U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU.

INSTRUCTIONS

TO THE

MARINE METEOROLOGICAL OBSERVERS

OF THE

U. S. WEATHER BUREAU.

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INSTRUCTIONS TO THE MARINE METEOROLOGICAL OBSERVERS OF THE U. S. WEATHER BUREAU.

The form of Weather Report at present issued to vessels by the U. S. Weather Bureau is a slight modification of that devised by the U. S. Signal Service for the purpose of its series of International Simultaneous Meteorological Observations, covering the period 1878–1887, which form in its turn superseded the once well-known Meteorological Journal. The last-mentioned form of record, which went into effect in 1876, and which was in many respects identical with that recommended by the Maritime Conference held at Brussels in 1853, contemplated that the various meteorological observations should be entered at the end of every two hours throughout the twenty-four, or a total of twelve sets of observations a day. The new form demanded, in place of this series, a single daily observation—this, however, to be taken over the entire sea at the same instant of time, viz, mean noon on the meridian of Greenwich, the object of the change being the utilization of a principle whose value, already recognized ashore, had meanwhile been shown to be equally applicable to meteorological observations at sea.

The principle in question was the study of weather changes by means of daily synoptic weather charts, i. e., charts showing the conditions of pressure, temperature, wind, etc., existing at a given instant of time, over a wide extent of territory. In the days of Maury, and for some years subsequent to the period of his greatest activity, the common aim of the various institutions engaged in the study of ocean meteorology was to obtain for each unit area of the sea's surface, generally a field bounded by the even 5° parallels and meridians, 5°, 10°, 15°, etc., a reasonable number of observations of wind, weather, etc., extending over any period of years. The observations were then assembled by months, the average for each month taken, and the result stated as the normal conditions for the month, i. e., the condition which the mariner might expect to find most frequently prevailing throughout the given field or square during the given month. Sailing routes were then laid down for the successive months in accordance with these normal conditions, and shipmasters were instructed to adhere to these routes as rigidly as the winds would permit, even when convinced by their own experience of weather changes, as well as by the indications of their meteorological instruments, that better results might be attained by adapting the course of the voyage to the conditions actually encountered.

With the advent of weather forecasting as a science, using as a basis the daily synoptic weather charts, a new importance was attached to the sailor's meteorological observations. It was seen that in taking them he was not only adding to the stock of general knowledge of the climatology of the sea, the value of which to him was future and problematical, but also that he was putting himself in possession of certain special knowledge, the value of which might prove absolute and immediate. His last preceding observation revealed a certain existent condition of the meteorological elements, his present observation a more or less different condition. What did the changes which had taken place during the time intervening between the observations foretell? Did the existence of adverse winds in his immediate neighborhood imply better or worse conditions elsewhere? If better, would he not in this instance be justified in abandoning the route which had been laid down for him as the best under average circumstances, and seeking that which his present observations led him to believe would prove more favorable?

A satisfactory answer to these various questions demands, in addition to a knowledge of the general periodic changes which occur in the several meteorologic elements from season to season, and from month to month, a knowledge of what may be termed the nonperiodic or accidental changes which occur from day to day; of the relation which exists between the simultaneous changes in the several elements, and of the effect which a decided variation of pressure, temperature, or wind in any one neighborhood has upon the conditions existing in other parts of the ocean.

To obtain this latter knowledge it is requisite that we have at hand for the purposes of study a series of charts or pictures, as it were, of the weather covering the entire ocean at a given instant of time, taken at regular intervals so brief that we may be confident that no marked change can occur without appearing, in its different stages, upon several of these pictures in succession. An examination of this series will then serve to reveal what changes have taken place in the interval separating any two of them; to trace the development and progress of any disturbance of the normal conditions that may have arisen; to compare the conditions of wind and weather prevailing simultaneously at points of the sea more or less remote from each other; to determine the constant relation, if any, which exists between these conditions; to make plain the manner in which a vessel, beset by foul winds, might have been navigated with the result that these winds would have been avoided, or even been replaced by fair; and finally, to instruct the navigator as to the conclusions to be drawn from his meteorological observations, in order that this result may be accomplished.

It was with a view to combining these two equally essential methods of meteorological investigation—the old, having for its aim the collection of a large number of observations, independent as to time, to serve as a basis for the study of the climatological changes as they occur from month to month, and the new, having for its aim the collection of a large number of daily simultaneous observations, to serve as a basis for the study of the weather changes as they actually occur from day to day—that the present form of weather report was adopted. It demands but a single observation a day, instead of the twelve demanded by the Meteorological Journal, this large reduction being made in the hope that the number of observers would increase in the same ratio as the services required of them would diminish, a hope which has proved more than justified. This single observation, however, is to be taken each day over the entire globe at the same instant of time, viz, Greenwich mean noon. The local or ship's time of the observation will thus vary with the longitude; on the meridian of Greenwich it will be local or ship's noon; in longitude 60° E. it will be 4 p. m.; in longitude 60° W. it will be 8 a. m.; in 120° E. it will be 8 p. m.; in 120° W. it will be 4 a. m. On the meridian 180° it will be midnight.

TREATMENT OF THE OBSERVATIONS.

When about to sail, the master of a vessel or his representative should call at, write, or telephone to the local office of the U.S. Weather Bureau and request the official in charge to furnish him with a supply of blank weather reports and envelopes sufficient to last until his return to a United States port; also with cards for barometer comparisons.

A local Weather Bureau Office is maintained in each of the larger cities on the Atlantic, the Pacific, and the Gulf coasts of the United States; also at Honolulu, Hawaii. The address of these several offices is as follows:

Portland, Me., First National Bank Building, 57 Exchange street.
Boston, Mass., Public Building, Post-Office Square.
New York, N. Y., American Surety Building, 100 Broadway.
Philadelphia, Pa., Public Building, Ninth and Chestnut streets.
Baltimore, Md., Custom-House.
Norfolk, Va., Citizen's Bank Building, 191–5 Main street.
Wilmington, N. C., Public Building, Front and Chestnut streets.
Charleston, S. C., Public Building, 200 East Bay street.
Savannah, Ga., Public Building, President and Whittaker streets.
Jacksonville, Fla., Dyall-Upchurch Building, southeast corner Main and Bay streets.
Key West, Fla., Weather Bureau Building, Eaton and Front streets.
San Juan, P. R., No. 5 Allen street.
Tampa, Fla., Government Building.
Pensacola, Fla., Public Building, Palafox and Government streets.
Mobile, Ala., City Bank Building, 12 and 14 St. Joseph street.

New Orleans, La., Public Building, Decatur and Custom-House streets.
Galveston, Tex., Improvement Loan and Trust Building, 2222 Post-Office street.
Tacoma, Wash., Chamber of Commerce Building, corner C and Ninth streets.
Seattle, Wash., Alaska Building, Second avenue and Cherry street.
East Clallam, Wash., Withrow Building.
Neah Bay, Wash., Indian Agency Building.
Portland, Oreg., Public Building, Davis and North First streets.
San Francisco, Cal., Merchants Exchange, California and Leidesdorff streets.
San Diego, Cal., Keating Building, Fifth and F streets.
Honolulu, Hawaii, Alexander Young Building.

Local offices are supplied with books, charts, and pamphlets relating to meteorology. They are equipped with standard meteorological instruments, both land and marine, which shipmasters and officers are requested to inspect, and with which they are invited to have their own instruments compared, free of cost. Publications, blank Weather Reports, Barometer Comparison Cards, etc., will be furnished marine observers upon application, either by mail or in person, to any one of these offices; also to the Chief, U. S. Weather Bureau, Washington, D. C.

For the convenience of those masters who rarely visit an American port, a limited supply of blanks, etc., is maintained at each of the following-named American consulates:

Acapulco, Mexico.
Algiers, Algeria.
Amoy, China.
Antwerp, Belgium.
Apia, Samoa.
Bahia, Brazil.
Bangkok, Siam.
Barbados, West Indies.
Barranquilla, Colombia.
Batavia, Java.
Bordeaux, France.
Bremen, Germany.
Buenos Ayres, Argentina.
Cadiz, Spain.
Calcutta, India.
Callao, Peru.
Cape Town, South Africa.
Cardiff, Wales.
Cartagena, Colombia.
Christiania, Norway.
Cienfuegos, Cuba.
Colombo, Ceylon.
Colon, Panama.
Copenhagen, Denmark.
Dundee, Scotland.
East London, South Africa.
Edinburgh, Scotland.
Funchal, Madeira.
Genoa, Italy.
Glasgow, Scotland.
Goreedakar, Senegal.
Guayaquil, Ecuador.
Hamburg, Germany.
Hamilton, Bermuda.
Habana, Cuba.
Havre, France.
Hongkong, China.
Huelva, Spain.
Iquique, Chile.
Kobe, Japan.
Lisbon, Portugal.
Liverpool, England.
London, England.
Lourenco Marquez, East Africa.
Malaga, Spain.
Manzanillo, Mexico.
Marseille, France.
Martinique, West Indies.
Mazatlan, Mexico.
Melbourne, Victoria.
Montevideo, Uruguay.
Montreal, Canada.
Newcastle, New South Wales.
Newcastle-on-Tyne, England.
Panama, Canal Zone.
Para, Brazil.
Pernambuco, Brazil.
Port Stanley, Falkland Islands.
Progreso, Mexico.
Queenstown, Ireland.
Rio de Janeiro, Brazil.
Rotterdam, Holland.
Rouen, France.
St. Johns, New Brunswick.
St. Michaels, Azores.
St. Pierre, St. Pierre Island.
St. Thomas, West Indies.
Santiago de Cuba.
Santo Domingo.
Santos, Brazil.
Seoul, Korea.
Shanghai, China.
Singapore, Straits Settlement.
Stockholm, Sweden.
Sydney, New South Wales.
Tahiti, Society Islands.
Tampico, Mexico.
Teneriffe, Canary Islands.
Tientsin, China.
Trieste, Austria-Hungary.
Tunis, Tunis.
Valparaiso, Chile.
Vera Cruz, Mexico.
Yokohama, Japan.

A comparison card should be filled out while the vessel is lying in port and should be mailed before sailing. These cards require (if mailed in a United States port) neither envelope nor postage.

Instructions as to the manner of making these comparisons are given on page 34.

Having arrived at his destination he should inclose the forms, containing the observations recorded during the voyage, in one or more of the envelopes furnished for that purpose.

If in a foreign port, this envelope should be addressed to the Chief of the U. S. Weather Bureau, Washington, D. C., and *handed* to the United States consul, who is under instructions from the Secretary of State to forward it with his official mail, free of all expense. If *mailed* at any port outside of the United States, postage must be prepaid at letter rates.

In any United States port the package should be addressed to the nearest local office of the U. S. Weather Bureau and mailed. The franked envelope does not require any postage when mailed within the United States, Hawaii, the Philippine Islands, Porto Rico, Wake Island, Guam Island, Howland Island, Tutuila Island, or Midway Island.

The forms should be returned promptly at the close of each voyage, or even at the first port of call. They should not be held until the return of the vessel to the United States.

Upon the receipt of the completed forms, either at the central office in Washington or at any one of its branches, a letter of acknowledgment is at once addressed to the master of the vessel, thanking him and the officer charged with the duty of taking the observations for their services, and replying to any inquiry or request that the master or the observer may have made upon the pages allotted to that purpose. These letters of acknowledgment should in all cases be preserved, as they may prove of value in identifying the bearer as an observer at the several local offices, and as such entitled to the various official publications.

To insure the prompt receipt of these letters of acknowledgment, as well as of other material, observers are instructed to give in each weather report returned to the Weather Bureau the post-office address to which all communications should be sent. Page 16 of the weather report is reserved for this purpose. American addresses are preferred.

Having been duly acknowledged, the reports are immediately forwarded to the central office in Washington. Here each report is first examined with regard to the reliability of the observations. Where these bear evidence on their face of having been hastily or carelessly taken and recorded, or that the instruments used were untrustworthy, the report is rejected, and the fact of its rejection is noted for future reference.

The daily synoptic weather charts.—The next step is the utilization of the observations in the construction of the daily synoptic weather charts.

A suitable series of outline charts of the various oceans having been prepared and dated, one for every day in the year, the observations contained in the report are plotted, one by one, each in its proper position, upon the chart of corresponding date. For this purpose a system of symbols is employed which shows at a glance the height of the barometer, the direction and force of the wind, the proportion of clouded sky, the nature of the precipitation, whether rain, snow, or hail, the presence of fog, the character of the weather, etc., all precisely as recorded by the observer, with the exception of the reading of the barometer, which is first corrected for initial error, and, if mercurial, reduced to standard temperature and gravity. For the North Atlantic Ocean the first reports to reach the office, and consequently the first observations to appear upon the chart, are those returned by the westward-bound transatlantic liners. These are closely followed by the slower steamships from Europe and the West Indies, and these in turn by the homeward-bound sailing vessels. The last reports to appear are those from sailing vessels outward bound to distant ports, such as those of eastern Asia. These are sometimes as much as a year late in reaching the U. S. Weather Bureau, owing to the practice of holding them until the return of the vessel to the United States. Masters are therefore earnestly requested to avoid this delay by forwarding their observations on reaching their first port. The observations taken aboard sailing vessels are of the highest value, as they are free from certain constant sources of error caused by the speed of steamships.

