Henry Tyndall

OFFICIAL No. 8.

BAROMETER MANUAL.

Board of Trade.

COMPILED BY DIRECTION OF THE METEOROLOGICAL COMMITTEE

BY

ROBERT H. SCOTT, M.A., F.R.S.,

DIRECTOR OF THE METEOROLOGICAL OFFICE.

SECOND THOUSAND.

LONDON:
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PREFACE.

THE Board of Trade Barometer Manual compiled by the late Admiral FitzRoy, of which the last edition was published in 1865, being now out of print, the Meteorological Committee have instructed me to re-write the book. This has accordingly been done. The first few pages of the present Manual are an improved reprint of the Fishery Barometer Manual published in 1869. To this has been added a chapter on Weather Telegraphy. I am indebted to the kindness of Capt. Toynbee for the remarks on the use of the Barometer to Seamen. The description of the instruments, which will be found at the end of the book, has been drawn up under my directions by Mr. R. Strachan.

ROBERT H. SCOTT.

Feb. 1871.

CONTENTS.

BAROMETER MANUAL.

METEOROLOGICAL INSTRUMENTS, AND WHAT THEY TELL US.

Introduction. The appearance of a barometer is familiar to most persons, but although the instrument is very commonly used, at sea as well as on land, comparatively few are able to understand much about what it tells us. The general opinion is that the *rise** of level of the mercury USUALLY shows that there will be less wind or rain; its *fall* that more wind or rain may be expected; that when the level remains steadily high a long spell of fine dry weather is probable; while when the level is low the weather will be wet and unsettled, and a sudden change may be looked for.

These conclusions are correct in many cases, but they require modification in many others, for we shall show that there are other matters besides mere barometrical indications to be taken into consideration, so that in some instances the barometer taken by itself is wholly misleading. It is the object of these pages to give the best general rules to be observed in making use of meteorological instruments, and more particularly of the barometer, to aid in forming a judgment as to probable weather. There are three instruments essential to this end, the barometer, the thermometer, and the hygrometer, and we shall commence by giving a short explanation as to their nature and object. A more complete account of the instruments, with some tables of general utility, will be found at a subsequent page.

Briefly we may say that,—

The barometer shows the pressure of the air.

The thermometer (in the shade) shows the temperature of the air.

The hygrometer shows the degree of moisture present in the air, or its dampness.

THE BAROMETER.

Description of a barometer. The barometer, in its simplest form, consists of a glass tube closed at one end, which is filled with pure mercury, and is a little less than three feet long. It is placed, standing upright with the open end downwards, in a cup or cistern partly filled also with mer-

* The rise of level of the mercury is indicated in the case of a wheel barometer by the motion of the hand, from left to right, in the direction of the hands of a watch. The motion of the hand of an aneroid is similar.

cury. If this be done carefully, without allowing any air to get into the tube, the level of the mercury in the tube will sink until it stands at a height of about thirty inches above the surface of the mercury in the cistern.

The space in the tube above the top of the column of mercury is then empty, forming what is called a *vacuum*.

In general terms it may be said that the level of the mercury in the tube rises when the air becomes heavier,* falls when it becomes lighter, and remains at rest when it is unchanged in weight.

Atmospherical pressure. Air like all other substances has weight, and the atmosphere presses on everything at the surface of the earth with a force or weight of nearly fifteen pounds on a square inch of surface. We do not feel this as a burden upon us because the tissues of our bodies allow the air to permeate through them, and so the air in them supports the pressure of that outside them.

Accordingly, we see that the air presses on the surface of the mercury in the cistern of the barometer with a force of about 15 lbs. on the square inch, and consequently it will keep up such a column of mercury in the glass barometer tube, standing in that cistern, as will press on the same surface with an equal downward force. Now, a cubic inch of mercury weighs about half a pound, so that 30 cubic inches weigh about 15 lbs. Accordingly a column of mercury 30 inches in height, in the tube, will press on the surface of the mercury in the cistern with a force of about 15 lbs. on the square inch, or with the same force as the air outside the tube does. Every change which occurs in atmospherical pressure will be shown by the rising or falling of the mercury in the tube.

If the liquid in the barometer were water instead of mercury, the column required to balance the pressure of the atmosphere would be thirteen and a half times higher than the column of mercury, because mercury is thirteen and a half times heavier than water. Water barometers have been made in this way, but they are not so handy or useful as mercurial barometers. However, in making an ordinary pump, use is made of the fact that the pressure of the atmosphere will support a column of water in an empty tube the lower end of which is plunged in water. The sucker draws the air out of the pipe, and the water is forced up out of the well after it by the pressure of the atmosphere on the surface of the water round about the pipe, so that in a good pump, which "holds its charge," the water would, if required, stand at a level of more than 30 feet above the surface of the well below.

Effect of elevation above sea level. It must be remembered that it is only at the level of the sea that the column of mercury in the barometer stands on the average at the height of 30 inches. If the instrument be placed on the top of a hill there will be a lesser thickness of air above it, and if at the bottom of a mine a greater, than there is at sea level; so in the former case the average height of the column will be less and in the latter greater than 30 inches. It is most important to bear

* To speak more correctly, we should say that when the weight of the atmosphere becomes greater, it presses more heavily on the earth's surface.

this in mind, for the difference in the height of the column amounts to more than a tenth of an inch for each hundred feet of elevation above the sea or depression below it.

Motion of the barometer. The barometer is commonly said to be *falling* when the level of the mercury in the tube is sinking, (at which time its surface is frequently slightly concave or hollow,) or when the hand of a wheel barometer or aneroid moves to the left. On the other hand the barometer is said to be *rising* when the level of the mercury in the tube is rising, (at which time its surface is usually convex or rounded,) or when the hand of a wheel barometer or aneroid moves to the right.

Graduation of scale. The scale for reading the barometer is divided into inches and tenths. For yet greater precision a sliding scale called a "vernier" is attached (p. 57). By means of this contrivance readings to hundredths and even thousandths of an inch can be obtained.

Barometrical range. In both Temperate Zones, and therefore in these islands, the mercury at sea level ranges, or rises and falls through a space of about three inches on *extraordinary* occasions, namely, between thirty-one inches (31·0) and twenty-eight inches (28·0) or even a little lower. An uninterrupted fall exceeding an inch and a half (1·5 in.) is very rare in this country. The usual range is from 30·5 in. to about 29·0 in. In the Torrid Zone or near the Equator the mercury usually ranges only through the space of a few tenths, but on *extraordinary* occasions, such as the very severe storms called hurricanes or cyclones, the level sometimes falls as low as 27·0 in.

Attached thermometer. The thermometer attached to a barometer shows the temperature of the mercury within the barometer. The column of mercury in the barometer tube is a trifle longer or shorter according as it is warmer or colder, as will be explained hereafter; it is therefore necessary to allow for the difference in weight of the mercury which this produces when accurate observations of its length are being made.

Barometer reductions. All readings of the barometer intended for comparison with those taken elsewhere should be reduced to what they would have been had the instrument been at sea level, and had the temperature of the column been 32°. Tables for effecting these reductions will be found at pp. 64–69.

Words scale. The words which are generally placed on the scales of barometers are of no value as indications of weather,* for it is not to the mere height of the mercury in a barometer on a particular day that we ought to look in order to judge of the weather, but to the fact of its *rising* or *falling* or *remaining steady*. If having lately stood at *Change* it rises towards *Fair*, it shows that a change of wind or weather is likely to take place; on the contrary, if having stood at *Fair* it then falls, it shows that there will probably be a

* The words referred to are *not* those proposed by Admiral FitzRoy. See page 11.

change of wind or weather, though the level may not reach the point marked *Change*. It must be remembered that the changes of level of the mercury are much greater in winter than in summer, so that the same scale of words cannot suit all seasons. It is also evident that it cannot suit all stations, for if the mercury stands at "*fair*" at the sea level, it may perhaps stand at "*change*" at a station situated at some height above it.

A barometer tells more about wind than about rain.

The barometer, feeling the pressure of the air, shows at once when that pressure is changing in amount. If, owing to any cause, the pressure at one place on the earth's surface be greater than at another, the air has a tendency to move from the place where the pressure is greater towards that where it is less, and thus WIND is caused. Hence we see that the barometer shows pretty accurately when wind may be expected. A change of weather comes almost always with a change of wind, and the extent of this change of weather depends on the fact of the new wind being warmer or colder, damper or drier, than that which has been blowing. Now because landsmen generally, such as farmers and gardeners, care more about rain or snow than about wind, many people have fallen into the habit of looking at the barometer in order to see whether the weather is going to be wet or fine, without thinking from what point the wind is blowing. Used in this way, the instrument will be at least as likely to mislead the person consulting it as to guide him aright. The barometer has but two motions, *rising* and *falling*, by which to indicate all changes of weather; and any conclusions drawn from its movements must be checked by observations of temperature, moisture of the air, present direction and force of wind, and state of the sky, before any correct opinion can be formed as to what may be expected.

Barometer Diagram, Plate IV.

A barometer is nearly as useful to a landsman as to a sailor, as may be seen from these pages, but both must remember that the usefulness of the instrument is much diminished if it be not observed carefully and regularly. If any one takes sufficient interest in the science to note the circumstances attending the various states of weather, and to enter his observations daily on a diagram similar to that given on Plate IV., he will derive great assistance in his study of the weather from a careful examination of the course of the curve from day to day.

Importance of Telegraphic Weather Reports.

It must be clearly understood that it is quite impossible to obtain a precise knowledge of the *general* conditions of the weather by observing a barometer at one station only. For this purpose a knowledge of the state of the barometer at nearly the same time at several neighbouring stations, such as is to be learned from the Daily Telegraphic Weather Reports, is necessary. A manual such as this is intended to show no more than can be learnt by the help of a single barometer, as it is, of course, quite impossible for many observers to gain access to these reports at an hour early enough for them to be able to make practical use of them. We shall return to this subject at a future page.

The Thermometer.

Description of a thermometer.

This instrument shows heat and cold, but does not show the pressure of the air in any way. The air has no access to the fluid in it. A thermometer consists of a long glass tube of very small bore, closed at one end, and having a small glass bulb filled with mercury at the other.* Almost all substances expand when they are heated and contract when they are cooled. Mercury is very much affected in this way, much more so than the glass which contains it, so that when the thermometer is heated the mercury in the bulb expands, and a portion of it is forced into the tube, when the thin thread of mercury in the tube becomes longer; when the instrument is cooled the mercury contracts, and the thin thread becomes shorter, as part of it is drawn back into the bulb. Thus, then, the thermometer shows, by means of the length of the thread of mercury, the temperature of the place where it is at the time. Some remarks as to the proper mode of exposing thermometers so as to give an accurate indication of the temperature will be found at p. 59.

Graduation of a thermometer.

The scale of a thermometer is divided into *degrees*. There are two fixed points on it, viz., that at which ice melts, and that at which water boils. In the thermometer in use in England, namely, that designed by Fahrenheit, the distance between these points on the scale is divided into 180 degrees. The point at which ice melts is 32 degrees, and that at which water boils, when the barometer stands at 30 ins., is 212 degrees. Table IV., p. 74, gives a comparison of the various thermometrical scales in use.

Range of temperature.

The usual range of a thermometer in the shade in the open air is about seventy degrees in England, viz., from 10° to 80°. In very hard frosts the temperature sometimes falls below 10°, and on very hot summer days it rises above 80°. If the sun shines on the instrument the mercury rises much higher. The range of the thermometer is greater in other countries, especially in the United States and Canada, where the winters are much colder and the summers hotter than they are in this country.

The Hygrometer.

Description of hygrometer, or dry and wet bulb thermometers.

This instrument measures the dampness of the air. There are several kinds of hygrometers, but the easiest to make and to manage consists of a pair of thermometers placed near each other and arranged as we are about to describe.

If a thermometer be fitted with a piece of linen fastened tightly round the bulb, and this be kept damp by means of a few threads of darning cotton or lamp wick, passed loosely round the

* Thermometers intended for use in very cold climates are filled with spirit instead of mercury, because, at the very low temperature at which mercury freezes, spirit still remains liquid.

bottom of the stem so as to touch the linen coating, and with their lower ends dipping into a cup of water placed close to the thermometer (see p. 60), it will in general show a temperature lower than that shown by an ordinary thermometer.

A thermometer so mounted is called a *damp* or *wet bulb thermometer*, to distinguish it from an ordinary thermometer which has its bulb *dry*.

Principle of the instrument.

The reason that the wet bulb thermometer reads lower than the dry is that, when the air is not quite saturated with moisture, evaporation takes place from all free water surfaces exposed to it, and continues until the air has received as much moisture as it can contain. The damp coating of the wet bulb will give off vapour like any other water surface, but in order that the water which is on it should be turned into vapour, it requires heat, which it takes partly from the thermometer itself. This action thus causes the thermometer to fall in proportion to the dryness of the air, and the consequent evaporation. The drier the air the greater is this evaporation, and accordingly the difference in readings between the dry and wet bulb is greater in the same proportion. When the atmosphere is very damp or moist, during or just before rain, when fog is prevalent or when dew is forming, the two thermometers read very nearly or quite alike, but at other times the wet bulb reads lower than the dry, and the difference sometimes amounts to ten or fifteen degrees in this climate, and to twenty or even more elsewhere. In winter, the difference between the dry and wet bulb readings is far less than in summer, and the same absolute amount of moisture in the air is indicated by a much smaller difference of reading between the two thermometers in the former season than in the latter.

