U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

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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series of International Simultaneous Meteorological Observations, covering the period 1878–1887, which form in its turn superseded the once well-known Meteorological Journal.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 per 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 absolute 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 condition 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 knowledege 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 per 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 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. Instructions as to the manner of making these comparisons are given elsewhere. 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.

For the convenience of those masters who rarely visit an American port, a limited supply of blanks, etc., is maintained at the U. S. consulate in each of the more important shipping centers abroad.

Having arrived at his destination, the forms containing the observations recorded during the voyage should be inclosed 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 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, or Porto Rico.

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 the post-office address to which all communications should be sent. The inside page of the back cover of the 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 contingent furnished by sailing vessels is of the highest value, as the observations taken aboard the latter are free from certain constant sources of error introduced 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.

A word as to the value of such a series of charts to the navigator. 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 path followed by each of the several barometric depressions that occur during the month, as given on the Pilot Charts of the North Atlantic Ocean, is derived, the aim in thus displaying the daily movement of the storm centers being not only that mariners may have at hand the means of explaining in accordance with the law of storms the occurrence of any heavy weather encountered, but also that by studying this feature of the Pilot Chart, seeing track after track repeat itself with some slight modifications, they may come to know 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 the hope of eventually predicting the weather over the ocean several days in advance rests. 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 supposed to be 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 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, and to record in each form no more than the proper number of observations. 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 before entering upon the actual duty of observing.

Notes on instruments used.—State the kind of barometer, whether aneroid or mercurial, the name of the maker, and the number on the U. S. Weather Bureau list. The name of the maker is in certain cases a guarantee of the instrument.

The same barometer should be employed continuously. The U. S. Weather Bureau preserves the record of the initial error of but one barometer for each vessel. If for any reason it becomes necessary to adopt the readings of another instrument, the fact should be plainly stated, the reasons given, and the second instrument fully described.

Give the initial 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 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 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.

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.

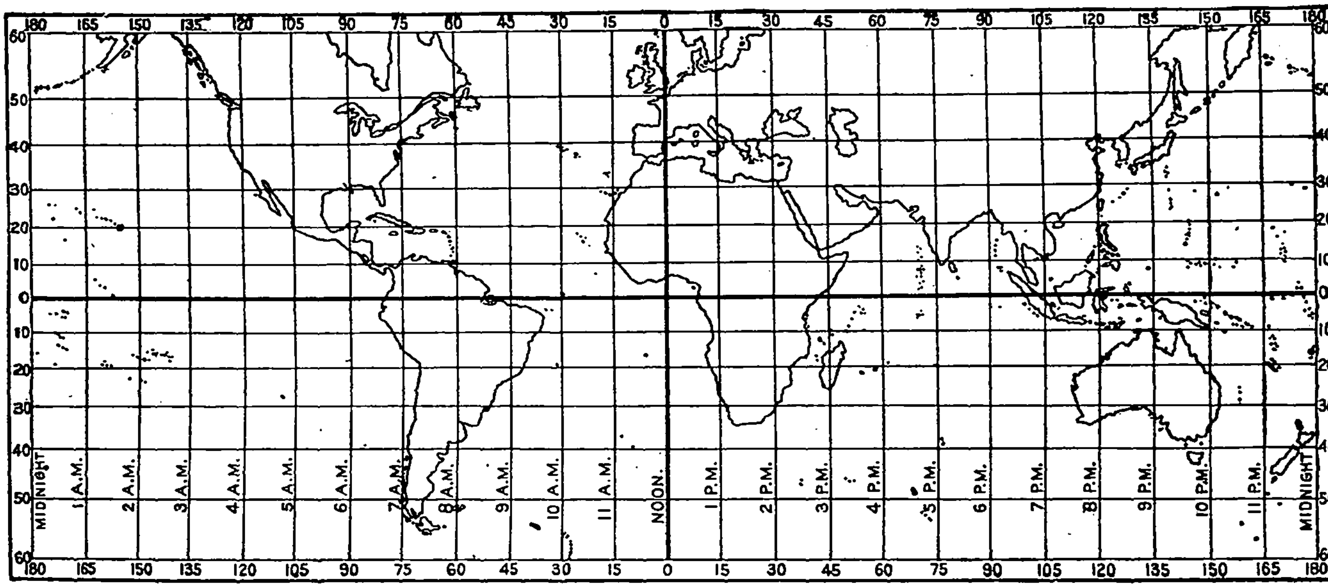
Take a case of a westward-bound vessel making 4° of longitude per day, and suppose the longitude at Greenwich mean noon of April 15 is 178° W. The local date and time of the observation is April 15, 0h. 8m. a. m. The local date and time of the next observation will be 23h. 44m. later than this, or (disregarding the change of date) April 15, 11h. 52m. p. m.; and advancing this date for the change from west to east longitude gives for the true local date and time of the observation April 16, 11h. 52m. p. m.

Again, let the vessel be eastward bound, and suppose the longitude at Greenwich mean noon of April 15 be 178° E. The local date and time of the observation is April 15, 11h. 52m. p. m. The local date and time of the next observation will be 24h. 16m. later than this, or (disregarding the change of date) April 17, 0h. 8m. a. m.; and setting back the date for the change from east to west longitude gives for the true local date and time of the observation April 16, 0h. 8m. a. m.