As the reports from these various sources accumulate, the plotted observations become more and more densely distributed over the chart, each plotting representing the position of an observing vessel at the instant of Greenwich mean noon, and the conditions prevailing in its vicinity at that instant, until in its final shape the chart for each day offers to view a complete picture of the pressure, wind, and weather covering the entire ocean at the hour and minute of Greenwich mean noon of the day in question.

As is well known, the governing features of the weather in the extratropical regions of both hemispheres is the practically ceaseless procession of areas of alternately high and low barometer which move around the earth with varying velocity in a general easterly direction, each accompanied by its own system of winds circulating about the center, the direction of the circulation being cyclonic around the area of low barometer, anticyclonic around the area of high. The synoptic charts of the various oceans enable us to follow up the movement of these areas from day to day, to mark the changes which take place in them, and to study the effect of these changes in modifying the weather. It is from this source that the Weather Bureau is enabled to trace the path of each barometric depression and to furnish for every month, for publication on the Pilot Chart of the North Atlantic Ocean, the tracks of all important storms that have occurred for a series of years. The opportunity is thus afforded mariners of explaining in accordance with the law of storms the occurrence of any heavy weather encountered, also of knowing in what part of the ocean to expect disturbances, what will be their character, extent, and duration, and what the direction and velocity of motion of the vortex.

It is, however, in the light of the assistance which careful study of these charts will ultimately furnish the mariner in properly interpreting his own isolated observations that they have their main value. If we look through a series of such charts, the first impression gained is that they are of endless variety, each one being apparently a law unto itself. Close observation, however, will soon reveal certain points of similarity, especially in the position and extent of the areas of high barometer, and consequently in the outflowing winds which surround them, a given distribution of pressure often appearing to hold sway for several days in succession, only to be supplanted by some quite different but equally persistent arrangement. Careful study has thus shown that the daily synoptic weather charts of the North Atlantic Ocean may, with certain restrictions, all be referred to one or another of a limited number of types, each type possessing certain characteristic features, which vary from season to season, and each exhibiting a certain degree of persistency.

It is upon the study of these *types* of weather, their character, duration, and order of succession, that rests the hope of eventually predicting the weather over the ocean several days in advance. Such a study demands that the meteorologist have at hand a series of daily synoptic weather charts, accurate in every respect, and covering the ocean, especially in the higher latitudes, as widely and as completely as possible, and it is to the merchant marine that he must look for the material necessary for the construction of these charts. Once having attained a knowledge of these types, moreover, the ability of the mariner to forecast the weather from his own isolated observations would be vastly increased. Knowing the type of weather prevailing, his observations of pressure, temperature, winds, and clouds would gain a new importance, showing whether the type was about to change, and in what direction.

The tabulation of the observations.—Having served their purpose in the construction of the daily synoptic charts, the observations are ready for tabulation. For this purpose the surface of the ocean is divided into a number of fields or squares, bounded by the even 5° parallels of latitude and meridians of longitude, 0°, 5°, 10°, 15°, etc. The observations are then separated according to months, and all of those within a given square and during a given month, irrespective of the year, are assembled. The next step is to obtain for each month and each square the average pressure and temperature of the air, the average temperature of the surface water of the sea, the ratio that the winds from each compass point bear to the total number of winds, the average force of the winds, the frequency of the various forms of clouds, varieties of weather and character of the sea, and the average velocity and set of the current. These final values are then carefully tabulated and mapped, and the results given to the seafaring community in the shape of the Monthly Pilot Charts.

INSTRUCTIONS AS TO THE MANNER OF TAKING THE OBSERVATIONS.

The weather report is issued to the observers in two forms, the first containing blanks sufficient for fifteen days, the second containing blanks sufficient for thirty-one days.

Observers are requested to provide themselves with an ample supply of forms before leaving port. The form should remain intact. The portion remaining unused should not be cut out, nor should additional leaves be inserted.

The preliminary pages of the report are devoted to definitions and brief instructions. These should be carefully read and fully comprehended.

Notes on instruments used.—State the kind of barometer, whether aneroid or mercurial, and the number furnished by the U. S. Weather Bureau.

The same barometer should be employed continuously.—If for any reason it becomes necessary to use another instrument, the fact should be stated, the reasons given, and the second instrument fully described, in order that the readings of the latter may not be confused with the readings of the barometer listed by the Weather Bureau.

Give the error of the barometer as determined by the last comparison with a standard; also the place and date of this last comparison.

State the scale of the attached thermometer employed, whether Fahrenheit, Centigrade, or Réaumur.

The readings of the barometer may be given either in millimeters or in English inches, and the temperatures on any scale. All are alike acceptable.

Record the readings of the barometer and thermometer precisely as made. All necessary corrections are subsequently applied in the U. S. Weather Bureau.

The report calls for a single observation each day. A complete page, as shown by samples, is allotted to each observation.

Observations should commence the day of sailing and should continue without interruption up to and including the day of arrival in port.

GREENWICH MEAN NOON OBSERVATIONS.

Date, ..., 190

LOCAL MEAN TIME.	PORT OR POSITION.		WIND.		BAROMETER.	
Of weather observation.	Latitude.	Longitude. (Greenwich.)	True direction.	Force 0-12.	As read off.	Att. ther.
11.00 p. m..........	36°-00′ N......	165° 30′ E.....	North......	7	29.68	58

TEMPERATURE.			WEATHER.	CLOUDS.			SEA.
Air, dry bulb.	Air, wet bulb.	Water at surface.	State of, by symbols.	Forms of, by symbols.	Direction, moving from.	Amount, scale 0 to 10.	True direction from which coming.
54	50	52	o. m. r. q.	N.	North........	10	North.

The above form calls for a precise statement of the meteorological conditions prevailing at the actual time of observation and nothing should be entered thereon which refers to any other hour.
(Daily Journal on back.)

Daily journal of weather experienced between the observations, to be taken from ship's log.

[Use only local time.]

The date.—The date given at the head of each page should be the civil day, beginning at a given midnight and ending at the following midnight.

In crossing the one hundred and eightieth meridian, observers aboard westward-bound vessels sometimes make the mistake of dropping a day from the record of the Greenwich mean noon observations, and conversely of using the same date twice when eastward bound. This is incorrect. The observations in both cases should be dated consecutively, as a little consideration will show.

Take the case of a vessel westward bound and at longitude 178° W., at Greenwich mean noon of April 15. The local date and time of observation would be April 15, 12 hr. 8 min. a. m.; also recorded as 12.08 a. m. The time by chronometer for the next observation would be 24 hours later or at Greenwich mean noon of the 16th. At such hour the vessel making 4° of longitude a day would be at longitude 178° E., and the true local date and time of observation would be April 16, 11 hr. 52 min. p. m.; also recorded as 11.52 p. m.

Again, let a vessel be eastward bound and at longitude 178° E. at Greenwich mean noon of April 15. The local date and time of observations would be April 15, 11 hr. 52 min. p. m.; also recorded as 11.52 p. m. The time by chronometer for the next observation would be 24 hours later or at Greenwich mean noon of April 16. At such hour the vessel making 4° of longitude a day would be at 178° W. and the true local date and time of observation would be April 16, 12 hr. 8 min. a. m.; also recorded as 12.08 a. m.

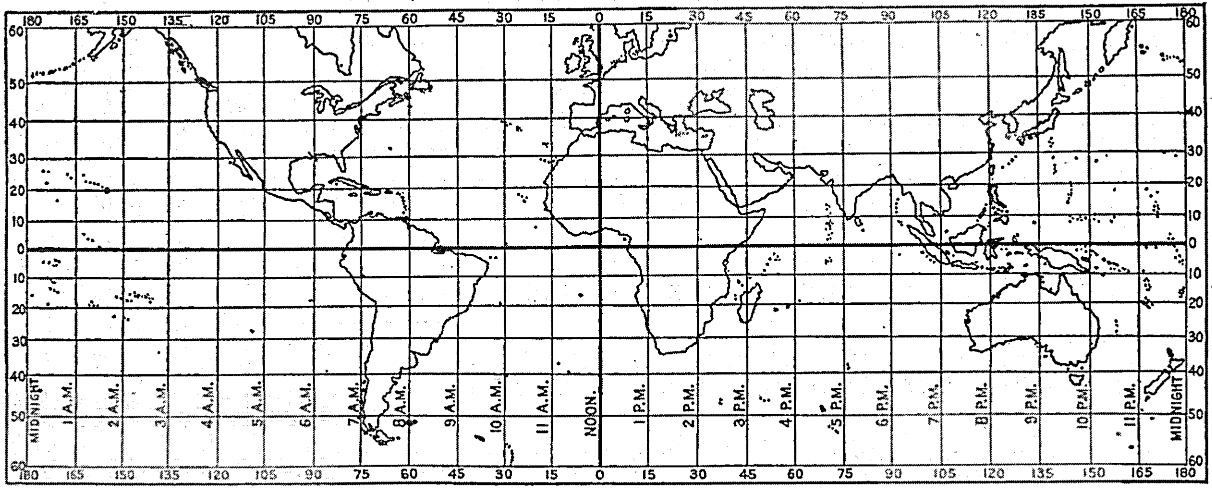
It will be seen, in the cases mentioned, that according to local mean time the interval between the two observations of the vessel bound westward would be 23 hr. and 44 min., and the interval between the two observations of the vessel bound eastward would be 24 hr. and 16 min., while by chronometer time the interval between consecutive observations taken at the proper time, or Greenwich mean noon, is invariably 24 hours.

Local mean time.—The single daily meteorological observation should be taken and recorded at the instant of mean noon on the meridian of Greenwich, i. e., at the instant when the mean sun crosses that meridian. If there is on board a chronometer set to Greenwich mean time this instant will coincide with noon as given by that chronometer after correction for error and rate.

In the column headed "Local mean time" should be entered the local or ship's time at which the meteorological observation is taken, as given by the deck clock or other timepiece, which is corrected from day to day for the change in longitude.

The small chart given on the following page shows the local time corresponding to Greenwich mean noon, for each 15° of longitude east and west; i. e., the local (ship's) time at which the daily observation should be taken to the nearest hour. The exact ship's time at which the observation in any longitude, east or west, should be taken may easily be found from the tables of longitude and time which follow. In east longitude the observation should always be taken during the afternoon (p. m.) hours; in west longitude during the forenoon (a. m.) hours.

Port or position.—In this column should be entered the position of the vessel at the actual time of the meteorological observation. This column should always be filled out to the best of the observer's ability, even though no astronomical observations have been obtained for several days past. When the given position is doubtful, a remark should be made to that effect.



This chart gives the local time corresponding to Greenwich Mean Noon.

The remaining ruled columns call for a precise statement of the meteorological conditions prevailing at the *actual time of observation,* and nothing should be entered in them which refers to any other hour. Previous changes, shifts of the wind, readings of the barometer, etc., should all be briefly noted under the heading "Daily Journal."

TIME OF OBSERVATION, WEST LONGITUDE.

Ship's longitude. (West.)	Local mean time. a. m.	Ship's longitude. (West.)	Local mean time. a. m.	Ship's longitude. (West.)	Local mean time. a. m.	Ship's longitude. (West.)	Local mean time. a. m.
°	h. m.	°	h. m.	°	h. m.	°	h. m.
0	**Noon.**	**45**	**9 00**	**90**	**6 00**	**135**	**3 00**
1	11 56	46	8 56	91	5 56	136	2 56
2	11 52	47	8 52	92	5 52	137	2 52
3	11 48	48	8 48	93	5 48	138	2 48
4	11 44	49	8 44	94	5 44	139	2 44
5	11 40	50	8 40	95	5 40	140	2 40
6	11 36	51	8 36	96	5 36	141	2 36
7	11 32	52	8 32	97	5 32	142	2 32
8	11 28	53	8 28	98	5 28	143	2 28
9	11 24	54	8 24	99	5 24	144	2 24
10	11 20	55	8 20	100	5 20	145	2 20
11	11 16	56	8 16	101	5 16	146	2 16
12	11 12	57	8 12	102	5 12	147	2 12
13	11 08	58	8 08	103	5 08	148	2 08
14	11 04	59	8 04	104	5 04	149	2 04
15	**11 00**	**60**	**8 00**	**105**	**5 00**	**150**	**2 00**
16	10 56	61	7 56	106	4 56	151	1 56
17	10 52	62	7 52	107	4 52	152	1 52
18	10 48	63	7 48	108	4 48	153	1 48
19	10 44	64	7 44	109	4 44	154	1 44
20	10 40	65	7 40	110	4 40	155	1 40
21	10 36	66	7 36	111	4 36	156	1 36
22	10 32	67	7 32	112	4 32	157	1 32
23	10 28	68	7 28	113	4 28	158	1 28
24	10 24	69	7 24	114	4 24	159	1 24
25	10 20	70	7 20	115	4 20	160	1 20
26	10 16	71	7 16	116	4 16	161	1 16
27	10 12	72	7 12	117	4 12	162	1 12
28	10 08	73	7 08	118	4 08	163	1 08
29	10 04	74	7 04	119	4 04	164	1 04
30	**10 00**	**75**	**7 00**	**120**	**4 00**	**165**	**1 00**
31	9 56	76	6 56	121	3 56	166	12 56
32	9 52	77	6 52	122	3 52	167	12 52
33	9 48	78	6 48	123	3 48	168	12 48
34	9 44	79	6 44	124	3 44	169	12 44
35	9 40	80	6 40	125	3 40	170	12 40
36	9 36	81	6 36	126	3 36	171	12 36
37	9 32	82	6 32	127	3 32	172	12 32
38	9 28	83	6 28	128	3 28	173	12 28
39	9 24	84	6 24	129	3 24	174	12 24
40	9 20	85	6 20	130	3 20	175	12 20
41	9 16	86	6 16	131	3 16	176	12 16
42	9 12	87	6 12	132	3 12	177	12 12
43	9 08	88	6 08	133	3 08	178	12 08
44	9 04	89	6 04	134	3 04	179	12 04

TIME OF OBSERVATION, EAST LONGITUDE.