This will be easily seen from the following example :—

The moisture is usually measured by the pressure or tension of its vapour, and if this tension be 0·288 in.—

When the dry bulb is at	the wet bulb will be at	and the difference
75°	57°	18°
„ 64°	„ 54°	„ 10°
„ 54°	„ 49°	„ 5°
„ 44°	„ 44°	„ 0°

Rules to explain the Indications of the Instruments.

Indications precede changes.

It should always be remembered that changes in weather generally give signs of their coming, for the instruments are affected before the wind actually begins to blow or the rain to fall; thus they may be said to enable us to feel the pulse of the atmosphere. It must not be forgotten that the length of time which passes between the first appearance of a change of weather and its actual setting in is not always the same. It is much greater when a south-west wind is going to succeed a north-east wind than when the opposite change is about to take place. We shall see, a little further on, why this is the case, and also how the

appearance of the sky will aid us in forming an opinion as to probable weather.

The general principles on which the following rules are founded have been laid down by Professor Dove, of Berlin, on the basis of a long series of accurate observations made at several stations situated in the North Temperate Zone between the parallels of 49° and 65°, to which region they specially refer. The rules themselves may be shortly stated thus* :—

The average height of the mercury in the barometer, at sea level, in the British Islands, is about 29·9 ins.

Explanation of Dove's rules.

If the barometer rises steadily above its mean height while the weather gets colder and the air becomes drier, North-westerly, Northerly, North-easterly winds, or less wind, less rain or snow may generally be expected.

On the contrary, if the barometer falls while the weather gets warmer and the air becomes damper, wind and rain may be looked for from the South-east, South, or South-west.

Exceptions to the rules.

The deviations from these general principles which are noticed correspond to the various changes of weather.

If the weather gets warmer while the barometer is high and the wind North-easterly, we may look for a shift of wind to the South. On the other hand, the weather sometimes becomes colder while the wind is South-westerly and the barometer low, and then we may look for a sudden squall or perhaps a storm from the North-west, with a fall of snow if it be winter time.

N.E. winds.

No absolute laws for weather can however be laid down; the most striking exceptions to the rules are those noticed by Admiral FitzRoy. They occur with North-east winds, which sometimes bring rain, sleet, or snow, especially during gales, although the barometer may be high and rising. On the other hand, when the wind is North-easterly and light, and the barometer begins to fall, rain may set in before the wind changes to East or East South-east.

Law of "veering" and "backing" of wind.

Besides these rules for the instruments, there is a rule about the way in which the wind changes, which is very important. It is

* Admiral FitzRoy proposed the following words for barometer scales instead of those referred to at p. 7, they are taken almost exactly from these rules, and have been very generally used :—

RISE FOR	FALL FOR
NORTH	SOUTH
N.W.–N.–E.	S.E.–S.–W.
DRY	WET
OR	OR
LESS	MORE
WIND.	WIND.
EXCEPT WET FROM NORTH.	EXCEPT WET FROM NORTH.

A few short maxims were often added.

Dove's rules and these words will suit the Southern hemisphere if we put S. for N., and N. for S., throughout.

well known to every sailor, and is contained in the following couplet—

> When the wind shifts against the sun,
> Trust it not, for back it will run.

The wind usually shifts *with the sun*, i.e. from left to right* in the Northern Hemisphere. A change in this direction is called *veering*.

Thus an East wind shifts to West through South-east, South, and South-west, and a West wind shifts to East through North-west, North, and North-east.

If the wind shifts the opposite way, viz., from West to South-west, South, and South-east, the change is called *backing*, and it seldom occurs unless when the weather is unsettled.

However, slight changes of wind do not follow this rule exactly; for instance, the wind often shifts from South-west to South and back again.

Winds: polar and equatorial currents.

In most parts of the world it has been observed that there are two prevailing wind-currents, whose directions vary with the circumstances of the place, but are on the whole nearly opposite to each other. In these islands these directions are about North-east and South-west, and the latter of these winds blows for about ten times as many days in the year as the other does. What is it that causes these winds to blow and makes them so different from each other as we know them to be? The simplest account of them is that the air is always flowing towards the equator from the poles and back again. It then forms two great currents; one is called the Polar current—as it flows from the direction of the pole, and is felt here as a North-east wind. The other is called the Equatorial current—as it flows from the direction of the equator, and is felt here as a South-west wind.

The air of the Polar current has been chilled, and is heavy, cold, and dry: while it is blowing, the barometer is high and the weather usually dry.

The air of the Equatorial current has been heated, and is light, warm, and moist: while it is blowing, the barometer is low and the weather usually wet.

If we keep the idea of these two great wind-currents clearly in our heads, we shall easily understand most of the signs of the weather which are noticed.

South-west winds give early notice of their coming.

The air of the equatorial current is lighter than that of the polar, and so southerly winds will begin to blow aloft before they are felt on the ground, while northerly winds will begin to blow close to the ground. Accordingly South-west winds give much more warning of their coming than North-easterly ones. The South-west wind will often show itself first by long streaks of cirrus cloud at a great height, called "mare's tails;" or, when a gale is very near, by driving scud.

* In the Southern Hemisphere motion *with the sun* is, of course, from right to left.

Signs of weather.

Signs of weather, such as those just noticed, are important to any one watching for changes, as they will enable him to confirm or modify the opinions formed from the behaviour of his instruments.

Motion of instruments.

As to the instruments themselves, we have already seen that when the barometer rises, owing to a change of wind, the weather usually becomes colder; while when the barometer falls, owing to change of wind, the weather usually becomes warmer.

Barometer high and steady.

If the barometer be high (above 30·5 inches), and *remain steady* for some days, it is because there is, so to speak, a surplus of air at the place. The wind will be light, and the weather will probably be dry. A gale can set in only when the air flows away, and it will not at first be severe at the place.

Barometer low and steady.

If the barometer be low (below 29·0 inches) and *remain steady*, there is a deficiency of air at the place. The wind will be light also, but the weather will probably be cloudy and wet. However, there may be fine weather for a short time, what is called a "pet day," but there is great danger of a serious storm, because the air will try to force its way into the district where the readings are low, and increase the pressure there, so as to restore the atmospherical equilibrium.

Barometer rising slowly.

If the barometer rises slowly from a low level, the weather may become drier, and the wind lighter, or perhaps die away. There may also be local fogs.

Barometer falling slowly.

If the barometer falls gradually from a high level, the weather may become wetter and more unpleasant, and there will never be a certainty of having a fine day, though there need not be much wind.

In general, whenever the level of the mercury continues steady we may expect settled weather, but when it is unsteady we must look for a change and perhaps a serious gale.

Sudden changes.

A sudden rise of the barometer is very nearly as bad a sign as a sudden fall, because it shows that atmospherical equilibrium is unsteady. In an ordinary gale the wind often blows hardest when the barometer is just beginning to rise, directly after having been very low.

Uncertainty of conclusions based on observations from isolated stations.

It must never be forgotten that it is impossible for any one to interpret the meaning of all the changes in his barometer, at first, or perhaps for a day or two, inasmuch as he requires to learn what is going on at stations in his neighbourhood, for without this information he cannot know whether these changes are due to mere local causes, or are the first symptoms of the approach of a more serious disturbance. A storm may be raging at a comparatively short distance from him, but his barometer, *taken by itself*, will not necessarily enable him to detect its existence. However in many cases a good guess at what is likely to happen may be formed by an experienced observer who watches his instrument closely, records its indications on such a form as shown at Plate IV. and interprets them by the rules provided in this Manual. He will, however, require to call to his aid not only observations of the temperature and of the dampness of the air, but all his experience as to the influence of the several seasons, the ordinary character of the weather at the place, and the local signs of its change.

Daily Weather Reports.

The Daily Weather Reports issued by the Meteorological Office are calculated to render important service to any one who wishes to study weather; they contain observations made daily at 8 a.m. at twenty British and about as many foreign stations.* Great care has been taken to ensure the accuracy of these reports, and the result is that a mass of information of very great value is published every day. The table shows the readings of the barometer, and the dry and wet bulb thermometers, the direction and force of the wind, &c., and from it a very good idea may be gathered of the weather which is actually prevailing on or near our coasts.

This Report is published in the newspapers and is sent by post to coast stations. It is of course impossible that it can reach observers at a distance from London in time to be of any use for the day on which the observations are taken, but a study of the Report of the previous day will often be of very great service to any one seeking to gain a knowledge of probable weather.

Changes of weather usually come from the west.

When we look at these Weather Reports for two or three days together, we find that it is very seldom that a change of weather or a storm is felt along one line of coast, and nowhere else, for more than 24 hours at a time. Generally wet weather begins in Ireland at least a day sooner than it does in England; and as for storms, we need only give as an instance the storm of December 1, 1867, which began on the south coast of Ireland, on the afternoon of the 29th of November, nearly 36 hours before it reached London, or the gales of October 12 and 13, 1870, represented on Plates I. and II. We say *generally*, because some changes of weather travel faster than others, and they do not all of them move from West to East.

Buys Ballot's law.

As regards the use which may be made of these reports a most important principle has been discovered of late years. Professor Buys Ballot, of Utrecht, and others have shown that we can tell with considerable certainty what wind may be expected to blow at any place, if we know the readings of the barometer, taken a short time previously, at a number of stations situated within a distance of, say, 100 or 200 miles from that place.†

The rule is: Stand with your left hand towards the place where the barometrical reading is lowest, and with your right hand towards that where it is highest, and you will have your back to the direction of the wind which will blow during the day.

* A few stations send reports at 2 p.m. also.

† See also "Report of an Inquiry into the Connection between Strong Winds and Barometrical Differences," by Robert H. Scott. Non-official papers, No. 1. Potter, Poultry; and Stanford, Charing Cross.

Thus the wind may be expected to be—

Easterly when the pressure is highest in the North, lowest in the South;
Southerly pressure highest in East, lowest in West;
Westerly ,, ,, South ,, North;
Northerly ,, ,, West ,, East.

The force of the wind on each day bears some proportion to the amount of difference in barometrical readings noticed between any two stations situated near the place where the wind was felt. Thus we find that it has been shown that a Westerly gale hardly ever blows in the British Isles unless, at least a few hours before, the pressure in the North of Scotland is half an inch less in amount than it is on the South coast of England.

We shall return to this subject when dealing with Weather Telegraphy (p. 20). At present it is sufficient for us to say, with reference to the principles above laid down for the behaviour of the instrument, that whenever a storm is blowing, the level of the barometer will be very different at stations near each other, so that as the storm travels across the country, the barometer at any station will show signs of its coming and going by the mercury sinking or rising in the tube. This shows us why it is that when the barometer is steady, there is no great likelihood of a sudden change of weather, while when it is changing quickly, there is great danger of the wind freshening to a gale.

"A few of the more marked signs of weather*—useful alike to " seaman, farmer, and gardener, are the following:—

Colour of sky.

" Whether clear or cloudy—a rosy sky at sunset presages fine " weather:—a sickly, greenish hue, wind and rain; tawny, or " coppery clouds—wind: a dark (or *Indian*) red, rain; a red " sky in the morning bad weather, or much wind (perhaps also " rain):—a grey sky in the morning, fine weather,—a high dawn, " wind:—a low dawn, fair weather."†

" Soft-looking or delicate clouds foretell fine weather, with " moderate or light breezes:—hard edged oily-looking clouds,— " wind. A dark, gloomy blue sky is windy;—but a light, bright " blue sky indicates fine weather. Generally, the *softer* clouds " look, the less wind (but perhaps more rain) may be expected;— " and the harder, more 'greasy,' rolled, tufted, or ragged,—the " stronger the coming wind will prove. Also—a bright yellow " sky at sunset presages wind: a pale yellow, wet: orange or " copper coloured, wind and rain—and thus by the prevalence of " red, yellow, green, grey, or other tints, the coming weather may " be foretold very nearly:—indeed, if aided by instruments, almost " exactly.

* This account of weather signs is extracted from that given by Admiral FitzRoy.

† "A 'high dawn' is when the first indications of daylight are seen above a bank " of clouds. A 'low dawn' is when the day breaks on or near the horizon, the first " streaks of light being very low down."

"Light, delicate, quiet tints or colours, with soft, indefinite
" forms of clouds, indicate and accompany fine weather: but gaudy
" or unusual hues, with hard, definitely outlined clouds, foretell
" rain, and probably strong wind.

Clouds.

" Small inky-looking clouds foretell rain:—light scud clouds
" driving across heavy masses show wind and rain; but, if alone,
" may indicate wind only—proportionate to their motion.

" High *upper* clouds crossing the sun, moon, or stars, in a direc-
" tion different from that of the lower clouds, or the wind then
" felt below,—foretell a change of wind toward *their* direction.*

" After fine clear weather, the first signs, in a sky, of a coming
" change, are usually light streaks, curls, wisps, or mottled patches
" of white distant cloud, which increase and are followed by an
" overcasting of murky vapour that grows into cloudiness. This
" appearance, more or less oily, or watery, as wind or rain will
" prevail, is an infallible sign.

" Usually the higher and more distant such clouds seem to
" be,—the more gradual, but, general, the coming change of
" of weather will prove.

" Misty clouds forming, or hanging on heights, show wind and
" rain coming—if they remain, increase or descend. If they rise,
" or disperse—the weather will improve, or become fine.

Flight of sea-birds.

" When sea birds fly out early, and far to seaward, moderate
" wind and fair weather may be expected. When they hang
" about the land, or over it, sometimes flying inland, strong winds
" with stormy weather are probable. As, besides birds, many
" creatures are affected by the approach of rain or wind: their
" indications should not be slighted by an observer who wishes
" to foresee changes.