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.



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

Port or position.—In this column should be entered the position of the vessel at the actual time of the meteorological observation, as determined by account from the nearest noon. 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.

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 "Weather experienced during the twenty-four hours preceding the observation on this page."

TIME OF OBSERVATION, WEST LONGITUDE.

Ship's longitude. (West.)	Ship's time. a. m.	Ship's longitude. (West.)	Ship's time. a. m.	Ship's longitude. (West.)	Ship's time. a. m.	Ship's longitude. (West.)	Ship's 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.)	Ship's time. p. m.	Ship's longitude. (East.)	Ship's time. p. m.	Ship's longitude. (East.)	Ship's time. p. m.	Ship's longitude. (East.)	Ship's 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**	**165**	**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, "Weather experienced." 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 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 closehauled. The scale, with the estimated velocity of the wind in both statute and nautical miles per hour, is as follows:

BEAUFORT'S SCALE.

Force of wind.	Velocity.		Mean pressure in pounds on the square foot.
	Statute miles per hour.	Nautical miles per hour.	
0.—CALM. Full-rigged ship, all sails set, no headway	0 to 3	0 to 2.6	0.08
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	1.0
5.—FRESH BREEZE. All plain sail, "full and by"	28	24.3	2.9
6.—STRONG BREEZE. Topgallantsails 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 pen-

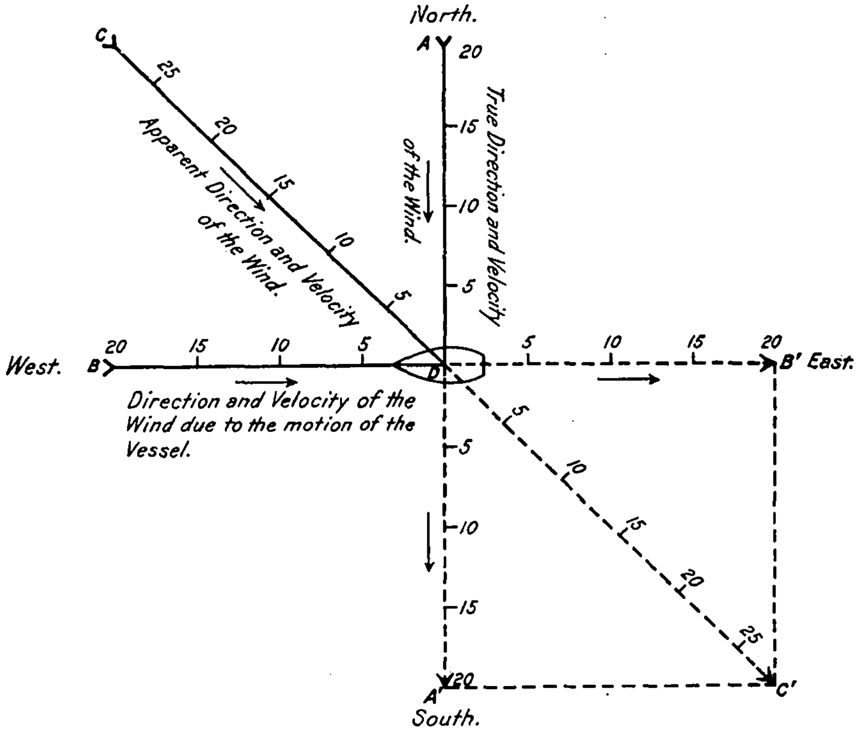


Fig. 1.

nant 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, 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 per 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 per 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 per hour (force 4), will apparently be NW. (4 points off the starboard bow) and will have an apparent velocity of 28 miles per hour (nearly force 6).

The true direction of the wind is thus always further 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).

Apparent force of the wind (Beaufort scale).	Speed of the vessel, knots.	0		1		2		3		4		5		6		7		8	
		True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.
0	10	16	1	16	1	15	1	15	1	15	1	15	1	15	2	15	2	15	2
	15	16	2	16	2	16	2	15	2	15	2	15	2	15	3	15	3	15	3
	20	16	3	16	3	16	3	16	4	15	4	15	4	15	4	15	4	15	4
1	10	16	0	14	0	13	0	12	1	12	1	12	1	12	2	13	2	13	2
	15	16	1	15	1	14	2	14	2	14	2	14	2	14	3	14	3	14	3
	20	16	2	15	2	15	3	15	3	14	3	14	3	14	4	14	4	14	4
2	10	0	0	6	0	7	0	8	1	9	1	10	2	10	2	11	3	12	3
	15	16	0	13	0	12	1	12	1	12	2	12	2	12	3	12	3	13	4
	20	16	1	15	2	14	2	13	2	13	3	13	3	13	4	13	4	13	5
3	10	0	1	3	1	5	1	6	2	8	2	8	2	9	3	10	3	11	4
	15	0	0	8	0	8	1	9	1	10	2	10	3	11	3	11	4	12	4
	20	16	0	13	1	12	1	12	2	12	3	12	3	12	4	12	5	13	5
4	10	0	2	2	2	4	2	6	2	7	3	8	3	9	4	10	4	10	4
	15	0	1	4	1	6	1	7	2	8	3	9	3	10	4	11	5	11	5
	20	——	0	9	0	9	1	10	2	10	3	10	4	11	4	12	5	12	5
5	10	0	3	2	3	3	3	5	3	6	4	7	4	8	5	9	5	10	5
	15	0	2	3	2	5	2	6	3	7	3	8	4	9	5	10	5	11	6
	20	0	0	5	1	7	2	8	3	9	3	10	3	10	5	11	6	12	6
6	10	0	4	2	4	3	4	4	4	6	5	7	5	8	6	9	6	10	6
	15	0	3	2	3	4	3	5	4	7	4	8	5	9	6	10	6	10	7
	20	0	2	3	2	5	2	7	3	8	4	9	5	10	6	10	7	11	7