Ship's longitude. (East.)	Local mean time. p.m.	Ship's longitude. (East.)	Local mean time. p.m.	Ship's longitude. (East.)	Local mean time. p.m.	Ship's longitude. (East.)	Local mean time. p.m.
°	h. m.	°	h. m.	°	h. m.	°	h. m.
0	**Noon.**						
1	12 04	46	3 04	91	6 04	136	9 04
2	12 08	47	3 08	92	6 08	137	9 08
3	12 12	48	3 12	93	6 12	138	9 12
4	12 16	49	3 16	94	6 16	139	9 16
5	12 20	50	3 20	95	6 20	140	9 20
6	12 24	51	3 24	96	6 24	141	9 24
7	12 28	52	3 28	97	6 28	142	9 28
8	12 32	53	3 32	98	6 32	143	9 32
9	12 36	54	3 36	99	6 36	144	9 36
10	12 40	55	3 40	100	6 40	145	9 40
11	12 44	56	3 44	101	6 44	146	9 44
12	12 48	57	3 48	102	6 48	147	9 48
13	12 52	58	3 52	103	6 52	148	9 52
14	12 56	59	3 56	104	6 56	149	9 56
15	**1 00**	**60**	**4 00**	**105**	**7 00**	**150**	**10 00**
16	1 04	61	4 04	106	7 04	151	10 04
17	1 08	62	4 08	107	7 08	152	10 08
18	1 12	63	4 12	108	7 12	153	10 12
19	1 16	64	4 16	109	7 16	154	10 16
20	1 20	65	4 20	110	7 20	155	10 20
21	1 24	66	4 24	111	7 24	156	10 24
22	1 28	67	4 28	112	7 28	157	10 28
23	1 32	68	4 32	113	7 32	158	10 32
24	1 36	69	4 36	114	7 36	159	10 36
25	1 40	70	4 40	115	7 40	160	10 40
26	1 44	71	4 44	116	7 44	161	10 44
27	1 48	72	4 48	117	7 48	162	10 48
28	1 52	73	4 52	118	7 52	163	10 52
29	1 56	74	4 56	119	7 56	164	10 56
30	**2 00**	**75**	**5 00**	**120**	**8 00**	**615**	**11 00**
31	2 04	76	5 04	121	8 04	166	11 04
32	2 08	77	5 08	122	8 08	167	11 08
33	2 12	78	5 12	123	8 12	168	11 12
34	2 16	79	5 16	124	8 16	169	11 16
35	2 20	80	5 20	125	8 20	170	11 20
36	2 24	81	5 24	126	8 24	171	11 24
37	2 28	82	5 28	127	8 28	172	11 28
38	2 32	83	5 32	128	8 32	173	11 32
39	2 36	84	5 36	129	8 36	174	11 36
40	2 40	85	5 40	130	8 40	175	11 40
41	2 44	86	5 44	131	8 44	176	11 44
42	2 48	87	5 48	132	8 48	177	11 48
43	2 52	88	5 52	133	8 52	178	11 52
44	2 56	89	5 56	134	8 56	179	11 56
45	**3 00**	**90**	**6 00**	**135**	**9 00**	**180**	**Mid.**

Wind, direction, and force.—The direction of the wind to be recorded is the *true* direction, not the *magnetic*. Its direction as given by the compass should therefore be corrected for the magnetic variation and for the deviation, if this is large, as is frequently the case on board iron vessels.

The shifts of the wind should be noted under the heading, "Daily Journal." In recording any large shift, specify the time at which it occurred, the direction of the shift, and the force; for example, "at 10 a. m. wind shifted from SE., 3, through South to West, 8."

Observers sometimes fail to distinguish between shifting winds and variable winds. The former term applies to winds whose direction is changing in accordance with some decided cyclonic or anticyclonic system, the latter to winds of feeble intensity (force 3 or less) whose direction is indefinite, coming in puffs first from one point, then from another.

In recording the force of the wind the scale devised by the late Admiral Sir F. Beaufort is employed. According to this scale the wind varies from 0, a calm, to 12, a hurricane, the greatest velocity it ever attains. In the lower grades of the scale the force of the wind is estimated from the speed imparted to a man-of-war of the early part of the nineteenth century sailing full and by; in the higher grades from the amount of sail which the same vessel could carry when close-hauled. The scale, with the estimated velocity of the wind in both statute and nautical miles an hour, is as follows:

BEAUFORT'S SCALE.

Force of wind.	Velocity. Statute miles an hour.	Velocity. Nautical miles an hour.	Mean pressure in pounds on the square foot.
0. CALM. Full-rigged ship, all sails set, no headway.	0 to 3	0 to 2.6	0.03
1.—LIGHT AIR. Just sufficient to give steerage way.	8	6.9	0.23
2.—LIGHT BREEZE. Speed of 1 or 2 knots, "full and by"	13	11.3	0.62
3.—GENTLE BREEZE. Speed of 3 or 4 knots, "full and by"	18	15.6	1.2
4.—MODERATE BREEZE. Speed of 5 or 6 knots, "full and by"	23	20.0	1.9
5.—FRESH BREEZE. All plain sail, "full and by"	28	24.3	2.9
6.—STRONG BREEZE. Topgallant sails over single-reefed topsails	34	29.5	4.2
7.—MODERATE GALE. Double-reefed topsails	40	34.7	5.9
8.—FRESH GALE. Treble-reefed topsails (or reefed upper topsails and courses)	48	41.6	8.4
9.—STRONG GALE. Close-reefed topsails and courses (or lower topsails and courses)	56	48.6	11.5
10.—WHOLE GALE. Close-reefed main topsail and reefed foresail (or lower main topsail and reefed foresail)	65	56.4	15.5
11.—STORM. Storm staysails	75	65.1	20.6
12.—HURRICANE. Under bare poles	90 and over.	78.1 and over.	29.6

The column headed "Mean pressure in pounds on the square foot" shows the pressure due to a wind of the given velocity on each square foot of a stationary rigid plate, the direction of the wind being perpendicular to the plane of the plate. The value is, therefore, in each case, the maximum pressure on each square foot of sail area to which the given wind can give rise.

The apparent and the true direction and force of the wind.—When steaming or sailing with any velocity, the apparent direction and force of the wind as determined from a vane or pennant aboard ship, or from the smoke emerging from the funnel, may differ considerably from the true direction and force. For instance, let the wind have a velocity of 20 miles an hour (force 4) and take the case of two vessels, each steaming 20 knots, but in opposite directions, the first with the wind dead aft, the second with the wind dead ahead. The former vessel will be moving with the same velocity as the air,

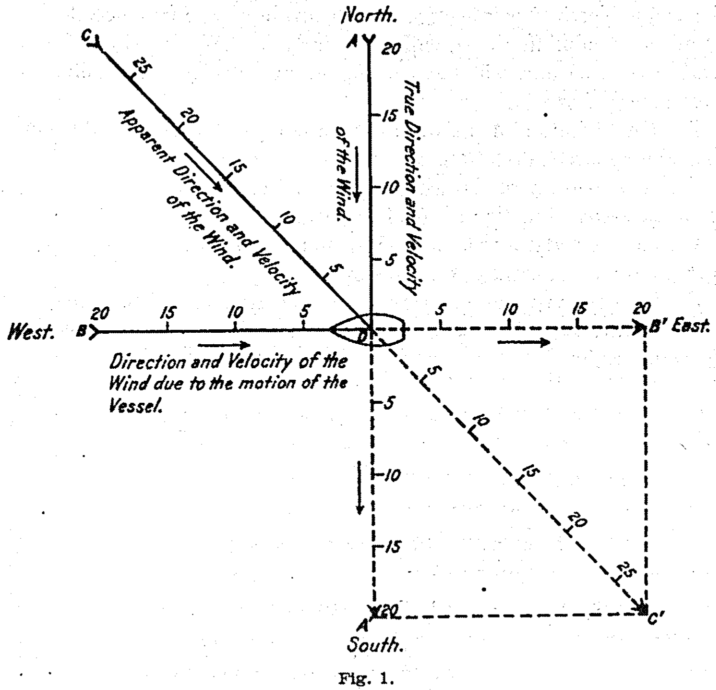


Fig. 1.

and in the same direction. The relative velocity of the two will thus be the difference of the two velocities, or zero, and on the deck of the vessel an apparent calm will prevail, and the pennant will hang up and down. The latter vessel will be moving with the same velocity as the air, but in the opposite direction. The relative velocity of the two will thus be the sum of the two velocities, or 40 miles an hour, and on the deck of the latter the wind will apparently have the velocity corresponding very nearly with a fresh gale.

The apparent direction and velocity of the wind is thus the resultant of both motions, that of the vessel and that of the air. As an example of this, take the case of a vessel steaming westward 20 knots, and let the *true* direction of the wind be due North, or 8 points off the starboard bow, its *true* velocity 20 miles an hour (force 4). Let *A D* (fig. 1) represent the *true* direction and velocity of the wind; *B D* the direction (West) and the velocity (20 miles an hour) of the wind created by the motion of the steamer. Then *C D*, the resultant of *A D* and *B D* will be the apparent direction and velocity of the wind as observed aboard the steamer; i. e., the wind, while its true direction is due North (8 points off the starboard bow) and its true velocity 20 miles an hour (force 4), will apparently be NW. (4 points off the starboard bow) and will have an apparent velocity of 28 miles an hour (nearly force 6).

The true direction of the wind is thus always farther from the bow than the apparent direction.

The true velocity of the wind is greater than the apparent as long as the apparent direction is aft of the beam.

The true velocity of the wind is less than the apparent as long as the true direction is forward of the beam.

Having observed the apparent force and direction of the wind, in points off the bow, the *true* force and direction may be taken from the following table:

TABLE FOR OBTAINING THE TRUE DIRECTION AND FORCE OF THE WIND FROM THE DECK OF A MOVING VESSEL.

Apparent direction of the wind (points off the bow): 0 to 5

Apparent force of the wind (Beaufort scale).	Speed of the vessel, knots.	0: True direction, points off the bow.	0: True force, Beaufort scale.	1: True direction, points off the bow.	1: True force, Beaufort scale.	2: True direction, points off the bow.	2: True force, Beaufort scale.	3: True direction, points off the bow.	3: True force, Beaufort scale.	4: True direction, points off the bow.	4: True force, Beaufort scale.	5: True direction, points off the bow.	5: True force, Beaufort scale.
0	10	16	1	16	1	15	1	15	1	15	1	15	1
	15	16	2	16	2	16	2	15	2	15	2	15	2
	20	16	3	16	3	16	3	16	4	15	4	15	4
1	10	16	0	14	0	13	0	12	1	12	1	12	1
	15	16	1	15	1	14	2	14	2	14	2	14	2
	20	16	2	15	2	15	3	15	3	14	3	14	3
2	10	0	0	6	0	7	0	8	1	9	1	10	2
	15	16	0	13	0	12	1	12	1	12	2	12	2
	20	16	1	15	2	14	2	13	2	13	3	13	3
3	10	0	1	3	1	5	1	6	2	8	2	8	2
	15	0	0	8	0	8	1	9	1	10	2	10	3
	20	16	0	13	1	12	1	12	2	12	3	12	3
4	10	0	2	2	2	4	2	6	2	7	3	8	3
	15	0	1	4	1	6	1	7	2	8	3	9	3
	20	....	0	9	0	9	1	10	2	10	3	10	4
5	10	0	3	2	3	3	3	5	3	6	4	7	4
	15	0	2	3	2	5	2	6	3	7	3	8	4
	20	0	0	5	1	7	2	8	3	9	3	10	3
6	10	0	4	2	4	3	4	4	4	6	5	7	5
	15	0	3	2	3	4	3	5	4	7	4	8	5
	20	0	2	3	2	5	2	7	3	8	4	9	5

Apparent direction of the wind (points off the bow): 6 to 11

Apparent force of the wind (Beaufort scale).	Speed of the vessel, knots.	6: True direction, points off the bow.	6: True force, Beaufort scale.	7: True direction, points off the bow.	7: True force, Beaufort scale.	8: True direction, points off the bow.	8: True force, Beaufort scale.	9: True direction, points off the bow.	9: True force, Beaufort scale.	10: True direction, points off the bow.	10: True force, Beaufort scale.	11: True direction, points off the bow.	11: True force, Beaufort scale.
0	10	15	2	15	2	15	2	15	2	15	2	15	2
	15	15	3	15	3	15	3	15	3	15	3	15	3
	20	15	4	15	4	15	4	15	4	15	4	15	4
1	10	12	2	13	2	13	2	13	2	14	3	14	3
	15	14	3	14	3	14	3	14	3	14	4	14	4
	20	14	4	14	4	14	4	14	4	15	5	15	5
2	10	10	2	11	3	12	3	12	3	13	3	13	4
	15	12	3	12	3	13	4	13	4	13	4	14	5
	20	13	4	13	4	13	5	14	5	14	5	14	6
3	10	9	3	10	3	11	4	12	4	12	4	13	5
	15	11	3	11	4	12	4	12	5	13	5	13	6
	20	12	4	12	5	13	5	13	6	13	6	14	6
4	10	9	4	10	4	10	4	11	5	12	5	13	5
	15	10	4	11	5	11	5	12	6	12	6	13	6
	20	11	4	12	5	12	5	12	6	13	7	14	7
5	10	8	5	9	5	10	5	11	6	12	6	12	6
	15	9	5	10	5	11	6	12	6	12	7	13	7
	20	10	5	11	6	12	6	12	7	13	7	13	8
6	10	8	6	9	6	10	6	11	7	11	7	12	7
	15	9	6	10	6	10	7	11	7	12	7	13	8
	20	10	6	10	7	11	7	12	7	12	8	13	8