Dew.

" Dew is an indication of coming fine weather. Its formation
" never *begins* under an overcast sky, or when there is much
" wind.

Clearness of the air.

" Remarkable clearness of atmosphere, especially near the
" horizon: distant objects, such as hills, unusually visible, or
" well defined; or raised (by refraction)†—and what is called
" 'a good *hearing* day,' may be mentioned among signs of wet,
" if not wind, to be expected, in a short time.

" More than usual twinkling or apparent size of the stars;
" indistinctness or apparent multiplication of the moon's horns;
" haloes; 'wind-dogs,'‡ — and the rainbow; are more or less
" significant of increasing wind, if not approaching rain, with or
" without wind.

* " Between the tropics, or in the regions of the Trade Winds, there is generally
" an upper and counter current of air, with very light clouds, which is not an
" indication of any approaching change. In middle latitudes such upper Currents
" are not so frequent (*or evident?*) except before a change of weather.

† " Much refraction is a sign of easterly wind."

‡ " Fragments or pieces (as it were) of rainbows (sometimes called 'wind-galls')
" seen on detached clouds."

Wind dying down at night.

"Near land, in sheltered harbours, in valleys, or over low
" ground, there is usually a marked diminution of wind and a
" dispersion of clouds during the early part of the night. At
" such times an eye on an overlooking height may see a body of
" vapour extending below (rendered visible by the cooling of
" night) which *seems* to check the wind."

Remarks on Weather.

Weather. A complete change "with the sun."

A few remarks as to the ordinary varieties of weather, and as to storms, based, as before, on the principles laid down by Dove,* may be of use.

Commencing with the usual wind in these islands, the true equatorial current, blowing from the South-west. If the wind shifts from South-west through West to North, the barometer rises and the thermometer falls. While this change is going on we frequently have in winter snow, in spring sleet, and in summer, if the weather be hot, thunder-storms, after which the weather gets cooler. If the wind draws further round through North to North-east, the weather becomes clearer, the barometer high, and the air dry; and in winter there is generally a hard frost. After a frost, as soon as the barometer begins to fall, the wind veers towards East, thin streaks of whitish clouds cover the sky, and the snow which falls comes from the South wind which has set in aloft already. If the barometer falls quickly the snow turns to rain, while the wind veers further through South-east and South to South-west.

Signs of Southerly winds.

The change from a clear sky to a cloudy one almost always begins with the appearance of long streaks of cloud, pointing from S. or S.E. towards N. or N.W., which show the track of the southerly wind in the sky. At night we often see rings (haloes) round the moon when such clouds as these are observed. If they stretch right across the sky, forming what is called a "Noah's Ark," we know that the wind above us has set in in earnest, and that wet weather is sure to follow.

Reason that atmosphere clears before rain.

The probable reason that the air clears and that mountains look near just before rain is that after a long spell of dry weather there is a great deal of dust in the air, and when the air gets damp, as it does just before rain, the moisture settles on the dust and makes it sink, leaving the air clear.

Rainbow.

Our rain comes generally from the West side, so that a clear sunset tends to show that the weather will be fine for a little time, as there are no clouds to the West of us. On the same principle the saying—

A rainbow in the morning
Is the sailor's warning,
A rainbow at night
Is the shepherd's delight.

* See his Law of Storms (London, 1862), p. 300.

may be explained. In the morning the sun is to the East of us, and the rain which occasions the rainbow must be falling to the Westward, and therefore likely to come over us. In the evening, if we see a rainbow it must be in the East, and the sky must be clear in the West.

Sky clearing at night not a certain sign of fine weather.

However, after a wet day the whole of the sky often clears at night. This is not a certain sign of fine weather. The clouds may, and often do, form just as heavily after sunrise next morning.

Thunder-storms.

Thunderstorms almost always occur when the weather is hot for the season: they are generally caused by a cold wind coming over a place where the air is much heated. They do not cool the air: it is the wind which brings them which makes the weather cooler. Thunderstorms are more violent the greater is the difference of temperature between the two currents of wind which produce them: they are most frequent in these islands in summer, but are also very common in stormy weather in autumn on our West and North coasts.

Sudden rise of barometer, with fog, dangerous.

If in winter the barometer suddenly rises very high, and a thick fog sets in, it is a sure sign that the S.W. and the N.E. winds are, as sailors say, fighting each other. Neither of them can make head against the other, and there is a calm, but there is great danger of such a state of things being followed by a bad gale. Thus the storm of December 1, 1867, before referred to, was preceded by a very high pressure with a great deal of fog, at the entrance of the English channel, where the gale first began.

Storms.

The changes shown by the instruments in stormy weather are like those just described, but they take place more quickly and are greater when they come.

The storms which are felt on our coasts are generally South-westerly, during which the wind may blow from any point between South-east, round by South, to West and West-north-west.

South-west gales.

In winter, after a prevalence of Easterly winds, if the barometer begins to fall, and the thermometer to rise, the sky being densely clouded, a gale which commences to blow from South-east will veer to South-west, while the barometer falls constantly. As soon as the wind passes the South-west point, the barometer begins to rise, the thermometer falls suddenly, a heavy shower of rain falls, and a strong West-north-west or North-west wind may follow, with a clear sky.

Wind backing.

If the wind "backs" from North-west towards West and South-west, the bad weather is very likely to continue.

Most of these gales are felt first on the west coast of Ireland, and later at stations lying to the eastward. Accordingly, if the change of direction of the wind takes place rapidly, the storm may be blowing from North-west on the coast of Ireland, while it is only beginning to blow from South or South-south-east on the east coast of England. See Plates I. and II.

Such gales are very violent, and being produced by a South-west (equatorial) current which is apparently forcing its way against a North-east (polar) current, the changes of pressure and temperature are very rapid, and the storms are often accompanied by thunder and lightning.

North-easterly storms.

North-easterly storms are not so common as those from the South-west. They are very dangerous on the east coast of Great Britain, as they do not give so much local warning of their approach as South-west gales (see page 12.)

The weather generally becomes much colder before they begin to blow.

These (North-east) polar storms do not "veer" to the same extent as the (South-west) equatorial winds: they seldom change their direction more than 2 or 3 points, while a shift of wind *with the sun* through 6 or 7 points is very common in the case of South-west storms.

WEATHER TELEGRAPHY.

The object of the foregoing pages has been to provide rules for the guidance of those who have no access to any sources of information respecting weather beyond the observation of their own instruments and of natural phenomena. The recent development of the system of Meteorological Telegraphy, in the introduction of which this country and France have taken so prominent a part, has, however, thrown a totally new light on the science of our weather and its changes, so that a few remarks on this subject will scarcely be out of place here.

Buys Ballot's Law. The facilities afforded us, by means of telegraphy, for comparing observations taken simultaneously at several stations have revealed to us the existence of great differences, even between adjacent stations, as regards the instrumental readings and the actual phenomena observed, under various conditions of weather.

In seeking to assign causes for these differences, we have been greatly assisted by applying the principle to which allusion has already been made at p. 14 under the name of Buys Ballot's Law.

The immediate result of the law is to show that whenever barometrical readings are lower over any area than over those adjacent to it, the air will sweep round that area as a centre, and the direction of its motion will be opposite to that of the hands of a watch.* Conversely the air will sweep round an area of relatively high barometrical readings in the direction in which the hands of a watch move. The former of these motions is said to be *cyclonic*, the latter *anticyclonic*. These names are derived from the word "cyclone," the general name for hurricanes and typhoons, in all which storms the motion of the air takes place around an area of diminished barometrical pressure.

We see therefore that the existence of a deficiency of atmospherical pressure, or what is termed a barometrical depression, over any district, is accompanied by cyclonical movement in the air in the neighbouring districts. The actual movement of the air has no reference either in direction or velocity to the absolute readings of the barometer at the point where it is lowest, or to the distance of the particles of air which are in motion from that point, but is related almost entirely to the distribution of pressure in accordance with Buys Ballot's Law.

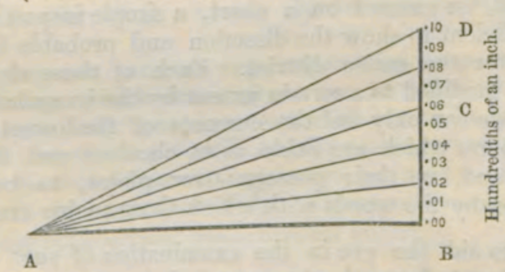
* These remarks have reference to the Northern Hemisphere. In South latitude the direction of rotation of the wind in cyclonic or anticyclonic motions respectively is exactly reversed.

The law gives the direction of motion, and its truth for these islands and the adjacent parts of the earth's surface is incontestable; it appears moreover to hold good generally.

Barometrical gradients. The velocity of the air depends, at least in a great measure, though not absolutely, on the difference of barometrical readings over a given distance, or on what is termed the barometrical "gradient."

The gradients adopted by the Meteorological Office are expressed in hundredths of an inch of mercury per fifty geographical miles.*

In the accompanying figure the horizontal distance between the two stations A and B is supposed to be 50 geographical miles. The divisions on the vertical line B D are hundredths of an inch, and they correspond to the differences between the barometrical readings taken at the same hour at the two stations. The gradients are the ratios between the intercepts B C, B D, &c., and the line A B which is supposed to be = 1. The gradients are given as 6 for the angle B A C, 10 for the angle B A D, corresponding to the several observed differences. These lines A C, A D, &c., are imagined to be drawn every morning, between the most important stations given in the Daily Weather Report,† and from their inclination conclusions as to the probable direction and force of the wind for the day are drawn. It is found, for instance, that the force of the wind will not exceed the figure 5 or 6, a fresh breeze, on Beaufort's Scale, unless the gradient be as high as 6 (A C on the diagram).



Example. To reduce this statement to a practical form, we may put it in these words. The distance from Penzance to Brest is 113 geographical miles. A gradient of 6 between these stations represents a difference in barometrical readings of 0·14 in., so that, in accordance with what has just been said, whenever a westerly gale is blowing at the entrance of the Channel we may expect that the barometer at Penzance will be at least 0·14 in. lower than that at Brest; *vice versâ*, the readings at Brest will be proportionably lower than those at Penzance, whenever an easterly gale is felt in the district in question. An instance in point is the gale

* This is nearly exactly equivalent to a quarter of a millimètre per fifty geographical miles.

† A table for the calculation of gradients will be found in the Quarterly Weather Report for 1869.

Westerly gale. of the 8th of January 1870, during which the reading at Brest at 8 a.m. was 29·38, and that at Penzance, at the same hour, was 29·19. The difference between these readings is 0·19, and the resulting gradient 8. The actual winds reported that morning were West-South-West 9 from Brest, South-West 10 from Penzance, and West 11 from Plymouth. The converse conditions, accompanying an easterly gale, were observed on the 14th of May 1869, when the reading at Penzance was 29·92 and that at Brest 29·68. The resulting gradient is 10, and accordingly heavy easterly gales were felt on our channel coast.

Easterly gale.

Conclusions from the foregoing.

To apply the same principles to the weather of the British Islands generally, it may safely be asserted that no storm of any serious extent is ever felt over the United Kingdom unless there be an absolute difference in barometrical readings exceeding half an inch of mercury between two of our stations.*

The difference in readings between Rochefort and Aberdeen on the 1st of February 1868, when a tremendous westerly gale was raging, was as much as 1·76 in. The reading at Rochefort being 30·16, and that at Aberdeen 28·40 ins. These figures give a gradient of 13·5 over the entire distance of 673 miles, and we find that gales were reported from 16 stations that morning.

Synoptic charts.

If, then, simultaneous barometrical readings for any considerable tract of country such as that represented in the Daily Weather Reports, which embraces these islands and the adjacent coasts of the continent, be entered on a chart, a simple inspection of that chart is sufficient to show the direction and probable force of the winds felt over the entire district. Each of these elements will, however, be modified to a certain extent by the irregularities of the surface, for we can only feel the currents of the lowest stratum of the atmosphere, which are liable to be checked and deflected by mountains, and, in their passage over plains, to be seriously retarded even by the woods with which those plains are covered.

Isobaric lines.

In order to aid the eye in the examination of such charts, the different points where the barometrical readings are equal are joined, and the lines so drawn are called Isobarometrical, or, for brevity, Isobaric Lines.

Whenever on such a chart we find the Isobaric Lines closely packed, we know that the wind will be strong, for their closeness indicates that the gradients are high in that part of the map.

Specimens of such charts for two consecutive days, Oct. 12 and 13, 1870, are given (Plates I. and II.), and they will be amply sufficient to illustrate the foregoing statements.

On these charts the barometrical and thermometrical readings are given, and the wind is represented by arrows flying with it; the force, Beaufort Scale, is represented by the number of feathers.

* Local storms, which occasionally do great damage, may be felt when the barometrical disturbance is itself only local, and when the actual amount of difference between the extreme readings is less than half an inch, although the gradients for a short distance may be high.

We see from these charts that the motion of the air is regulated by the shape and contour of the area of depression. The wind cannot blow with equal force all round the point or the district where the barometrical readings are lowest, unless the isobaric lines form concentric circles, or rather are parallel to each other throughout their course. This latter condition is never completely fulfilled, and consequently a cyclone, properly so called,* is perhaps never felt in these islands. All the winds are nearly coincident with the isobaric curves, and as their force is approximatively proportional to the gradients we see that—

High gradients on the N. side of the area of depression indicate Easterly gales,

"	E.	"	Southerly "
"	S.	"	Westerly "
"	W.	"	Northerly "

and so on for the intermediate points of the compass.