Apparent force of the wind (Beaufort scale).	Speed of the vessel, knots.	9		10		11		12		13		14		15		16	
		True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.
0	10	15	2	15	2	15	2	15	2	15	2	15	2	16	2	16	2
	15	15	3	15	3	15	3	15	3	16	3	16	3	16	3	16	3
	20	15	4	15	4	15	4	16	4	16	5	16	5	16	5	16	5
1	10	13	2	14	3	14	3	14	3	15	3	15	3	16	3	16	3
	15	14	3	14	4	14	4	15	4	15	4	15	4	16	4	16	4
	20	14	4	15	5	15	5	15	5	15	5	15	5	16	5	16	5
2	10	12	3	13	3	13	4	14	4	14	4	15	4	15	4	16	4
	15	13	4	13	4	14	5	14	5	15	5	15	5	16	5	16	5
	20	14	5	14	5	14	6	15	6	15	6	15	6	16	6	16	6
3	10	12	4	12	4	13	5	14	5	14	5	15	5	15	5	16	5
	15	12	5	13	5	13	6	14	6	14	6	15	6	15	6	16	6
	20	13	6	13	6	14	6	14	7	15	7	15	7	16	7	16	7
4	10	11	5	12	5	13	5	13	6	14	6	15	6	15	6	16	6
	15	12	6	12	6	13	6	14	7	14	7	15	7	15	7	16	7
	20	12	6	13	7	14	7	14	7	14	8	15	8	16	8	16	8
5	10	11	6	12	6	12	6	13	7	14	7	15	7	15	7	16	7
	15	12	6	12	7	13	7	14	7	14	7	15	8	15	8	16	8
	20	12	7	13	7	13	8	14	8	14	8	15	8	15	8	16	8
6	10	11	7	11	7	12	7	13	7	14	7	14	8	15	8	16	8
	15	11	7	12	7	13	8	13	8	14	8	15	8	15	8	16	8
	20	12	7	12	8	13	8	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		1		2		3		4		5		6		7		8	
		True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	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		10		11		12		13		14		15		16	
		True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	True force, Beaufort scale.	True direction, points off the bow.	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 East, 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.

Barometer.—The barometer, whether mercurial or aneroid, is supposed to register the pressure of the atmosphere at the time and place of observation. Upon the distribution of this pressure depend the force and direction of the winds prevailing at the time. To completely understand the relation holding between these two, it is essential that the former should be accurately known at as many points as possible. Observers should, therefore, use every endeavor to insure this accuracy, not only by exercising the greatest care in making the readings, but also by comparing the indications of the barometer used in taking the observations with some standard ashore as often as opportunity presents itself. Under the conditions met aboard ship, the initial 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 pressure of the atmosphere.—The atmosphere which completely envelopes 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 air, or material of which the atmosphere is composed, is a transparent gas, which, like all other gases, is perfectly elastic and highly compressible. It is not a simple or elementary substance, but is made up of a mixture of other transparent gases, the principal of these being nitrogen, oxygen, and water gas, i. e., water in a gaseous form. Each of these exists in the atmosphere independently of the others, and it is quite possible, by proper methods, to separate the several components from one another. Under ordinary circumstances the first two constitute the main volume of the atmosphere, and are always present in the same relative proportion. Compared with these, the quantity of water vapor present is always small, the amount contained in a given volume of air rarely exceeding 3 per cent (by weight) of the total weight of that volume. It is moreover variable, being more abundant when the atmosphere is warm and moist than when it is cold and dry. There is, however, for each condition of temperature and pressure a fixed limit to the quantity of water vapor which the atmosphere can sustain. As soon as this limit is exceeded a portion of the vapor is precipitated in the form of liquid or solid water, appearing as rain, fog, mist, hail, snow, etc.

Although extremely light, the atmosphere has a perfectly definite weight, a cubic foot of air at ordinary pressure and temperature weighing 1.22 ounces, or about one seven hundred and seventieth part of the weight of an equal volume of water. In consequence of this weight it exerts a certain pressure upon the surface of the earth, amounting on the average to 14.7 pounds for each square inch, which is approximately equivalent to 1 ton for each square foot.

The mercurial barometer.—To accurately measure the pressure of the atmosphere, which differs from place to place, and for the same place, from hour to hour, we ordinarily employ a mercurial barometer, an instrument in which the weight of a column of air of given cross section is balanced against and supported by that of a column of mercury of equal cross section. Under these conditions the pressure exerted by the atmosphere is exactly equivalent to that exerted by the mercury; in other words, to the weight of the mercury.

