up with the other.

5. Place the paper round the drum, the right end under the left one and in such a way that the latter is in a line with the two slots in which the spring binder fits, so that, when the binder is fixed on again, the two ends of the paper are pressed equally and without passing the binder. Care must be taken to lay the paper perfectly flat and to see that *its lower edge rests on the projection at the bottom of the cylinder.*

6. Put the ink in the pen *without filling it up.* No ink must be allowed to remain on the style, especially if it be made of aluminium, as it would corrode it. If the ink overflows, the pen must be taken off, dipped in water and allowed to dry. The style must also be washed and dried, a drop of oil placed on the thin end of the style and the pen re-fitted.

The length given to the style is indispensable to ensure the exactitude of the indications; the point of the style must be in the same axis as the point of the pen.

7. Turn the cylinder round its axis so as to make the time correspond with true local time. Also, if there is a standard instrument (barometer or thermometer), make sure that the indication of the self-recording one is exact; if there be any difference, turn to the right or left, as may be required, with the smaller end of the key, the square nut, which is placed above the thermometric tube.

8. Push back the pivoted pin which kept the pen away from the paper and give the pen a slight up and down motion to make sure that it writes.

In order to trace a regular diagram, the pressure of the pen on the paper must be *very slight;* to test for this, *the instrument must be tilted forward* to an angle of about 30° to 45°; when in that position, the pen *ought to lose contact with the cylinder;* if it does not, the pressure must be regulated till it does, by means of the milled edged nut placed at the broadest part of the style, the elasticity of which is sufficient to give the necessary pressure.

9. Close the case of the instrument.

B. *Cleaning the pen.*—When the pen is dirty let it remain for some time in clean water and wipe it with a piece of thin linen or a fine brush. This is needed only once in every three or four months. Generally, if the pen ceases writing, it is sufficient to take it off and slip the edge of a piece of *thin writing paper* between its two blades.

Ordinary ink must never be used, as a single drop would decompose the special ink.

C. *Important Notice.*—The pen-bearing style must always be *in front* of the pivoted pin which serves to keep it away from the cylinder. If, on receiving the instrument, it is found that during the transit, the style has got between the pin and the cylinder, it must be lifted up and placed again in front of the pin.

D. *Instructions for taking off and putting on the cards.*—The clock, it should be remembered, requires to be wound up once a day or once a week, according to the kind of instrument. It should never be allowed to run down.

When it is desired to take off a trace and replace it by a blank form, the following procedure is to be followed:—

First undo the case and lift it up. Then press the lever, and by means of the pivoted pin lift the pen from the cylinder as far as it will go.

Then (if necessary) wind up the clock in accordance with the instructions given above in paragraph 4. Remove the spring binder and the paper at once comes off. Proceed exactly as stated in paragraph 5 to put on another sheet. Then turn the cylinder on the axis so as to make the time indicated by the pen on the sheet to correspond as nearly as possible with the clock time. Then bring the pen down on the cylinder by the pivoted pin and see that it marks the card. Finally, close the instrument by lowering and fixing the glass case.

E. *General instructions.*—When the thermograph trace is taken off, the period to which it refers should be stated on the back of the card, *and any special comparative observations which were taken from the ordinary thermometer during that period should also be given on the back of the card, and the time when they were taken.*

As a rule, the instruments should only be adjusted so as to agree with the standard instrument by an inspecting officer during an inspection visit, and in no case should the adjustment be made by the observer, except with the permission of the Provincial or Imperial Reporter, first obtained, when all necessary instructions will be given.

The cards or traces should be sent weekly or monthly to the Imperial Meteorological Office at Alipore (Calcutta), where they will be examined, and instructions given, if defects in the working of the instrument are detected.

WIND-VANE AND ANEMOMETER.

71. Construction of wind-vane.—Wind-vanes are used to show the direction of the wind. The ordinary form is a balanced lever, turning freely on a vertical axis; one end of which exposes a broad surface to the wind, while the other is narrow, and serves to point the direction *from* which the wind blows, and, therefore, that by which the wind direction is named. In ordinary wind-vanes, the vane alone revolves, and the vane rod bears a fixed cross immediately below the vane, the arms of which indicate the four cardinal points. By comparing the pointer of the vane with these, its direction is easily estimated with sufficient exactness.

72 Compass notation.—The notation universally adopted for registering wind directions is that of the mariner's compass.

Sometimes, for the sake of brevity, numbers are employed to denote the direction of the wind. The numbers selected are the even numbers from 2 to 32 and correspond to the 32 compass points as given on a mariner's compass card.

The following are the names of the sixteen compass points employed to indicate wind direction with their respective letter-symbols and numbers. The intermediate points (*viz.*, north by east, north-east by north, etc.,) are not used for wind registration.—

Name.	Symbol.	No.
North	N.	32
North North-East	N. N. E.	2
North-East	N. E.	4
East North-East	E. N. E.	6
East	E.	8
East South-East	E. S. E.	10
South-East	S. E.	12
South South-East	S. S. E.	14
South	S.	16
South South-West	S. S. W.	18
South-West	S. W.	20
West South-West	W. S. W.	22
West	W.	24
West North-West	W. N. W.	26
North-West.	N. W.	28
North North-West	N. N. W.	30
Calm	C.	

73. Calms.—If the wind be insufficient to move the wind-vane, the position of the vane is not to be recorded; but in lieu thereof, the letter C, indicating a calm. The anemometer will also show whether a wind direction or a calm should be entered on the register. If the cups are motionless, or only moving slowly at intervals, with intervening pauses, a calm should be recorded.

74. **Dial vanes.**—The wind-vanes supplied to some of the meteorological stations are made with the vane firmly keyed to the vane rod, which is so suspended as to revolve with the vane; and, passing through the roof of the house on which it is fixed to the room below, shows the direction of the vane on a fixed dial, by a pointer keyed on the rod, and exactly parallel with the pointer of the vane above. The advantage of this form is, that it may be read at night as accurately and conveniently as by day.

75. **Choice of site and fixing.**—In selecting a place for the wind-vane, the following points must be attended to:—

1. The place selected must be as open as possible, and there must be no object loftier than the wind-vane for a long distance (as far as possible) around. Large trees and buildings in the neighbourhood are always objectionable. Even if not lofty enough to screen the vane when the wind blows from their direction, they nevertheless serve to cause eddies or whirls (such as may frequently be noticed in streets and among buildings, from the dust they carry up and whirl round) which act on the vane from a direction different from that of the general air current in the open neighbourhood.

2. The vane must be fixed on the highest accessible point. If on a building, it should be fixed on the highest point of the building and at least 4 feet above it. It must, however, be easily accessible for the purpose of oiling, etc.

3. *Its cardinal points must be set by compass* (and not by guess) *to true* (not magnetic) *north*. The declination of the compass (or difference between magnetic and true north) is very small in any part of India, not exceeding 3°, and *magnetic north is east of true north*. This variation, small as it is, must not be disregarded; for it must be borne in mind that all errors, however small, which are constant in kind and amount, are reproduced when the average of a very large number of observations is taken, however roughly approximate the observations into which they enter.

76. **Robinson's anemometer.**—This instrument records the movement of the air by means of a revolving vane acting on a system of wheels, and the total movement is read off periodically on a dial. The revolving vane consists of four arms, radiating horizontally in the form of a cross, and carrying four hemispherical cups of thin sheet copper. While revolving, these present alternately their concave and convex faces to the wind, and it has been shown by calculation that, in virtue of the form of the two surfaces, the pressure of the wind on the former is to that on the latter nearly as 3 to 2. Consequently the vane revolves with about one-third [1] of

[1] Later experiments have shown that it is somewhat less than one-third, and also that the ratio varies in different instruments.

the velocity of the wind. This, however, is practically the case only with large instruments, the arms of which are 2 feet and upwards in length; and in all cases a correction has to be applied for friction, etc., which varies with each instrument, and is usually determined before issue by comparison with a standard instrument at the Alipore Observatory.

In the form of the instrument in general use in India, the system of wheels by which the motion of the air is registered, consists of a pair of wheels on the same axis. The front wheel of the two bears an engraved dial with two concentric scales, and the readings are indicated by two pointers, one of which is fixed to the outer case of the instrument, the other is carried by the hinder wheel and revolves with it. The fixed pointer indicates the division on the inner circle graduated from 0 to 5 miles, the miles being divided into tenths; and a complete revolution of the dial wheel therefore corresponds to 5 miles of wind. This pointer serves to show distances under 5 miles. The hinder wheel has one tooth less than the dial wheel; so that, at each revolution, the pointer carried by it advances on the dial wheel through the space of one tooth. Now one tooth corresponds to one division of the outer circle, and therefore to five miles. There are 101 divisions making 505 miles (in some instruments 100 divisions, equal to 500 miles), which therefore is the maximum distance registered by this form of anemometer.

77. Reading.—This is very simple. All distances *above* five miles are read off by the position of the moveable pointer on the outer circle, the division next behind the pointer being taken. To this is added the amount indicated on the inner circle by the pointer fixed to the case of the instrument. When, in the interval of two readings, the moveable pointer has passed the zero, the first reading is to be deducted from either 505 or 500 miles (according to the graduation of the instrument), and the remainder added to the actual reading. The reading of the dial represented in Fig. 23 is $285 + 1 \cdot 5 = 286 \cdot 5$ miles.

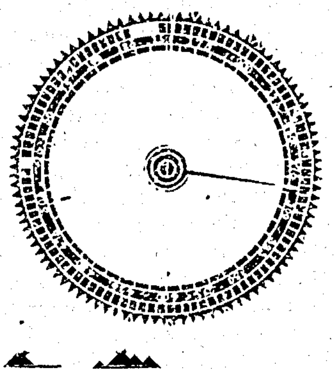


Fig. 23.—Anemometer dial.

78. Precautions to be observed.—Anemometers are very liable to go wrong if not carefully looked after. The teeth of the wheels may, for example, wear away, and the instrument fail to record, more

especially in the case of light winds. The bearings may become clogged with hardened oil and dust, and in consequence of the friction thus set up, the cups will move less freely than they should do, and hence the instrument will record a smaller amount than it ought to do under the circumstances. The following instructions should hence be carefully carried out by observers in order to maintain their anemometers in proper working order:—

1st.—The anemometer should be fixed as rigidly as possible to its supports, so as not to sway about in strong winds. Hence if at any time it becomes loosely attached and sways about, the fact should be reported to the Imperial Meteorological Office at Alipore (Calcutta), whence instructions will be issued.

2nd.—The instrument should be carefully cleaned and oiled at intervals, depending upon the character of the weather. Thus, in dry dusty weather, it should be oiled and cleaned at least once a fortnight; and in the rains, about once a month.

3rd.—When oiling the instrument, care should be taken to oil only the parts which really require oil, in order to diminish friction and enable the instrument to work freely. The oil should hence be applied only to the bearings in which the vertical and horizontal rods or axles rotate.

4th.—When cleaning or oiling the instrument, great care should be taken not to displace or lose the steel shot placed in the cup at the bottom of the vertical spindle on which the cups turn.

5th.—In rainy or damp weather the steel portions of the working part of the instrument should be cleaned with kerosine oil in order to prevent their rusting.

79. **Method of finding the wind velocity at 8 A.M.**—It is desirable for various reasons, more especially in connection with storm warning, to know not only the average hourly velocity during the past 24 hours, but also the velocity at the time of observation, and the majority of observatories are provided with sand-glasses in order to enable this to be determined. These sand-glasses, if in good condition, take exactly three minutes to pass the sand in the glass from one bulb to the other. To ascertain the force of wind at 8 A.M. the observer should invert the sand-glass as soon as he has taken the ordinary reading of the anemometer (to give the amount of wind since the last previous observation), and wait until the whole of the sand has fallen into the lower bulb. He should then again read the anemometer as quickly as possible, and the difference between this and the first reading will give the movement of the wind during this interval of three minutes. This number expressed in tenths of a mile should be telegraphed in accordance with the instructions given in para. 4, pages v and vi of the Telegraph Code.

In the case of stations not provided with sand-glasses, the observers should use their watches (if provided with the second-hand) for the purpose and follow the instructions given above.

80. **Beckley's Anemograph.**—These instruments are in use at seven first class observatories, at nine second class observatories and at one third class observatory. They are constructed on the principle of Robinson's anemometer, but record the direction and movement of the wind continuously on a sheet of metallic paper. The direction is obtained by means of a pair of wind-vanes on the principle of the wind-mill regulator. These are keyed on the same axis and are set in motion by the wind, until they are presented to it edge-wise, when they cease to revolve. Their axis carries an endless screw, which works into a toothed disc (see Fig. 24) fixed to the cast-iron standard of the instrument. The frame, which carries the vanes and screw, is firmly attached to a disc-shaped cover of cast-iron, from which a hollow cylindrical shaft passes down inside the hollow standard, and being supported on friction rollers, the whole is made to revolve by the motion of the vanes. At its lower end, inside a cast-iron box at the base of the standard, the shaft carries a toothed disc, which communicates its motion to a light hollow brass rod; and this, in its turn, works the recording apparatus presently to be described.

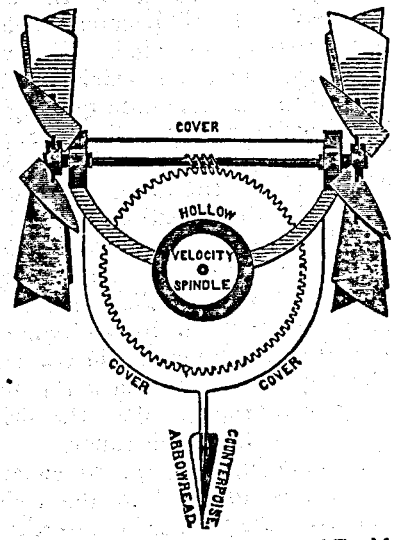


Fig. 24.—Direction vanes of Beckley's anemograph.

The distance, travelled by the wind, is obtained by means of Robinson's hemispherical cups, 9 inches in diameter, carried on a frame of four arms, each 2 feet in length. The spindle, to which the cup frame is keyed, passes down the axis of the hollow direction shaft, and by means of suitable gearing in the box at the base of the standard, communicates its motion to a second brass rod, which works the pencil cylinder in a room below.

The recording apparatus is placed in a room below the vane-standard, and consists of a clock, which drives a horizontal brass cylinder, 4¼ inches in diameter. This completes a revolution in two or three days, and carries a sheet of metallic paper, fastened by clips, and lithographed with two ruled forms, the one for direction, the other for velocity. These forms are adapted for one or two days' registers, and are divided transversely into hour spaces duly numbered. The direction form is ruled longitudinally with lines corresponding to the eight principal compass points. That for velocity is divided into five spaces, each of which corresponds to a movement of 10 miles, so that the whole width of the form corresponds to a trace of 50 miles. Above the cylinder are two rollers, each bearing a spiral plate, the edge of which presses on the recording sheet, and, with the least friction, leaves a mark on the metallic paper. These may be termed the pencil rollers. Now, the spiral pencil makes one turn in the width of the form; and, if turned continuously, traces a line across the form, and then, coming into contact again at its further end, begins another line, which it carries across the form in like manner. But as, during this movement, the form-cylinder is being carried round by the clock-work, the trace in the case of the velocity pencil becomes oblique, and the more so, the lower the velocity of the wind. The velocity pencil roller can revolve only in one direction, which is determined by that of the Robinson's cups and the intermediate gearing, while the direction pencil roller rotates one way or the other according to the changes of the wind.