Buys Ballot's Law, then, shows us what winds are blowing at any epoch for which the barometrical readings are known; and it has further been shown in the Report (Non-official Papers, No. I.) referred to at p. 14, that if we make certain allowances for the "veering" of wind and for the translation of conditions of weather over the earth's surface, we can, under ordinary circumstances, form a fair judgment as to the wind which *will* blow at each station during any day for which we know the distribution of pressure, say at 8 a.m.

The law does not give us any information respecting the disturbing agencies which have given rise to those winds. Even though we can admit that these agencies are to be looked for in the unequal and varying distribution of barometrical pressure, we have made no real advance, for we are not as yet able to assign causes for all the barometrical fluctuations observed, at least not with anything approaching mathematical accuracy.

Relation of the motion of the air to the average distribution of pressure.

The great currents of the atmosphere, already referred to under the names of Equatorial and Polar, are as closely dependent on the distribution of pressure as the motion of the air in a storm. Thus we have already said that South-west winds are much more common in these islands than North-east winds. If this be true, we should expect to find the mean level of the barometer in Iceland to be lower than it is in these islands. This is really the

* The *strict* definition of a cyclone is a mass of air sweeping in a circular path round a limited district where there is no wind at all. The diameter of this calm district is comparatively small, and the barometrical reading over it is much lower than at the outside of the storm; the difference at times amounting to two inches. The gradients in such a storm are very steep and are uniform all round the centre, so that the force of the wind from all points of the compass is equal. As a rule the violence of the storm increases as you approach the central calm. It is stated by some authors that the air in cyclones moves in a spiral course, tending to flow in towards the centre and rise there. No satisfactory *proof* has as yet been given of this statement.

case, for while the mean annual pressure at Stykkisholm is 29·634 in., and at Sandwick in the Orkneys 29·791, it is 29·958 at Greenwich. Again, the general prevalence of South-westerly winds in the United Kingdom is not unusually interrupted by Easterly winds in the end of spring; and we find that in May the mean pressure at Stykkisholm is 29·886, at Sandwick 29·924, and at Greenwich 29·966. The mean northern pressures are still lower than the southern ones, but the difference between them in May is only one fourth of what is noticed on the average of the year. Hence, although in May the prevailing wind is still Westerly, the amount of disturbance of the general equilibrium of the atmosphere, which is requisite to render the Northern pressures higher than the Southern, and so produce an Easterly wind, is much less in the month of May than at other times of the year.

Motion of changes of weather over the earth's surface.

We see that Buys Ballot's Law in itself does not enable us to *foresee* weather so far as to gain any great practical advantage from it; all that it indicates is the probable course of the wind for a very few hours in advance. If we revert to Plates I. and II., it is evident that the conditions represented on Plate I. on the 12th of October gave no indication *per se* that the state of things represented on Plate II. would have established itself on the 13th. The probability of this is inferred from experience of the Weather Reports for consecutive days, and from the consideration of the changes which are taking place in localities at a distance from that affected by the storm.

It is found that the weather prevailing on the day in one district does, in general, advance to another district within the space of a day, and that the most usual direction of this advance is from west to east. A proof of this statement may be seen in the fact that out of 23 storms which passed over Hamburg in the year 1869, 22 had previously passed over some portion of the British Islands.

Difficulty of scientific prediction of weather.

All the storms which we feel are accompanied by a considerable relative reduction of pressure; and these barometrical depressions travel over the country, carrying their own wind systems with them. If, therefore, we could determine beforehand the direction of advance, and the rate of motion of each successive area of depression, as well as its shape, its gradients in each direction, and the rate of their increase or decrease in intensity, we should have made a considerable advance towards forecasting weather.

Of these several conditions our knowledge is very incomplete. The attempts which have been hitherto made to lay down laws for any of these undetermined quantities have met with a very limited amount of success. The *shape* of the area of depression is far from uniform, and is liable to modification, firstly, according to the character of the ground over which it passes; and, secondly, according to the conditions of pressure in the neighbourhood. The *direction of advance* takes place most usually from some point between S.W. and N.W., but not unfrequently lies in

a different direction, and it is stated that occasionally a motion even from the eastward has been recognized. The *velocity of motion* varies from five or six miles an hour to as much as 60 or 70: this latter rate of motion having been reached by the storm of December 16, 1869.

Storms in relation to temperature and moisture.

Hitherto we have spoken of storms and weather in general, with exclusive reference to the barometer. It should now be stated that the different winds exhibit nearly as strong a contrast with each other with regard to their temperature and hygrometrical condition as they do with regard to barometrical pressure.

It is a remarkable fact, that although each barometrical depression has its own special wind-system, the air which is set in motion thereby has as marked characteristics as if it were influenced by the two great currents, Equatorial and Polar, already referred to. In general the wind which comes from the S.E., S., or S.W. is warm and damp, while that which comes from the N.W., N., or N.E. is cold and dry. Accordingly, along the eastern and southern side of the path of the centre of depression, where the winds belonging to the first category are felt, the temperature will be high and the weather wet, while where the winds from the polar quarters prevail there will be cold weather, and a great difference between the wet and dry bulb thermometers.

It is also found that a coming storm sometimes influences the thermometer even previously to its affecting the barometer, and therefore if in winter we find the temperature rising unexpectedly we have reason to fear the approach of a gale, and the danger is greater if the disturbance of temperature be local.

A difference in thermometrical readings of nearly 30° between the north of Scotland and the south coast of England is not very uncommon immediately before and during some of our great winter storms. One of the most marked phenomena about these storms is the sudden chill which accompanies the shift of wind from W.S.W. to N.W., see p. 18. On some occasions the fall in temperature registered by self-recording instruments has amounted to 10° or even 15° in a few minutes.

Difficulty of dealing with thermometrical readings.

Owing to the extreme sensitiveness of the thermometer to changes of weather, it has been frequently proposed to consider its indications as fully equal in importance to those of the barometer; but great caution is necessary in acting on this idea. The accuracy of thermometrical observations depends on a great many conditions, such, as aspect, exposure to the air, elevation above sea level and above the surface of the ground, all of which are either immaterial or can be allowed for in dealing with the barometer.

In the case of each instrument we meet with the question of daily range and its influence on the readings; but while this is so slight for the barometer that it may be, and is, almost invariably disregarded in discussing weather, it forms a most serious consideration in the treatment of thermometrical observations; varying, as it does, through wide limits, and being influenced, not only by the character of the weather, but to a considerable extent even by the height of the thermometer bulbs above the ground.

An idea of the extreme difficulty of obtaining a record of temperature which shall be thoroughly unexceptionable, may be gained from the fact that the highest meteorological authorities are far from unanimous as to the best form of screen in which to expose the thermometers.

It is obvious, therefore, that any statements as to the value of thermometrical, and, even more so, of hygrometrical indications of weather, must for the present be couched in the most general terms.

Conditions which have been noticed to precede storms.

Mention has been made of the existence of great contrasts of temperature previously to the breaking out of a storm. Experience shows that there are certain circumstances concerning the relative positions of the warm and cold currents which are indicative of more serious atmospherical disturbance than others.

Not unfrequently hard frost prevails over France, while these islands, especially on their north and west coasts, are enjoying mild weather, and this state of things may exist for days in succession, without any storm ensuing. The reverse conditions of great cold in these islands while the weather in France is warm are never observed for a long period at a time. These are the conditions which exist *during* one of our great storms, as may be gathered from what has just been said, and it appears that whenever they are noticed, if a storm is not actually blowing on our coasts, one is very likely to follow in a day or two.

From what has already been stated about the different temperatures of the two great wind currents, it will be readily seen that the conditions of temperature just referred to are those which are produced by the existence of the polar current in the north while the equatorial current prevails in the south. Under such circumstances the barometer will be lowest in the space between these currents. It is therefore a sign of disturbance of weather if we find the barometer to be lower, even to a very slight extent, over central England than in the north and south of these islands.

The reverse condition, of westerly winds being felt over Scotland while the east wind sweeps down the Channel, accompanied by a relative barometrical maximum over England, is not found to be a sign of bad weather.

Advance of storms from the Atlantic

In conclusion, we may notice certain general principles regulating our weather which have been established by the comparison of the Daily Weather Reports with observations made at sea outside our coasts.

It will be shown at p. 32 that the changes of weather experienced by ships crossing the Atlantic may be explained by the hypothesis that a number of successive barometrical depressions, each with its own cyclonic wind-system more or less completely developed, are advancing across the Atlantic in a manner almost analogous to that in which the eddies chase each other down a river. Whenever a series of these depressions reach our coasts, we are visited by a continuance of stormy and wet weather, the

gales following each other with brief intervals of calm, for the space of perhaps a month, or even longer. Thus in the spring of 1868 27 separate storms passed successively over the north of Europe between the 13th of January and the 26th of March.

Probable direction from which a storm will blow.

We have already shown that there are as yet no *certain* means of knowing *à priori* whether a given depression will be accompanied by a storm from any given point of the compass. This much only can be anticipated, on the principles already so frequently urged in these pages:—

If a depression comes in from the Atlantic, at a time when barometrical readings are very high over North Germany and the South of Norway, there is danger of a *southerly* storm. If the region of high pressure be situated over Spain and the South of France, the storm will be *westerly*.

In the case of *northerly* and *easterly* storms, we, in the United Kingdom, are placed at a great disadvantage, for the area over which the excess of pressure would be noticed, previous to the storm, in each case respectively is frequently situated over the open sea, so that no telegraphic information respecting its existence is obtainable.

This latter consideration is one of the reasons, but not by any means the only reason, why storms from the polar quarters come on us more suddenly than those from other points of the compass.

Value of Dove's rules.

What then are we to regard as the bearing of the principles we have just laid down, on the explanation of weather changes given previously on the authority of Dove?

It must not be forgotten that at the time that his work, the "Law of Storms," was written, weather telegraphy was in its infancy, and the fact that barometrical pressure is differently distributed according to the point from which the wind blows had not attracted the attention which it merits.

Dove's rules are deduced from a careful discussion of trustworthy observations made over a definite, though limited, district of the earth's surface, and consequently they deserve the very greatest attention. If, however, they be applied to the purposes of daily weather study, a very brief experience is sufficient to show how inferior such rules, for observations from isolated stations, are to the information derivable from a general view of simultaneous weather conditions as represented on a Daily Telegraphic Weather Chart.

These latter sources of information are unfortunately only accessible to a very limited class of meteorologists, so that Dove's rules are now, and are likely to remain, most valuable guides for the individual observer.

ON THE USE OF THE BAROMETER TO SEAMEN.

By Capt. H. Toynbee, F.R.A.S., Marine Superintendent.

Buys Ballot's law.

Buys Ballot's law has already been explained, but it is so important to seamen that, at the risk of repetition, I propose alluding to it again, as it must take a prominent place in these remarks.

It has long been known that if an observer turns his back to the wind of a hurricane in the Northern Hemisphere, the barometer will be lower on his left hand than on his right, and that this rule is reversed in the hurricane of the Southern Hemisphere, where the barometer will be lower on his right than on his left. We now know that this rule applies to all winds, even the lightest, at any rate in moderately high latitudes, and it is supposed that, excepting in the neighbourhood of the equator, where the two hemispheres meet, its application is universal. In the neighbourhood of the equator it seems probable that, with your back to the wind, the lowest pressure faces you;* at any rate, most seamen know that in the equatorial doldrums there is a comparatively low barometer, and that as they are approached the respective Trades draw more directly from North and South.

Plates I. and II.

Plates I. and II. illustrate this law; they represent the state of the barometer as well as the direction and force of the wind over these islands during an ordinary heavy gale on our South coasts, which lasted for two days, and in which the direction of the wind was, at first, Southerly, and then veered to West.

Barometrical gradient.

It has also been established that the strength of the wind usually bears some proportion to the amount of barometrical difference in a given distance, *i.e.*, to steepness of gradient.† It will be seen *e.g.* on Plate I. that the isobars or lines of equal barometrical readings are very close, and there is a very hard gale at certain places, amounting to force 10 in the South of Ireland. The wind also blows nearly parallel to the isobars, the lowest pressure being on its left side.

It is a common remark with seamen that at one time they have had a heavy gale when the barometer did not fall very low, whilst at another the barometer was very low, but the wind light. It is now clear that in the former case, although the barometer was not very low, there was a great difference of pressure in a short distance; whilst in the latter, in spite of the low barometrical reading, there was but little difference of pressure in a given distance.

* It is hoped that this question will be satisfactorily answered by the minute investigation into the meteorology of that part of the ocean, which is now being carried out in the Office.

† See No. 1, Non-official Papers, "On the connection between Strong Winds and Barometrical Differences," published by this Office.

What holds good for special readings of the barometer is equally true for mean pressures and mean directions of wind, as has already been shown. It seems clear then that, in as far as Buys Ballot's law holds good, a knowledge of the relative distribution of atmospherical pressure on the earth's surface will indicate the prevailing direction and force of the winds; whilst, on the other hand, a knowledge of the prevailing direction and force of the winds will indicate the relative distribution of atmospherical pressure. It is very important that the seaman should bear these facts in mind, as sometimes he is well acquainted with one and sometimes with the other of these conditions.*

Relation between pressure and wind.

To illustrate what has been said, we propose alluding to certain facts of pressure and prevailing winds which are well known to experienced seamen.