The accurate determination of the weight of such a column of mercury is, however, a problem of some difficulty, and would necessitate that every barometer should be supplied with a delicate weighing apparatus. The accurate determination of its height, to which its weight is exactly proportional, is, on the other hand, a matter of the greatest facility, demanding only a graduated scale extending from the surface of contact of the air and the mercury to the top of the column. In expressing atmospheric pressures we therefore employ the height in lieu of the weight; and in place of saying that the pressure of the atmosphere is a certain number of pounds, ounces, etc., on each square inch, we say that it is a certain number of inches of mercury, meaning thereby that it is equivalent to the downward pressure of a column of mercury that many inches in height. At sea level and in middle latitudes the actual height of this column ranges from 28 to 31 inches.

The ordinary ship's barometer consists simply of such a column of mercury inclosed in a glass tube sealed at the top and open at the bottom. In order to free the tube wholly of air, it is first inverted and completely filled with pure mercury, every precaution being exercised in the course of this operation to prevent the adherence of air bubbles to the walls. The open end being then firmly closed by the tip of the finger, the tube is restored to its upright position, the large end immersed in the mercury contained in the cistern of the barometer, and the finger removed. The level of the mercury in the tube at once falls until the height of the column is such that its downward pressure is just equal to the downward pressure of the atmosphere on the surface of the mercury in the cistern. A scale of inches is then attached, the zero point of which is made to coincide as nearly as possible with the level of the mercury in the cistern, and of sufficient length to extend above the level of the mercury in the tube. Along this scale slides a vernier, a device by means of which the observer is enabled to estimate small fractions of a scale division with greater accuracy than by means of the unaided eye; and the barometer is complete.

Fortin barometer.—The pattern of barometer employed at the various land stations of the U. S. Weather Bureau is shown in figures 2, 3, and 4. In this barometer the glass tube is for the sake of protection incased in a tube of thin metal, through which openings are cut on opposite sides, exposing to view the glass and the upper portion of the mercurial column. The graduated scale, by means of which the height of the column is determined, is laid off along the edge of this opening, and a short tube or sleeve, shown at *C*, figures 1 and 2, carrying the vernier graduation, encircles the barometer tube and slides smoothly within the metal part, motion being given to it by means of the milled head *D* and a small rack and pinion on the inside. At *E*, figure 2, is shown what is called the attached thermometer. The bulb of this is entirely concealed within the metal tube, so as to show as nearly as possible the mean temperature of the brass tube and the mercury.

A difficulty encountered in the use of the mercurial barometer is that the level of the mercury in the cistern is itself variable, rising when the mercury in the tube falls, falling when the latter rises; and inasmuch as the graduated scale must register the exact height of the top of the mercurial column above the level of the mercury in the cistern, some means of restoring this level to the foot of the scale must be provided. In the Fortin barometer, as barometers of the type under description are usually called, this is accomplished by making the bottom of the cistern *N* of flexible leather, supported by an adjusting screw *O*, by means of which the surface of the mercury may be brought into delicate contact with the point *q* of the ivory pin *h*. The point of this pin coincides with the zero of the graduated scale; hence when the surface of the mercury is flush with this point, the scale serves to measure true heights above this

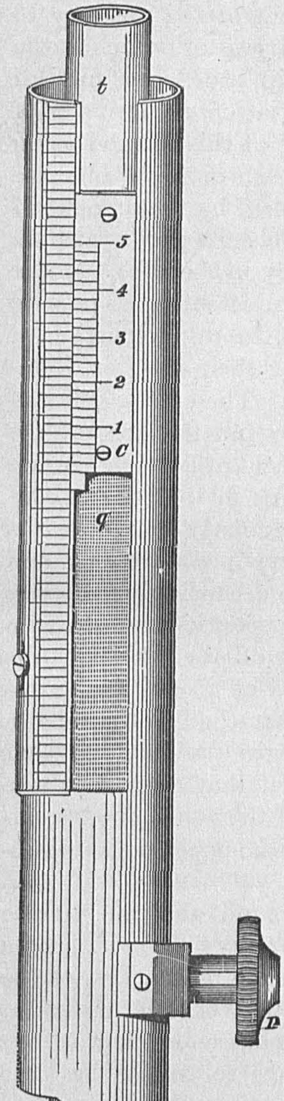


FIG. 2.

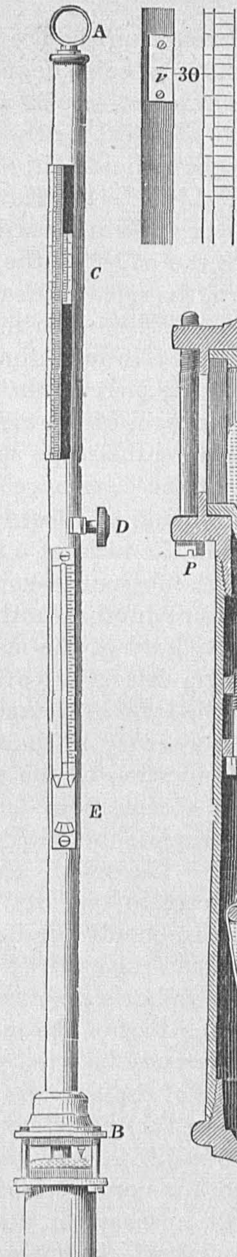


FIG. 3.