The record sheet is adjusted to the cylinder by certain marks lithographed on the form. This being done, the arrow head, which is carried by the direction disc (Fig. 24), must be brought round by hand till it is directed to true north (which point must have been previously ascertained by compass or a meridian observation). The "direction" pencil roller having been thrown out of gearing by raising the bevelled toothed wheel on the driving rod, is then set, so that the spiral pencil is in contact with the north line lithographed on the register sheet; and in this position it is brought into gearing by depressing the wheel of the driving rod, till the teeth interlock with those of the pencil roller.

On removing the record sheet, the date, hour and minute at which it was adjusted to the roller and removed, the name of the observatory, etc., are to be entered in the blank spaces left for these entries before it is put aside.

81. Dines's Pressure Tube Anemometer.—Recording Form.— This instrument consists of two independent parts,— the head, Fig. 25, which is exposed to the wind, and the recording apparatus, Fig. 26, which may be put a considerable distance away, and in any convenient place.

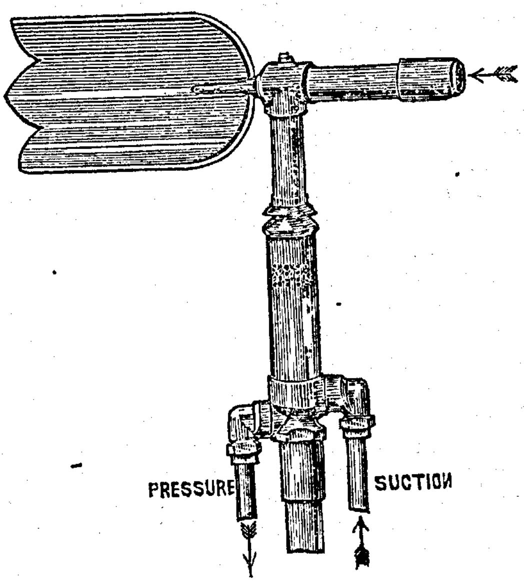


Fig. 25.—Head of Dines's Anemometer.

The head consists of a vane, formed of a piece of tube with an open end, which is kept facing the wind, and into which the wind blows, while just below the vane is another and larger tube, perforated by several holes arranged in rings, the action of the wind in blowing across which is to

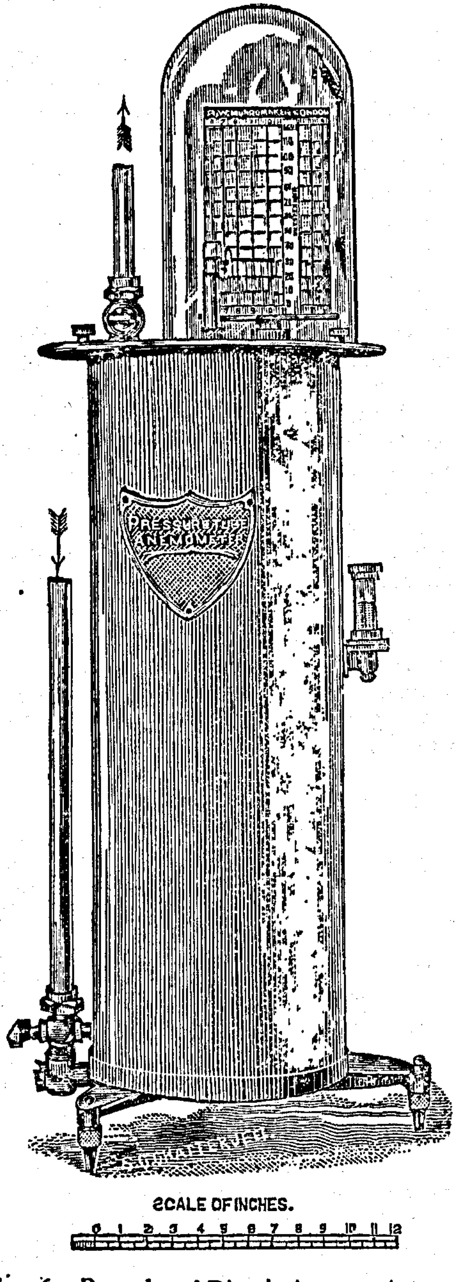


Fig. 26.—Recorder of Dines's Anemometer.

suck out the air from the inside. These two tubes are separately connected with soft metal pipes, which are led down to the recording apparatus, wherever it may be placed.

The "recorder" consists of a float, specially shaped, which is placed in a closed vessel containing water. The vane is connected with the inside of this float by means of the soft metal pipe; through which every variation of wind-pressure experienced at the mouth of the vane is transmitted, and in accordance with which the float rises or falls in the water. The pipe connected with the perforated tube below the vane opens into the top of the closed vessel, above the float and consequently a reduction of pressure, caused by the suction of the wind at the holes, takes place above the float, simultaneously with the increase of pressure inside it. The two causes operate, therefore, in the same direction, and synchronously, to lift the float. To the top of the float is attached a rod which carries a pen; and the arrangement is such that its every oscillation is recorded graphically upon a sheet of paper, which is uniformly moved by clock work.

82. Instructions for setting up the Dines's Pressure Tube Anemometer:—The following instructions are issued with the instrument:—

Exposure.—It is essential that the Head should be fixed in such a position as to secure a free exposure to the wind; if erected upon a building it should be at a height sufficient to be above the disturbing influence of the building, but it is recommended to erect the Instrument, wherever it is possible to do so, at a distance from any building, trees, or other obstacles which would be likely to interfere with the free movement of the wind.

Support.—Iron gas barrel forms a very convenient support for the Head, as it can be obtained in lengths which can be easily screwed together, to any desired height, and of suitable diameter for securing the amount of stability required. But, whatever the support may be, whether gas barrel, pole, etc., it should be fixed truly vertical, so as to secure a proper bearing for the vane and firmly enough to resist the heaviest winds. Galvanised iron wire-rope stays may generally be used with advantage for this purpose, and they should be fixed a few feet below the head, and tightened by means of the nsual screw links attached to hooks or staples fixed in the ground, or to the roof of the building; three stays, if well spread, are, as a rule, sufficient for the purpose. If gas barrel of large diameter is employed for the support, a diminishing socket must be used at its upper end to carry the Head; and it will protect the composition tube from possible injury to carry it down inside the barrel, which may be done by leading it through a hole cut in the side of the tube, a few inches below the point where the Head is screwed on.

Joints.—Screw together all joints of gas barrel, stays or bolts, Head, etc., with tallow, or better still, with beeswax and mineral fat, to prevent rust; this will facilitate the occasional examination of the Head, which may be readily unscrewed for the purpose of cleaning, once a year, if desired. Waxed paper washers should be used between the gun-metal faces of the unions, to ensure sound joints and prevent leakage.

Head.—The Head is sent out with the passages and suction holes protected from dust, but before fixing it is desirable to see that these are all quite free from dirt or grit. The coils of Compo. tube are also sent out with their ends closed, and it is advised that these should be cut off, and the pipes blown through to ensure their being quite free; after which they can be plugged with a cork until they are required for fixing.

Connecting Tubes.—The gun-metal unions must be first soldered firmly to the ends of the Compo. tubes, and then made secure to the Head by means of the union nuts provided for the purpose. Lead the Compo. pipe down to the Recording Apparatus by gentle and easy curves, avoiding as much as possible sharp bends, and being especially careful not to allow any U shaped loop, or kink, to exist, in which water from condensed moisture could accumulate. This is most important, for if there is any place left in the tubes in which water can accumulate, the accuracy of the record is utterly destroyed. It is desirable for purposes of comparison that all instruments should have the same length of tube between the Head and the Recording Apparatus, and 40 feet is suggested as a suitable length. Ten feet more or less will not make much appreciable difference, but if the length is greatly increased, the effect would be to retard somewhat the movements of the float, and very transient gusts might pass away before being fully registered, owing to the friction of the air in the pipes. When the distance between the Head and the Recording Apparatus exceeds fifty feet, a larger pipe should be used. Departure from this rule does not interfere with the values given for mean velocities, but prevents the possibility of comparison of the maxima obtained with those of the many instruments already in use.

Water-Cylinder.—After unpacking the float, remove carefully any dust which may have collected and then place the instrument upon its stand, which should be about 18 inches in height. Now place the float inside the Cylinder and fill up with clean water, avoiding splashing as much as possible, until the water can be seen level with the centre of the sight-holes in the gauge-glass Tube. The float must be kept on the bottom of the Cylinder whilst the water level is being adjusted. The cover should now be put on and screwed down, inserting at the same time the guide, which prevents the float from rotating, and which must be screwed in its place. Now connect the Compo. tubes with the Cylinder taking care that the *Pressure* tube is joined to the stop-cock at the *bottom* of the Cylinder, and that the *Suction* tube is connected to the stop-cock attached to the *cover* of the Cylinder.

Adjustment of Float.—The pen attachment is now to be placed temporarily upon the top of the rod projecting through the centre of the cover, and the Cylinder is to be levelled by means of the screws at the bottom, until the rod floats exactly central in the hole; in doing this, make sure that the float is off the bottom of the Cylinder. The pen is now to be removed, and the guide collar placed over the rod, and fastened in its place; after which, the pen may be replaced, ands hot be placed in the cup at the top until the float just, and only just, sinks to the bottom on being tapped gently. Place a chart upon the Clock Cylinder and fix the Cylinder in its place; adjust the pen to the zero of the chart; open the stop-cocks of the pressure and suction tubes, and the instrument will commence to record.

Changing Charts.—In changing the charts, both stop-cocks should be turned off so as to connect the inside of the Water Cylinder with the air of the room, and the balance of the float should then be examined, and, if necessary, re-adjusted by means of the shot in the cup before re-starting. The amount of shot should be such that the float, when raised one quarter of an inch, should just fail to fall back to the bottom without tapping. The level of the water in the glass tube should also be examined occasionally (the float being kept upon the bottom of the Cylinder), as the accuracy of the record depends upon the accuracy with which this point is maintained.

Glass Shade.—The glass shade should be kept over the Clock Cylinder, and in dry weather a small shalow vessel of water, about one inch in diameter, kept under the shade, will suffice to keep the air moist, and prevent the ink from drying on the pen. It is a good plan to let the shade rest upon a ring cut out of two or three thicknesses of blotting paper.

Pen.—The pressure of the pen on the paper can be varied by altering the angle at which it hangs from its support. The pen must be kept clean, *and especially from grease*, and it is advisable to wash it in warm water once a week or oftener in very dry weather.

Cleaning the Instrument.—If the instrument is taken asunder for cleaning, be careful not to damage the float or its attachments in any way, or the sensitiveness of the instrument will be destroyed. Care must also be taken not to raise tne float too rapidly so as to cause water to get into the pressure tube; if this occurs it must be drawn off at once by means of the screw valve immediately under the Water Cylinder.

The water used for charging the Water Cylinder should be either filtered rain water or distilled water. Hard water will cause an incrustation on the central air tube, and such incrustation prevents the free movement of the float.

83. **Dines's Pressure Tube Anemometer—Sight Indicatingand maximum form.**—In these instruments, each of which consists of two distinct parts (Fig. 27) the Exposed Head is of precisely the same form as that used with the Recording Type of these Anemometers. Fig. 28 is the Sight Indicating Arrangement, and may be fixed, if desired, as much as 100 yards away from the Exposed Head. Fig. 27 and Fig. 28 are connected by two composition metal tubes about 5-16th inch diameter; these tubes are provided with unions so that the connections are easily made.

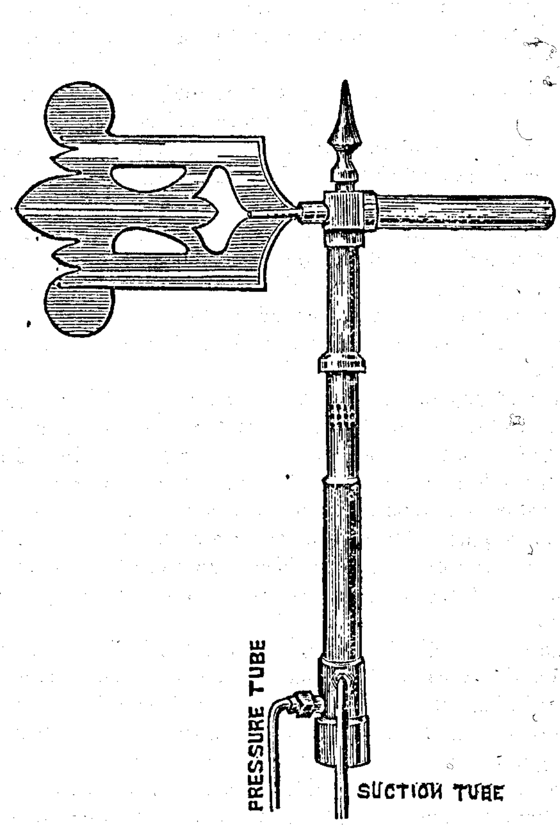


Fig. 27.—Head of Dines's Sight Indicating Anemometer.

The Exposed Head has an orifice which is kept continually facing the direction of the wind by a vane. The wind blowing into this orifice causes a pressure, which is transmitted by the composition tube direct to the Indicating Arrangement. This transmittingtube is on the engraving marked *pressure.*

On Fig. 27, a system of small holes is shown, these are openings into an outer tubular chamber; the wind blowing across these holes rarefies the air within, causing suction, which is transmitted by the Suction Tube to the Indicating Arrangement (Fig. 28).

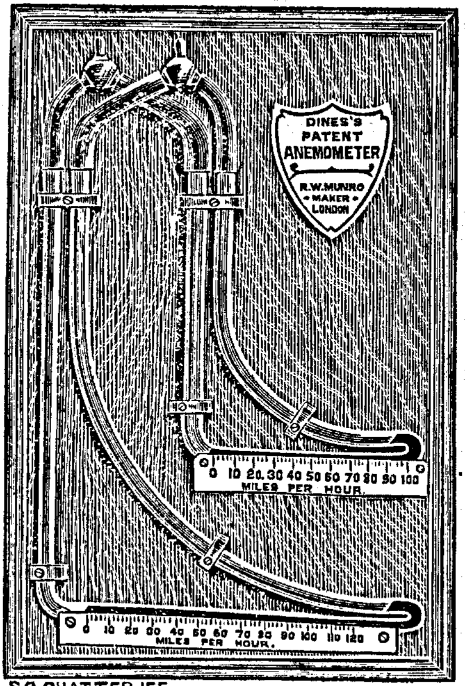


Fig. 28.—Dines's Sight Indicating Anemometer.

This part of the Anemometer consists of two separate bent glass tubes, each of which has one of its extremities connected to the Pressure and its other extremity to the Suction Tube. Within each glass tube is a column of liquid, and this column is displaced by the pressure exerted upon it at one end, and the suction at the other, the amount of displacement may be read upon the scales, and gives the wind's velocity in miles per hour. One of these scales and tubes gives the velocity at the moment; the other, and smaller, has in one part a contraction of its bore, causing it to show the wind's mean velocity. In each of these tubes is an index similar to that in a spirit minimum thermometer, the one in the larger tube registers the highest velocity that has occurred at any instant since the instrument was set, whilst that in the smaller tube registers the highest mean velocity sustained for any length of time.