Plate III.

The areas of high and low pressure on Plate III. are taken from Buchan's Chart for the month of December, that for the South Pacific being added from the Charts of Meteorological Data for Cape Horn and the West coast of South America, in process of publication by this Office. The directions of wind are from the Admiralty Pilot Charts, Horsburgh, Buchan, and from the general experience of seamen as gathered from an examination of their logs.

Here we must warn the reader that this plate refers to the sea only, and does not give more than a rough outline of the shapes and positions of these areas, which vary with the seasons. It must also be remembered that the boundary lines of areas of high and low pressure are not supposed to contain areas of equal pressure; they only show that the pressure inside is higher or lower than that surrounding them.

As we have already been told, the motion of the air round areas of high pressure has been termed anti-cyclonic, because the air flows round their centres in a direction opposite to that which it has in cyclones, at the centre of which there is always an area of low pressure. The reader must not suppose that all areas of either high or low pressure are circular, as the term cyclone seems to indicate, for they vary very much in shape, especially in high latitudes. Daily experience, however, shows that, whatever the shapes of the areas of high and low pressure may be, the wind works round them. The wind also does not blow exactly at right angles to the line joining the highest and lowest pressure. In cyclones the air is supposed by some to draw inwards towards the lowest pressure, as if there were an ascending current at the calm centre; in anti-cyclones it is thought to draw outwards from the central area of highest pressure, as if it were a descending current.

* For further information on this subject I would refer the reader to a paper by A. Buchan, Esq., M.A., F.R.S.E., in the "Transactions of the Royal Society of Edinburgh," vol. xxv. It gives isobars and prevailing winds for each month in the year, showing the changes caused by the seasons. A resumé of it will be found in his "Handy Book of Meteorology."

Horse latitudes or Doldrum of Cancer. All seamen familiar with the use of the barometer in tropical seas are aware that there is an area of high pressure at the polar edge of each Trade Wind. It seems to be proved by Buchan's diagrams, and the Meteorological Charts of the West coast of South America,* that this high pressure does not extend up to the land. Referring to the area of high pressure in the North Atlantic, Plate III. shows that it is situated between the parallels of 30 and 40 North; according to Buys Ballot's law, the wind will draw round it, being Northerly on its Eastern, Easterly on its Southern, Southerly on its Western, and Westerly on its Northern side.

Keeping in mind this area of high pressure, we shall now refer the experienced navigator to a few of the winds which he most frequently meets with in its neighbourhood; for instance,—outward bound from England, as he approaches the coast of Portugal the wind very generally comes from North-west, gradually shifting to North and North-east as he proceeds to the Southward; this fact, according to the law just quoted, shows that he passes from the North-east to the East and South-east side of an area of high pressure lying to the Westward of him.

Then, again, what is the experience of the homeward bounder in the neighbourhood of the same area?

As he approaches the Northern verge of the N.E. Trades, he finds that the wind draws to the Eastward, with a fast rising barometer, until he very probably arrives at a spot where the barometer ceases to rise, and the wind dies away. These are the dreaded "Horse Latitudes," or, as Maury calls them, Doldrums of Cancer. It has been shown that where there is no difference of pressure there is no wind, be the barometer high or low, so that these Horse Latitudes are really formed of a large shoal of high and even pressure, with little or no wind, until the ship creeps to a part where the pressure commences to decrease.

The above case does not, however, represent the experience of all homeward bounders. It is frequently found, especially at certain seasons of the year, that the N.E. Trade gradually turns into a S.E., S., and S.W. wind, and, from what has already been said, we know that such vessels have passed round the S.W., W., and N.W. sides of this area of high pressure, thereby avoiding the Horse Latitudes altogether.

Area of high pressure in South Atlantic. The analogy in their action on the wind between this area of high pressure, and that in the South Atlantic, makes this the place for a slight allusion to the latter.

The homeward-bound ship, after rounding the Cape of Good Hope, is at the polar edge of the Trade on the Eastern side of the Atlantic, just as the outward bounder is when off the coast of Portugal (see Plate III.), and the first wind experienced is from S.W., changing to S. and S.E. as the ship proceeds to the Northward, which (according to Buys Ballot's Law, when applied to the Southern Hemisphere,) shows that she passes on the S.E., E., and N.E. sides of an area of high pressure.

* Now in process of publication by the Meteorological Office.

But the outward-bound ship, as she draws towards the Southern verge of the S.E. trades on the Western side of the Atlantic, very generally experiences a change of wind to N.E., N., and N.W., which correspond to the N.W., W., and S.W. sides of an area of high pressure, agreeing with the experience of the fortunate homeward bounder on the Western side of the North Atlantic.

That part of the South Atlantic which corresponds to the high and equal pressure of our "Horse Latitudes" is not in the great highway of ships, so that we have not such proof of its existence from direct barometrical observations, though the Admiralty Pilot Charts give decided indications of its presence, by the number of circles denoting calms in the neighbourhood.

Areas of low pressure. With regard to the areas of low barometrical readings, it will be seen from Plate III. that there is one in the North Atlantic in the neighbourhood of Iceland; this is much more decided in the winter than in the summer months. Another exists in the Antarctic Ocean, where there appears to be a permanent deficiency of pressure, which is most serious in the vicinity of Cape Horn. Lastly, over the district of the Atlantic Doldrums, between the north-east and south-east Trade Winds, the barometer reads lower than it does in the Trade Wind region itself.

A cursory examination of these areas of high and low pressure indicates, by the rules already explained, how the wind may be expected to circulate, and there is no doubt that the main currents of air do draw round them in certain parts of the ocean. If these differences of pressure were the only atmospherical disturbances, our winds would be comparatively simple; but this is not the case.

Track of West India hurricane. Let us suppose that in 15° N. and 50° W. a sudden serious local depression of the barometer took place, (it is not the present object to consider its cause, but merely to instance the fact,) we have what actually exists when a hurricane is formed. We know that a higher pressure exists to its North than to its South, a condition which gives rise to a prevailing Easterly wind, and we may well suppose that the hurricane will be carried to the Westward in this main stream of air, eventually recurving to the North-eastward round the Western edge of the area of permanent high pressure.* The tracks of West India hurricanes, as shown in the Admiralty Pilot Charts and other works on the subject, show that their course is similar to that which has been described.

Track of Mauritius hurricane. A recurving of hurricanes, under circumstances analogous to those just noticed, is commonly experienced in the longitude of the Island of Mauritius. It will be found (see Plate III.) that

* In the Nautical Magazine for 1842, p. 145, there is a paper by T. C. Hunt, Esq., British Consul for the Azores, showing that the gales of these islands generally travel to the S.E. Twenty cases are given between June 1840 and September 1841. Mr. Hunt is of opinion that in some instances they are related to the West India hurricanes; if so, it may be possible that some of these latter storms may recurve still further, travelling round the N.E. side of the area of high pressure, and coming under the influence of the North-westerly wind which exists there, advance towards the South-east.

the area of high pressure to the S. of the S.E. trades in the Indian Ocean does not extend up to the island of Madagascar; a fact well borne out by the N.E., or "Fort Dauphin" winds, which Horsburgh tells us prevail to the S.E. of that Island.* If, now, we suppose a sudden barometrical depression to appear in about 12° S. & 80° E. in the main stream of the South-east Trade, which carries it to the Westward, the hurricane will then work its way in a manner precisely similar to that just described, recurving to the S.E. as it passes to the Southward of the Western end of the area of high pressure. It has happened to ~~me~~ the writer to escape the strength of a Mauritius hurricane by carrying on to the Westward with the South wind of its Western side, knowing that its advance to the Westward was likely to cease in about this longitude.

Areas of low pressure belonging to gales of high northern latitudes.

In addition to the areas of low pressure which cause the hurricanes of the tropics, there are others, belonging to the gales of high latitudes; for instance, in the main stream of air which circulates to the South of the area of low pressure near Iceland, shifting areas of low pressure frequently make their appearance, and travel to the East or North-east. This is indicated by the diagrams of the Quarterly Weather Report published by the Meteorological Office, which show that certain atmospherical disturbances advance in a North-easterly direction from Valencia to Armagh, Glasgow and Aberdeen. One of the papers published by this Office† proves that the same movement prevails across the Atlantic, for it shows that the homeward bound steamer from America can come to the Eastward in company with and often faster than one of these areas of low pressure, whilst the steamer bound to the Westward meets several of them. Since this paper was published, several captains of steamers crossing the Atlantic have drawn diagrams similar to those given in the Report, which agree entirely with these conclusions.

One great peculiarity of these gales is that they generally commence at S. and end at W. or N.W., with little or no E. wind. The probable reason of this is that the areas of low pressure to which they are related have steep gradients only on their E., S.E., S., and S.W. sides, there being little or no difference of pressure between them and the more permanent depression which lies to the North. Here let it be borne in mind that the depression related to a West India hurricane is bounded on the North by an area of high pressure, a fact which may possibly account for the strength of its Easterly wind as compared with the frequent deficiency of force in that wind in the gales of high latitudes.

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* Here let us call attention to the similarity between this N.E. wind and that on the western side of the South Atlantic at the southern verge of the S.E. trades; both are in the same latitude on the western sides of great oceans with heated land to the westward of them. The S.E. wind, which so often prevails on the western side of the North Atlantic, at the polar edge of the trades, seems to have a similar cause.

† Report on the Meteorology of the North Atlantic by Capt. H. Toynbee (Non-official No. II.), Potter, Poultry, and Stanford, Charing Cross.

Gales of high southern latitudes.

The ordinary gales of high southern latitudes are similar in character to those we have alluded to in the Northern Hemisphere. They also are accompanied by areas of low pressure travelling to the Eastward, and considering that their equatorial wind is North instead of South, their winds are similar, for they commence at N., and end at W. or S.W., with little or no Easterly wind accompanying them, possibly because the pressure to the S. is so much lower than that to the N. of them.

Areas of high and low pressure alternating.

So far we have chiefly treated of areas of high and low pressure in the North and South Atlantic, as these seas, and their prevailing winds, are generally well known to seamen. There are other parts of the world where high and low pressures alternate according to the seasons. Central Asia is the most decided instance. There, in January, the mean pressure is 30·4, whilst in July it is 29·5. This immense difference is supposed to reverse the direction of the wind over the South of Asia periodically, causing the N.E. and S.W. monsoons of India.

Direction of wind not a safe guide.

Whenever areas of both high and low pressure pass over any district it is obvious that the direction of the wind, taken alone, will not be a sufficient guide as to what weather is to be expected. If in the Northern Hemisphere an area of *high* pressure be passing off to the eastward, the wind in the rear of it will veer through S.E. to S. Although this direction of the wind shows that the barometrical readings are lower to the westward than to the eastward, it is not by any means an indication that a serious diminution of pressure, which may possibly bring a storm with it, is approaching, although the wind in front of such a depression would be southerly also. It is therefore necessary to look for other signs besides the mere direction of the wind when striving to foresee what is coming.

Practical use of barometer indications.

We shall now say a few words on the practical use of barometrical indications to seamen.

From what has already been stated (p. 24), it is clear that if we could tell the shape of an area of low pressure, its gradients or the difference of pressure in a given distance on all sides, the rate at which it is increasing or decreasing in intensity, the direction in which it is moving, and its speed per hour, we could calculate very correctly what sort of weather would be experienced at a land station or on board a ship at sea; but at present we have no certain knowledge of these data.

Ordinary gales of high Northern latitudes.

We shall first deal with the ordinary gales of the North Temperate Zone, which commence at S.E. or S. and end at W. or N.W.

Suppose a ship in these latitudes experiences a fresh S. or S.E. wind, with a relatively high temperature and falling barometer. Buys Ballot's law shows that there is an area of low pressure to the W. or S.W. of her; and from what has already been said, her Captain may expect that it is travelling to the E. or N.E. Experience shows that on board a ship hove-to or standing to the Westward, the barometer will fall until the wind shifts to the Westward, (which generally happens during a heavy shower of rain, together with a sudden fall of temperature,) when the barometer will probably rise as fast as it previously fell, and a strong N.W. wind will set in. The curves of wind, barometer, and thermometer for January 5th, 1869, in the Quarterly Weather Report published by this Office, afford a very good illustration of these phenomena.

Speed of barometer fall.

It is generally believed that the speed at which the barometer falls is an indication of the strength of a Southerly gale in these latitudes. The fact that the force of wind is more or less related to the amount of the barometrical gradient supports this idea; but we must also take into consideration the speed at which an area of low pressure is travelling. Suppose, for instance, that one with a very steep gradient stood still, as sometimes happens, the wind would blow furiously although the barometer would cease falling, unless the depression were becoming deeper. Then, again, suppose that a depression with a slight gradient were passing very quickly, the barometer would fall quickly, though the wind would not be strong.

Influence of a ship's course and speed on the action of the barometer.

The importance of considering the ship's course and speed in connection with those of the area of low pressure is well shown by the Diagrams of the Report above quoted (No. 2, Non-official), where it is shown that the observer on board a steamer bound to the Westward meets the advancing areas of low pressure, and finds that his barometer falls and rises again more rapidly than it would were he on shore, whilst the observer on board a steamer bound to the Eastward finds that the usual order is frequently reversed, and that his barometer *rises* during a Southerly gale, instead of falling until the wind shifts to the Westward. (See Diagrams 1 and 4 in that Report.)

Different effect of the tack a ship is on.