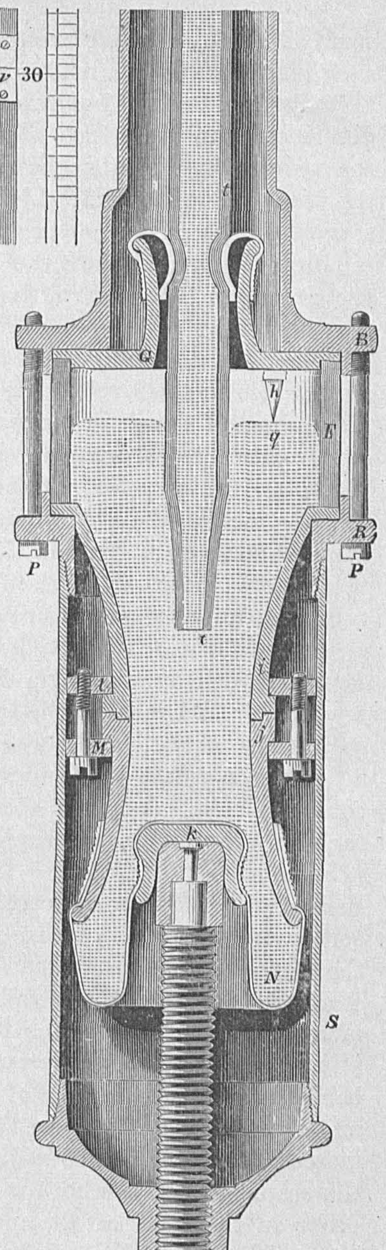


FIG. 4.

Mercurial barometer, with Fortin cistern.

surface. This process of restoring the level must be repeated before each reading, and is a matter of some delicacy.

Kew or marine barometer.—Such a barometer as that just described is unsuited for use at sea, for the reason that the motion of the vessel would render the delicate adjustment of the mercury to the ivory point impracticable. In the Kew barometer, which is the standard type of barometer for use aboard ship, a different method is employed to eliminate the effect of the variation of the level of the mercury in the cistern, the essential feature of this method being the shortening of the scale divisions, so that each division, in place of being a true inch, is in fact an inch diminished by the amount of fall or rise in the level of the mercury in the cistern produced by a rise or fall of 1 inch in the level of the mercury in the tube. In the construction of barometers of this type special attention is paid to the relative dimensions of the cistern and of the upper portion of the barometer tube, these being so chosen that their interior diameters stand to each other in the ratio of 5 to 1. The cross section of the exposed portions of the mercurial surface and the bore of the tube consequently stand to each other in the ratio of 24 to 1. A rise or fall of 0.96 inch in the level of the mercury in the tube is consequently accompanied by a fall or rise of one twenty-fourth of this amount, or 0.04 inch, in the level of the mercury in the cistern; and such a rise or fall of the mercury in the tube accordingly indicates an actual increase or diminution of the atmospheric pressure of a complete inch. In place, therefore, of laying off the scale in units each one of which is a complete inch, it is laid off in units each one of which is but 0.96 inch. The scale is then attached to the tube in such a way that some certain one of the graduations, say that corresponding to 30 inches, stands precisely at that distance above the surface of the mercury in the cistern; and the result is a barometer which gives true atmospheric pressure without previous adjustment of that surface to the foot of the scale.

Another point of difference between the land and the marine barometer is that the tube of the latter is for a portion of its length made with a very fine bore, in order to check the oscillations of the mercurial column which would otherwise occur from the motion of the ship. When the bore is not sufficiently contracted, fluctuations occur in the level of the mercury in the tube to which the term "pumping" is applied, and which at times becomes so pronounced as to render accurate readings a matter of great difficulty.

In well-made barometer tubes there is also inserted at some point between the cistern and the scale portion a small funnel or pipette, such as is shown in figure 5, the object of which is to check the ascent into the vacuum above the mercury of any traces of air or moisture which may by accident enter the tube. These, creeping up along the glass, will naturally lodge at A, as shown. The smallest particle of either air or moisture in the Torricellian vacuum renders the indications of the barometer worthless.

Sometimes, though very rarely, a particle of dirt or a bubble of air lodges in the very fine contraction of the tube of a marine barometer and completely stops the action of the instrument. In case, therefore, a marine barometer becomes stationary or inactive when it evidently ought to be moving under the influence of atmospheric changes, there being no evidence of the fracture of the glass, the cause may be surmised to be of this nature. The instrument should then be dismounted, slowly inverted, and placed aside, cistern end up, for several hours. On replacing it, the cause of the stoppage will generally be found to have been removed to a part of the tube where it can do no harm.

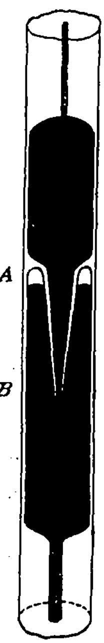


FIG. 5.