These instruments may be very easily fixed by any competent mechanic: the Head, and especially the Indicating Arrangement, should be truly vertical.

The advantages claimed for this instrument is that the Head requires no oiling or attention, and may be exposed on the roof, or any suitable support, such as a flagstaff in the grounds of a house, whilst the Indicating Arrangement may be within the building 100 yards distant or more, if desired, hence a very good exposure can be obtained without inconvenience to the observer.

These instruments are sensitive to light winds, indicating as low a velocity as two miles per hour, but notwithstanding this, they are not liable to damage by the most violent gales.

They are especially suited for mountain observatories, as it is possible to render them independent of both hoarfrost and snow.

84. **Instructions forsetting up the Sight Indicating form of Dines's Anemometer.**—The following instructions are issued with the instrument:—

In fixing the Tube Head with Vane, it is essential to place it at least 6 feet above the highest part of the building or structure to which it is fixed.

The gas pipe or barrel to which the Tube Head is fixed must be quite firm and rigid in the heaviest winds and also be fixed truly vertical, so that the Vane may turn quite freely and without any bias. If the building or structure should be such that the gas tube has to be some considerable height, it should be larger in diameter in proportion to its height, and a diminishing socket can be used at the top end to carry the Vane Head. A high support, say a tube pillar 20 feet high, may consist of a 10 feet length of 2½ in. gas barrel, then 8 feet of 1½ in. barrel, and about 2 feet of 1 in. barrel at the top. Whenever stays are needful to make the gas tube pillar perfectly rigid and safe in heavy gales, three light wire-rope stays should be used and attached as near as convenient to the base of the Vane Head; if wire stays are used it is desirable to have the usual pattern of screw tightening hooks or links, since with these the stays can be made tight and the gas tube pillar made truly vertical. All the joints of gas pipe or bolts and Vane Head should be screwed together with tallow, or better still, with a mixture of beeswax and mineral fat, to prevent any rust. There should be no risk of the Head getting fixed by rust to the gas tube, so that it may be unscrewed once a year for cleaning or examination if found needful. Before fixing the Head, see that all holes and passages are quite free from any dust, dirt, or grit. (The Head is sent out with the passages and suction holes protected from the entry of dust or grit.) Waxed paper washer may be used, if thought needful, between the gun metal faces of the unions to prevent leakage of air. The gun metal pipe unions must be well and securely soldered on to the compo. pipes, and made quite secure to the Heads by the union nuts. The compo. pipe coils are sent out with closed ends. It is a good plan to cut off the closed ends and blow through the pipes to test them. After freeing from dust or grit plug them with a cork until quite ready to solder the unions on and then connect up. Lead the compo. pipes down to the Sight Indicating Instrument by gentle, easy curves, carefully avoiding any kinks or sharp bends. There must be no depression or U shaped loop in the pipes to favour the accumulation of water in any part of their length through condensation of moisture from the air in them. The Instrument is so constructed that rain cannot get into the pipes. It is desirable that all Instruments should have the connecting composition pipes of approximately the same length so that the frictional resistance of the air in the pipes of all Instruments may be about the same: for instance, it would not be wise for one Instrument to be fixed with Head and Indicator 50 feet apart, and another Instrument only 15 or 20 feet apart. The differences in frictional resistance of the air in the pipes would not be very great, but it is well that it should be about the same in all Instruments so that their indications may be strictly comparable. Brass union nipples are provided to *solder* on the lower ends of these compo. pipes and to carry short pieces of rubber tubes to connect to the brass T piece tubes of the Sight Indicator.

Place the Sight Indicator in a vertical position and introduce into the two glass tubes sufficient of the coloured liquid to fill them from the zero mark on the scale to the mark on the glass tube just beyond the bend on the right hand side. The last few drops of the liquid should be dropped into the tube from the glass pipette or dropper, so that the amount of the liquid may be nicely adjusted. It is most important to have exactly the right quantity, hence care must be taken to see that there are no air bubbles in the liquid column, and that after sufficient time has elapsed for all of it to drain down the sides of the tube the space between the two marks is exactly filled. If a little too much has been introduced accidentally it may be got out by pushing a piece of string down the tube, and withdrawing the string when the end has become wet.

The Instrument should now be fastened to a wall, or to some immovable support. No spirit level is needed, because the liquid in the tube serves the same purpose. The left hand end of the column should coincide with the zero mark on the scale, the other end of course coinciding with the other mark. The Instrument should be rigidly fixed at the level which gives this result, and the ends of the glass tubes may then be connected with the metal tubes from the Head, the left hand end being connected to the *pressure*, and the right hand to the exhaust or *suction* tube.

At present a suitable liquid which is absolutely free from evaporation has not been found; methylated spirit coloured with methylene blue has been found to answer fairly well, but there is a slight loss from evaporation. Hence now and then the rubber tubes should be disconnected, and if the liquid does not quite fill the space between the two marks the loss should be made good.

The left hand tube shows the variations of the wind and the strength of the gusts which only last for a few seconds. The right hand tube is added to show the average velocity which has been maintained for some considerable time. This is accomplished by making the air pass through a very small opening, in reality through a plug of compressed cotton wool, the oscillations being thus damped while the same average is obtained. For purposes of comparison it is desirable that all Instruments should be similarly damped. When the amount is correct the liquid should take five minutes to fall naturally from 45 to 35 miles per hour.

Place the piece of brass tube which contains the damping arrangement in the pressure pipe as close to the glass as possible, and be sure that the connection between it and the glass is absolutely air-tight.

Avoid using the mouth for blowing or sucking the tubes, for if any moisture gets in, the index is liable to stick, and the only remedy is to clean, dry thoroughly and refill the tube.

85. Force of wind, how estimated in absence of Anemometer.— Whenever an observatory is not supplied with an anemometer or the one in use has become unserviceable, the wind force should be estimated according to the following scale, and the measure (stated in words) be entered in the column for "amount of wind" in the observation book:—

Scale of wind force.

Name.	Corresponding velocity in miles per hour.	Apparent effect of wind.
Calm .	0	No visible horizontal motion of leaves of trees.
Light .	1 to 2	Causes smoke to bend from the vertical.
Gentle .	3 to 5	Moves leaves of trees.
Moderate .	6 to 9	Moves small branches of trees.
Fresh .	10 to 14	Blows up dust.

Name.	Corresponding velocity in miles per hour.	Apparent effect of wind.
Brisk .	15 to 20	Sways ordinary trees.
Strong .	21 to 26	Sways the largest trees.
High .	27 to 35	Breaks small branches.
Gale .	36 to 50	Blows down exposed shrubs, etc., and small trees.
Storm .	51 to 70	Prostrates exposed trees and frail houses.
Hurricane .	over 70	Prostrates every thing.

Observers at such stations, when sending weather telegrams, should give as the fourth word of the telegram the word denoting the strength of the wind, as for example, "moderate," "brisk," "high," etc., as the case may be, and not the word for "no instrument report." Also, when these words are used, it will be understood that they refer strictly to the strength of the wind at the hour of observation, and not to its average force during the interval since the last preceding observation.

RAIN-GAUGE.

86. **Object and principle.**—The object of the rain-gauge is to show the quantity of rain that falls. This is expressed in inches and decimal parts of an inch; the meaning being that, if the rain were to fall on a level surface which does not absorb it, and from which it cannot run off or evaporate, it would form a sheet of water so many inches or parts of an inch in depth.

87. **Construction.**—The instrument consists essentially of a funnel with a round mouth, and a receiving vessel. The quantity of rain received is determined by *the area of the mouth of the funnel;* and this area, if the rim of the funnel is round, is equal to the square of half its diameter multiplied by 3·1416. Thusa circular funnel 4 inches in diameter has a receiving area of $(\frac{4}{2})^2 \times 3{\cdot}1416 = 12{\cdot}5664$ square inches. One 6 inches in diameter $(\frac{6}{2})^2 \times 3{\cdot}1416 = 28{\cdot}2744$ square inches, etc. *Any change in the form of the opening* (such as may be produced by a blow or a squeeze) *diminishes its area, and the gauge will no longer register truly, and must be rejected.* To provide against any accident of this kind, the rim of the funnel is generally strengthened by a stout brass ring.

The reservoir is either a large bottle, or a vessel of sheet zinc or copper, or tin plate; but this last is objectionable, being liable to rust. The water received is measured in a graduated glass measure.

Rain-gauges with a graduated glass measure are all alike in the essentials of their construction, differing only in shape, dimensions, and certain other details; and bear the different names of their inventors, as Symons's gauge, Glaisher's gauge, etc. The float gauge, formerly in general use in some parts of India, is known as Fleming's gauge.

88. **Symons's Rain-gauge.**—The rain-gauge which is prescribed by the Government of India for use at all rainfall measuring stations in India is that known as "Symons's Rain-gauge." It is a small cylindrical gauge or vessel, 5 inches in diameter and 14 inches in height. The rain is received in a funnel provided with a brass rim, which should be truly circular, and be exactly 5 inches in diameter.

The water collected by the funnel runs into a glass bottle, and is measured by means of a cylindrical glass vessel which holds one-half inch of rain-water when filled up to a certain engraved mark. The space below this mark is graduated in tenths and hundredths of an inch.

The gauge is furnished with a foot of the shape shown i
the accompanying figure (Fig. 29), which gives a sketch of th
instrument.

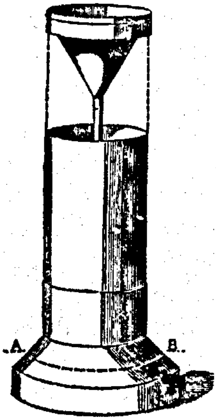


Fig. 29.—Rain-gauge.

The foot gives a firm hold in the brick or masonry in which i
should be imbedded. It also prevents it being blown over, an
assists in keeping it perfectly level, when, as has hitherto been fre
quently the practice in India, the rain-gauge is merely placed in th
ground to the depth of an inch or two.

89. **How to fix the rain-gauge.**—It is very desirable that the rain
gauge should be firmly fixed in a masonry or brick pillar. Th
masonry or brick pillar should be at least 2 feet square and 2 fee
high, buried in the ground to a depth of 1 foot 10 inches, so tha
the top should stand at a height of 2 inches above the level o
the ground. In this there should be a cylindrical space into whic
the lower part of the rain-gauge is firmly imbedded. The bottom o
this hollow space should be truly horizontal and at a level of 2 inche
below the ground and 4 inches below the level of the top of th
pillar, so that the rim of the funnel of the rain-gauge, when placed i
it, would be 12 inches above the ground and 10 inches above th
top of the masonry platform or pillar.

If there is any difficulty in having the pillar properly made, i
would be advisable to have the work done by the Public Works
Department, so as to secure that the instrument is properly level.

The following (Fig. 30) gives a sketch of the arrangements :—

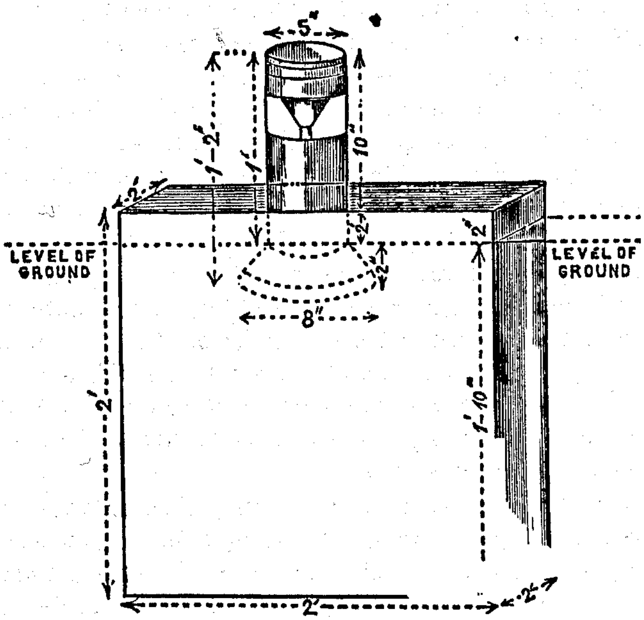


Fig. 30.—Arrangements for fixing rain-gauge.

At stations where a masonry pillar is not provided for the rain-gauge and the instrument is placed in the ground, it should be carefully noted that the lower part of the gauge should be very firmly buried with the mouth of the funnel 1 foot above the ground. The cylinder must be vertical, and the mouth of the funnel exactly level.

In stormy weather a rain-gauge is liable to be blown over, and its contents spilt, unless it is quite firmly fixed. But the mouth must be so far above ground that no gravel or dust may be blown or splashed into it. The height should not exceed 1 foot, because the quantity of rain received diminishes with increased elevation. If the gauge be surrounded by grass, this must not be allowed to grow to the edge of the funnel, but must be kept short-clipped. The mouth must be perfectly level; otherwise the gauge will receive more rain when the wind is blowing from the quarter towards which it inclines than when it blows from any other.

If the gauge is protected by a railing, the height of the railing above the mouth of the gauge must not be more than half its distance from the gauge.

The mouth of the gauge being 1 foot above the ground, if the railing be 3 feet high, it must be at a distance of 4 feet at least from the gauge; if it were placed at a less distance, it might obstruct a portion of the rain that would otherwise enter the funnel.

90. **Measurement of rainfall.**—The measure-glass usually supplied to rain-gauge stations by the Meteorological Department holds only half an inch.[1] If the receiver contains more than can be measured by filling the glass to the upper mark once, fill it up to the top line of the graduations, then empty it, drain it thoroughly, and refill it as before. Each complete filling represents half an inch of rainfall. The last partial filling is read off by means of the graduations as tenths and hundreths of an inch, and to this is added the amount measured by the previous fillings and the sum of the two reported.

For example.—As the measuring glass is only graduated to contain half an inch, if the glass be filled by the rain-water to the top graduation three times, and the remainder of the water measures 24 on the graduated scale, then the amount of rainfall will be three times half an inch, or one and a half inches, together with twenty four hundredths, that is, $1{\cdot}50+0{\cdot}24=1{\cdot}74$ inches of rainfall, which is the amount to be registered.

If it should happen that the measuring glass at any station not provided with a spare one should be broken, then in that case the following arrangements should be made for the measurement of the rainfall during the interval between the breakage of the measuring glass and the arrival of a new measuring glass, which should be indented for without delay from the Imperial Meteorological Office, Calcutta. An ordinary apothecary's fluid measure-glass should be temporarily used to measure the rainfall (the measurement being recorded in the monthly return in fluid ounces) until the broken measure-glass is replaced. In such a case care must be taken to strike out the printed word "inches," and to substitute "ounces," which must be clearly and boldly written. In the event of the measure-glass being broken, and an apothecary's ounce measure-glass not being procurable or available, the rainfall collected on each day must be stored up in a separate bottle and kept corked. Each bottle containing the rainfall for each particular day should be labelled, and on receipt of a new measure-glass the rainfall can be measured and entered as usual.

91. **Rules and precautions to be observed in the measurement of rainfall.**—Measure the rain-water in the gauge every day at 8 A.M. During heavy rain measure it three or four times in the day, lest the receiver fill and overflow; but take the last measurement at 8 A.M., and enter as the rainfall of the day the sum total of all the measurements during the day or previous 24 hours.