These facts prove that Captains of sailing ships must consider the tack they are on and the progress they are making, when judging of the weather by the speed with which the barometer falls. For instance, suppose that a homeward bound ship in about 45° N. and 30° W., fell in with a fresh Southerly wind, from what has been said, the Captain will know that there is a lower pressure to the West of him, and he may safely consider that it is travelling to the Eastward; but as he is also going East, his barometer may remain steady or even rise, if, like the homeward-bound American steamers already alluded to, he is outstripping the low pressure in its advance.

State of sea, &c., to be considered.

In such a case, the state of sea and other weather appearances must be taken into consideration; and if the ship is closing with the land, where she may have to heave-to for daylight or a pilot, it might be well to make snug, as by delay she would give the storm, which may be chasing her, the chance of catching her up. After heaving-to, the amount of fall in the barometer per hour is a good though not certain guide, as shown above; a fall of ·04 to

·10 per hour is usually considered to be a valuable warning of a Southerly gale, which is likely to be followed by an equally fast rise, accompanied by a W. or N.W. gale.

From what has been said it will be clear to the navigator that in these latitudes, at the setting in of a Southerly wind, a sailing ship as well as a steamer bound to the Westward will, by her course and speed, cause the barometer to fall quicker than if she hove-to or stood to the Eastward, so that in this case also the state of the sea and other appearances ought to be considered, or her Captain may be led to anticipate worse weather than is really coming.

Starboard tack always toward high, port towards low pressure in Northern, and *vice versâ* in Southern Hemisphere.

Whilst speaking on the effect of a ship's tack on the motion of the barometer, it may be well to point out that in the Northern Hemisphere, with all winds, except when near the Equator, the starboard tack takes a ship towards a higher barometer, whilst the port tack takes her towards a lower one, and that this order is reversed in the Southern Hemisphere.

Effect of tack in English Channel.

It is not to be understood that the barometer will always rise on the starboard or fall on the port tack. In the former case the high pressure towards which the ship is going may be receding from her faster than she sails, and the lower may be coming up astern; while in the latter the lower pressure towards which the ship is sailing may be moving away faster than she sails. Still the influence of the tack must always be felt. As an illustration see Plate I., which represents the state of the barometer in England and France during a south-westerly gale. There it will be seen that the barometer at Brest is about 0·2 in. higher than that at Penzance; accordingly, a ship on the starboard tack will find the barometer rise as she nears the French coast, while one on the port tack will find it fall as she approaches the English coast. I have more than once noticed a rising barometer on the starboard tack when beating down Channel with a Westerly gale, and, expecting the wind to draw towards North, have tacked to take advantage of the change, when to my sorrow the barometer fell again when on the port tack. The cause of this is now evident. Hence we may conclude that in the Northern Hemisphere, with a rising barometer on the starboard tack, other signs should be looked for before trusting it. In all cases a rising barometer on the port tack is a valuable indication of improving weather, while on the starboard tack a falling barometer is a great warning.*

Effect of tack off Cape of Good Hope.

This order is reversed in the Southern Hemisphere, so that a ship beating round the Cape of Good Hope against Westerly gales may very likely find the barometer rising on the port tack when standing towards the land, whilst it will probably fall again as she stands off. This effect has been noticed by some experienced navigators.

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* Diagram 9, in Non-official No. 3, illustrates more clearly the effect of tack on a ship beating down Channel, because both wind and isobars run directly up the Channel.

It may be worthy of remark, that in the Southern winter the barometer at the Royal Observatory at the Cape of Good Hope reads nearly three tenths higher than in the summer, and as this is probably not the case over the warm sea to the Southward, we have at once a steep gradient for the Westerly gales of winter.

Ordinary gales of high Northern latitudes.

In treating of the gales of high Northern latitudes, it may be well to say a few words on the use of the barometer when handling a ship in them. As they seem to be related to areas of low pressure extending over many degrees of latitude, and generally travel to the Eastward, differing so much in shape and size from hurricanes, similar rules cannot be laid down for avoiding them. We have already seen that a steamer from America may keep in front of them, but they are still following her.

If the wind begins at S.E., with a falling barometer, the ship bound to the Westward might gain by running to the N.W. with the object of getting the wind more easterly, but the type of gale in which this is possible is more of a cyclone, and does not represent the ordinary gales of these latitudes which begin at S. and end at W. or N.W. In these gales it might be possible for a ship, with the first of the southerly wind which exists on the east side of the areas of low pressure, to get less wind by running to the north, but as their extent in latitude is not well known, and as there is no certain proof that she would get into more moderate weather by doing so, she might do herself more harm than good.

Weak ship.

It seems then probable that the ship bound to the Southward or Westward must face them. The weak ship, whose one object is to stem the sea and get safely through, without considering progress, should heave-to on the starboard tack, as the wind generally shifts from S. to S.W., W., and N.W. This would of course be the best plan for any ship which found the gale too heavy for her. But the well-conditioned ship, bound to the Westward, which does not fear to face one of these gales, should keep on the port tack until the wind shifts to West with a rising barometer, and then tack to the South-westward. This plan would, of course, tend to bring her into the trough of the sea, and she would be more likely to be caught aback as the wind changed, but we are assuming that her Captain will be prepared to meet these risks.

Best progress to the Westward.

When the wind has shifted to N.W. the starboard tack takes her away from that disturbance, though she may soon sail into the Southerly wind of the Eastern side of another low pressure coming towards her. This is very common in the Winter.*

Ordinary gales of high Southern latitudes.

The prevailing gales of high Southern latitudes resemble those of Northern, and in describing them it is only requisite to remember that *there* North is the equatorial, and South the polar wind, so that they change places. For instance, as an outward bound ship gets into 40 S., "the Roaring Forties," she experiences a series of gales which, commencing at N. or N.E., end at W. or S.W. Now with a Northerly wind in the Southern Hemisphere there

* See Diagram 1 of the Non-official Report No. 2.

is a low pressure to the Westward, and the way in which the wind usually changes proves that those areas of low pressure are also travelling to the Eastward. When, therefore, we hear that the Australian Clipper Ships keep a steady Westerly wind for days as they run to the Eastward in high Southern latitudes, we know that they are probably keeping company with one of these areas of low pressure, and that if they hove-to or commenced beating to the Westward they also would experience many changes, just in the same manner as our steamers bound *to* America do, whilst those *from* America frequently keep a steady barometer and Westerly wind for days. This idea receives abundant confirmation from the frequency of the barometrical oscillations, and changes of wind, experienced by ships bound to the Westward, in rounding either the Cape of Good Hope or Cape Horn.

Weak ship in bad gale, Southern Hemisphere.

The best method for dealing with a very bad gale, or with a weak ship in an ordinary gale, is reversed for high Southern latitudes: there the port is the coming up tack, which enables her to stem the sea, as the wind usually shifts from N. by N.W. to S.W., and the port tack with a S.W. wind takes her away from the low pressure to which the wind is related, though of course it may, and in the winter months most probably will, soon take her into the Northerly wind of the Eastern side of another low pressure coming towards her.

Best progress to the westward.

For a ship beating to the Westward, of course the best progress is made by keeping on the starboard tack with the wind N. and N.W. until it shifts to W. and S.W., when she ought to tack to the North-westward; but it will be seen that, as in the best method for making progress to the Westward in high Northern latitudes, the ship will be headed off, and get into the trough of the sea: she will also be more liable to be taken aback, as the wind changes, than if she were on the port tack.

From what has been said respecting the ordinary gales of high latitudes which have usually little or no Easterly wind, it must not be supposed that there are not some which have steep gradients on *all* sides, and consequently strong Easterly as well as Westerly winds. These are not nearly so common as the others, and must be dealt with more as cyclones.

The use of the barometer in hurricanes or cyclones.

The shape, size, and tracks of hurricanes are better understood, than are those of the gales of higher latitudes. Then, again, it is a duty for the *best* ship to avoid their centres if possible, whereas a large number of the gales of higher latitudes need not be avoided. For these reasons many works have been written on the subject of handling ships in cyclones; still their importance makes it necessary to allude to them here. It is generally known that a cyclone is related to an area of very low pressure. This area is supposed to have more or less a circular form, with very steep sides, descending quickly from its outer edge to the centre, in a manner somewhat similar to the crater of a volcano, or, to use a more homely simile, to the interior of a wash-hand basin. The wind circulates round this centre according to the law so often alluded to: its strength is believed to be in proportion to the steepness of the sides or gradient, and a short calm is usually experienced at the centre, where there is a small area of very low but uniform pressure.

South wind in West India Cyclone.

In the tropics, during the season for hurricanes, the careful navigator will look suspiciously on any wind stronger than usual, especially if his barometer shows signs of falling. Suppose this to happen to the Eastward of the West India Islands, and the wind be Southerly, by Buys Ballot's Law it is known that the area of low pressure is to the Westward. Now by referring to the Admiralty Pilot Charts or other works showing the tracks of these hurricanes, it will be seen that in this part of the sea they generally go to the Westward, so that a ship with a Southerly wind is comparatively safe, and if bound to the Westward, may follow a cyclone at a respectful distance, making use of its wind.* The barometer will be a capital guide here, for if it falls it will show that the ship is closing with the centre, and that it will be well to reduce sail or heave-to for a short time. But if the ship bound to the Westward were further West, and in the position where these cyclones generally recurve to the North, she ought to heave-to on the starboard tack with a Southerly wind, until it shifted to the Westward.

If, instead of a Southerly wind, the ship to the Eastward of the West India Islands experiences a Northerly wind with a falling barometer, it is evident that the centre will be to the East of her, and as it is right to suppose that the cyclone is coming to the West, the ship may be right in front of the centre. This is the most dangerous position. Here it may be well to remark on the alleged indraft of the wind towards the centre of a cyclone, because in so critical a position a point may be of value. Suppose that the wind is *due* North, then with the back to this wind *due* East will be to the left, and according to the common rule, *there* will be the centre of the cyclone; but if the wind draws spirally inwards towards the centre, instead of blowing in an exact circle, then with the back to the wind the centre will not be exactly to the left, but a trifle towards the front of the person so standing; *e.g.*,

Wind drawing in towards the centre of cyclones.

With the wind	North	the centre will bear	South of East;
"	West	"	East of North;
"	South	"	North of West;
"	East	"	West of South;

the amount depending upon the angle which the direction of the wind makes with the tangent to a circle round the centre of the hurricane.

North wind in West India cyclone.

But to revert to the case of a ship in front of a West India cyclone coming to the West, wind and sea-room permitting, it seems

* In "Maury's Sailing Directions," Vol. I., 1858, p. 273, is a Diagram showing how the "Gloriana" made such use of a cyclone near Madras.

Heave-to on port tack in southern half of West India hurricane.

best to run, (or, if possible, to keep the wind on the starboard quarter, because running before a wind drawing spirally inwards towards the centre must bring a ship nearer to it), and try to shift the wind from N. to N.W., bringing the centre to the N.E. This puts the ship in the southern half of the cyclone. Then, if running takes her out of her course, or for any other reason it is wished to heave-to, it seems well to bring her to on the port tack, because although this puts the ship's head *towards* the centre, it enables her to come up and stem the sea, and also lessens the risk of being caught aback, for, as the centre passes to the north of her, the wind will shift from N.W. to W. and S.W. It is not supposed that a ship hove-to in a hurricane will fore-reach much in the direction of her head; still it must be borne in mind that all she does go in that direction whilst on the port tack in the Northern Hemisphere will be towards the centre.

Necessity of considering the track of a cyclone.

It is quite clear that the *track* of a cyclone must be considered before steps can be taken to avoid it. For instance, the North wind, just alluded to, proves a ship to be in front of a West Indian cyclone *if* it be moving to the West; but where it recurves to the North, an East wind shows that a ship is in its front, and *there* the ship, with a North wind, might gain by carrying on to the West. Then, again, as some West Indian hurricanes are supposed to recurve to the North-east in a certain part of the sea, *there* a South-east wind and falling barometer would indicate being in its front. Hence the importance of considering both the barometer and wind in connection with the average track of storms in that part of the sea. If the wind continues steady in one direction, but increases in force, and the barometer falls, it is a strong proof that the centre is coming direct for the ship. If the wind shifts from North to North-west, with a falling barometer, it is a sign that the bearing of the centre has changed from East to North-east, but that it is nearer the ship. If the wind shifts from North to North-east, with a falling barometer, it is a sign that the bearing of the centre has changed from East to South-east, and that it has closed with the ship. On the Northern side of a Northern Hemisphere hurricane, travelling to the West, in which the wind veers from North-east by East to South-east, the starboard is the best tack to heave-to upon, as the ship comes up to stem the sea, avoids the risk of being caught aback, and looks away from its centre.

Heave-to on starboard tack in northern half of West India hurricane.

As the wind revolves similarly in all cyclones North of the Equator, the above remarks refer equally to those of the Bay of Bengal and the China Sea, so that the navigator should make himself familiar with the usual tracks laid down by Piddington and others for these seas; and, as many of those tracks vary very much in direction, he should not fail to study the changes of barometer and wind which he is actually experiencing, by which he may form a good idea of the track of the special cyclone with which he is dealing, in time to enable him to avoid its centre. The transparent storm cards in Piddington's Horn Book are very useful in trying to estimate the track of a hurricane.

Hurricanes of Southern Hemisphere.

The hurricanes of the Southern Indian Ocean should perhaps also be alluded to. There, the order of revolution being reversed, the Captain, with a Northerly wind, knows that the centre is to the West, and, if the ship be well to the Eastward where their tracks are usually to the West, the North is a very safe wind, until he arrives at the place where they usually recurve, South of the Mauritius. Hence the necessity of considering their probable tracks, together with the changes of the wind and action of the barometer.