Apparent direction of the wind (points off the bow): 12 to 16

Apparent force of the wind (Beaufort scale).	Speed of the vessel, knots.	12: True direction, points off the bow.	12: True force, Beaufort scale.	13: True direction, points off the bow.	13: True force, Beaufort scale.	14: True direction, points off the bow.	14: True force, Beaufort scale.	15: True direction, points off the bow.	15: True force, Beaufort scale.	16: True direction, points off the bow.	16: True force, Beaufort scale.
0	10	15	2	15	2	15	2	16	2	16	2
	15	15	3	16	3	16	3	16	3	16	3
	20	16	4	16	5	16	5	16	5	16	5
1	10	14	3	15	3	15	3	16	3	16	3
	15	15	4	15	4	15	4	16	4	16	4
	20	15	5	15	5	15	5	16	5	16	5
2	10	14	4	14	4	15	4	15	4	16	4
	15	14	5	15	5	15	5	16	5	16	5
	20	15	6	15	6	15	6	16	6	16	6
3	10	14	5	14	5	15	5	15	5	16	5
	15	14	6	14	6	15	6	15	6	16	6
	20	14	7	15	7	15	7	16	7	16	7
4	10	13	6	14	6	15	6	15	6	16	6
	15	14	7	14	7	15	7	15	7	16	7
	20	14	7	14	8	15	8	16	8	16	8
5	10	13	7	14	7	15	7	15	7	16	7
	15	14	7	14	7	15	8	15	8	16	8
	20	14	8	14	8	15	8	15	8	16	8
6	10	13	7	14	7	14	8	15	8	16	8
	15	13	8	14	8	15	8	15	8	16	8
	20	14	8	14	9	14	9	15	9	16	9

TABLE FOR OBTAINING THE TRUE DIRECTION AND FORCE OF THE WIND FROM THE DECK OF A MOVING VESSEL—Continued.

Apparent direction of the wind (points off the bow).

Apparent force of the wind (Beaufort scale).	Speed of the vessel, knots.	0: True direction, points off the bow.	0: True force, Beaufort scale.	1: True direction, points off the bow.	1: True force, Beaufort scale.	2: True direction, points off the bow.	2: True force, Beaufort scale.	3: True direction, points off the bow.	3: True force, Beaufort scale.	4: True direction, points off the bow.	4: True force, Beaufort scale.	5: True direction, points off the bow.	5: True force, Beaufort scale.	6: True direction, points off the bow.	6: True force, Beaufort scale.	7: True direction, points off the bow.	7: True force, Beaufort scale.	8: True direction, points off the bow.	8: True force, Beaufort scale.
7	10	0	5	1	5	3	5	4	6	5	6	6	6	7	7	8	7	9	7
	15	0	4	2	4	3	4	5	5	6	5	7	6	8	6	9	7	10	7
	20	0	3	2	3	4	4	6	4	7	5	8	6	9	7	10	7	11	8
8	10	0	6	1	6	3	7	4	7	5	7	6	7	7	8	8	8	9	8
	15	0	5	2	6	3	6	4	6	6	7	7	7	8	8	9	8	10	8
	20	0	4	2	5	4	5	5	6	6	6	8	7	9	8	9	8	10	9
9	10	0	8	1	8	2	8	4	8	5	8	6	8	7	9	8	9	9	9
	15	0	7	1	7	3	7	4	7	5	8	6	8	8	8	9	9	10	9
	20	0	6	2	6	3	6	5	7	6	7	7	8	8	8	9	8	10	9
10	10	0	9	1	9	2	9	4	9	5	9	6	9	7	10	8	10	9	10
	15	0	8	1	8	3	8	4	8	5	9	6	9	7	9	8	10	9	10
	20	0	7	2	7	3	8	4	8	6	8	7	9	8	9	9	10	10	10
11	10	0	10	1	10	2	10	4	10	5	10	6	10	7	11	8	11	9	11
	15	0	9	1	9	3	9	4	10	5	10	6	10	7	11	8	11	9	11
	20	0	9	1	9	3	9	4	9	5	10	7	10	8	10	9	11	10	11
12	10	0	11	1	11	2	11	3	11	4	11	6	12	7	12	8	12	9	12
	15	0	11	1	11	2	11	4	11	5	11	6	11	7	12	8	12	9	12
	20	0	10	1	10	3	10	4	11	5	11	6	11	7	12	8	12	9	12

Apparent force of the wind (Beaufort scale).	Speed of the vessel, knots.	9: True direction, points off the bow.	9: True force, Beaufort scale.	10: True direction, points off the bow.	10: True force, Beaufort scale.	11: True direction, points off the bow.	11: True force, Beaufort scale.	12: True direction, points off the bow.	12: True force, Beaufort scale.	13: True direction, points off the bow.	13: True force, Beaufort scale.	14: True direction, points off the bow.	14: True force, Beaufort scale.	15: True direction, points off the bow.	15: True force, Beaufort scale.	16: True direction, points off the bow.	16: True force, Beaufort scale.
7	10	10	7	11	8	12	8	13	8	14	8	14	8	15	8	16	8
	15	11	8	12	8	12	8	13	9	14	9	15	9	15	9	16	9
	20	11	8	12	9	13	9	13	9	14	9	15	10	15	10	16	10
8	10	10	8	11	9	12	9	13	9	14	9	14	9	15	9	16	9
	15	11	9	11	9	12	9	13	10	14	10	15	10	15	10	16	10
	20	11	9	12	10	13	10	13	10	14	10	15	10	15	11	16	11
9	10	10	9	11	10	12	10	13	10	13	10	14	10	15	10	16	10
	15	10	10	11	10	12	10	13	10	14	11	14	11	15	11	16	11
	20	11	10	12	10	12	10	13	11	14	11	15	11	15	11	16	11
10	10	10	10	11	11	12	11	13	11	13	11	14	11	15	11	16	11
	15	10	11	11	11	12	11	13	11	14	11	14	11	15	11	16	11
	20	11	11	11	11	12	11	13	12	14	12	15	12	16	12	16	12
11	10	10	11	11	11	12	11	12	12	13	12	14	12	15	12	16	12
	15	10	11	11	12	12	12	13	12	14	12	14	12	15	12	16	12
	20	10	12	11	12	12	12	13	12	14	12	14	12	15	12	16	12
12	10	10	12	11	12	12	12	12	12	13	12	14	12	15	12	16	12
	15	10	12	11	12	12	12	13	12	13	12	14	12	15	12	16	12
	20	10	12	11	12	12	12	13	12	14	12	14	12	15	12	16	12

The following examples will serve to illustrate the manner of using the table:

1. Let the course and speed of the vessel be SSW., 20 knots, the apparent force of the wind, 0 (dead calm). The true direction of the wind is NNE. (16 points off the bow); its true force is 3.

2. Let the course and speed be WSW., 15 knots, and let the apparent wind be NW. (6 points off the bow), force 1; referring to the table we see that the true direction of the wind in this case is 14 points off the bow (NE.) and that its true force is 3.

3. Let the true course and speed be E., 10 knots, the apparent wind SW. (12 points off the bow), force 3. The true direction of the wind is 14 points off the bow (WSW.), the true force is 5.

4. Let the true course and speed be NE., 20 knots, the apparent wind SW. (16 points off the bow), force 6, the true direction is still SW.; the true force, however, is 9.

Extra copies of the above table will be furnished observers upon application.

The pressure of the atmosphere.—The atmosphere which completely envelops the earth may be considered as a sea at the bottom of which we live, and which extends upward from the earth's surface to a considerable height, probably 200 miles or more, constantly diminishing in density as the altitude increases. The pressure of the atmosphere upon any given surface is simply the weight of a column of air above that surface up to the limits of the atmosphere. This pressure differs from place to place and for the same place from hour to hour. The instrument which is employed to measure the atmospheric pressure is called a barometer; various forms are fully described in the paragraphs which follow.

The force and direction of the winds prevailing at any time over any extended region depend very largely upon the distribution of pressure over the region in question. To completely understand the relation between the pressure and the wind it is essential that the former should be accurately known at as many places as possible. Observers should, therefore, use every endeavor to observe the pressure accurately by exercising the greatest care in reading the barometer. They should also, when in port, compare readings of the ship's barometer with readings of the standard barometer at the local Weather Bureau office, or any other recognized standards, as often as opportunity permits.

Specific instructions relative to comparative readings are given on page 34.

Under the conditions met aboard ship the instrumental error of even the very best marine barometer is subject to change, while the ordinary aneroid is hardly to be trusted from day to day.

The hydrostatic principle, by virtue of which the pressure of the air is measured by the ordinary barometer, was first formulated at Florence in 1643 by Torricelli, whose famous experiments demonstrated, not only that the air exerted a very great pressure, but that this pressure changed slightly from day to day.

Torricelli's barometer.—To repeat Torricelli's experiment, fill a clean, dry, preferably warm, glass tube, closed at one end, with pure, dry mercury, so as to carefully exclude all air. The length of the tube must, in general, exceed 30 inches. Close the open end of the tube firmly with the finger tip, and submerge it in an open cup of mercury. Upon removing the finger and causing the tube to stand vertically, a portion of the mercury will pass from the tube into the cup, leaving a space, known as Torricelli's vacuum, in the top of the tube. The column of mercury remaining in the tube is, at sea-level stations, about 30 inches high; the weight of this mercury is sustained by and exactly balances the downward pressure of the air upon the surface of the mercury in the cup. The height of such a mercurial column, therefore, becomes a measure of the pressure of the air, and Torricelli seems to have been the first to discover that the height of such a column varied from day to day.

Pressure of one atmosphere.—Suppose the area of the inside of the barometer tube is just 1 square inch, then a 30-inch barometric column will contain just 30 cubic inches of mercury. Now, 1 cubic inch of mercury weighs 0.4906 pound, which, multiplied by 30, gives the ordinary sea-level pressure of the air to be 14.718 pounds per square inch. This quantity is frequently used by engineers, and is called a pressure of one atmosphere.

This pressure of 14.7 pounds per square inch is, in the main nothing more than the weight of an air column having a sectional area of 1 square inch and extending vertically to the upper limits of the atmosphere. In addition to the weight, pure and simple, however, such influences, as the winds, the rapid heating and cooling in confined layers of air, and other causes, also, modify by small amounts the elastic pressure of the air.

Mercurial barometer for marine use.—Simple mercurial barometers, constructed upon the principle of Torricelli's experiment, are almost universally used on land for the measurement of atmospheric pressure, and no other form of barometer affords as great accuracy in the measurement of that pressure. If, however, such an instrument were placed aboard ship at sea, the column of mercury would surge up and down the tube more or less violently with every motion of the vessel and readings of the air pressure would be rendered inaccurate or impossible.

This difficulty has been quite wholly overcome in a form of instrument known as the Kew, or the marine, barometer. Its distinguishing characteristics consist in substituting for the simple, straight tube of uniform bore, commonly employed in land barometers, a tube having a wide bore for 6 or 8 inches of the upper portion only. Below this the tube has thick walls with a small capillary bore only a few hundredths of an inch in diameter. Near the bottom end, the bore of the tube is again enlarged to form an air trap; all as shown in fig 2. If small quantities of air chance to enter the open end of the tube, they are not likely to enter the small point of the inner tube but lodge instead in the surrounding space, as indicated, where the air must remain and does not affect the barometric readings. It may even be removed from the trap when the barometer is undergoing repairs.

The flow of the mercury through the capillary bore takes place so slowly that the column can not surge up and down the tube seriously with the relatively quick motions of the vessel; at the same time the height of the column adjusts itself to the slow changes of atmospheric pressure, and thus more or less perfectly answers the purpose of a barometer, notwithstanding the disturbing motion of the vessel.

Figure 2 shows a high-grade mecurial barometer adapted to all requirements of marine use, together with a special gimbal-supporting bracket and small wooden box into which the barometer and bracket are folded and thoroughly protected and secured when not in use.

The glass tube and box-wood cistern, all as shown in fig. 2, are secured inside the bronze-metal jacket provided at the top with a long slotted opening through which the top of the glass tube and mercurial column can be seen. A scale of graduations is fixed beside the opening and a short piece of tube with a vernier is arranged to slide up and down the slotted opening so as to enable accurate measurements of the height of the mercurial column to be made, as will be more fully explained presently.

For marine use it is necessary that the barometer be free to hang in a vertical line despite the rolling and pitching of the vessel. For this purpose the well-known arrangement of the gimbal rings is fixed to the outer extremity of a hinged bracket and secured to the barometer at a point some inches above the middle.