8 A.M. is the hour at which the rainfall is measured at all

[1] Some observatories are supplied with measure-glasses graduated up to *1 inch*. The rule will apply in such cases if *an inch* is substituted for half an inch throughout.

rainfall recording stations in India by order of the Government of India. The entry for any given day in the register book represents the quantity that has fallen during the 24 hours preceding 8 A.M. of that day, and hence 8 hours of which are those of the day of record, and 16 hours those of the previous day. It is of importance that the same hour be observed everywhere.

The receiving bottle, as a rule, does not hold more than three or four inches of rain. During heavy falls this quantity is frequently exceeded. If, owing to neglect of the above directions, the receiving bottle has overflowed, the outer cylinder must be taken up and its contents measured and added to that of the receiver. The gauge must then be reset and levelled.

It is very desirable that observers should examine the rain-gauge every day, even when they are certain no rain has fallen. By doing this they will make sure of the rain-gauge never being choked with dirt, and hence of not losing a portion or the whole of the first rainfall after a period of dry weather.

See that the measuring glass is quite empty before measuring the rainfall. Place it on a large dish or in a basin, and pour the contents of the receiver into it slowly and carefully to avoid risk of spilling.

The amount of the rainfall for each day should be entered immediately after measurement in the observers' note-book and should be recorded in inches, tenths and hundredths, the two latter being written as a decimal.

Great care must be taken when writing down the numbers to distinguish between hundredths of an inch, tenths of an inch, and inches. Thus, three hundredths of an inch should be written 0·03 inch, three tenths of an inch should be written 0·30 and three inches be written 3·00 inches. In order to avoid the probability of confusion from the omission of the zeros, all entries must show decimals of two places.

It would be desirable that every observatory should be supplied with an extra measuring glass, which could be brought into use on the breakage of the measure-glass in ordinary use. When a measure-glass is broken at a meteorological observatory supplied with a spare measure-glass, the latter should be at once brought into use, and the Imperial Meteorological Office, Calcutta, be asked to supply another measure-glass to replace the broken one.

92. **Precautions to be observed in using the instrument.**—Whenever the funnel has been removed for the purpose of taking the reading of the gauge, take care in replacing it to see that it is pressed down evenly on the rim of the reservoir.

If the level of the rim or mouth of the funnel be accurately adjusted by means of a spirit level when it is placed in position on the pillar, it is evident that this precaution will ensure that the mouth of the funnel when in position shall always be level. The necessity for this precaution is shown by the fact that an inclination of 5° (an angle almost inappreciable to the eyes) of the rim might cause an error of 2 or 3 per cent. in the measurement of the rainfall.

Examine occasionally the tube at the bottom of the collecting funnel, to see that it is free from obstruction. Should a straw or dirt have entered the tube, clear it by passing a straight wire down it.

As a rule, it is very desirable that no change should be made in the exposure of a rain-gauge, and the longer it has been exposed under any circumstances, the greater is the objection to any change. The reason of this is evident. A change might introduce a considerable alteration in the amount of rainfall measured, and hence might make a comparison with the rainfall data of previous years misleading.

93. **Selection of site for a rain-gauge.**—Fix the gauge in an open place, as far as possible from trees, houses and other obstructions. It should, in no case, be within thirty yards of any building or tree.

The object of this rule is to prevent the obstruction by surrounding objects of any of the rain which should be received by the gauge. When the rain falls in a slanting direction, a tree or a house at a considerable distance to windward evidently offers such an obstruction. On the other hand, the rain-water dropping from the trees at a moderate distance is likely to be blown into the rain-gauge. The instrument should, therefore, be placed at a distance from all such objects not less than that mentioned above.

The rain-gauge should at meteorological observatories be near the ground and not be placed on a building of any kind unless more rain-gauges than one are employed for the purpose of comparing the rainfall at the ground level and at an elevation above the ground. The latter is always less than the former, and the difference may amount to as much as 5 or 10 per cent. It is hence necessary in order that the results of different observatories may be comparable that the same elevation should be adopted. The rule now generally adopted is that the mouth of the rain-gauge should be *one foot above the ground level.*

Some observatories are provided with instruments or gauges for testing whether the funnels of rain-gauges are of the proper shape and size, and hence whether the rain-gauge, if otherwise in good condition, will register the rainfall accurately.

94. **Instructions for use of measuring-gauges to test the funnels of rain-gauges.**—On one side of the gauge for measuring the

funnels of rain-gauges parallel lines of different lengths are drawn. The length of the middle line is exactly five inches, and this is shown by the mark 5″ at its ends. The others increase or diminish by ·02 inch, and the lengths of the various lines are 4·94, 4·96, 4·98, 5, 5·02, 5·04, and 5·06 inches respectively. Except in the case of the middle line the last figure only is marked, so that 4·9 or 5·0 has to be supplied for the shorter or longer lines.

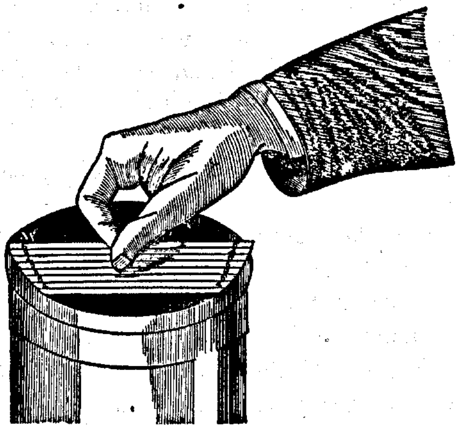


Fig. 31.—Measuring-gauge to test funnels of rain-gauges.

When using the gauge take hold of it in the middle by the thumb and first finger as shown in the above woodcut (Fig. 31), and place it in the funnel of the rain-gauge with the longer side up, and the lines as nearly horizontal as possible. Should it then coincide with a diameter of the funnel, the length of this diameter will be indicated by the figures at the end of the line on the face of the measuring-gauge joining the points where it touches the edge of the funnel. If this line be the middle one, the diameter of the funnel is five inches, but if the mouth be larger than it ought to be, the measuring-gauge will go further down, say, till the next line above the middle one fits the mouth of the funnel. In this case its diameter will be 5·02 inches. If the mouth be less than 5″, the lower lines (of 4·98 inches, 4·96 inches, or 4·94 inches) will enable the length of the diameter to be measured, and if more than five inches, the higher lines (of 5·02, 5·04 and 5·06 inches) will enable the diameter to be gauged.

It is not likely that the diameter will be exactly the length of one of the lines drawn on the face of the measuring-gauge, but sufficient accuracy will be obtained if the length be given correct to one hundredth of an inch. This may be easily done by observing whether the line joining the points of contact of the measuring-gauge with the edge of the funnel coincides most nearly with one of the lines on the measuring instrument or with a line midway between two of the lines traced on the measuring-gauge.

Care should be taken that the measuring-gauge is not forced into the mouth of the funnel, but placed in it with the ends of the gauge lightly touching the edge at equal distance from the middle line. If this be attended to, the lines on the face of the measuring gauge will be horizontal, and the diameter of the funnel may be measured correct to even less than a hundredth of an inch.

To test whether or not the measuring-gauge lies along a diameter of the funnel, keep one end fixed and try if the other can be moved to one side or the other. When this is no longer possible, the diameter has been found.

When the instrument is used to test a rain-gauge, it is employed to determine—

(1) Whether the mouth of the funnel is truly circular.

(2) Whether the circle is of the proper diameter.

In order to test if the instrument is truly circular or not, measurements should be made in different directions across the mouth of the funnel. If those agree within the hundredth of an inch, the rim may be accepted as circular. If not, the measurement of the greatest and least diameters or distances across the rim should be given, in order to enable, if desired, a correction to be applied to the actual measurements of rainfall to allow for the error due to the change of shape of the rim.

If the mouth of the rain-gauge is found to be circular, the measurement of the diameter should be taken as carefully and exactly as possible, so as to be certainly correct within a hundredth of an inch, which is the limit of error adopted by the Meteorological Department for rain-gauges in actual use. If the error exceeds this the instrument should be replaced as soon as convenient by a new rain-gauge.

CLOUD OBSERVATIONS.

95. **Object of cloud observations.**—No kind of meteorological observation is of more importance than that of the forms and movements of the clouds; but it requires some study and experience to know how and what to observe, and unfortunately there is no kind of observation that, in India at least, is less satisfactory than this.

The forms and movements of the clouds afford us the only information we can obtain of the changes in progress in any part of the atmosphere above the very lowest stratum; for it is only the stratum which rests immediately on the earth's surface, the motions and conditions of which we can study by means of the instruments in use at meteorological observatories.

In the first place, the very existence of a cloud at any elevation is an indication that the atmosphere there is in a state of saturation; and the lower the cloud, the more humid is the atmosphere. In the second place, the forms of the clouds may give information as to the changes of temperature, and the causes of these changes; and thirdly, their movements, if properly observed, show the direction and velocity of the winds that are blowing high up in the atmosphere.

The observations usually made, include the amount, form and movement of the two chief kinds of clouds generally visible, and which are known by their forms to be clouds of the upper and of the lower atmosphere, and are hence termed upper and lower clouds.

96. **Cloud proportion.**—The proportion of the sky covered by cloud is estimated by simple inspection. A sky wholly overcast is recorded as '10' of cloud; and all minor degrees of cloudiness by the lower numbers, the figure '0' being used to indicate an unclouded sky. From the nature of the observation, an approximate estimate only is possible; but, with a little practice, it will be found easy to make it with sufficient accuracy for practical requirements.

In making the estimate, clouds at a great distance and near the horizon, are not to be regarded.

In the case of a fog prevailing near the surface of the ground, it is clear the observer will be unable to determine whether there is any actual cloud in the sky or not. In such cases the observer should note "*foggy*" in the column of the note-book referring to cloud proportion.

In other cases also a fog may gradually lift or rise and at the time of making an observation though near the ground it may be clear, yet there may be a layer of fog at some little distance from the ground and which may quite obscure the sky. In such a case also as the observer will be unable to state whether there are any clouds in the sky or not, he will fill in "*foggy*" under the head of cloud proportion.

97. **Kinds of Clouds.**—Clouds may be roughly divided in respect of their apparent shape and form into two great classes—first, separate or globular masses (most frequently seen in dry weather), and second, forms which are widely extended, or completely cover the sky (chiefly occurring in wet weather). Each of these two forms is subdivided, partly according to their shape and partly according to their altitude.

98. **Classification of Clouds.**—The following gives the classification of clouds, arranged chiefly in order of their elevation, as used by observers at meteorological observatories in India :—

A. Upper clouds, average altitude about 30,000 feet :—

1. Cirrus	2. Cirro-stratus.

B. Intermediate clouds, between 10,000 feet and 25,000 feet in elevation :—

3. Cirro-cumulus. 4. Alto-cumulus.	5. Alto-stratus.

C. Lower clouds, averaging 7,000 feet in elevation :—

6. Strato-cumulus.	7. Nimbus.

D. Clouds of diurnal ascending currents :—

8. Cumulus; base 5,000 feet in elevation.

9. Cumulo-nimbus; apex, 10,000 feet to 27,000 feet and base, 5,000 feet in elevation.

E. High Fogs, under 3,000 feet.

10. Stratus.

99. **Description and Forms of Clouds.**—The following gives a description of these forms so far as is possible in words :—

1. *Cirrus* (*Ci*).—Detached clouds, delicate and fibrous looking, taking the form of feathers generally of a white colour, sometimes arranged in belts which cross a portion of the sky in "great circles," and by an effect of perspective, converge towards one or two opposite points of the horizon (the Ci. S. and the Ci.Cu. often contribute to the formation of these belts).

2. *Cirro-Stratus* (*Ci. S.*).—A thin, whitish sheet, at times completely covering the sky and only giving it a whitish 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 and moon.

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

4. *Alto-Cumulus* (*A.Cu.*).—Largish globular masses, white or greyish, partially shaded, arranged in groups or lines, and often so closely

packed that their edges appear confused. The detached masses are generally larger and more compact (changing to S. Cu.) at the centre of the group; at the margin they form into finer flakes (changing to Ci. Cu.). They often spread themselves out in lines in one or two directions.

5. *Alto-Stratus* (*A. S.*).—A thick sheet of a grey or bluish colour, showing a brilliant patch in the neighbourhood of the sun or moon, and which, without causing halos, may give rise to coronæ. This form goes through the same changes as Cirro-stratus, but its altitude is much less.

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

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

8. *Cumulus* (*Cu.*) (*Wool-pack Clouds*).—Thick clouds of which the upper surface is dome-shaped and exhibits protuberances while the base is horizontal. These clouds appear to be formed by a diurnal ascensional movement which is almost always observable. When the cloud is opposite the Sun, the surfaces usually presented to the observer have a greater brilliance than the margins of the protuberances. When the light falls aslant, these clouds give deep shadows, and 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 by strong winds, and the detached portions undergo continual changes. These may be distinguished by the name of *Fracto-cumulus.*

9. *Cumulo-Nimbus* (*Cu. N.*).—Frequently termed Thunder-cloud and Shower-cloud.—Heavy masses of clouds, rising in the form of mountains, turrets, or anvils, generally having a sheet or screen of fibrous appearance above ("false cirrus") and underneath, a mass of cloud similar to "nimbus." From the base there usually fall local showers of rain or of snow (occasionally hail or soft hail). Sometimes the upper edges have the compact form of cumulus, forming into

massive peaks round which delicate "false cirrus" floats, and sometimes the edges separate into a fringe of filaments similar to that of the cirrus cloud. This last form is particularly common in spring showers. The front of thunderclouds of wide extent frequently presents the form of a large bow spread over a portion of the sky which is uniformly brighter in colour.

10. *Stratus* (*S.*).—A horizontal sheet of lifted fog. When this sheet is broken up into irregular shreds by the wind, or by the summits of mountains, it may be distinguished by the name of *Fracto-stratus.*

The cloud forms numbered 1, 3, 4, 6, 8 and 9 consist usually of separate and globular masses and are most frequently seen in fine weather.

Forms numbered 2, 5 and 7 are, on the other hand, usually widely extended completely covering the whole or a part of the sky and are usually seen in wet weather.

100. **Instructions for cloud observation.**—The following are the instructions for the observation of clouds issued by the International Committee for cloud observation.

For each observation the following points should be noted and entered in the register :—

1. *The kind of cloud, indicated by the international letters of the name of the cloud* (*Sect. 101*).

2. *The direction from which the clouds come.*—By remaining perfectly still for several seconds, the movement of the clouds may easily be observed in relation to a steeple or pole erected in an open space. If the movement of the cloud is very slow, the head should be steadied by using a rest. This method of observing must only be used for clouds near the zenith, for if they are distant from it perspective may lead to errors. In such cases a nephescope alone will give correct results.

3. *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 the belts or their prolongations meet the horizon. This point on the horizon should be indicated in the same manner as the direction of the wind, *e.g.*, N, NNE, etc.

4. *Undulated clouds.*—It often happens that the clouds have the appearance of regular striæ, parallel and equidistant, like waves on the surface of water. This is most frequently the case with cirro-cumulus and strato-cumulus (roll cumulus). It is important to note the direction of these striæ. When two distinct systems are apparent, as is often seen in clouds separated into globular masses by

striæ in two directions, the directions of these two systems should be noted. As far as possible, these observations should be taken of striæ near the zenith, so as to avoid errors caused by perspective.