The cisterns of all good marine barometers are made of iron and are completely closed, the air gaining access to the surface of the mercury through a tiny aperture which is sealed internally by a piece of leather through which the air can act from without, but which effectually prevents the escape of the mercury from within. Of this the supply is always sufficient to cover the open end of the tube in whatever position the instrument may be placed. The barometer should, however, always be handled with the utmost caution, as the escape of even the smallest quantity of the mercury in the cistern necessitates a readjustment of the zero point. All changes in the position or suspension of the instrument should, moreover, be made with extreme deliberation, as the jar produced by a rapid movement will sometimes give the metallic mercury sufficient force of impact to crack the glass of the tube.

The forms of mercurial barometer here described are the only ones in which reliance can be placed. In addition to these, numerous other forms of the instrument are manufactured and exposed for sale, in general of cheap and showy construction and having but little value as true measures of the atmospheric pressure. In these cistern and scale are ordinarily made of boxwood; no provision is made for the error introduced by the variation of the level of the mercury in the cistern, and the scale errors are frequently considerable. A common fault is that the cistern is not of sufficient size to contain all the mercury which would otherwise enter it from the tube at periods of very low atmospheric pressure. In such exigencies, therefore, the cistern having reached the limit of its capacity, the level of the mercury in the tube becomes stationary, and the instrument by its treacherous indications is converted from a supposed safeguard into a positive menace.

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.

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 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 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 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

*In the diagram all dimensions are increased to twice their actual size.

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

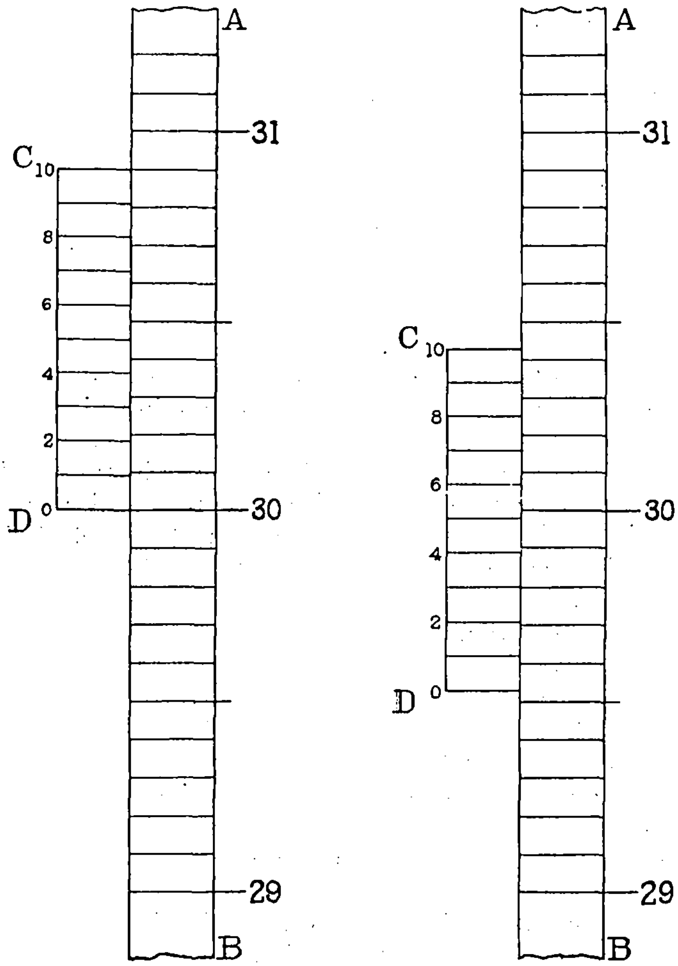


FIG. 6.

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 is warm than when it is 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, 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 (+) showing that the correction is to be added to the reading of the ship's barometer, the minus sign (—) showing 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

and the latter 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.

The aneroid barometer.—If by pumping we remove the air from the interior of a flat metal box, such as *A* in the figure below, 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 unless kept apart by some mechanical means, to finally collapse. If, however, we reenforce the box by properly attaching to one of the lids a spring of sufficient stoutness, this collapse will not occur, but the lid will yield and be distorted by a certain slight amount, which amount will vary with the atmospheric pressure, increasing when this is high, diminishing when it is low. By a suitable system of levers this slight motion of the lid may be rendered apparent to the eye, and we thus have an instrument which sensibly 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