In the position shown in the picture the barometer is ready for reading and the tube will swing on the gimbals so as to remain nearly or quite vertical.

After a reading has been taken, the barometer must not be left exposed, as it is very liable to injury by violent oscillations in heavy weather. In the equipment of the standard Weather Bureau design the whole bracket, barometer, and all, is arranged to fold up compactly within the small mahogany case, the lid of which closes with a spring clasp and not only secures the barometer from accidental damage but from atmospheric influences as well.

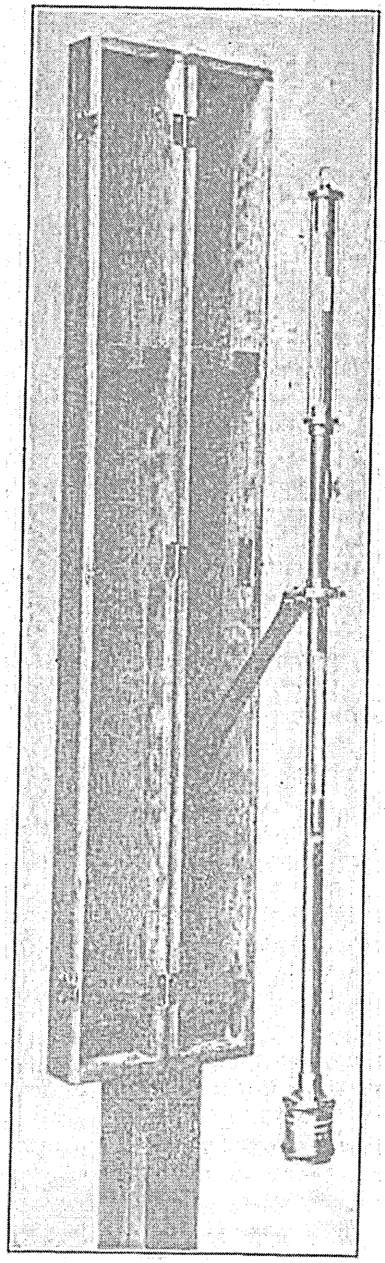


Fig. 2.

The form of mercurial barometer here described is the only one in which reliance can be placed. Numerous other forms of the instrument are manufactured and for sale, of cheap and showy construction and having but little value as true measurers of the atmospheric pressure.

Standard types of both the land and the marine mercurial barometer are found in each of the local offices of the U. S. Weather Bureau, and mariners are urged to visit these offices for the purpose of inspecting and familiarizing themselves with these and other meteorological instruments. Especially is it desired that those contemplating the purchase of instruments visit these stations, in order that they may fully inform themselves of the conditions which reliable instruments should fulfill.

Explanation of scale of marine barometer.—From what has been said in the foregoing it will be understood that the pressure of the air at any time is proportional to the height of the mercurial column above the level of the free surface of mercury in the cistern of such barometers as have been described. Under certain conditions this height at sea level varies from say about 28 inches in rough, stormy weather, to about 31 inches during fair weather. Ordinarily the variations in the barometer from hour to hour, or day to day, are generally only small fractions of an inch, or a few millimeters, and such considerations render it necessary that the barometer be supplied with very accurate means for measuring the height of the mercurial column and its small variations.

All marine barometers are of the fixed-cistern type as it is called, and the only setting required is to bring the vernier column accurately to the level of the top of the mercurial column; whereupon, the scale reading gives directly the observed or uncorrected air pressure. This result is realized by shortening the graduations on the scale so that instead of representing true standard inches or millimeters, as the case may be, the graduations have such a value as to eliminate or take account of the slight rise and fall of the level of the mercury in the cistern as the column falls or rises.

If, for example, the column of mercury in the tube falls say 1 inch, there will be a rise of the mercury in the cistern, but the amount will be small because the area of the cistern is so much greater than that of the tube. For example, in the barometer from which the illustration in fig. 2 was prepared, the rise of the mercury in the cistern for a fall of 1 inch in the tube amounts to only about three hundredths of an inch (0.03). Consequently, in this barometer, an observed fall of 1 inch in the tube means a fall of 1.03 inches in the pressure. If, now, we prepare a special scale for this barometer such that each true inch of space on the scale represents 1.03 inches of the arbitrary scale values, and, if we set this scale so that the barometer reading at any one point of the scale agrees exactly with the reading of a standard barometer alongside of it, then the readings should agree closely at all other points of the scale. Slight irregularities in the bore of the tube and diameter of the cistern may introduce small errors; otherwise, the contracted scale barometer, with settings made only at the top of the mercurial column, is capable of yielding pressure readings of great accuracy, and this artifice is universally employed in the ordinary marine barometer.

Errors of barometers.—No matter how carefully a barometer may be made, certain errors due to various causes can hardly be eliminated. In the first place, if any residual air or vapor or any kind of gaseous matter remains in the top of the barometer tube, the column of mercury will be depressed and not rise as high as it should. We know, likewise, from physical laws, that the capillary forces acting between the free surface of mercury and the glass walls at the top of the column also operate to prevent the mercury from rising as high as it should in the tube. Still other errors arise from faults in the graduation of the scale and from errors in placing it and the vernier at exactly the positions they should occupy.

It is not practicable, or necessary, as a rule, to determine these errors separately. When an instrument is completed, its readings are carefully compared with those of a standard barometer. The differences found in this way represent the outstanding effect of the several sources of error mentioned above and are commonly called the "correction for instrumental error and capillarity."

Still another source of considerable variation in the readings of mercurial barometers is the influence of temperature; a rise of temperature expands both the metal scale and the mercurial column. If both mercury and scale expanded the same amount, no correction would be necessary, but the mercury expands much more than the metal scale, so that a large correction is required, as will be explained more fully on page 29.

Position of the barometer.—If the ship carries a mercurial barometer, it should invariably be employed in the meteorological work of the U. S. Weather Bureau. It should, therefore, be hung in a place which is at all times accessible to the officer charged with the duty of taking the observations.

It should be hung in a position where the temperature is fairly uniform—i. e., at some distance from any steam pipes, stove, lamp, etc.,—where there is a good light, and at such a height from the deck as to conveniently admit of the observer's eye being brought opposite the level of the mercury in the tube. It should also be as far as possible free from the jar of the machinery.

Any simple method of suspension may be employed, as long as it is secure. An excellent device is a stout bracket 10 or 12 inches in length, firmly attached to the bulkhead; at the outer extremity of the bracket is a ring swung on gimbals, in which ring the barometer is clamped at a point one-half of its length from the top. A spiral check spring or a strong rubber band, carried from the grommet at the top of the barometer to the deck above, serves to prevent the cistern from collision with the bulkhead or other object during heavy weather. At the moment of observation it is absolutely essential that the barometer be vertical, as any deviation from the plumb line will result in a reading greater than the truth. During this moment, therefore, and only during this moment, the check spring should be detached, and the tube should be allowed to swing freely from its suspension, not even being steadied by the hand. In order that this interval be as brief as possible, the following method of procedure should be followed:

1. Read and record the temperature of the attached thermometer.
2. Bring the lower edge of the vernier to coincide with the top of the arched surface of the mercury, as nearly as the pumping will permit.
3. As the ship is approaching an even keel, release the check spring from the grommet at the top of the tube; with a touch of the set screw once more bring the edge of the vernier to the top of the mercurial surface, and immediately attach the check spring.
4. Read and record the position of the vernier.

In setting the vernier, the eye of the observer should be brought to the same level as the top of the mercury. A piece of clean white paper placed immediately behind the tube will be found of great assistance in the final adjustment. When observing at night, a bull's-eye lamp should be so held as to throw a strong light on this paper.

The principle of the vernier and the method of reading it.—The vernier is the sliding piece attached to the scale, moving up and down the latter by means of a rack and pinion. By its assistance the barometer may be read with much greater accuracy than without.

The principle of the vernier and the method of reading it will be readily understood from the following diagram, in which *A B* is the fixed scale and *C D* is the movable vernier. The smallest division shown upon the scale is 0.1 inch.[a] A close examination of the left-hand figure will show that ten divisions of the vernier are exactly equal to nine divisions of the scale, or 0.9 inch. Each division of the vernier is therefore equal to one-tenth of this, or to 0.09 inch, and is therefore shorter than a division of the scale by 0.01 inch.

When any graduation of the vernier is exactly opposite a given graduation of the scale, the first preceding graduation of the vernier will thus stand 0.01 inch higher than the corresponding graduation of the scale, the second preceding graduation of the vernier will

[a] In the diagram all dimensions are increased to twice their actual size.

stand 0.02 inch higher than the second preceding scale graduation, and so on, the amount increasing 0.01 inch for each vernier graduation.

Having, by means of the rack and pinion, brought the lower edge of the vernier just flush with the extreme top of the mercury, the first step in the reading is to note what scale division immediately precedes the zero division of the vernier. This will give the inches and tenths. Next, carry the eye upward along the vernier, counting the

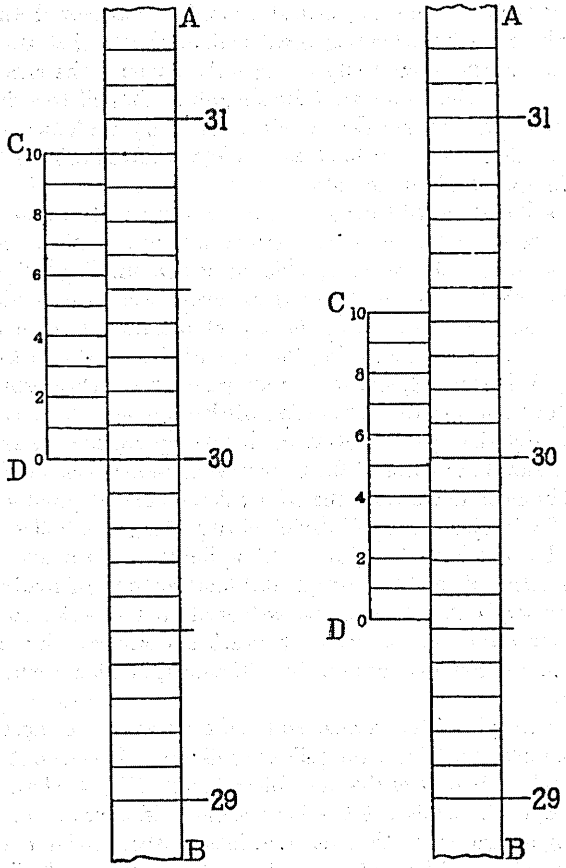


Fig. 3.

successive graduations until that one is reached which is coincident with the opposite scale graduation. This will give the hundredths.

The example given in the right-hand figure, which represents the vernier, set ready for reading, will serve to illustrate this method. The scale division immediately preceding the zero of the vernier is 29.50 inches. Carrying the eye upward along the vernier, we see that the third graduation of the latter exactly coincides with the opposite scale graduation. By the above principle, then, the zero of the vernier is higher than the scale graduation preceding it by three times 0.01 inch, or by 0.03 inch in all. Adding this to the scale reading, 29.50 inches, we obtain for the complete reading 29.53 inches.

	Inches.
Scale reading	29.50
Vernier reading	.03
Height of the mercury	29.53

In recording the height of the mercury always use the full four figures, even though the final is zero. Thus 30 inches should be recorded 30.00.

Correction for temperature.—Other things being equal, the mercury will stand higher in the tube when it and the metal scale are warm than when they are cold, owing to expansion. To eliminate this effect, and for the purpose of comparison, all barometric observations must ultimately be reduced to a standard temperature. The standard universally adopted is the freezing point of water, corresponding to 32° on the Fahrenheit scale and to 0° on the Centigrade and Réaumur scales.

The subchart given on the monthly Pilot Charts shows the normal atmospheric pressure for the month at the standard temperature. A shipmaster desirous of knowing whether the atmospheric pressure at the time and place of observation is above or below the normal—a point of the utmost importance in the Tropics—must therefore reduce the reading of his mercurial barometer to standard temperature before comparing it with the chart. The following table gives the value of this correction for each 2° F.; the plus sign (+) indicates that the correction is to be added to the reading of the ship's barometer, the minus sign (−) indicates that it is to be subtracted:

Temperature. F.	Correction.	Temperature. F.	Correction.	Temperature. F.	Correction.
°	*Inch.*	°	*Inch.*	°	*Inch.*
20	+0.02	48	−0.05	76	−0.13
22	+0.02	50	−0.06	78	−0.13
24	+0.01	52	−0.06	80	−0.14
26	+0.01	54	−0.07	82	−0.14
28	0.00	56	−0.07	84	−0.15
30	0.00	58	−0.08	86	−0.15
32	−0.01	60	−0.09	88	−0.16
34	−0.02	62	−0.09	90	−0.16
36	−0.02	64	−0.09	92	−0.17
38	−0.03	66	−0.10	94	−0.17
40	−0.03	68	−0.10	96	−0.18
42	−0.04	70	−0.11	98	−0.18
44	−0.04	72	−0.12		
46	−0.05	74	−0.12		

As an example, let the observed reading of the mercurial barometer be 29.95 inches, the temperature as given by the attached thermometer 74°; then we have—

	Inches.
Observed height of the mercury..	29.95
Correction for temperature (74°)..	—0.12
Height of the mercury at standard temperature............	29.83

The result should be compared with the subchart, to decide whether the existing atmospheric pressure is above or below the normal.