A Captain in the neighbourhood of one of these cyclones, standing to the Westward, with a Northerly wind, must be guided by the strength of wind and by his barometer. If the barometer falls, and the wind increases, he is closing with the centre, and must not go on so fast. Then, if, with a Northerly wind, and signs getting worse, he is approaching the longitude of the Mauritius, where they recurve, it will be well to heave-to on the port tack until the wind shifts to the Westward: a sign that the centre has passed to the Southward. I have practised this manœuvre successfully.

With a South wind and fast-falling barometer in a Mauritius cyclone, the centre is to the East, and when its track is to the West this is a very dangerous position. Under such circumstances it seems best to stand to the North or North-west, if possible, until the wind shifts to South-west, when the ship will be in the Northern half of the cyclone, and may, if preferred, be hove-to on the starboard tack. This puts her head *towards* the centre; but, as in the similar case for the Northern Hemisphere, it is the tack on which she will come up and stem the sea when the wind changes to West and North-west, and it is not supposed that she will fore-reach towards the centre. This plan also reduces the risk of being caught aback.

Starboard tack best to heave-to upon in Northern half of Mauritius cyclone.

When one of these cyclones has ceased advancing to the West, and recurved to the Southward, the best plan is to carry on to the Westward with its South wind, in which case the barometer will rise and wind decrease, as already remarked.

Port tack best in southern half of Mauritius cyclone.

When a Captain expects to experience the change of wind belonging to the Southern half of a Mauritius cyclone, viz., from South-east by East to North-east, and wishes to heave-to, the port is the best tack, because his ship will come up and stem the sea, avoid the risk of being caught aback, and her head will be turned from its centre.

In cyclones of both hemispheres, the West wind on their equatorial sides is easily dealt with, for they seldom move on a track towards the equator, so the ship may take that route until the barometer rises and weather improves.

But in the part of a cyclone's track where it moves towards the pole, an East wind proves that a ship is in front of it; and running, until the wind has changed so as to make it safe to heave-to, even though running takes the ship out of her course, seems to be the best method to escape it.

The bearing of the centre of a hurricane in the Southern Hemisphere will also be affected by the indraft of the wind towards

the centre, if such an indraft exists. In this case also, with the back to the wind, the centre will be not exactly towards the right hand, but slightly more in front of the observer; for instance,—

Indraft of wind towards the centre.

With the wind South,	the centre will bear	North of East;
„	West,	„	East of South;
„	North,	„	South of West;
„	East,	„	West of North.

The amount depending upon the amount of indraft, or the angle which the wind makes with the tangent to a circle round the centre of the cyclone.

To be pasted over the corresponding paragraph on p. 41 of the Barometer Manual.

General conclusion.

As a general rule, when a Captain has discovered the direction in which a cyclone is moving, he should imagine it to be cut in half by its own track; then, supposing himself to be on the track in the rear of the cyclone, and looking towards the direction in which it is moving, if he wishes to heave-to, he should put his ship on the *starboard tack* if the direction of the wind shows that she is in the *right-hand half*, and on the *port tack* if she be in the *left-hand half*. This holds good in *both* Hemispheres.

It is very important to bear in mind that the parts of a cyclone which form its right and left halves change as it changes the direction of its track.

Action of the barometer in squalls.

The seaman will naturally say, if there can be no wind without a corresponding difference of pressure, how is it that the barometer does not fall with each squall and rise again? Experience shows that this does occur, though the change is too small and transient to be detected by the ordinary method of observing. King's self-registering barometer at the Liverpool Observatory has a very large time-scale, and on its records the oscillations caused by squalls are clearly shown.

In conclusion, it need hardly be said that we have still much to learn respecting the wind and its relation to the barometer. The data to illustrate what has been said have been taken from parts of the world generally known to seamen, and the same ideas may easily be applied to other districts.

It is hoped that, from the excellent logs coming into the Meteorological Office, we may ultimately be able to give monthly charts of the direction and force of wind, with relative pressure, for the most important parts of the sea. It must, however, be borne in mind, that it is only the *prevailing* winds and weather that can be indicated for each month, as no amount of observations will enable us to deprive them of their proverbial changeableness.

CONSTRUCTION AND MANAGEMENT OF BAROMETERS.

Principle of the instrument.

The barometer, as usually constructed, consists of a tube of glass, about 34 inches in length, closed at one end, filled with mercury, and placed vertically with the open end dipping into a cup containing mercury, which is commonly called the cistern. The mercury does not entirely fill the tube so placed, but, occupies at the level of the sea from 31 to 27 inches of the tube, measured above the mercury in the cistern, according to the changes of atmospherical pressure. When the instrument is carried above the sea level, the stratum of air below it does not affect it, and the column falls in relation to the elevation. Conversely, if it be carried below the sea level, as down a mine, an additional thickness of air presses upon it, and the column rises in relation to the depth. The barometer is, therefore, an exponent of the changes incessantly taking place in the pressure of the air over it, and it may also be used differentially for the purpose of estimating the magnitude of elevations and depressions of the earth's surface.

Barometer scales.

Although the instrument exhibits only the effects of pressure, usually estimated by *weight*, its indications are considered in relation to the *length* of the column.

A lineal scale is therefore a necessary accompaniment, and it may be given in inches or millimetres, or in any other recognised measure of length. During the changes which take place in the length of the column, the mercury which leaves the tube must enter the cistern, or *vice versâ ;* hence the level of the mercury in the cistern undergoes changes related to those of the column. In measuring the length of the column we must therefore take into consideration these changes of level, and this necessity has led to various constructions of the cistern. The cistern need not be covered; but, in order to render the instrument portable, it usually is closed up, as explained further on, and firmly cemented to the tube. The whole is then supported by a frame.

Material for frames.

There is much variety in the fashion, though less in the material, of barometer frames. Brass is considered the best material, because its coefficient of expansion by heat is well known; and, what is very important, because the tables for correcting barometer readings for temperature, founded upon the coefficients of expansion of mercury, glass and brass always give, with such barometers, identical results, although the nature of the alloy forming such frames may not in all cases be exactly similar. Aluminium has been lately used, but we are not aware of any reduction tables adapted to it. Barometers are also framed in various woods. In different, and even in similar, species of wood, the expansive coefficient is not

the same; nor is it constant for the same specimen, as wood is affected by moisture as well as temperature. A reduction table has been calculated, founded on an average of various determinations of the expansive coefficients of certain woods, such as oak, walnut, and mahogany, but it cannot be relied upon for accurate results, like that for brass. Barometers in wood, however well made, must always be inferior in accuracy to those mounted in brass.

Material for scales.

The scale, or the greater part of it, is commonly measured along the frame; but if a scale be applied which is quite independent of the frame, then, of course, the reduction for temperature would depend upon the material of the scale, and not upon that of the frame. In such a case wood answers the purpose of a frame, even better than brass. It is not the practice to divide the whole length of the scale, but only the part usually required; viz., that from 27 to 32 inches. This portion may actually be divided on ivory, porcelain, or enamel, and fixed in its proper position, but if the frame which bears it be brass the entire scale is considered to be on brass, and if the frame be wood the scale is virtually on wood.

Cistern level.

The change of level of the mercury in the cistern may be compensated for either (1) by a so-called *capacity correction ;* (2) by a flexible cistern base; or (3) by a contracted scale.

"Capacity" correction.

The first method must be resorted to when the cistern is entirely covered up, and a scale of standard inches is engraved on the frame. In such a barometer, a certain height of the column is correct, by the scale. When the mercury sinks below this position, called the *neutral point,* the level rises in the cistern above the zero of the scale, and then the height read off must always be too great. When the mercury rises above the neutral point the level in the cistern sinks below the zero point, and the reading is too small. On the scale of such a barometer the maker should mark the neutral point, and state the relative interior sections of the tube and of the cistern thus: Capacity 1 to 50. From these data, the correction for capacity is found by taking a 50th part of the difference between the height read off and that of the neutral point, adding it to the reading when the column is above, and subtracting it from the reading when it is below, the neutral height.

Fortin's method.

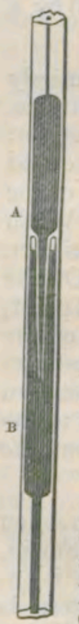
By the second method, the necessity for the capacity correction is avoided by a peculiar construction of cistern invented by Fortin, after whom such barometers have been named. The scale is engraved to show true inches. The upper part of the cistern is made of glass, and the base is flexible, and acted upon by a lifting screw. The zero of the scale is visible in the cistern, being generally a piece of ivory, called the *fiducial point.* The level of the mercury in the cistern must be set to this point, before taking the reading, by raising or lowering the cistern base by means of the thumb screw. This construction of cistern is best adapted for high class or standard barometers; but it cannot be employed for barometers required for use at sea.

Contraction of scale.

The third plan was adopted by the Kew Committee of the British Association in 1854, and by means of it we obtain a standard marine barometer which does not require a capacity correction. By this method the highest point of the scale is made the neutral point, and the inches are shortened in proportion to the relative size of the diameter of the tube and of the cistern. In the Government marine barometers the diameter of the cistern is about 1·25 in., and that of the tube about 0·25 in. The scale, therefore, instead of being divided into inches in the usual way, is shortened in the proportion of 0·04 of an inch for every inch.

This method has also grown into favour for station barometers. For the ordinary kind, mounted in wood, it is especially suited, as it does away with the necessity for a capacity correction; but for standards it is not to be preferred to Fortin's plan. All marine barometers should be graduated on this principle. In nearly all the barometers which till recently have been employed at sea the index correction has varied through the range of scale readings in proportion to the difference of capacity between the cistern and the tube. Barometers with scales contracted or compensated in this way are now known as Kew barometers.

Air or moisture in tube.

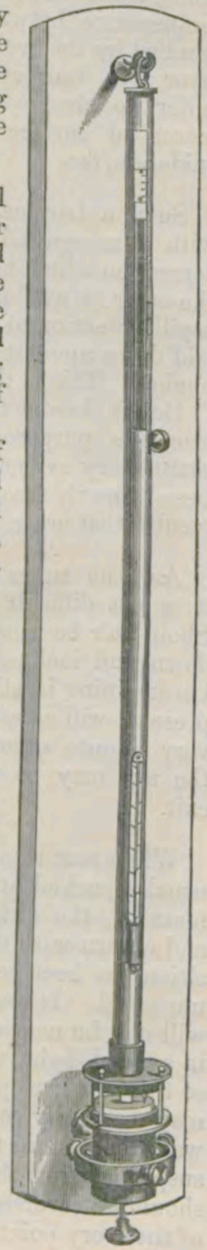


The Air Trap.—In well made barometer tubes it is the practice to insert a small funnel or pipette, somewhere between the range of the column and the cistern neck. The figure in the margin represents the portion of a marine barometer tube which contains the pipette A B. The lower part of the tube has a contracted bore down to the cistern. The upper part, as far as the scale portion, in marine barometers, is contracted even to a finer bore than that represented in the figure, to obviate "pumping," see p. 49. The pipette was first suggested by Gay Lussac, in order to stop the ascent into the vacuum of air or moisture which may work its way from the cistern into the tube between the glass and the mercury, for it will lodge at the shoulder A as represented by the white space. Experience proves that instruments deteriorate less rapidly with this contrivance than without it. Cases, however, occasionally occur in which it does not effectually prevent the ingress of moisture, and it becomes necessary to boil the tubes over a gas or charcoal stove to expel it. All barometer tubes should be thus treated as soon as made, in order to expel any air or moisture which may have been left behind in the process of filling. The slightest trace of moisture is very detrimental, as it makes the mercury adhere to the glass, and so causes the barometer to be sluggish in its action, and, of course, also affects its accuracy as its tension depresses the column. Should the glass be even slightly smeared by the mercury, or should the mercury appear always to cling to the tube, the presence of air or moisture may be assumed, and the instrument should be sent to the maker to be reboiled, or refilled, or fitted with a new tube as may be necessary. To know whether a tube with mercury has been well boiled, it is unnecessary to *watch* the tedious process. It is usually sufficient to examine it with a lens. The absence of small specks and minute bubbles may be considered a satisfactory condition. It is sometimes recommended to cause the mercury to strike the top of the tube; a clear metallic "click," indicating a good condition of the mercury, while a dull sound is evidence of the presence of air or vapour; but, unless this be done with very great care, the tube may be broken by the momentum of the heavy mercury, and there seems to be no general necessity for incurring such a risk: it should therefore never be attempted without very good reason.

Attached thermometer.

Attached Thermometer. — Every mercurial barometer should have an accurate thermometer attached to its frame, the bulb of which should be turned inwards so as to be as near as possible to the barometer tube. The degrees should be etched upon its stem, and, of course, a numbered scale must be placed by its side. No reading of a barometer is complete without a notation of the temperature at the same time.

A short description of the principal kinds of barometers will now be given, omitting all mention of constructions which have not proved generally useful, such as long-range barometers, and those with distorted scales, such as the instruments with spiral and diagonal tubes.



Land Standard Barometer.

Barometers on Fortin's principle. Standard Barometer.