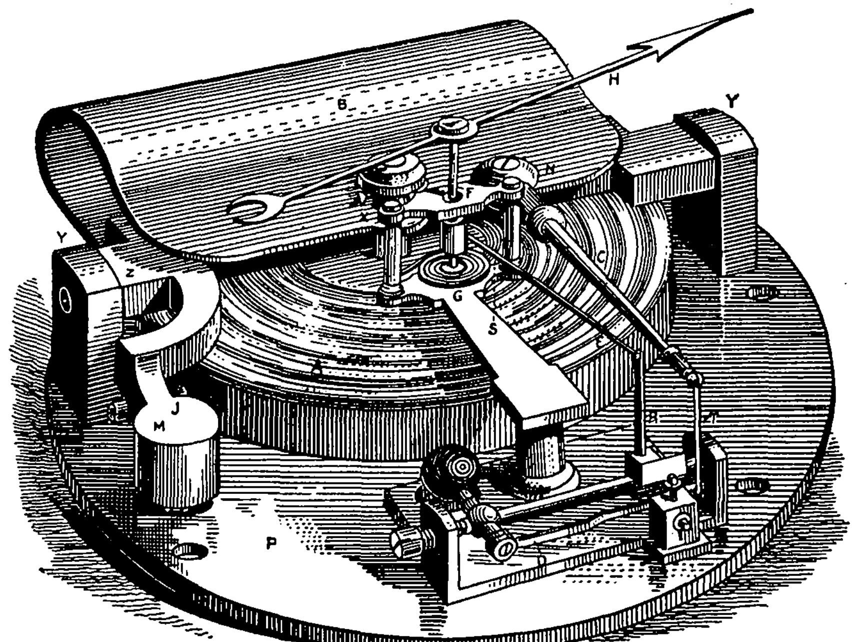


FIG. 7.

whose lower flange, *Z*, is extended into two arms of which the extremities form little trunnious that work in bearings in the two supports *Y*, and whose upper flange is attached at *X* to 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 communicates to the stem F and to the index hand H attached to it, a rotation 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. An arc graduated in inches and hundredths is now attached, and the index hand is by adjustment made to indicate the reading (corrected for temperature, etc.) given by an adjacent standard mercurial barometer. 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.

No temperature correction is necessary in the case of the aneroid barometer, the instrument being always compensated for temperature before leaving the hands of the maker. The necessity for this compensation is due to the fact that the elasticity of the spring B diminishes with rising temperature. It is accomplished by making 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.

The mechanism of the aneroid barometer is delicate, and is liable to derangement, especially by shocks or jars, such as a vessel is bound to undergo while loading. It is also subject to slow deterioration.

Self-recording aneroid.—The self-recording aneroid, shown in figure 8, 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 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 regulating stud 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.

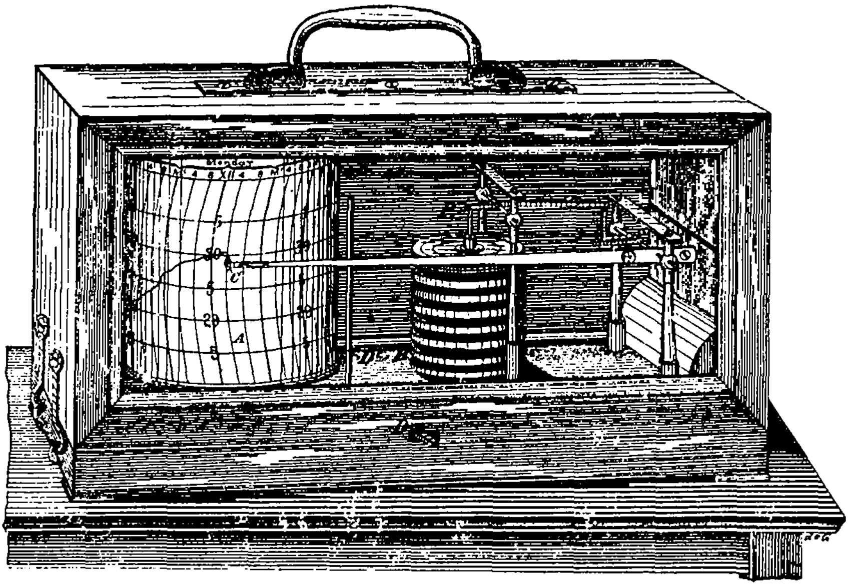


FIG. 8.

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 glass face 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.

The initial error of the barometer—Comparisons with a standard.—All ordinary barometers, mercurial as well as aneroid have a certain initial 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 initial 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 correct, unless the error exceeds a half inch. Such attempts only serve to increase the irregularities of the instrument, and if persistently repeated, will entirely destroy its accuracy. 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.* The height of the mercury as given by this observation, corrected for temperature and reduced to sea level and standard gravity (45°), is published upon the daily weather maps issued by the U. S. Weather Bureau and in the daily newspapers.

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.

12871——3

The list of coast ports at which local offices of the U. S. Weather Bureau are established is as follows:

Portland, Me.
Boston, Mass.
New York, N. Y.
Philadelphia, Pa.
Baltimore, Md.
Norfolk, Va.
Wilmington, N. C.
Charleston, S. C.
Savannah, Ga.
Jacksonville, Fla.
Key West, Fla.
Tampa, Fla.
Pensacola, Fla.
Mobile, Ala.
New Orleans, La.
Galveston, Tex.
Tacoma, Wash.
Seattle, Wash.
Portland, Oreg.
San Francisco, Cal.
San Diego, Cal.
Honolulu.

Blank cards (Form 1202 O. 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 O. 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 meterological 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 Reduced.	3 will leave these col Standard.	4 umns blank.) Correction.
October 23	*8 a. m.*	*30.06*	*47*			
" *24*	"	*30.13*	*50*			
" *25*	"	*30.13*	*58*			

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 initial error of the observer's barometer. This is at once inscribed upon a barometer tag (Form 1203 O. 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. The Bureau preserves the record of but one barometer aboard each observing vessel.