5. *The density and situation of a bank of cirrus.*—The upper clouds often assume the form of a tangled web or sheet, more or less dense which, as it appears above the horizon, looks like a thin bank of a light or greyish colour. As this form of cloud is closely connected with barometrical depressions, it is necessary to observe:

a. Its density, whether,
- (1) very thin and irregular,
- (2) thin, but regular,
- (3) fairly thick,
- (4) thick, or
- (5) very thick and of a dark colour.

b. The direction in which the sheet or bank appears thickest.

6. *Remarks.*—All interesting particulars should be noted, such as:

a. During summer all low clouds, as a rule, assume special forms, more or less resembling cumulus. In such cases an entry should be made in the column for "Remarks," *stratus* or *nimbus cumuli-formis.*

b. It sometimes happens that a cumulus presents a mammillated lower surface. This appearance should be noted under the name of *mammato-cumulus.*

c. It should always be noted whether the clouds seem to be stationary or in very rapid motion.

101. International symbols for cloud forms.—The following gives the International designations for the cloud forms mentioned above, as suggested by the International Committee:—

Ci.	Cirrus.	Cu. N.	Cumulo-nimbus.
Ci. S.	Cirro-stratus.	S.	Sratus.
Ci. Cu.	Cirro-cumulus.	Fr. Cu.	Fracto-cumulus.
A. Cu.	Alto-cumulus.	Fr. N.	Fracto-nimbus.
A. S.	Alto-stratus.	Fr. S.	Fracto-stratus.
S. Cu.	Strato-cumulus.	S. Cf.	Stratus cumuliformis.
N.	Nimbus.	N. Cf.	Nimbus cumuliformis.
Cu.	Cumulus.	M. Cu.	Mammato-cumulus.

102. Movement of clouds.—This subject deserves more attention than has hitherto been given to it in India. There is but little difficulty in observing the direction of the movement of clouds; but, like other kinds of observations, if it be attempted as a mere matter of routine, and without some care and attention, the register is likely to be so erroneous as to be only misleading and worse than worthless.

The besetting difficulty in obtaining a true estimate of the direction of the cloud movement is the elimination of the effects of perspective. It is very difficult, and indeed impracticable, without the aid of some suitable instrument, as the Nephescope of M. Marie Davy, to estimate truly the direction of clouds which are not moving either directly towards, or directly away from, the observer; and this, therefore, is the condition to be secured.

Set up a pointed pole, reaching 6 or 8 feet above the observer's head; and through the top, an inch or two below the point, fix two stout cross-wires or thin iron rods set truly by compass to the four cardinal points. The space around the pole must be sufficiently open to allow of a good view of the expanse of the sky in all directions. Let the observer then station himself at such a distance from the pole, and in such a position, that some recognizable limb of a cloud appears to move vertically upwards from the top of the pole or vertically downwards towards it. The direction of the pole from the observer's position (which may be judged accurately by means of the cross-wires on the top) is the direction of the cloud's true movement.

With a little care in selecting the position, the pole may be dispensed with. Any pointed object will serve the purpose, provided the observer has previously acquainted himself accurately with the directions of the compass points.

In recording the direction of the cloud movements, the kind of cloud on which the observation is made should be noted by its appropriate symbol, and the observation should be entered in the note-book in its proper column in the following manner:—

Ci. from W.

Fr. Cu. from S. W.

This is necessary, since the kind of cloud observed affords a rough indication of the elevation to which the observation relates.

The velocity of the movement of a cloud may be measured, in favourable situations, by observing the time that the shadow takes to traverse a certain space of country, the distance of which is accurately known.

103. **Marie Davy's Nephescope.**—This instrument, which is in use at a few Indian observatories, is of very simple construction. A square or disc of plate-glass, having two lines ruled across it with an engraving diamond, to indicate the four cardinal points, is painted black on the back, and then set, with the painted surface downwards perfectly level, on a pedestal 3 feet 6 inches or 4 feet high, the cross lines being accurately adjusted to the compass points (corrected for the magnetic variation). This forms a perfectly level mirror, in which the reflection of the clouds can be watched without distressing the eye, however brilliantly they may be illuminated. A disc of brass, lead, or other metal, about two inches in diameter, and half an

inch thick, is furnished with a stout wire pointer, about $1\frac{1}{2}$ inches long, projecting vertically upwards from the margin of the disc, and the lower face of the disc, turned flat, is covered with cloth to prevent its scratching the glass when placed on it.

To make an observation: having selected an easily recognizable limb of a cloud, take up such a position, that its reflection in the mirror coincides with the cross or intersection of the cardinal lines. Then place the pointer on the glass in such a position that the point of the wire also appears to coincide with the cross. Leave this arrangement undisturbed for one or two minutes (according to the cloud's rate of movement). Then, returning to the instrument, bring the eye into the same position as at first, *viz.*, with the point of the wire coinciding with the cross. The reflection of the cloud will now be in some other part of the mirror. Mark it with the finger, and its direction from the cross in the centre gives the exact direction in which the cloud has moved in the interval of the two observations.

GENERAL WEATHER OBSERVATIONS.

BEAUFORT'S INITIALS AND VIENNA SYMBOLS.

104. In addition to the readings of the instruments, and such observations on the clouds as were explained in the last section, general observations on the appearance of the atmosphere, and the occurrence of occasional weather phenomena are a very important addition to a meteorological register. These observations should have reference not only to the regular hours at which the instruments are read, *but also to the intervening periods*, and, as far as possible, the time of each occurrence also should be noted in the register.

In no part of a meteorological register is there more scope for the display of intelligence than in the selection of the phenomena to be recorded under this section. Those observers who are deficient in intelligence, or apathetic, are found to make stereotyped entries, generally restricted to the use of one or two symbols, while all others are neglected, and probably forgotten. Others, again, use certain symbols without ascertaining what they denote; and it is only careful and observant persons who, while duly recording those phenomena that are of frequent or almost daily recurrence, are also constantly on the watch for those of a less usual character.

The principal facts to be recorded are—

1st.—The general appearance of the atmosphere and the sky during the interval preceding the observation, including the cloudiness, transparency or haziness of the atmosphere, and such phenomena as coronas or halos round the sun and moon, etc.

2nd.—The occurrence of dew, rain, hail, snow, dust-storms, thunderstorms, lightning, squalls of wind or rain, hot winds, etc.

3rd.—The hour, or at least the approximate time, at which any of these took place.

105. **Beaufort's initials and the Vienna Conference symbols.**— The former of these have long been used by English meteorological observers to denote brief phrases indicating important features of the weather. At a conference of Meteorologists held some years ago at Vienna, it was suggested to retain some of these initials to represent weather conditions and to employ certain additional symbols to denote other conditions, some of which were not represented in the Beaufort notation. The following is a list of all the more important words or phrases denoting either the condition of the weather at the time of observation, or the occurrence of abnormal features during

the interval since the last observation. In addition are given in the second column, the letters which may be employed to denote any of the words or phrases, and in the third column the symbols (chiefly taken from the Vienna Code of Symbols) used to denote these weather remarks. Observers may use either the "initials" or the "symbols," but should adhere to one method, and not on one occasion use "symbols" and on another, "initials" or letters. On the whole, observers are recommended to use letter initials as giving least trouble, and also as suggesting more readily the weather phrases intended.

WEATHER PHRASE	Initial.	Symbol.
Blue sky	*b.*	*b.*
Partial clouds	*c.*	*c.*
Fog	*f.*	≡
Dark gloomy weather	*g.*	*g.*
Misty, dust haze	*m.*	∞
Overcast	*o.*	*o.*
Drizzling rain	*d.*	*d.*
Passing temporary showers	*p.*	*p.*
Snow	*z.*	✻
Soft hail	~~hs~~	△
Continued rain	*r.*	●
Thunder	*t.*	*t.*
Thunderstorm	~~ts~~	K
Lightning	*l.*	<
Lightning reflection	~~lr~~	*lr.*
Hail	*h.*	▲
Dew	*w.*	⌓
Visibility; referring to distant objects . .	*v.*	*v.*
Ugly, threatening	*u.*	*u.*
Strong wind	*a.*	/
Squally	*q.*	*q.*
Dust-whirl or devil	~~dw~~	§

Weather phrase.	Initial.	Symbol.
Dust storm	~~ds~~	
Hot wind	~~hw~~	
Hoar frost	y.	⌴
Slight sea	s.	S.
High sea	$\underline{\text{S.}}$	$\underline{\text{S.}}$
Very high sea	$\underline{\underline{\underline{\text{S.}}}}$	$\underline{\underline{\underline{\text{S.}}}}$
Solar corona	~~sc~~	⊕
Solar halo	~~sh~~	⊙
Lunar corona	~~lc~~	
Lunar halo	~~lh~~	

In order to avoid confusion in all those cases in which two letters have been combined to obtain intials, a line is drawn crosswise through the combined letters in order to indicate that they are to be taken together as one initial and not as two separate initials.

In connection with these symbols or phrases the following should be carefully noted.

106. Blue sky (*b*).—For a *cloudless* sky, whether the atmosphere be clear or hazy.

107. Clouds (*c*).—Either for clouds in detached masses, or in sheets with openings. It is not to be used when the sky is overcast.

108. Fog (*f*).—Except among hills and in the cold weather in the damper parts of India, this symbol will not be much used. It is not to be used for haze, but only for such fogs as form over damp places in the early morning and evening.

109. Hoar frost (*y*).—This is tolerably common in the cold weather, in certain parts of the Upper Provinces. It is simply dew deposited from air at or below the freezing point. It should be noted when it occurs.

110. Soft hail (~~hs~~).—Small, soft, rounded, opaque, white pellets consisting of frozen snow. Known on the hills only.

111. Lightning (*l*).—Not to be used for the flashes that are sometimes seen to illumine the sky low down near the horizon. These, if noticed at all, may be entered as (~~lr~~) (lightning reflection).

112. Misty (*m*).—To be used for the dust haze so common throughout the dry season in the interior of India.

113. Overcast (*o*).—To be used when the sky is completely covered with *nimbus*.

114. Passing showers (*p*).—This is not to be used for north-westers and similar storms, but for the case when showers, lasting for a short time, succeed each other, with intervals of finer weather.

115. Squally (*q*).—This initial may be used for a short burst of a violent wind, such as, for example, occurs in north-westers. Squalls are of frequent occurrence during cyclonic storms, and are then usually accompanied with more or less heavy rain. The initial or symbol for a thunder-storm may be used for a nor'wester, when, as is usually the case in Bengal, it ends in a severe thunderstorm.

116. Visibility (*v*).—This symbol is very frequently misused. It has reference to the *transparency* of the atmosphere, and indicates that the details of distant objects can be seen with *unusual distinctness*. On the plains of India such a state is rarely experienced, except either immédiately before, or immediately after, rain.

117. Coronas and halos.—These must be carefully distinguished. *Coronas* are very common, especially around the moon and are produced by the rays passing through a thin layer of cloud. They are small circles around the luminary, as many as three concentric circles being sometimes seen at the same time. They are frequently coloured, red being the outside colour.

Halos are large circles of about 46° and 92° in diameter, *i.e.*, the diameter of the circle is equal to either one-eighth or one-fourth the circumference of the horizon, or subtends either one-fourth or one-half the arc of the celestial vault. They are very rare phenomena, especially in India, but are occasionally seen in the Himalayan hill districts. Solar halos are frequently accompanied by mock suns or *parhelia*.

Coronas and halos are of interest, rather as optical phenomena, than as affording important indications of changes in the state of the atmosphere. In this latter connection, the chief information afforded by them is the nature and consistency of the cloud on which they are projected; coronas being formed on water drops, halos only on snow crystals. Other optical phenomena of interest, as such, are rainbows, fogbows or anthelia, mirage, etc., and the beautiful opal fringes of clouds (that is clouds the edges of which show colours like those seen in a rainbow), which may be witnessed not infrequently towards the evening, more especially in Bengal, in the hot weather and rains. All such phenomena are well worthy of observation and study; but, for information respecting them, the reader is referred to treatises of a less elementary and restricted character than the present.

HOURS OF ORDINARY OR REGULAR OBSERVATION.

118. **Regulating conditions.**—Instruments, such as the barograph, thermograph, anemograph, etc., which are in use at the Alipore and other first class observatories in India and register automatically and continuously the readings of the instruments, afford, of course, the most perfect record that can be desired of the march of the several atmospheric phenomena; but even these require to be controlled by eye observations, since the best machinery has or may have, inherent faults, which require to be ascertained and their effects eliminated; and, moreover, it is not always practicable to give the instruments the same kind of exposure which is practised in the case of smaller instruments. Next to self-registering instruments, hourly observations are the most effective; but they can be carried out continuously only where a large establishment of observers is available. But in most cases the question is,—what is the smallest number of observations that will serve a useful purpose, and at what hours should they be recorded. Moreover, it is of great importance to preserve uniformity, and it is, therefore, desirable that the same hours be observed at all stations. Meteorological observations are recorded in India primarily for two important objects. The first object is to obtain sufficient data to give the average or *mean* value of the various elements of observation, in order to use these as standards to compare the actual weather and meteorological conditions at any time with what may be termed the *mean* or *normal* conditions of the time and place. The second object is to collect daily by the most rapid means of communication (*viz.*, the telegraph) meteorological observations and publish them for general information and utilize them in issuing warnings of approaching storms, floods, etc., to the districts likely to be injuriously affected.

For the first object, *viz.*, that of collecting data for the determination of the mean values of the elements of meteorological observation or the normal meteorological conditions in any part of India, it is evident that the hours should be such as will show, as nearly as possible, the average range of the principal elements, and also afford the means of computing their mean values.

119. **The adopted hours for observations to determine normal meteorological conditions.**—These conditions are best fulfilled by adopting the hours of 10 and 16 (10 A.M. and 4 P.M.) *mean local time* (*not railway time*) for reading the instruments. These hours are, on an average, nearest to the epochs of the maximum and minimum barometric pressure of the day, and this is the chief reason

for selecting them. The mean of the two gives a close approximation to the mean pressure of the day, while their difference is the approximate range. The temperatures are both above the mean temperature of the day; but by using self-registering maximum and minimum thermometers, the 10h and 16h temperatures afford data which, together with the former, allow of a near approximation to the mean temperature of the day; more especially when certain corrections are applied. A similar remark applies, with less accuracy, to the hygrometric elements, if a minimum wet bulb thermometer be also used. The observations proper to be recorded at each of these hours are—

At 10h.	At 16h.
Barometer.	Barometer.
Dry and wet bulb thermometers.	Dry and wet bulb thermometers.
Minimum dry and wet bulbs.*	Minimum dry and wet bulbs.
Maximum thermometer.*	Maximum thermometer.
Anemometer.	Anemometer.
Wind direction.	Wind direction.
Rain measurement.	Rain measurement.
Cloud proportion, kind and movement.	Cloud proportion, kind and movement.
General weather.	General weather.

General weather observations will, if the observer is interested in his work, also be made in the intervals. Thus, the occurrence of dew or fog or hoar-frost should be noted in the early morning; rain or a thunderstorm or duststorm, at the hour at which it occurs. Meteorological observation can never be regarded as a mere mechanical performance. It requires alert intelligence, like most other work.