This correction should never be applied to the entry made in the Weather Report. The height of the mercury and the temperature of the attached thermometer should be entered exactly as read.

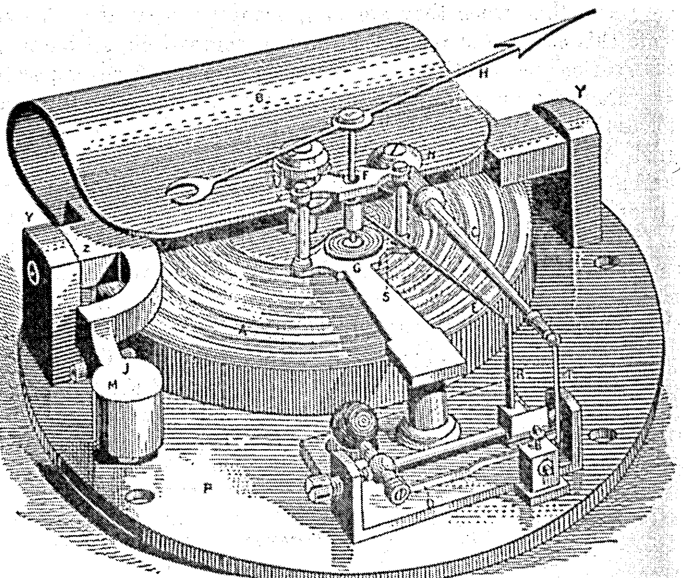


Fig. 4.

The aneroid barometer.—If by pumping we remove the air from the interior of a flat metal box, such as *A* in figure 4, and then hermetically seal the opening by which the air was removed, the pressure of the external atmosphere will cause the upper and lower lids to approach each other, and if these lids are rendered quite flexible, by such corrugations as are shown in the picture, the pressure of the air on the lids will cause them to approach each other to the extent of a complete collapse unless they are kept apart by the application of a suitable spring. By this means any change in the pressure of the air will cause a movement of the lids and spring. The addition of a suitable system of levers will render any motion of the lids and spring apparent to the eye, and we thus have an instrument which indicates changes in the atmospheric pressure, without, however, furnishing us any estimate of the amount of the pressure itself.

It is upon this principle that the aneroid barometer is constructed. *A* is the metallic box, the top and bottom of which are corrugated in concentric circles, and the bottom of which is firmly attached to the plate forming the back of the instrument. *B* is a curved spring whose lower flange, *Z*, is extended into two arms of which the extremities form little trunnions that work in bearings in the two supports *Y*, and whose upper flange is attached at *X* to a stem rising from the center of the corrugated box *A*. The arm *C* is riveted to the upper flange at *N*, and by the system of rigid levers, *T*, *D*, *R*, and *E*, is connected with the chain *S*, the other end of which is coiled around and attached to the stem *F*. This chain is kept taut by the opposing tension of the spiral spring *G*. As the box *A* is compressed by the increasing weight of the atmosphere the upper flange is drawn down, the arm *C* is depressed, and this motion is transmitted by the successive levers *T*, *D*, *R*, and *E* to the chain *S*, which in turn causes the index hand *H* to rotate in a right-handed direction. When the pressure decreases, the box *A* and the spring *B* both relax; the chain *S* slackens, which slack is taken up by the spiral spring *G*, causing the stem and the index hand to rotate in a left-handed direction.

The dial of the instrument is graduated to indicate pressure in inches and fractions and the index hand is adjusted so that the aneroid gives the same pressure reading as an adjacent standard mercurial barometer (corrected for temperature, etc.). This adjustment is effected by means of the screw found in the back of the aneroid, which acts upon the arm *M* and by means of which the spring may be slightly moved upon its trunnions.

All aneroids are more or less affected by temperature, due to the weakening of the steel spring as it becomes warmer. The amount of this effect, however, is irregular and uncertain and must be determined for each instrument. Some aneroids are more or less perfectly compensated for temperature by the arm *C* of two strips of metal, brass and steel, soldered together, the effect of which is to impart to the arm a slight curvature with rising temperature, which corrects the yielding of the spring.

Errors and defects of aneroids in general.—Owing to the uncertainty of temperature corrections for aneroids such corrections are not, as a rule, applied. Violent knocks and shaking will, especially with the common aneroid, almost certainly change or shift the various links and levers in their joints, and change, more or less permanently, the position of the index. For such reasons aneroids are very liable to acquire unknown and often large accidental errors, and can not, therefore, be regarded as very satisfactory instruments.

Errors due to very slow changes, "creeping."—If an aneroid, adjusted to read correctly under ordinary air pressures, is placed within the receiver of an air pump, the index will quickly fall to a lower pressure upon a partial vacuum being formed. If, however, the vacuum be maintained at constantly the same pressure for many days in succession, the reading of the aneroid will be found to gradually become lower and lower, but after three or four weeks further changes cease, or are very small. The amount of this slow change differs greatly, and may be from one-half inch or less to over an inch, according to the diminution of pressure and other circumstances. Again, when the barometer is removed from the air pump it does not immediately return to its original correct reading, but its indications will be found to be too low, several weeks being again consumed in a slow return to approximately its former correct reading.

This "creeping" action depends, no doubt, upon some molecular changes, as yet not clearly understood, that take place within the materials of the aneroid box and steel springs. In any case the readings are liable to be very seriously in error, and tourists and others who carry with them aneroids for the purpose of ascertaining the elevation of summits and places visited, should have means to determine and eliminate the very serious errors referred to above. A further discussion of these errors will be found in the Monthly Weather Review for September, 1898, page 410.

The aneroid barometer is a convenient instrument for showing more or less accurately *the character and the amount of barometric changes* going on from day to day, but the mercurial barometer is the only instrument which gives atmospheric pressures with that degree of precision required in simultaneous meteorological observations.

Test of condition of aneroid.—Aneroids, seemingly good, are often defective, because some of the joints of the levers and pivots are too tight, causing the hand to stick and not move with the perfect freedom it should. The condition of an aneroid can be quickly tested in this respect by tapping the instrument on the side or bottom with the fingers or knuckles, or perhaps better by lifting the instrument about one-fourth of an inch from a table or cane-seated chair and placing it back again somewhat sharply. Under this treatment, if the joints and levers are perfectly free, the hand will jump away from its position and return quickly with a vibratory and quivering movement, returning accurately to its original position. If the instrument is defective, the hand in some cases will not respond to the slight knocks, or will do so without exhibiting any vibratory quivering movement, or upon being disturbed it may move a little, but will not return to its original position.

The case of the aneroid should always be lightly tapped before reading, in order to free the index from any constraint. The direction in which the hand moves under this action will ordinarily show whether the pressure is increasing or diminishing.

Self-recording aneroid.—The self-recording aneroid, shown in figure 5, is a modification of the ordinary aneroid, with the addition of parts by means of which a continuous record of the barometric oscillations are traced from hour to hour upon a sheet of moving paper. It consists of a cylinder, *A*, on which the recording paper is wound, revolving once a week by means of clockwork contained inside. A series of corrugated metallic shells, *B*, eight in number, joined one above the other and exhausted of air, form an aneroid system eight times as sensitive as a single chamber. The movement of the shells

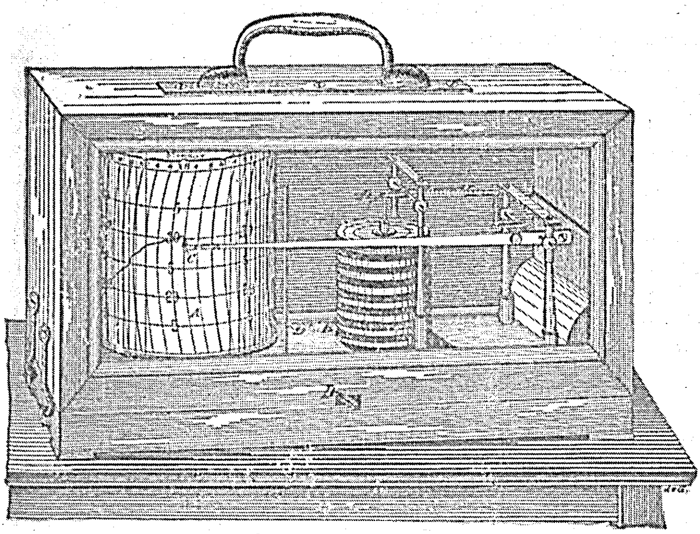


Fig. 5.

is still further greatly magnified and transmitted to the recording pen *C* by a series of connecting levers. The pen may be released from the paper by pushing the lever *D* to the right.

The corrugated shells are the same as used in ordinary aneroids, the steel springs for distending the shells being placed inside. The shells are made into a vertical column by screwing the one on the other. The lower base of the column being fixed, the upper end rises and falls with every variation in the atmospheric pressure by a quantity which is the sum of the displacements of each elementary shell. The instrument is compensated for temperature.

Having wound the record sheet upon the barrel, the pen is brought to the correct day and hour by forcibly twisting the cylinder backward, i. e., against the motion imparted by the clockwork, into the proper position. It is not necessary to twist the sheet around upon the cylinder, nor to lift the latter partly upon its axis. The clockwork should be regulated to keep correct time by means of the regulator within the cylinder, the letters "A" and "R" near the latter signifying "accelerate" and "retard," respectively.

In use aboard ship, the clock should always be set to Greenwich time. Local noon should each day be marked by tapping the box with sufficient force to slightly disturb the index hand.

Recording sheets for use with these instruments, to be returned at the end of the voyage, are furnished by the U. S. Weather Bureau to cooperating observers without cost.

Position of the aneroid.—In selecting a position for the aneroid barometer the same precautions should be exercised as apply to the mercurial barometer.

The instrumental error of the barometer—Comparisons with a standard.—All ordinary barometers, mercurial as well as aneroid, have a certain instrumental error. In a good mercurial barometer this error, although it may be considerable, changes slowly, except in case of accident. In an aneroid barometer it is subject to large and irregular fluctuations.

Owing to the severe usage to which it is exposed aboard ship, the instrumental error of the barometer is especially liable to be disturbed. Observers should therefore, in their own interest, embrace every opportunity of obtaining a comparison of the ship's barometer with a standard.

Aboard steam vessels such a comparison should be made at least once a month and the record promptly forwarded to the U. S. Weather Bureau. Aboard sailing vessels a comparison should be made immediately before each sailing and immediately after each arrival in port.

If an aneroid is employed, no attempt should be made to set the barometer correctly, unless the error exceeds a half inch. Such attempts are likely to increase the irregularities of the instrument. The error should be allowed to accumulate, and should be determined by frequent comparisons.

Methods of obtaining a comparison—United States ports.—At every port in the United States the standard barometer is each day read and recorded by the official U. S. Weather Bureau observer at the local time corresponding to 8 a. m., *seventy-fifth meridian time*—corrected for temperature and reduced to sea level and standard gravity (45°).

In order to obtain a comparison of the ship's barometer with this standard, it is therefore only necessary to observe and record the reading of the former with the temperature of the attached thermometer, at this hour (8 a. m., seventy-fifth meridian time) three days in succession.

During the comparison the barometer should hang in its customary position aboard ship, and the readings should invariably be made and recorded by the ship's officer charged with the duty of taking the meteorological observations.

Blank cards (Form 1202–M.) for recording the observations are furnished by the U. S. Weather Bureau upon application. The style of this card, completely filled out by an observer, is given below:

Form No. 1202-M.

U. S. WEATHER BUREAU BAROMETER COMPARISON CARD.

Nationality. Rig. Name.
Vessel, *Am. S. S. St. Paul.* Captain, *Passow.*
In port of *New York.* Observer, *Church.*
W. B. List Barometer No. *2706.* Mercurial or Aneroid? *Mercurial.*
Address tag to *Pier 15, North River, N. Y.*

INSTRUCTIONS.—*In U. S. and Canadian ports*, read the barometer regularly employed in taking the daily Greenwich mean noon meteorological observations for the U. S. Weather Bureau at 8 a. m., 75th meridian time, on three successive days, and enter the readings, with the temperature of the attached thermometer, in column 1. *In foreign ports*, read at 8 a. m., local time.
In U. S. ports mail this card before you sail; no postage is required; in foreign ports hand to the U. S. consul.

Date. 1905.	Time (local).	1 Ship's barometer (as read off).	Attached thermometer.	2 (Observers will Reduced.	3 leave these col Standard.	4 umns blank. Correction.
October 23	*8 a. m.*	*30.05*	*47*			
" *24*	"	*30.13*	*50*			
" *25*	"	*30.13*	*53*			

Having entered in column 1 the reading of his barometer, along with that of the attached thermometer, at the appointed time for three successive days, the observer will dispatch the card to the nearest local office of the U. S. Weather Bureau. Here the observer's readings are corrected for temperature and reduced to standard gravity (45°), the result being entered in column 2. In column 3 are given the corresponding readings of the standard Weather Bureau barometer, likewise corrected for temperature and reduced to standard gravity, as well as to sea level. The difference between the simultaneous readings of the two barometers is entered in column 4 and the mean of the three values of this difference given by the successive days is adopted as the instrumental error of the ship's barometer. This is at once inscribed upon a barometer tag (Form 1203–M.), along with the official number of the barometer on the Weather Bureau list, and the tag mailed the observer, by whom it should be attached to the barometer.