Observers will frequently note that the initial 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.

In case the interval between the date of the report and that of the nearest barometer comparison exceeds three months, the barometric readings given in the report are ordinarily rejected as worthless.

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

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

Before using, the thermometers should always be carried to the local office of the U. S. Weather Bureau, and allowed to remain there for several days for comparison with the 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 always somewhat *less* than the temperature of the free air.

From the difference of these two temperatures we are able to compute the proximity of the air to saturation, i. e., to determine how near the air is to that point at which it will be obliged to precipitate some of its moisture (water vapor) in the form of liquid or solid water.

With the envelope of the wet bulb removed, the two thermometers should read precisely the same; otherwise they are practically useless.

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 the figure. 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 circulation of the air. The doors should be kept closed except during the progress of the readings. 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

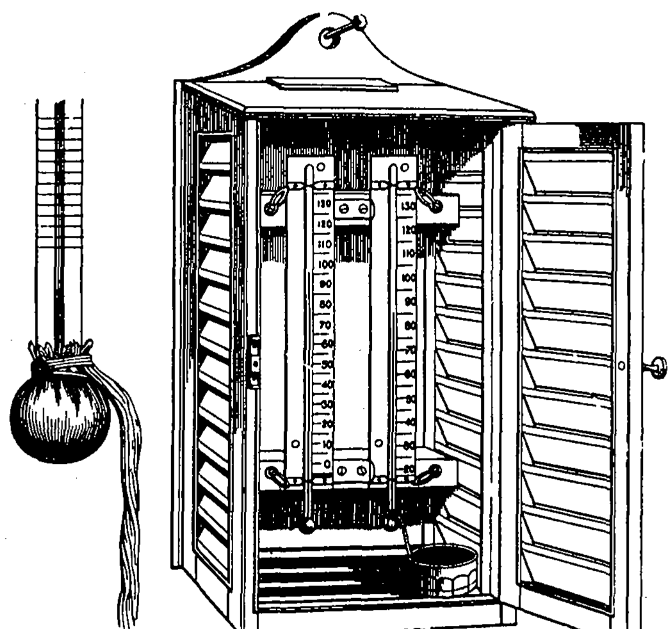


FIG. 9.

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 always 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 cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
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
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 sufficies 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: r, heavy rain; 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 "Weather experienced" 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** 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 "Weather experienced, etc.," 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.

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* 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.

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 "Weather experienced."

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.

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.

Current.—The current given on each page should be that experienced from the ship's noon preceding the observation given on that page to the ship's noon following. The amount of the set should be to the nearest mile; the direction to the nearest compass point (*true*).

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.**—The date and hour of entering and of emerging from the fog should be given, 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.

III. **Ice reports.**—Give the date, time, and position of the ship; the distance, direction, and character of the ice; when many bergs or large fields are sighted, give first and last position.

If no ice is sighted, make an explicit statement to that effect, precisely as in the case of fog.

IV. **Wrecks, derelicts, etc.**—Give date, time, and position of the ship; also a brief description, whether new or old, etc. If a derelict, endeavor to ascertain the name, rig, or at least the nationality.

V. **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 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.

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, sailing and steamship routes, or navigation, 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 inside page of the back cover 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	*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

* *For example*, 754 millimeters = 29.68 inches.

EQUIVALENT TEMPERATURES—CENTIGRADE AND FAHRENHEIT.

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

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; $F^\circ = \frac{9}{4} R^\circ + 32^\circ$.

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

Date, ***December 23, 1900.***

WEATHER REPORT FOR GREENWICH MEAN NOON FOR ONE DAY.

LOCAL MEAN TIME	PORT OR POSITION.		WIND.		BAROMETER.		TEMPERATURE.			WEATHER.
OF WEATHER OBSERVATION.	LATITUDE.	LONGITUDE. (Greenwich.)	TRUE DIRECTION.	FORCE 0–12.	AS READ OFF.	ATT. THER.	AIR, DRY BULB.	AIR, WET BULB.	WATER AT SURFACE.	STATE OF, BY SYMBOLS.
11.00 p. m.	*36 00 N.*	*165 30 E.*	*North.*	*7*	*29.68*	*58*	*54*	*53*	*59*	*o. m. r. q.*

CLOUDS.			SEA.	
FORMS OF, BY SYMBOLS.	MOVING FROM.	AMOUNT, SCALE 0 to 10.	STATE OF, BY SYMBOLS.	TRUE DIRECTION FROM WHICH COMING.
N.	*North.*	*10*	*B.*	*North.*

WEATHER EXPERIENCED DURING THE 24 HOURS PRECEDING THE OBSERVATION ON THIS PAGE:—

Midnight to 9 a. m., b.; wind SSE., 4. 9 a. m. to 2. p. m., c. p.; wind southerly, 6; barometer falling. 2 p. m. to 9 p. m., wind variable, coming out from north, 6, at 9.30 p. m. Glass still falling at time of observation. Clouds scudding rapidly.

Current for the
Day's Run ***18*** *knots.*

Setting toward ***South.***