120. **The adopted hour for observation to be utilized in weather telegrams.**—It is evident that either of the hours, 10 A.M. or 4 P.M., would be unsuitable for the despatch of weather telegrams as they would be sent off at the time when the telegraph lines are most largely occupied by ordinary business and commercial messages. They would hence arrive so late in the day that their reduction and publication would usually have to be postponed until the following day. It is hence desirable that these telegrams should be sent off as early in the day as possible before public business commences, without, however, requiring the attendance of observers at an unusually early hour. 8 A.M. was selected as the hour most suitable for the work and as least inconvenient to observers, and hence at all observing

* Where 8 A.M. observations of these instruments are recorded, they are not read again at 10 A.M.

stations at which there are telegraph offices, observations are taken at 8 A.M., and as soon after as possible, daily weather telegrams embodying these observations, are despatched to the Simla Meteorological Office and in the case of some of the stations, copies of these telegrams are sent to the Calcutta, Bombay or Madras Meteorological Offices. A large number of observatories take observations only at this hour and are termed third class observatories. A certain number of observatories record observations also at 10 and 16 hours for the objects stated in the preceding section, and these observatories which record observations at 8 hours, 10 hours and 16 hours are designated second class observatories.

The observations recorded at 8 hours by all observatories, whether second or third class, are those of the—

Barometer.	Minimum wet thermometer.
Attached thermometer.	Anemometer.
Dry bulb "	Wind vane.
Wet bulb "	Rain-gauge.
Maximum "	Cloud.
Minimum dry thermometer.	General weather.

121. Importance of punctuality.—It cannot be too strongly impressed on *observers* that they *must be strictly punctual to the hours assigned.* The clock or watch that regulates the observations must be kept at the true *local* time, and the observer should make it his business to be ready 5 minutes before the time of observations, so that there may be no delay and irregularity. The whole process of taking the observations requires about 5 minutes, so that it is best to begin 2 minutes before the hour, and to read the instruments always in the same order. It depends on the Superintendents of observatories to enforce regularity, seeing that laxity and unpunctuality are besetting sins, to which observers in India are unfortunately especially liable. If an observer be unavoidably absent at the proper hour, it is better to omit the observations than to record them, perhaps, a quarter of an hour or 20 minutes after the proper time. A hiatus, however objectionable, is better than a deceptive entry.

122. Caution in respect of "Railway time."—The practice of keeping railway time, which is also the time kept at all telegraph stations in India (*i.e.*, the time of the Madras observatory), instead of true local time, is now so general at stations in India, that the Superintendents and Observers at several observatories have recently been found to ignore the distinction in practice, notwithstanding the repeated warnings given them on this head. It is hence necessary to impress on Superintendents and Observers, that, *however* *convenient it may be to some persons to observe a time which is locally false, it is not permissible to meteorological observers.* It is their business to ascertain the true local time, and to keep their clocks or watches regulated thereto.

Since the difference between railway or telegraph and local time is constant at any given place, it is easy, whenever the former is known, to regulate the clock or watch to the latter. Local time differs from Madras time by 4 minutes for each degree of longitude difference between Madras and the place in question; the local clock being in advance, if the place is east of Madras, and behind, if to the west of Madras.

The following table gives the Madras or Railway time corresponding to 8 A.M., local time at all stations, at which there are meteorological observatories under or working in connection with the India Meteorological Department.

STATION.	Madras, Telegraph or Railway time corresponding to 8 h. local time.
A	
Aden	10 h. 21 m.
Agra	8 „ 9 „
Ahmedabad	8 „ 31 „
Ahmednagar	8 „ 22 „
Ajmer	8 „ 22 „
Akola	8 „ 13 „
Akyab	7 „ 10 „
Allahabad	7 „ 53 „
Amini Devi	8 „ 30 „
Amraoti	8 „ 10 „
Arrah	7 „ 42 „
Astor	8 „ 21 „
Aurangabad	8 „ 19 „
B	
Baghdad	10 h. 23 m.
Bahraich	7 „ 54 „
Bahrein	9 h. 59 m.
Balasore	7 „ 33 „
Bangalore	8 „ 10 „
Bankura	7 „ 32 „
Bareilly	8 „ 3 „
Barisal	7 „ 19 „
Bassein	7 „ 2 „
Belgaum	8 „ 22 „
Bellary	8 „ 13 „
Benares	7 „ 49 „
Berhampore	7 „ 28 „
Bhagalpur	7 „ 33 „
Bhamo	6 „ 53 „
Bharatpur	8 „ 11 „
Bhavnagar Para	8 „ 32 „
Bhuj	8 „ 42 „

STATION.	Madras, Telegraph or Railway time corresponding to 8 h. local time.	STATION.	Madras, Telegraph or Railway time corresponding to 8 h. local time.
Bidar	8 h. 10 m.	Cochin	8 h. 16 m.
Bijapur . . .	8 „ 18 „	Cocos Island . . .	7 „ 8 „
Bikaner . . .	8 „ 28 „	Coimbatore . . .	8 „ 13 „
Bogra	7 „ 23 „	Comilla . . .	7 „ 17 „
Bombay . . .	8 „ 30 „	Cooch Behar . .	7 „ 23 „
Buldana . . .	8 „ 16 „	Cuddalore . . .	8 „ 2 „
Burdwan . . .	7 „ 29 „	Cuddapah . . .	8 „ 6 „
Bushire . . .	9 „ 58 „	Cuttack . . .	7 „ 37 „
Bussrah . . .	10 „ 9 „	**D**	
Buxar	7 „ 46 „	Daltonganj . . .	7 h. 45 m.
C		Darbhanga . . .	7 „ 37 „
Calcutta (Alipore) . .	7 h. 28 m.	Darjeeling . . .	7 „ 28 „
Calicut . . .	8 „ 18 „	Deesa	8 „ 32 „
Car Nicobar . . .	7 „ 10 „	Dehra Dun . . .	8 „ 8 „
Cawnpore . . .	7 „ 59 „	Dehri	7 „ 44 „
Chaibassa . . .	7 „ 38 „	Delhi	8 „ 12 „
Chakrata . . .	8 „ 9 „	Dera Ismail Khan . .	8 „ 37 „
Chaman . . .	8 „ 55 „	Dhubri	7 „ 22 „
Chanda . . .	8 „ 4 „	Diamond Island . .	7 „ 4 „
Chapra . . .	7 „ 42 „	Dibrugarh . . .	7 „ 1 „
Cherat	8 „ 33 „	Dinajpur . . .	7 „ 26 „
Cherra Poonjee . .	7 „ 14 „	Dodabetta . . .	8 „ 14 „
Chikalda . . .	8 „ 11 „	Dras	8 „ 18 „
Chitaldroog . . .	8 „ 16 „	Dunga (Zanzibar) . .	10 „ 43 „
Chitral	8 „ 33 „	Dwarka . . .	8 „ 45 „
Chittagong . . .	7 „ 14 „	**F**	
Cocanada . . .	7 „ 52 „	False Point . . .	7 h. 34 m.
		Faridpur . . .	7 „ 21 „

STATION.	Madras, Telegraph or Railway time corresponding to 8 h. local time.
G	
Gangtok . . .	7 h. 26 m.
Gauhat . . .	7 „ 14 „
Gaya	7 „ 41 „
Gilgit	8 „ 24 „
Goa	8 „ 25 „
Gopalpur . . .	7 „ 41 „
Gorakhpur . . .	7 „ 48 „
Gulbarga . . .	8 „ 13 „
Gulmarg . . .	8 „ 23 „
H	
Hanumkonda . .	8 h. 3 m.
Hassan . . .	8 „ 16 „
Hazaribagh . . .	7 „ 39 „
Hoshangabad . .	8 „ 10 „
Hyderabad (Deccan) .	8 „ 7 „
Hyderabad (Sind) .	8 „ 47 „
I	
Indore . . .	8 h. 17 m.
Indur	8 „ 8 „
Ispahan . . .	9 „ 54 „
J	
Jacobabad . . .	8 h. 48 m.
Jaipur	8 „ 18 „
Jalpaiguri . . .	7 „ 26 „
Jamnagar . . .	8 h. 41 m.
Jask	9 „ 29 „
Jessore	7 „ 24 „
Jhansi	8 „ 6 „
Jodhpur . . .	8 „ 29 „
Jubbulpore . . .	8 „ 1 „
K	
Kabul	8 h. 44 m.
Kailang . . .	8 „ 13 „
Kalat	8 „ 54 „
Karwar . . .	8 „ 24 „
Kashgar . . .	8 „ 16 „
Katmandu . . .	7 „ 40 „
Khandwa . . .	8 „ 15 „
Khushab . . .	8 „ 32 „
Killa Drosh . . .	8 „ 33 „
Kindat . . .	7 „ 2 „
Kodaikanal . . .	8 „ 12 „
Kotah	8 „ 17 „
Krishnagar . . .	7 „ 26 „
Kurnool . . .	8 „ 9 „
Kurrachee . . .	8 „ 53 „
L	
Lahore . . .	8 h. 24 m.
Lashio	6 „ 50 „
Leh	8 „ 10 „

Station.	Madras, Telegraph or Railway time corresponding to 8h. local time.	Station.	Madras, Telegraph or Railway time corresponding to 8h. local time.
Lucknow	7 h. 57 m.	Mount Abu	8 h. 30 m.
Ludhiana	8 „ 17 „	Muktesar	8 „ 2 „
Lungleh	7 „ 10 „	Murree	8 „ 27 „
		Muscat	9 „ 27 „
M		Mussooree	8 „ 8 „
Madras	8 h. 0 m.	Muzaffarpur	7 „ 39 „
Madura	8 „ 8 „	Mymensingh	7 „ 19 „
Mainpuri	8 „ 5 „	Mysore	8 „ 14 „
Malda	7 „ 28 „		
Malegaon	8 „ 23 „	N	
Mandalay	6 „ 56 „	Nagpur	8 h. 4 m.
Mangalore	8 „ 21 „	Nagpur (Sany. Commr.'s Office).	8 „ 4 „
Masulipatam	7 „ 56 „	Narayanganj	7 „ 19 „
Maymyo	6 „ 55 „	Naya Dumka	7 „ 32 „
Meerut	8 „ 10 „	Neemuch	8 „ 21 „
Mercara	8 „ 18 „	Negapatam	8 „ 1 „
Mergui	6 „ 46 „	Nellore	8 „ 1 „
Meshed	9 „ 26 „	Noakhali	7 „ 17 „
Midnapore	7 „ 31 „	Nowgong	8 „ 3 „
Minbu	7 „ 1 „	O	
Minicoy	8 „ 29 „	Ootacamund	8 h. 14 m.
Minimarg	8 „ 18 „		
Montgomery	8 „ 28 „	P	
Mooltan	8 „ 35 „	Pachmarhi	8 h. 7 m.
Mormugao	8 „ 26 „	Pachpadra	8 „ 32 „
Motihari	7 „ 41 „	Pamban	8 „ 4 „
Moulmein	6 „ 50 „	Para Chinar	8 „ 40 „

CALIFORNIA

Station.	Madras, Telegraph or Railway time corresponding to 8h. local time.
Patiala	8 h. 15 m.
Patna	7 „ 40 „
Perim	10 „ 27 „
Periyakulam	8 „ 10 „
Peshawar	8 „ 34 „
Pishin	8 „ 53 „
Poo	8 „ 11 „
Poona	8 „ 24 „
Port Blair	7 „ 10 „
Port Victoria (Seychelles)	9 „ 40 „
Puri	7 „ 37 „
Purnea	7 „ 31 „
Purulia	7 „ 35 „
Q	
Quetta	8 h. 53 m.
R	
Raichur	8 h. 11 m.
Raipur	7 „ 54 „
Rajkot	8 „ 37 „
Rampur Boalia	7 „ 26 „
Ranchi	7 „ 39 „
Rangoon	6 „ 56 „
Rangpur	7 „ 24 „
Raniganj	7 „ 29 „
Ranikhet	8 „ 3 „
Ratnagiri	8 „ 27 „

Station.	Madras, Telegraph or Railway time corresponding to 8h. local time.
Rawalpindi	8h. 29 m.
Roorkee	8 „ 9 „
S	
Salem	8 h. 8 m.
Sambalpur	7 „ 45 „
Sambhar	8 „ 20 „
Saugor	8 „ 6 „
Saugor Island	7 „ 29 „
Secunderabad	8 „ 7 „
Seistan	9 „ 18 „
Seoni	8 „ 3 „
Shillong	7 „ 13 „
Sholapur	8 „ 17 „
Sialkot	8 „ 23 „
Sibsagar	7 „ 2 „
Silchar	7 „ 10 „
Simla	8 „ 12 „
Sirajganj	7 „ 21 „
Sirsa	8 „ 21 „
Skardu	8 „ 18 „
Sonemarg	8 „ 19 „
Srinagar	8 „ 22 „
Surat	8 „ 30 „
Sutna	7 „ 57 „
T	
Taunggyi	6 h. 53 m.
Tavoy	6 „ 48 „

AMSCHULAC

Station.	Madras, Telegraph or Railway time corresponding to 8h. local time.	Station.	Madras, Telegraph or Railway time corresponding to 8h. local time.
Teheran . . .	9 h. 55 m.	**V**	
Tezpur . . .	7 „ 10 „	Vellore . . .	8 h. 4 m.
Thayetmyo . . .	7 „ 0 „	Veraval . . .	8 „ 39 „
Tinnevelly . . .	8 „ 10 „	**W**	
Toungoo . . .	6 „ 55 „	Waltair . . .	7 h. 47 m.
Trichinopoly . .	8 „ 6 „	Wellington . . .	8 „ 14 „
Trivandrum . . .	8 „ 13 „	**Y**	
Tura	7 „ 20 „	Yamethin . . .	6 h. 56 m.
		Yatung . . .	7 „ 27 „
U		**Z**	
Udaipur . . .	8 h. 26 m.	Zanzibar . . .	10 h. 44 m.
Umballa . . .	8 „ 13 „		

SPECIAL OBSERVATIONS.

123. **Special observations.**—These are of various kinds. The most important are observations of storms. Storms form one of the most important features of the weather of any country. Their observation and study are hence among the more important duties of all meteorological departments and observers.

Storm observations are of two kinds in India.

The first includes observations taken at certain selected stations (chiefly on the coasts of the Bay of Bengal and Arabian Sea) during the formation and approach of cyclonic storms to some part of the coast of India. These observations are telegraphed in accordance with special arrangements to the Calcutta or Simla Meteorological Offices, and are utilised to follow out the course of these storms and to give early, definite and effective warning to the coast districts likely to be affected by them. This work forms a part of the recognized duties of the observers at the selected stations, and for which they receive an increased meteorological allowance.

The second class includes all storm observations recorded voluntarily by observers, and not as a recognized part of their meteorological duties for which they receive monthly pay. Some observers have other duties which prevent them taking observations at any except the regular hour or hours. Others do not take sufficient interest in their work to do more than is absolutely required. The accurate observation of storms, it may also be noted, requires far more judgment and intelligence than the regular or routine observations at 8 A.M., 10 A.M., and 4 P.M. Storm observations were for many years regarded as a part of the ordinary duties of observers. Thus Mr. Blanford in the Vade Mecum laid down, "During storms, the barometer is always greatly affected, and should be read, if possible, every 5 or 10 minutes (together with the attached thermometer). The direction of the wind and the movements of the clouds should be observed also at short intervals; and with the thermometer, hygrometer, and, if possible, the anemometer, recorded half-hourly or hourly. When accompanied by very heavy rain, it is desirable to empty the rain-gauge and to record its readings two or three times during the day." These instructions were with very few exceptions systematically neglected, and no progress was hence made in the study of such meteorological phenomena as the occurrence of thunderstorms, hailstorms, nor'westers, etc., in India. It was therefore decided to consider storm observations as no longer forming part of the regular duties of all observers, but to grant special awards for all observations of storms voluntarily taken by observers from a fund for "storm and special observations" sanctioned for this purpose. The amounts of the awards granted are decided in part by the importance of the storms, and in prat by the value of the observations as full and accurate records of the chief features of the storms. Large numbers of "voluntary storm observations" are now recorded, many of which are of much interest and value, and throw additional light on the more important phenomena of thunder-storms, hailstorms, etc., in India.