No other barometer than that bearing the Weather Bureau list number should be employed in the meteorological work of this bureau, and the list number should be stated in each report, barometer comparison card, etc., returned.

Observers will frequently note that the instrumental error of their barometers, as furnished by the U. S. Weather Bureau, will differ by several hundredths of an inch from the error as furnished by other institutions, being, if additive, somewhat greater; and if subtractive, somewhat less. This arises from the fact that the error furnished by the U. S. Weather Bureau includes the reduction to sea level, while the error obtained elsewhere does not, in general, include this reduction.

Comparisons in foreign ports.—At every foreign port of moment daily meteorological observations are maintained, the hour for these observations in a majority of cases being 8 a. m., local time. The record of these observations ultimately reaches the U. S. Weather Bureau. In foreign ports it will then in general suffice to enter upon the card the reading of the ship's barometer at 8 a. m., local time, for three successive days. The card should then be handed to the United States consul for transmission to the United States free of postage.

The necessity for accuracy in reading the barometer, and for frequent comparisons of the ship's barometer with a standard, can not be too strongly impressed upon observers.

Lack of agreement in the observations.—In case any one of three or more individual values of the error differ from the final mean value by as much as six hundredths (0.06) of an inch (=1.5 millimeters) the card is returned to the observer with the statement to the effect that the several observations do not agree sufficiently well among themselves to furnish a reliable correction for the instrument.

The correction for the instrumental error should never be applied to the entry made in the Weather Report. Record the barometer precisely as read.

Temperature.—Mercurial thermometers (wet and dry bulb) of some reliable manufacture should be employed in determining temperature of the air and of the surface of the water. The graduation should be etched upon the glass stem. The ordinary cheap household thermometers are worse than useless.

The thermometers should always, when practicable, be carried to the local office of the U. S. Weather Bureau for comparison with standard instruments. Such comparisons are made without charge.

No thermometer should be employed the indications of which at any point on the scale differ more than 1° from the true temperature as given by the standard.

Temperature of the air.—The dry-bulb thermometer is supposed to give the temperature of the free air.

The wet-bulb thermometer, i. e., an exactly similar thermometer, the bulb of which is surrounded by an envelope of moistened cloth, gives what is known as the *temperature of evaporation*, which is somewhat *less* than the temperature of the free air.

From the difference of these two temperatures we are able to determine the amount of moisture or water vapor present in the air.

With the envelope of the wet bulb removed, the two thermometers should read precisely the same; otherwise their use introduces errors in humidity determinations.

The two thermometers, the wet and the dry bulb, should be hung within a few inches of each other, and the surroundings should be as far as possible identical. In practice, the two thermometers are generally inclosed within a small lattice case, such as that shown in figure 6. The case should be placed in a position on deck remote from any source of artificial heat, sheltered from the direct rays of the sun, and from the rain and spray, but freely exposed to the cir-

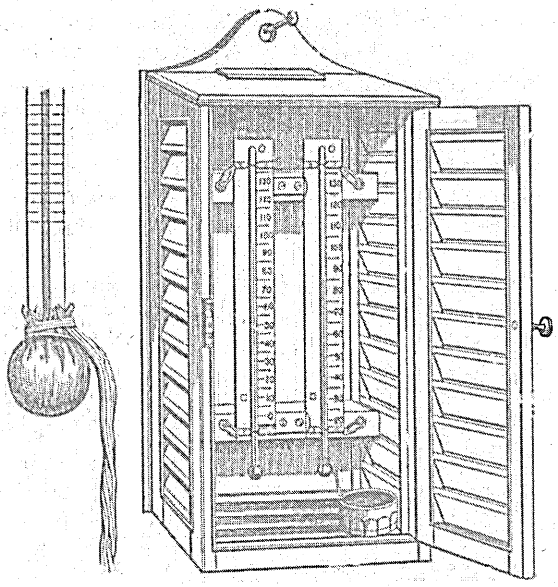


Fig. 6.

culation of the air. The doors should be kept closed except during the progress of the readings and then screened from the direct rays of the sun if necessary. The case should be hung about 5 feet from the deck.

Various forms of wet and dry bulb thermometers, and of the sheltering case, will be found at the local offices of the U. S. Weather Bureau, and observers are requested to inspect them.

The cloth envelope of the wet bulb should be a single thickness of fine muslin, tightly stretched over the bulb, and tied above and below with a fine thread. It should be renewed once a month, as the dirt which gathers on its surface from the atmosphere and from the impurities contained in the water which saturates it hinders the evaporation. The wick which serves to carry the water from the cistern to the bulb should consist of a few threads of lamp cotton, and should be of sufficient length to admit of 2 or 3 inches being coiled in the cistern. The muslin envelope of the wet bulb should be at all times thoroughly moist, but not dripping.

The cistern should be replenished with clean rain water *after* each day's observation, a bottle of the latter being kept for this purpose.

When the temperature of the air falls to 32° F. the water in the wick freezes, the capillary action is at an end, the bulb in consequence soon becomes quite dry, and the thermometer no longer shows the temperature of evaporation. At such times the bulb should be thoroughly soaked with ice-cold water shortly before the hour of observation, using for this purpose a camel's-hair brush or feather; by this process the temperature of the wet bulb is temporarily raised above that of the dry, but only for a brief time, as the water quickly freezes; and inasmuch as evaporation takes place from the surface of the ice thus formed precisely as from the surface of the water, the thermometer will act in the same way as if it had a damp bulb.

In certain cases, for instance during thick, wet fog, or in very cold, calm weather, the wet-bulb thermometer may read slightly higher than the dry. Such cases may be generally attributed to imperfections in the instrument.

Knowing the temperature of the wet and dry bulbs, the relative humidity of the atmosphere at the time of observation may be found from the following table:

Temperature of the air, dry-bulb thermometer.	Difference between dry-bulb and wet-bulb readings.									
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
°	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
24	87	75	62	50	38	26				
26	88	76	65	53	42	30				
28	89	78	67	56	45	34	24			
30	90	79	68	58	48	38	28			
32	90	80	70	61	51	41	32	23		
34	90	81	72	63	53	44	35	27		
36	91	82	73	64	55	47	38	30	22	
38	92	83	75	66	57	50	42	34	26	
40	92	84	76	68	59	52	44	37	30	22
42	92	84	77	69	61	54	47	40	33	26
44	92	85	78	70	63	56	49	43	36	29
46	93	85	79	72	65	58	51	45	38	32
48	93	86	79	73	66	60	53	47	41	35

Temperature of the air, dry-bulb thermometer.	Difference between dry-bulb and wet-bulb readings.									
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
°	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
50	93	87	80	74	67	61	55	49	43	37
52	94	87	81	75	69	63	57	51	46	40
54	94	88	82	76	70	64	59	53	48	42
56	94	88	82	77	71	65	60	55	50	44
58	94	89	83	78	72	67	61	56	51	46
60	94	89	84	78	73	68	63	58	53	48
62	95	89	84	79	74	69	64	59	54	50
64	95	90	85	79	74	70	65	60	56	51
66	95	90	85	80	75	71	66	61	57	53
68	95	90	85	81	76	71	67	63	58	54
70	95	90	86	81	77	72	68	64	60	55
72	95	91	86	82	77	73	69	65	61	57
74	95	91	86	82	78	74	70	66	62	58
76	95	91	87	82	78	74	70	66	63	59
78	96	91	87	83	79	75	71	67	63	60
80	96	92	87	83	79	75	72	68	64	61
82	96	92	88	84	80	76	72	69	65	62
84	96	92	88	84	80	77	73	69	66	63
86	96	92	88	84	81	77	73	70	67	63
88	96	92	88	85	81	77	74	71	67	64
90	96	92	88	85	81	78	74	71	68	65

A mere inspection suffices to understand this table. For instance, if the temperature of the air (dry bulb) be 60°, and the temperature of evaporation (wet bulb) be 56°, the difference being 4°, look in the column headed "Temperature of the air" for 60°, and for the figures on the same row in column headed 4°. Here 78 will be found, which means that the air is 78 per cent saturated with water vapor; i. e., that the amount of water vapor present in the atmosphere is 78 per cent of the total amount that it could carry at the given temperature (60°). This total amount, or saturation, is thus represented by 100, and any increase of the quantity of vapor beyond this point would mean that the excess would be precipitated in the form of liquid water.

Over the ocean's surface the relative humidity is generally about 90 per cent, or even higher in the doldrums; over the land in dry winter weather it may fall as low as 40 per cent

The temperature of the water at the surface.—The water whose temperature is taken should be drawn from a depth of 3 feet below the surface, the bucket in which it is drawn being weighted in order to sink it. The bulb of the thermometer should remain immersed in the water at least three minutes before reading, and the reading should be made with the bulb immersed.

Weather, state of, by symbols.—To designate the weather a system of symbols devised by the late Admiral Beaufort is employed. The system is as follows:

Upper atmosphere	*b.*—blue sky.
	c.—cloudy sky.
	o.—overcast sky.
Lower atmosphere	*v.*—visibility of distant objects.
	z.—hazy.
	m.—misty.
	f.—fog.
Precipitation	*d.*—drizzling.
	p.—passing showers.
	r.—rain.
	s.—snow.
	h.—hail.
	l.—lightning.
	t.—thunder.
	q.—squally.

To indicate greater intensity, underline the letter thus; $\underline{r}$, *heavy rain;* $\underline{\underline{r}}$, *very heavy rain, etc.*

Those symbols should be employed which describe the weather at the actual time of observation; not the average conditions throughout any period.

The information desired is a statement, by symbols, for each of the following particulars at the actual time of observation, using in general a single symbol for each; note that the absence of a symbol is in many cases significant:

1. The clearness of the upper atmosphere (sky).
2. The clearness of the lower atmosphere.
3. The character of the precipitation, if any (rain, snow, hail, etc.).
4. The character of the wind, whether constant in force or squally.
5. The presence of lightning and thunder.

The clearness of the upper atmosphere.—The symbols *b, c, o* (blue sky, cloudy, overcast) refer to the character of the sky at the time of observation.

The symbol *b* implies that the sky is a clear blue, although detached clouds may be abundant—a "fine weather" sky.

The symbol *c* implies that the sky is cloudy, although patches of blue may be apparent.

The symbol *o* implies that the sky is completely overcast, no blue appearing.

In addition to the above always enter under the heading "Daily Journal" a brief statement of the general character of the weather—"very fine weather," "fine weather," "cloudy weather," etc.

The clearness of the lower atmosphere.—The symbols *f, m, z, v* (fog, mist, haze, visibility) refer to the clearness of the lower atmosphere at the time of observation.

The absence of a symbol implies that the atmosphere is of the ordinary clearness.

The symbol *v* implies that distant objects (at sea, the horizon) are more sharply defined than usual, demanding exceptional clearness as well as exceptional steadiness of the lower atmosphere.

The symbols *f*, *m*, *z*[a] imply that distant objects are more or less obscured.

The symbol *f* should be employed when the fog is lying in banks, even though the ship is not actually enveloped at the time of observation. Always enter the occurrence of fog on the page devoted to that purpose at the close of the weather report.

Precipitation.—The symbols *d*, *h*, *p*, *r*, *s* (drizzling, hail, passing showers, rain, snow) refer to the character of the precipitation, if any, at the time of observation.

The absence of a symbol implies that precipitation was not in progress at the time of observation.

Precipitation at other hours should, however, always be entered in the space "Daily Journal," with the time at which it occurred.

The character of the wind.—The symbol *q* refers to the character of the wind and implies that the latter, instead of blowing steadily, is subject to periods of decided increase in intensity (squally).

Absence of a symbol implies that the wind is steady in force.

Lightning and thunder.—The symbols *l* and *t* (lightning and thunder) imply that these phenomena have been perceived within one hour of the actual time of observation.

All other phenomena, such as thunderstorms, squalls, etc., and all previous changes, such as shifts of the wind, lowest and highest barometer, etc., should be noted, with the hour of their occurrence, under the heading "Daily Journal."

Clouds, forms of, by symbols.—In designating the clouds, observers should conform strictly to the international system of nomenclature, which is given in Weather Bureau publication, "Classification of Clouds for the U. S. Weather Bureau." A single copy of this publication will be furnished each observer upon application.

The following remarks are explanatory of the plates:

According to the international system of nomenclature the clouds are classified, first, according to their extent; second, according to their height.

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[a] Fog, mist, and haze are all due to the presence in the air of numberless minute particles of water, which are held in state of suspense in the lower atmosphere, just as the clouds are held in suspense in the upper. The water is in liquid form, as water vapor would be invisible, being quite as transparent as air itself. The clearest air may contain large quantities of water vapor, as shown by the wet and dry bulb.

Haze is sometimes caused by the presence of very fine solid particles, such as that due to desert dust off the west coast of Africa, or to the smoke from the forest fires in the neighborhood of British Columbia.

With regard to their extent, the clouds are divided into two classes:

1. Clouds having separate or detached masses (most frequently seen in dry weather): Cirrus, cirro-cumulus, alto-cumulus, strato-cumulus. (Plates I, III, IV, and VI.)

2. Clouds which are continuous, or completely cover the sky (most frequently seen in wet weather): Cirro-stratus, alto-stratus, nimbus. (Plates II, V, and VII.)

With regard to their height, the clouds are divided into three classes:

1. Upper clouds (average altitude 28,000 feet): Cirrus, cirro-stratus. (Plates I and II.)

2. Intermediate clouds (altitude between 9,000 and 22,000 feet): Cirro-cumulus, alto-cumulus, alto-stratus. (Plates III, IV, and V.)