The rules for these two classes of observations have been fully explained by means of circulars to the observers concerned. The following give these instructions in a slightly modified form.

124. **Regular storm observations.**—The object of these special observations is to supply the necessary information during threatening or stormy weather to the Meteorological Reporter to the Government of India and Director General of Indian Observatories, Simla (Weather India, Simla) or the Meteorological Reporter to the Government of Bengal, Calcutta (Weather Bengal, Calcutta) in order to enable these officers to warn the ports likely to be affected by approaching storms, and to hoist the storm signals, whenever considered necessary, for the information of the port and shipping at certain selected seaports.

These observations are of great importance, and it is absolutely necessary that they should not only be accurately taken and telegraphed, but that they should be forwarded with the greatest possible quickness. The observers at the meteorological stations from which these special observations are required are supplied with storm observation note-books for the actual record of these observations at the time of observation, and a special telegraphic code for their conversion into storm weather telegrams for transmission to the Reporter who calls for them. A special code has been drawn up for these observations, as it was found that the ordinary code is not adapted for these special observations.

The following are the chief rules for guidance in recording and transmitting these observations:—

1st.—Whenever these observations and storm telegrams are required at any station, the observer will be instructed by urgent telegram by either Weather India or Weather Bengal to take these observations, and will be at the same time informed at what hours he should take the observations, and will also be instructed by telegram when to discontinue them.

2nd.—Whenever an observer is instructed by Weather India or Weather Bengal to send special observations at regular intervals (usually six-hourly or four-hourly), he should proceed to do so, commencing, if possible, at the hour named in the telegram, or in the storm telegraphic code where instructions are given as to the hours at which six hourly or four-hourly, etc., observations are to be made and telegraphed. If it is not possible to make an observation precisely at the hour named, take it immediately on receipt of the telegram of instructions, and the next observation at the hour indicated in the special code of instructions.

3rd.—At each hour of observation the observer should record the following readings, and convert the observations into a storm telegram by means of the special code :—

1.—Barometer and attached thermometer.
2.—Wet and dry bulb thermometers.
3.—Amount of rain since last telegraphed observation (either the ordinary 8 A.M. or the last telegraphed special storm observation).
4.—Wind direction, and amount of wind registered by the anemometer since the last telegraphed observation (*viz.*, the ordinary 8 A.M. or the preceding special observation, as the case may be).
5.—Cloud amount.
6.—General weather.

4th.—These telegrams should be carefully prepared in exact accordance with the instructions in the special code, and forwarded as speedily as possible after the observation.

5th.—These telegrams should invariably be sent "*urgent, service bearing*" unless the observer has been authorised to use the concession referred to in the next paragraph, and has been specially requested by the Reporter to whom he communicates these observations to send them "*precedence urgent, service bearing.*"

6th.—By special sanction of the Director General of Telegraphs the observers at the following stations :—

Kurrachee,	Karwar,
Bombay,	Cochin,
Ratnagiri,	Calicut,
Goa,	Mangalore,

are permitted to send "PRECEDENCE URGENT MESSAGES" when called upon by "Weather India" and the observers at the following stations :—

Akyab,	Chittagong,
Balasore,	Cocanada,
Bassein,	Cuddalore,
Barisal,	Diamond Island,

False Point,	Nellore,
Gopalpur,	Puri,
Madras,	Rangoon,
Masulipatam,	Saugor Island,
Moulmein,	Tavoy,
Negapatam,	Waltair (Vizagapatam),

when called upon by "Weather Bengal."

If observers at any other stations are added to this list, they will be specially informed of the fact.

7th.—When an observer is instructed to forward his storm telegrams by "Precedence urgency," he should mark his telegram as of class XXS and commence in each case the body of the telegram with the words "Storm signal." Strict orders have been given by the Director General of Telegraphs that all telegrams commencing with the words "Storm signal" sent by the observers at the stations named above are to be forwarded with the greatest expedition and to take *precedence of urgent* telegrams.

8th.—It is also very desirable that during cyclonic storms observers should, in addition to the observations called for by "Weather India" or "Weather Bengal," take additional observations at frequent intervals, more especially if the cyclonic storm is of great intensity and the centre likely to pass near or over the observatory, so as to obtain a complete record of all the more important features of the storm. These additional observations beyond those called for by telegram from "Weather India" or "Weather Bengal" will be treated as "voluntary storm observations," for which the observer will be awarded amounts in accordance with the rules for "voluntary storm observations."

9th.—If the weather at any time appears, in the opinion of the observer, to be threatening and indicative of the approach of a storm, it would be advisable for him, even if not called upon to furnish storm observations, to report the character of the weather to the Reporter by urgent telegram and ask for instructions.

10th.—It must be remembered that when extra storm telegrams are being sent, there will be no necessity for any storm telegram to be sent at 8 A.M. At this hour the telegram should be despatched according to the ordinary telegraphic code, and this telegram should give as usual the observations for the complete period from 8 A.M. of the previous day to 8 A.M. of the day of despatch. Hence it will give the total rainfall for the 24 hours, the total amount of wind for the 24 hours, etc., with the 8 A.M. readings of the wind direction, barometer, etc.

125. Voluntary storm observations.—The duty of recording observations during storms was, in past years, nominally recognised as a part of the work of observers, but no special arrangements were made for their record, nor was any penalty imposed on observers for neglect of this work. Hence, as the work of observation during stormy weather was unpleasant and onerous, and did not form part of the recognized essential work of observation for which definite pay was attached, it was in the great majority of cases, systematically neglected. The Government hence decided to separate this work from the ordinary work of observation, and to make its performance optional on the part of observers. It also sanctioned an annual grant, nearly equivalent in amount to the total special allowances previously allotted to observers, to be devoted to payment for these extra voluntary storm observations. As this work will necessarily not only vary in amount in the case of different observers, but will depend in value largely upon their zeal, judgment and intelligence, the amount of the payments will accordingly depend upon the value of the observations submitted, and will be awarded in the month of January or February of each year for the storm observations sent in by each observer during the preceding year. So far as can be at present stated, the amount granted to any one observer from this fund will not, except in the case of observations of extraordinary value and merit, exceed Rs. 60.

The chief classes of storms of which observations are required are as follows:—

1st.—Cyclonic storms of the rains and transition periods, which usually form in the Bay of Bengal or Arabian Sea, but occasionally over the land. Those of the transition periods (*i.e.*, May and the first half of June, and the second half of September, and October and November), are occasionally of excessive violence, but the storms of the rains are rarely accompanied by violent and destructive winds, although they frequently give excessive rain and cause high floods. In the case of these storms there are many features regarding which the information is as yet very scanty; as, for example, the rate at which rain falls during the progress of the storm, the character and motion of the lower and upper clouds, the changes in the direction and force of the winds during the storm, the manner in which the sky clouds over as the storm approaches, and the way in which it clears off as the storm passes away, and more especially the conditions in the calm centre (*e.g.*, temperature, humidity, amount and kind of cloud).

2nd.—Cyclonic storms of the cold-weather months (*i.e.*, December, January and February and sometimes March) in Northern India, during which the largest proportion of the cold-weather rains in the plains and the snowfall in the Western Himalayan mountain districts occurs. Even less is known of the more important features of these storms, than of the previous class of storms, except that they appear to extend to a much higher elevation, and frequently give strong winds to the hill stations, whilst they merely influence the air motion to a very slight (and frequently irregular) extent near the earth's surface. Although the indications of the approach of these storms are less marked than those of the preceding class, an observer may be tolerably certain that if the sky clouds over in the cold-weather months, and threatens rain in any part of Northern India (*i.e.*, Sind, Punjab, Rajputana, Central India, Central Provinces, United Provinces of Agra and Oudh, Bengal and Assam), a cold-weather storm is passing over the district in which his observatory is situated. A considerable proportion of these storms are of slight importance. Accurate observations are greatly desired of those which give moderate to heavy rain in any part of Northern India. Observations of changes in the form of the clouds, and of the character and direction of movement of the lower and the upper clouds (so far as they are visible), are even more important than in the previous case. Also, frequent observations of the barometer and wet and dry bulb thermometers to show the changes of pressure and humidity, and of changes of wind during the advance of the storm, are necessary for progress in our knowledge of these storms.

3rd.—Hot-weather storms accompanied with rain or hail, such as occur chiefly in the neighbourhood of the hills or the sea-coasts in India, more especially in the hot-weather months of March, April and May. In this class are included severe thunder and hail storms, nor'westers, tornadoes, etc. Observations giving the changes of pressure, temperature humidity and wind (which are usually very rapid), as well as accurate cloud observations, are greatly required; but in this case, as these storms generally extend over very limited areas, it would be a valuable addition if observers could ascertain, from local enquiry, roughly the area over which the storm for which they contribute observations extended. This information will probably be somewhat difficult to collect, and may require a little time, but it would be of very great value in certain cases; as for example, hail-storms in the United Provinces of Agra and Oudh and Assam, and nor'westers in Bengal. In the latter case especially, such information would probably help to throw much light on their character.

4th.—Hot-weather storms not generally accompanied with rain, and occurring chiefly as dust-storms in Upper and Central India in the months of March, April, May and June. These are occasionally very violent, and although unattended with rain, frequently give rise to much thunder and lightning. It would be very desirable, in addition to the observations of pressure, temperature, wind, cloud, etc., during the storm, to give special attention to the electrical discharges, *i.e.*, thunder and lightning, and also to the reduction of temperature which usually follows the storm.

The above remarks show briefly the kind of observations that are required, and also in dicae that observers in every part of India may assist in the work of recording storm observations and contribute useful and valuable information.

Observers should, however, carefully remember that accurate and minute observations of one or two storms are of far greater value, for the object in view, than a few hurried, and perhaps careless observations of every storm, large or small, which passes over an observatory. The Government does not wish the Department to collect additional observations without any reference to their value or utility. It desires accurate records of storms as they occur, in order that the information, thus obtained, may be utilized in ascertaining the causes and laws of their occurrence. Hence it will be seen that intelligent as well as accurate observations are what is desired.

Observers will be supplied with proper forms and note-books for recording these observations and communicating them to the Imperial Meteorological Office, Alipore (Calcutta) on application to that office.

The following brief hints and instructions for the guidance of observers in this work are given below:—

1st.—Do not commence to take storm observations when you have reason to believe that a storm is approaching, unless you are prepared to take frequent and accurate observations as long as the storm is likely to last, and to observe attentively the changes of sky and weather.

2nd.—It is not necessary to record the observations at regular intervals, or even to take a complete set of observations on each occasion of observation. In the case of the first and second class of storms, which usually last several hours and sometimes more than a day or two, it might not be necessary to take observations at shorter intervals than one or two hours; but as the third and fourth classes of storms rarely last for more than one or two hours, it would be desirable in their case to take observations at intervals of a few minutes. In these storms if you find it impossible to reach the thermometer shed, you should at least read the barometer at intervals of five or ten minutes, and take as many observations of the direction of the wind and cloud motion as you possibly can.

3rd.—The object of the observations should be to observe and record, so far as is practicable, *every important change of weather during the storm*, and to note the time of its occurrence so that the meteorological record may give a true and exact account of the progress and characteristic features of the storm.

4th.—Pay special attention to the form of the clouds and the direction of their motion, and observe, whenever possible, the form and movement of the higher, as well as of the lower, clouds.

5th.—Carefully record every unusual appearance and the time of its occurrence, even if it does not form part of a complete series of observations.

6th.—Be careful to record the accurate *local* time in making your observations; if you use telegraph or railway time, you should distinctly state in the storm report form what time you use in noting the observations.

7th.—Also remember that every observation carefully and accurately made should be recorded, as it is possible that an observation which the observer thinks of little value, may prove of very great importance in the work of investigation.

8th.—If the space in the forms allotted to weather remarks is not sufficient for all the notes made by you and entered in the note-book, you should send the whole of these remarks on a separate sheet of paper with the observations.

9th.—Whenever a very severe storm passes over your district and observatory, you should, whether you record special observations or not, forward an additional deferred telegram next day to " Weather India, Simla," stating briefly the time, duration and character of the storm. The Bengal observatories should at the same time forward by deferred telegram a copy of these storm telegrams to " Weather Bengal, Calcutta." The telegrams should be very brief, as a rule, not more than twelve or fifteen words. The following are examples :—

(*a*) " Violent hailstorm last night from north-east, 8 P.M., lasted 8 minutes."

(*b*) " Tornado yesterday evening 6 P.M. Occurred during nor'-wester and caused great destruction of property. Many lives lost."

(*c*) " Cyclone passed over station yesterday. Gave violent winds and heavy rain. Damage to property slight."

126. **Occasional special observations.**—Special observations are sometimes desired from one or more stations for various purposes. A recent example was cloud observations between the hours of 11 A.M. and 1 P.M. during the last twelve days of January 1894 at six stations, which were desired by a committee of astronomers in England in order to ascertain the probable amount of cloud likely to prevail in the path of greatest darkness or totality during the total solar eclipse of January 1898. Special instructions are given in such cases, and observers should, in recording such observations, endeavour to carry out the instructions as intelligently and carefully as possible, and record the observations with the greatest possible accuracy.

REGISTERS AND FORMS.

127. **Supply of Registers, etc.**—Observers are supplied with note-books for entering the observations at the time of taking them, and with register forms for communicating their observations by post to the Meteorological Office that deals with them. A sufficient supply (sufficient for a year's requirements) of all the forms that are likely to be required is sent out in the month of December to every observer.

The following is the usual supply to observers at third class observatories:—

1.—A note-book for recording the observations recorded at 8 A.M.

2.—Twelve monthly forms or registers (marked E) into which the 8 A.M. observations of each month are copied from the observation book and sent to the Simla or Calcutta Meteorological Office, where they are utilized and bound up into volumes for future reference.

3.—Telegraph form books.

4.—Note-book and forms for recording storm observations.

5.—A book for the preparation of daily weather telegrams and the translation of the observations into the proper code words.

6.—Forms for recording observations to test whether the maximum and minimum thermometers are acting properly as self-registering thermometers.

The following gives a list of the registers and forms supplied annually in December to second class observatories:—

1.—A note-book for recording the observations recorded at 8 hours, 10 hours and 16 hours.

2.—Twelve monthly forms or registers (marked E) into which the 8 A.M. observations of each month are copied, and are sent to the Simla Meteorological Office or the Imperial Meteorological Office, Alipore (Calcutta), where they are utilized and bound up into volumes for future reference.

3.—Twelve monthly forms or registers (marked F) into which the 10 hours and 16 hours observations of each month are copied and are sent to the Imperial Meteorological Office, where they are utilized and bound up into volumes for future reference.

4.—Telegraph form books.

5.—A book for the preparation of daily weather telegrams and the translation of the 8 A.M. observations into the corresponding code words.

6.—Note-book and forms for recording observations during storms.

128. **Observer's Note-book.**—This contains the original entries of the observations, and should hence be carefully preserved by the observer, as in case of any doubt respecting the accuracy of any observation as telegraphed or communicated in Form E or F, the observer can verify it only by reference to his note-book. All entries should, hence be carefully and legibly made. Observers should also note to carry out the following instructions in making the entries :—

(1) In line "Lower clouds—kind" enter cloud initials thus : Cu., Ci., Ci. Cu.

(2) In line "Lower clouds—direction of motion" give kind of clouds and directions thus : Cu. from SW.

(3) In line "Clouds at great height (cirrus, etc.), if visible, direction of motion" give kind of clouds and directions, thus : Ci. S. from W.

(4) The observer who actually takes the observations should record them at the time in the note-book, and should give his initials legibly at the foot of the page in Form E.

129. **Despatch of Registers.**—Registers E and F for any month should be filled in daily during the month, and should be despatched as early as possible in the first week of the succeeding month. If not sent off until after the 7th the observer should send an explanation of the delay.

Storm observations should also be despatched shortly after they are recorded, so that the information may be utilized in the Monthly Weather Reviews, which are now prepared and published shortly after the expiration of each month.

130. **Neatness.**—It is importan tthat observers should make the entries in the Register Books E and F carefully and neatly, and that they should compare the entries in these books, before they are sent off, with the original observations in order to be quite sure that they are correct and do not contain any clerical error. Some observers perform this part of their work in a very careless and slovenly manner, and it is sometimes hardly possible to decipher the figures. Careless, slovenly entries are, it is evident, liable to be read wrongly, and hence are a source of error, as much as incorrect observations. Observers should remember that the registers as received from them are bound up into volumes and form part of the permanent records of the Department, and it is hence desirable from this point of view that they should be written clearly and with good ink.

RULES FOR OBSERVERS AT GOVERNMENT OBSERVATORIES IN INDIA.

Rules.—The following paragraphs give in a brief form all the more important rules which observers should bear carefully in mind in order that they may carry out the work of observation properly and accurately.

I.—General.

1. *Punctuality.*—Take observations at the appointed hours according TO LOCAL MEAN TIME, AND NOT RAILWAY OR TELEGRAPH TIME. Keep your clock or watch accurately regulated, and begin to take the observations two minutes before the hour. Be punctual and accurate.

If an observer be more than ten minutes behind the appointed tim in commencing to take any one of the regular series of observations he should note in the observation note-book the exact time at whicl he began to take these observations.

Never allow any break or discontinuity in the register, if i can *possibly* be avoided, especially in the rain-gauge observations But if any such break is unavoidable, *make no attempt to fill it b interpolation.*

2. *Cleanliness—Every instrument is to be kept scrupulousl clean.*—The feather of a quill or a soft brush may be used to dus the more delicate instruments; a soft cloth, slightly damped, to clea the glass of the larger instruments.

3. *Change of instruments.*—Every instrument differs from other of the same kind in *some* particulars. Each has errors peculiar to it and requires its own special corrections. If, therefore, any instrumen be changed (*e.g.*, one thermometer substituted for another), repor the fact at once by letter to the Meteorological Reporter, givin the number and description of the substituted instrument and of tha replaced; and enter the same on the last page of the register forn with the hour and date at which the substituted instrument was firs observed or brought into use.

4. *Change of position.*—The place and position of an instrumen are *never* to be changed, unless the change be *absolutely necessar* In the case of most instruments, the barometer more especially, an change of place introduces a permanent change in the average read ings of the instrument. If unavoidable, the Meteorological Reporte should be informed beforehand of the proposed change, in order tha he may sanction it, and give any instructions that he may conside desirable for removing the instrument from the old to the new site

When the change has been made, the date and other particulars should be reported to the Meteorological Reporter, and be also noted in the register.

5. *Note-book of observations.*—Observers should invariably take this book with them at the time of observation, and should enter the observations as they are made in the note-book. The observations should *not* be first recorded on slips of paper, and be copied from these slips into the note-book afterwards, as has been the unauthorized practice of some observers during past years.

II.—Barometer.

6. *Order of observation.*—First read the attached thermometer and note the reading. Then regulate the cistern level. Next adjust the vernier, and then take the reading and enter in the note-book. The attached thermometer and barometer should be read a second time in order to verify that the entered reading is correct. The reading of the barometer should be most carefully taken, and the observer should take every precaution to ensure that it is correct to one-thousandth of an inch. The vernier is to be read to the nearest thousandth of an inch, and the attached thermometer to the nearest degree.

7. *Night readings.*—If it be necessary during stormy weather to take readings of the barometer at night, be careful not to place the candle or lamp near the barometer, but at a distance of not less than one foot.

Throw the light *on the paper* or piece of white glass or porcelain behind the cistern and column, while adjusting the cistern level and vernier.

8. *Barometer out of order.*—If the barometer has gone out of order (as for example, if the mercury be leaking, or has disappeared from the tube, the adjusting screws fail to work, or the mercury surface in the cistern has become dirty and black by oxidation due to the chemical action of the air upon it, etc.), or you have reason for believing it is going out of order or is not in good order, communicate the fact to the Imperial Meteorological Office, giving all the information you can respecting its state. If it be considered necessary, a new instrument will be supplied as early as possible. If the Indian Meteorological Office should for any reason request that a barometer should be returned for repairs, it will give full instructions as to the mode of transit. Take care in such a case to follow the instructions in the next paragraph for repacking barometers.

9. When it is necessary to return a barometer to Calcutta send it

packed in a bamboo *dooly* (Fig. 11). Detach the barometer from its suspension, screw up the mercury to the top of the cistern, then invert the instrument cautiously, and give the screw another turn, but leave an air space about equal to the bowl of a tea spoon. Place the barometer in its wooden box, *taking care to keep the cistern end higher* than the top of the barometer. Place the wooden case on the platform of the *dooly* with the cistern end of the barometer upwards and fasten carefully. Pack with straw and cover with gunny or coarse canvas, and note on the address that it is to be kept during the journey in this position.

10. *Change of instrument.*—The position of the barometer should *never* be changed *except* by express order of the Meteorological Reporter or the Inspector of Observatories, *previously* obtained.

11. When a new barometer is brought into use, information should be sent to the Imperial Meteorological Office, Simla, and the Imperial Meteorological Office, Calcutta. The information should be sent to Simla so as to reach it not later than the day on which the instrument is brought into use, and should hence be sent by telegram or post according to circumstances.

III.—THERMOMETERS AND HYGROMETERS.

12. *Suspension.*—Suspend the thermometers as shown in the diagram (Fig. 16) so that the bulbs may be between 3 feet 9 inches and 4 feet 6 inches above the ground, and the wet and dry bulbs as far from each other as the frame will admit of. Do not alter their mode of suspension or position unless the change has been ordered or sanctioned by the Provincial or Imperial Meteorological Reporter or an Inspecting Officer.

They must be protected, not only from direct sunlight, but also, as far as possible, from the radiation of surfaces strongly heated by the sun. They should however be freely exposed to the wind.

13. *Observations.*—Read thermometers as quickly as possible, taking care that the eye is in each case *exactly* on the level of the top of the column if the thermometer be vertical, and exactly opposite (neither to right nor left of it) if it be horizontal, as the smallest deviation from the proper position of reading the instrument introduces a small error into the observation.

Do not bring the hand or face near the bulbs of any of the thermometers. If you have to take observations at night during stormy weather, be careful not to place the lamp nearer to the instruments than is absolutely necessary to read them correctly, and take the readings as quickly as you can, consistent with accurate observation.

Read thermometers, by estimation, to the nearest tenth of a degree.

Before reading a minimum or other spirit thermometer, *always examine the tube to see that there are no drops of spirit in the upper part* of the tube and no air bubbles in the spirit column and bulb. Especially look beneath the brass staple that fixes the tube and in the expansion at the top of the stem. If the column is not entire, reject the reading and restore the column *at once.*

After writing down the reading of any thermometer in the note-book, look again at the instrument to check its accuracy.

14. *Setting the self-registering thermometers.*—Observers at *third* class observatories should set the maximum and minimum thermometers *after* reading them for the 8 A.M. observations.

Observers at *second* class observatories should read the maximum thermometer at 8 A.M. and 4 P.M. and duly enter the readings in the proper place. They should set the maximum thermometer *after* the 8-hour reading. They should also read the dry and wet minimum thermometers at 8 A.M. and 4 P.M. as minimum thermometers (*i.e.*, the end of the index or needle away from the bulb) and set them *after* the 4 P.M. reading. In preparing the daily weather telegram use the 8-hour reading of the day of observation for both the maximum and minimum temperatures of the previous 24 hours.

Observers should be very careful, when replacing their instruments after having set them, not to displace the index of the minimum thermometer or the upper portion of the column of the maximum thermometer.

15. *Wet-bulb thermometers.*—These must be freely exposed to the wind.

They must be kept clean, and free from encrustation. The muslin and thread should be washed at least once a week and renewed at least once a month.

If possible, use rain-water only, and store it for the purpose. In rainless regions, use distilled water if you can get it. If not, *boil* water well and long, and filter it before using it.

The muslin must fit closely to the bulb and not hang in folds. It must be thin and applied in one thickness only. To renew it, cut a piece about one inch square; wet it well, apply it to the bulb and draw it closely over it; tie it with a bundle of eight or ten clean and well-washed yarn threads, and cut off the free edges neatly. The free ends of the yarn (sixteen or twenty strands) are then loosely twisted together to serve as the feeder.

When the wet-bulb is below the freezing point, it must be dipped in water half an hour before the reading is taken.

16. *Test observations.*—Observers should immediately after they have set the maximum and minimum thermometers at 8 A.M., take

readings of the dry bulb, maximum, dry minimum and wet minimum thermometers, and enter them in the place indicated opposite to the proper headings of the INSTRUMENTAL TEST OBSERVATIONS. These observations, if correctly and carefully taken, in accordance with the instructions in Section 68, enable the Imperial Meteorological Office, Simla or Calcutta, to ascertain whether the maximum and minimum thermometers (which are peculiarly liable to go out of order) are in proper condition, and have not changed since they were issued.

17. *In case of accidents.*—If the dry bulb thermometer be broken, take the readings of the maximum till it can be replaced, re-setting at each observation before taking the reading.

If the dry minimum thermometer be broken, read the dry bulb half an hour *before sunrise* instead.

If the ordinary wet bulb be broken, take the *actual* reading of the minimum wet bulb to the top of the spirit column.

IV.—ANEMOMETER AND WIND-VANE.

18. *Reading the anemometer.*—For full directions, see Section 77.

19. *Oiling.*—Clean carefully all parts of the anemometer every three months. Oil the working parts of the anemometer and also the wind-vane, every fortnight, with neatsfoot oil; but add the oil sparingly, leaving no excess to take up dust and clog the bearings. If neatsfoot oil be not procurable, poppy, sesamum, olive, or kerosine oil may be used, but not mustard, castor, or cocoanut oil.

20. *Estimating wind force.*—At stations unprovided with an anemometer, the force of the wind is to be estimated and recorded as explained in Section 85.

V.—RAIN-GAUGE.

21. *Hours of observation.*—Read and empty the gauge regularly at 8 A.M. at 3rd class stations, and at 8 A.M., 10 A.M., and 4 P.M. at 2nd class stations; during heavy rain more frequently, and so often as to incur no risk of loss by its running over.

22. *Measuring.*—See that the measure-glass is empty before measuring. Place the measure-glass on a large dish, and pour the contents of the receiver into it slowly and carefully, to avoid spilling. The measure usually holds half an inch. If the receiver contain more than half an inch, fill it up to the half-inch mark. Then empty it and refill. Each entire filling represents half an inch of rainfall. The last partial filling is read off on the graduation as tenths and hundredths of an inch.

Record rainfall at each hour of observation carefully and make entries to decimals of two places; thus 0·52, 0·20, 0·06, 2·59, etc. For the daily weather telegram and in the monthly 8hr. register book (Form E) give the total rainfall from 8hr. of the previous day to 8hr. of the day of the report, and in the monthly register book of 10hr. and 16hr. observations (Form F) in use at second class observatories give the rainfall measured at each of the hours 8 A.M., 10 A.M., and 4 P.M.

If the measure glass of a Symons's rain-gauge be broken, measure the rainfall in an apothecary's glass graduated to fluid ounces, and compute therefrom the rainfall as directed in Section 90.

If the receiver of a rain-gauge leak, it may be repaired by an ordinary mechanic; but if the form of the rim of the receiving funnel is altered, so that it is not *truly* circular, and the gauge hence registers falsely, report the fact to the Imperial Meteorological Office, Alipore (Calcutta), which will arrange for the supply of a new rain-gauge.

VI.—Cloud and Weather Observations.

23. *Cloud.*—Estimate the proportion of clouded sky visible in tenths of the entire expanse. An unclouded sky is denoted by '0,' not by dots or a blank space; one entirely overcast is '10'. Omit from the estimate clouds low down near the horizon. Notice the kinds of clouds visible and the direction of their motion. If upper clouds as well as lower clouds are visible, enter both in the column "kind of clouds" in the observation book. Also, ascertain if possible their direction of motion, and enter in the appropriate column or columns in the observation book. Note carefully the amount of the cirrus clouds which invariably form in front of cyclonic storms, more especially those of the cold weather. It is very important that the direction of motion of the upper or cirrus clouds should be recorded.

24. *Weather symbols, etc.*—Learn the use of the weather initials or symbols, and use them *intelligently* to describe what is observed.

The hours of rainfall, of thunder-storms, dust-storms or hail, etc., should, as far as possible, be noted. But no entry should be made unless the hour of the occurrence of rain or wind was actually observed. Enter the weather for previous 24 hours in the column for 8 hours *only.*

The occurrence of fog in the early morning and evening should always be noticed and entered in the register.

In the case of fogs as described in the latter part of Section 96 in preparing the daily weather telegram, the sixth word should be selected from page 1 of Telegraphic Code (amount of cloud = 0), and the seventh word (general character of the weather at 8 A.M.) should be selected from page 11, where the description of the weather is "foggy."

VII.—REGISTERS.

25. *Registers.*—All entries should be made as carefully and neatly as possible.

Second class observers are required to send two registers monthly, *viz.*, the 8-hours observation register and the 10-hours and 16-hours observation register. The 8-hours (8 A.M.) register should be despatched not later than the 2nd of the following month, and the 10 and 16-hours observation register not later than the 4th.

The 8 A.M. observation registers are utilized to ascertain any discrepancies in the daily weather telegram occurring during transmission, and should hence be compared carefully with the actual observations in the note-book before they are despatched, so that they may not contain any clerical errors.

VIII.—WEATHER TELEGRAM.

26. *Telegraphic Code.*—Read carefully through the instructions given in the code on the subject.

27. *Daily weather telegram.*—Be careful to send off the daily weather telegram or telegrams as early as possible, so that they may arrive at Simla, Calcutta, Bombay, or Madras, in time for inclusion in the Daily Weather Reports issued by the several Meteorological Offices.

Take every precaution to secure early despatch of the telegrams, and if there be delay due to any cause, report it at once to the Simla Meteorological Office in order that steps may be taken to expedite their transmission in future.

G. I. C. P. O.—No. 12060 Meteor.—19-12-02.