3. Lower clouds (altitude under 6,000 feet): Strato-cumulus, nimbus. (Plates VI and VII.)

In addition to these, we have a class of clouds formed by the ascent of currents of air, the water vapor contained in the air becoming condensed into minute particles of liquid water, and consequently visible as the air rises to higher levels. These clouds have considerable depth. Their base marks the level at which active condensation begins; their apex the level at which it ceases. They are classified as follows:

1. Cumulus (altitude of the base 4,000 feet; of the apex 6,000 feet). (Plate VIII.)

2. Cumulo-nimbus (altitude of the base 4,000 feet; of the apex 9,000 to 25,000 feet). (Plate IX.)

Stratus is a uniform sheet or layer of opaque cloud, gray in color, and exhibiting but little variety of light and shade. It is a fine-weather cloud, which at times overspreads the whole sky. Average altitude 3,000 feet. (Plate XI.)

Stratus should not be applied to the thin cloud sheets commonly seen near the horizon about sunset. These clouds are really at a great altitude, and should be classed as alto-stratus, or strato-cumulus.

With the exception of the ordinary thundercloud, which should be classed as cumulo-nimbus (Plate IX), any heavy cloud sheet from which rain or snow is actually falling, or threatens to fall, should be called nimbus. (Plate VII.)

The thin, even haze which sometimes overcasts the sky at high levels, below which other clouds may be floating, should be classified as cirrus. Cirro-stratus is applied to layers of distinctly greater density; when heavier and lower still, they become alto-stratus. These clouds are not opaque. If not too dense, the cirro-stratus gives rise to halos, the alto-stratus to coronæ, around the sun and moon; and from this, as well as from their great altitude, they are known to be composed of ice crystals and not of water drops.

Directions from which moving.—The upper clouds serve as an index to the upper currents of the atmosphere, which are always much steadier and at times quite distinct from the lower currents. The direction of this motion and the velocity of the drift are a very important feature in weather changes. Thus observations of the loftiest clouds (cirrus) disclose their rapid movement and almost constant drift from some westerly point, and temporary departures from this direction in temperate latitudes are always associated with some passing cyclonic disturbance.

In estimating the point of the compass from which the clouds proceed, the direction and velocity of the vessel should be taken into account, precisely as in the case of the wind. The direction required is the *true* direction, *not* the magnetic.

In case the motion of the clouds is exceptionally rapid, always so specify.

Amount.—In the scale for the amount of cloud, 0 represents a sky which is cloudless at the time of observation, proceeding by successive steps to 10, a sky which is completely overcast at that time.

The reported "Amount of cloud" should to some extent tally with the symbol used to describe the clearness of the upper atmosphere, the symbol *b* corresponding to a proportion of clouded sky not greater than four-tenths; the symbol *c* to a proportion of clouded sky not less than five-tenths and not greater than eight-tenths; the symbol *o* to a sky that is at least nine-tenths covered. These rules are, however, by no means rigid.

In estimating the form, motion, and amount of cloud, attention should be devoted mainly to the neighborhood of the zenith. Near the horizon all of these features are much distorted by the effects of perspective.

In case the true sky is obscured by fog, mist, or haze, it should be described simply as overcast (*o*) with the amount, 10. The remaining spaces should be left blank.

Sea, state of, by symbols.—The state of the sea is expressed by the following system of symbols:

B.—Broken or irregular sea.
C.—Chopping, short, or cross sea.
G.—Ground swell.
H.—Heavy sea.
L.—Long rolling sea.
M.—Moderate sea or swell.
R.—Rough sea.
S.—Smooth sea.
T.—Tide rips.

The direction given as that from which the sea is coming should be the *true* direction, *not* the magnetic.

Special reports.—At the close of the regular weather report certain extra pages are appended for reports upon special topics. These pages should be used with the greatest freedom.

I. Gale and storm reports.—Upon this page should be entered a summary of every gale encountered during the period covered by the book.

II. Fog reports and fog charts.—Either may be used in recording fog, but the fog chart is preferred. The civil date and local mean time of entering and of emerging from the fog should be given in the fog report, along with the other special information. When the fog occurs in banks, the date and hour of entering and of final clearing should be given, and the word "Banks" added under the heading "Character of fog." Here also state whether the fog is light or dense; wet or dry. In case no fog is encountered during the period covered by the book, a statement should be made to that effect. Negative information is often of as much value as positive.

Instructions for making fog charts.—Enter on the fog charts, using as many charts as required, the data shown in the example:

1. Name of ocean.
2. Latitude and longitude.
3. Line showing course of vessel during voyage.
4. Dot (.) in each one-degree square in which fog was passed through.
5. Lines crossing course to designate each midnight (local mean time).
6. Civil dates.

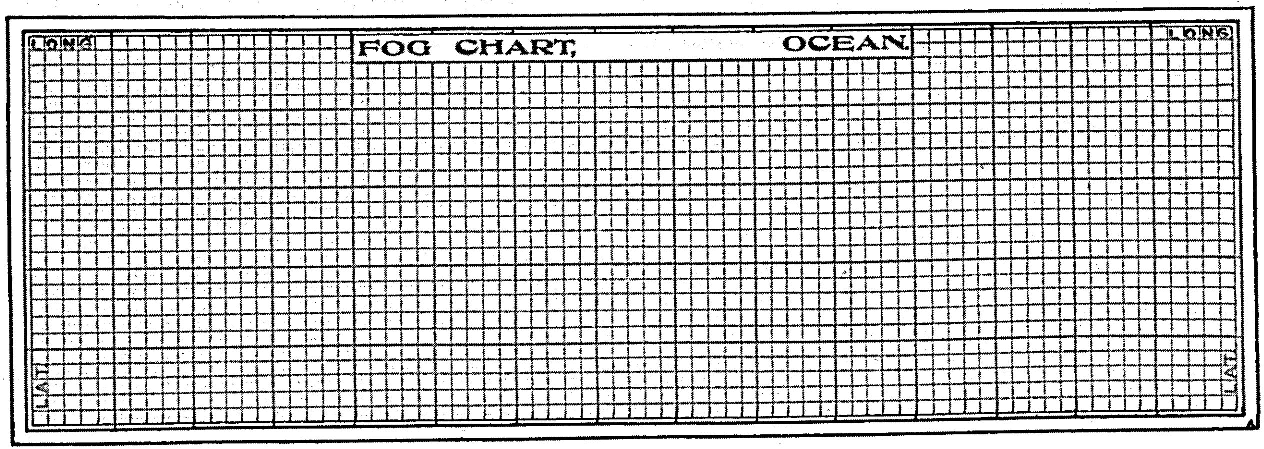
III. Abstract storm log.—During heavy weather, as well as at other times when the various meteorological elements are in a state of rapid change, observations at frequent intervals during the twenty-four hours are desirable. These observations are in all cases in addition to the regular Greenwich mean noon observation.

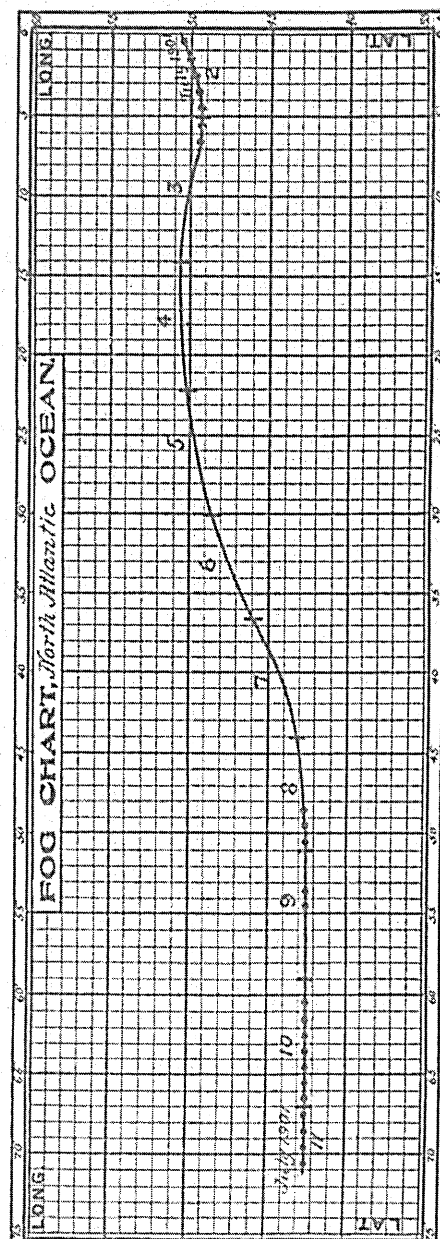
At such times regular observations should be made at the close of each watch, or even more frequently, and these observations should be entered in the pages of the abstract storm log.

In cases where it is impracticable to make a complete series of observations, the true direction and force of the wind, the height of the barometer, and the motion of the clouds should at least be recorded.

The lowest point reached by the barometer, the local mean time at which this occurred, and the shift of the wind accompanying it are of the greatest importance; also the direction in which the wind shifted during the squalls. These observations are absolutely essential for the accurate determination of the path pursued by the storm center.

FOG CHART FOR USE IN RECORDING FOG ENCOUNTERED IN ANY OCEAN AND FOR ANY LATITUDE AND LONGITUDE.





EXAMPLE OF COMPLETED FOG CHART.

Make the report of the storm as complete as possible, copying freely from the ship's log, if necessary. Always state whether or not the vessel was hove-to, and if so, in what manner and for what length of time.

Communications to the Chief of the Weather Bureau.—Requests for blank Weather Reports and other publications of the U. S. Weather Bureau, or for information upon any subject pertaining to meteorology, will receive prompt attention. Observers are requested to make free use of this privilege.

The name of the master and that of the observing officer should be entered in their appropriate place on the front page of the cover. The post-office address to which all communications from the office should be sent should be given on the proper page of each report returned. American addresses are preferred.

TABLES.

EQUIVALENT LENGTHS—MILLIMETERS AND ENGLISH INCHES.

(1 millimeter = 0.0393700 inch.)

MM.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
690	27.16	27.20	27.24	27.28	27.32	27.36	27.40	27.44	27.48	27.52
700	27.56	27.60	27.64	27.68	27.72	27.76	27.80	27.84	27.87	27.91
710	27.95	27.99	28.03	28.07	28.11	28.15	28.19	28.23	28.27	28.31
720	28.35	28.39	28.42	28.46	28.50	28.54	28.58	28.62	28.66	28.70
730	28.74	28.78	28.82	28.86	28.90	28.94	28.98	29.02	29.06	29.09
740	29.13	29.17	29.21	29.25	29.29	29.33	29.37	29.41	29.45	29.49
750	29.53	29.57	29.61	29.65	[a]29.68	29.72	29.76	29.80	29.84	29.88
760	29.92	29.96	30.00	30.04	30.08	30.12	30.16	30.20	30.24	30.28
770	30.32	30.35	30.39	30.43	30.47	30.51	30.55	30.59	30.63	30.67
780	30.71	30.75	30.79	30.83	30.87	30.90	30.94	30.98	31.02	31.06
790	31.10	31.14	31.18	31.22	31.26	31.30	31.34	31.38	31.42	31.46

[a] For example, 754 millimeters = 29.68 inches.

EQUIVALENT TEMPERATURES—CENTIGRADE AND FAHRENHEIT

C° = Temperature Centigrade; F° = Temperature Fahrenheit; $F° = \frac{9}{5}C° + 32°$

C°.	F°.	C°.	F°.	C°.	F°.	C°.	F°.	C°.	F°.
−10	14.0	0	32.0	10	50.0	20	68.0	30	86.0
− 9	15.8	1	33.8	11	51.8	21	69.8	31	87.8
− 8	17.6	2	35.6	12	53.6	22	71.6	32	89.6
− 7	19.4	3	37.4	13	55.4	23	73.4	33	91.4
− 6	21.2	4	39.2	14	57.2	24	75.2	34	93.2
− 5	23.0	5	41.0	15	59.0	25	77.0	35	95.0
− 4	24.8	6	42.8	16	60.8	26	78.8	36	96.8
− 3	26.6	7	44.6	17	62.6	27	80.6	37	98.6
− 2	28.4	8	46.4	18	64.4	28	82.4	38	100.4
− 1	30.2	9	48.2	19	66.2	29	84.2	39	102.2

EQUIVALENT TEMPERATURES—RÉAUMUR AND FAHRENHEIT.

R° = Temperature Réaumur; F° = Temperature Fahrenheit; F° = $\frac{9}{4}$ R° + 32°.

R°.	F°.	R°.	F°.	R°.	F°.	R°.	F°.
−10	9.5	0	32.0	10	54.5	20	77.0
− 9	11.8	1	34.2	11	56.8	21	79.2
− 8	14.0	2	36.5	12	59.0	22	81.5
− 7	16.2	3	38.8	13	61.2	23	83.8
− 6	18.5	4	41.0	14	63.5	24	86.0
− 5	20.8	5	43.2	15	65.8	25	88.2
− 4	23.0	6	45.5	16	68.0	26	90.5
− 3	25.2	7	47.8	17	70.2	27	92.8
− 2	27.5	8	50.0	18	72.5	28	95.0
− 1	29.8	9	52.2	19	74.8	29	97.2

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