The best standard barometers are made on Fortin's principle, which was explained on p. 43. The tube is mounted in a brass frame, which is suspended from a bracket at the top of a mahogany board, so as to ensure perpendicularity. At the lower end of the board is a socket or ring, with clamping screws, for steadying the instrument in a vertical position when an observation is to be made. The instrument is so suspended that it may be turned at pleasure to any source of light for setting and reading the vernier. A sheet of white notepaper fixed on the board, just behind the top of the mercury, will also be found serviceable in reflecting the light so as to enable a good observation to be made. The vernier is constructed to read to $\frac{1}{500}$ of an inch, or by estimation to ·001 inch, and is adjusted by a rack and pinion motion. For explanation of the vernier, see page 57.

Barometers on Fortin's principle can only get out of order by the ingress of air or moisture. They are not affected by any changes which may take place in the material of the cistern or the mercury therein. The scales are engraved by a dividing engine, and are usually laid down with accuracy. The only scale error likely to exist arises from incorrect measurement from the zero point, which the greatest care cannot obviate, as the difference of temperature between the machine scale and the tube, while being handled by the workman, may account for this final error. This error will, however, be constant throughout the scale, and can suffer no change from lapse of time; and the position of the mercurial surface is independent of loss of mercury from oxidation, &c.

Testing standard barometers.

Such a barometer should, when finished, be carefully compared with a recognised standard. The difference will be the constant correction which is to be applied to its reading, and will include the error of graduation combined with the error arising from the capillary action of the glass tube upon the mercury. The inches laid down upon it should also be tested by a standard dividing-engine. This is the plan followed at the Kew Observatory.

Before barometrical observations can be of any real use for scientific purposes, the computer or investigator should have satisfactory evidence that the errors of the instruments used have been properly ascertained. He can then allow for them, and deduce results that are comparable for different times or different places.

Removal of air bubbles from standard barometers.

As the tubes of standard barometers are not contracted it is not difficult to remove any air which may get into them. Should air be suspected in such a barometer, it should be taken down and inclined *very* gently till the mercury fills the tube. On inclining it still more, so as nearly to invert it, the air, if present, will ascend in a bubble into the cistern, unless it be a very minute quantity and detained by adhesion, in which case the top may be slightly tapped on the ground to facilitate its exit.

Management of standard barometers.

When sent into the country or abroad, a standard barometer is usually packed, apart from the mahogany board, in some soft elastic material, the cistern being screwed up so as to fill the tube and cistern with mercury. It should not be handled until a position has been selected for it, and then must be very carefully unpacked. It may be placed in any convenient room where it will not be near a fire nor exposed to the sunshine. It should be in a good light, with the scale about five feet from the ground, so that the zero point in the cistern and the vernier on the scale may be easily seen. The board should first be fixed against the wall, the cistern then inserted into the socket and the instrument suspended from the bracket. When this is done, the thumb screw should be reversed till the mercury falls in the cistern to the level of the ivory point.

Reading a standard barometer.

To set the barometer, first read the attached thermometer, then adjust the mercury by means of the thumb-screw, (the tube being held vertically by the clamping-screws,) so that it exactly touches the ivory point, which, with its reflection (if the surface of the mercury be clear,) will then appear as a double cone. Next adjust the lower edge of the vernier tangentially to the convex surface of the mercury in the tube, by keeping the eye in line with the back and front edges of the vernier. It requires some practice for the novice to make these adjustments properly and expeditiously. While it is all important that they should be done properly, it is advisable to do them quickly in order to avoid raising the temperature of the instrument by the proximity of the observer's person.

Ordinary Land Barometer.

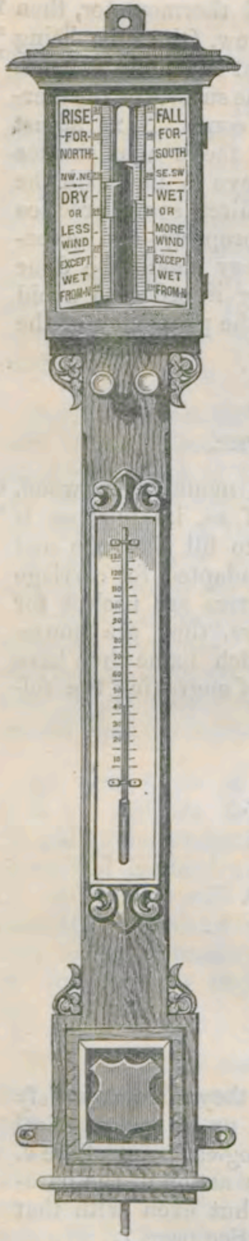
Ordinary barometers.

The common land barometer is generally mounted in wood. The cistern may have a flexible base, but if so, its purpose is merely for screwing up the mercury so as to fill the tube and cistern, and so render the instrument better adapted for carriage from place to place. As a rule these barometers are useless for scientific records. Like the wheel barometers, they are household instruments used as weather glasses, which name they have received from the practice among the makers of engraving the following formulary on their scales:—

At 31 inches	Very dry.
30·5 „	Settled fair.
30 „	Fair.
29·5 „	Changeable.
29 „	Rain.
28·5 „	Much rain.
28 „	Stormy.

These words are very objectionable, since they do not satisfy different conditions of elevation above the sea, or of geographical position, and are also wrong from a meteorological point of view. They were, no doubt, intended to refer to the action of the barometer when placed at or near the sea level; but even with that limitation they only apply to extreme cases. See page 7.

Fishery barometers.



Coast or Fishery Barometer.

The Meteorological Office has placed about 120 barometers at exposed positions on the coasts of the British Isles for the use of fishermen, seafaring persons, and the public generally.* This form of barometer was designed by Admiral FitzRoy, who also devised the lettering, and it has been copied by the opticians generally. It was intended to be simple, durable, and accurate for all practical purposes as a weather glass. The frame is made of oak, and fastened by brass screws. There are no glued pieces nor iron fastenings which might be acted upon by moisture. The tube shows a broad column of mercury. It dips in a well seasoned box-wood cistern, which has a flexible base made of sheepskin, and is in connection with a lifting screw. The scale plates are porcelain, and have the lettering burnt in. The vernier reads to hundredth parts of an inch. The attached thermometer is large and easily read. It gives the temperature of the air, as well as that of the barometer, when the instrument is freely exposed.

Management.

Directions for handling.—This barometer should be suspended on a hook or stout nail, against a frame or piece of wood, so that light may be seen through the tube. Otherwise a piece of white paper should be placed behind the upper or scale part of the tube. When first suspended, take the pinion key (from the lower end of the scale), and fit it on the square-headed brass pin at the lower extremity of the instrument, and turn gently to the left, or against the sun, till the screw stops; then take off the key, and replace it for use on the vernier pinion near the scale, where it should remain, to be used in moving the vernier. The cistern base being thus let down, the mercury in the tube comes at once to its proper level.

In removing this barometer it is necessary to slope it very gradually, till the mercury is at the top of the tube, and then, with the instrument reversed, to screw up the cistern base or bag, by the pinion key, used gently, and turned to the right till it stops. It will then be portable, but should be carried with the cistern end uppermost, or lying flat, but it must not be jarred or receive a concussion.

* Similar instruments have been issued by the National Life Boat Institution.

Marine Barometers.

Marine barometers.

The greater portion of the tube for a barometer intended for use at sea must be made with a very fine bore, in order to prevent the oscillations of the mercurial column which would otherwise occur from the motion of the ship. When the bore is not *sufficiently* contracted, the ship's motion causes fluctuations in the barometer, to which the term "pumping" is applied. Of course this condition is objectionable, as at times correct readings cannot be obtained. On the other hand, when the contraction has been over-done, the instrument is sluggish in responding to the varying pressure of the atmosphere, and is therefore equally objectionable for accurate observations.

Sometimes, though very rarely, a particle of dirt or a bubble of air lodges in the very fine contraction of the tube, and completely stops the action of the instrument. Whenever, 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 fracture of the glass, the cause may be surmised to be of this nature. It should then be taken down, the mercury allowed to fill the tube, and put aside in an *inverted* position for a few 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.

Kew barometers.

Standard Marine Barometer.—In 1854, by direction of the Committee of the Kew Observatory, Mr. John Welsh made special experiments to ascertain the appropriate limits of contraction for marine barometer tubes. The Committee had been requested to decide on the barometer best adapted for marine observations, then about to be commenced by the Admiralty and the Board of Trade. Their reply to the Board of Trade stated that "in selecting the form of marine barometer best adapted to " the purpose of making observations at sea, the Committee have " endeavoured to combine convenience and economy with " accuracy, durability, and simplicity in construction and ad- " justment.

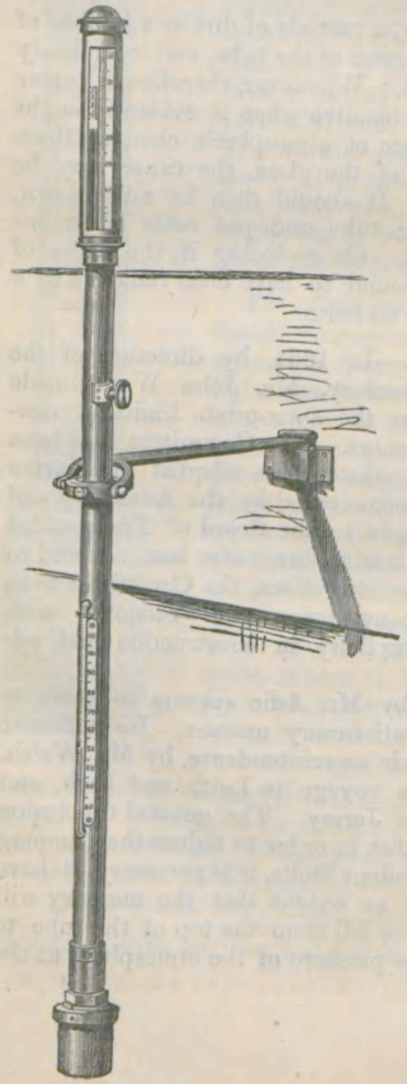
" The barometer proposed by Mr. Adie appears to them to " fulfil those conditions in a satisfactory manner. Its action at " sea has been tested, under their superintendence, by Mr. Welsh, " on two occasions; once in a voyage to Leith and back, and " subsequently to the island of Jersey. The general conclusion " arrived at in those trials, is, that in order to reduce the pumping " of the mercury within convenient limits, it is necessary to have " the tube contracted to such an extent that the mercury will " take about twenty minutes to fall from the top of the tube to " the height indicating the true pressure of the atmosphere at the " time."

Construction.

Accordingly this barometer has been adopted by the Government. It is in all respects a standard instrument, and is equally available for land or sea service. It is not too sluggish for accuracy on land, while at sea the motion of the ship is rather favourable than otherwise to its correctness of action. It is mounted in a brass frame, but, as this alloy is acted upon by mercury, the cistern is made of iron. The frame is open in front and rear so as to expose to view the range portion of the tube, and the scale is protected from dust by a glass shield. The vernier is engraved on a small piece of silvered brass tubing, and travels firmly by a rack and pinion motion, the parts being kept in position by friction. The vernier enables the height of the mercurial column to be read off to the nearest thousandth of an inch. See p. 57.

The inches of the scale are contracted to compensate for the alterations in the level of the mercury in the cistern, as has already been explained.

Suspension of marine barometers.



Standard marine barometer.

Barometers when in use at sea are slung in gimbals, and suspended from arms at least a foot long, so as to be perfectly free to assume the vertical position under every movement of the ship, and at the same time to keep clear of the bulkhead against which the arm is fastened. It is desirable to place the barometer in such a position as not to be in danger of a side blow and also sufficiently far from the deck above to allow for the spring of the metal arm in cases of sudden movements of the ship. If there be risk of the instrument striking anywhere when the vessel is pitching or rolling heavily, it will be well to put some soft padding on that place. It is essentially necessary that the instrument should have free swing. Neither steadying springs nor stays of any kind should be applied to a barometer, as by their weight they at all times keep it slightly out of the vertical, and when they come under stress the instrument is in an abnormal position altogether. *Care should be enjoined that no readings from a barometer which is not hanging truly vertically should ever be recorded.* Such readings will always be too high in proportion to the degree of obliquity.

Various contrivances have been resorted to for rendering the arm and gimbals elastic so as to yield to sudden jerks. Experience proves that a simple straight arm of well hammered brass has sufficient spring for the purpose.

"Gun" barometer.

A new marine barometer for the Naval Service, intended to withstand the concussion arising from gun-firing, was designed in 1861 by Admiral Fitz-Roy, and its use is rendered necessary by the greatly increased size of modern artillery. In this instrument the glass tube is surrounded as much as possible with vulcanized india-rubber tubing, as packing, which checks vibration from concussion, but does not hold it rigidly. The cistern is made entirely of seasoned box-wood, but would be improved by the substitution of iron, which is more durable, and preserves the mercury better from oxidation and moisture. Formerly they were only graduated to 0·01 in., but they have lately been fitted with improved verniers and accurate scales, so as to read to ·001 inch. The instrument, therefore, now differs only in details from the Kew marine barometer.

The cistern.

The cisterns of these barometers are closed. Each contains sufficient mercury to cover the open end of the tube when the instrument is laid flat or when inverted, for carriage; so that no adjustment of cistern whatever has to be made, either for portability or for observation. The observer should never attempt to meddle with the cistern. Those made of wood are sufficiently pervious to air for the mercury to be affected by the variations of the pressure of the atmosphere. Those made of iron are provided with a small aperture at the top or cover, which is closed internally by a leather washer through which the air can act, but the mercury cannot escape.

Every tube is constructed with an air-trap, similar to that already described.

Ordinary marine barometers.

Common Marine Barometers are usually made without system, either as regards the contraction of the tubes, the compensation of the scales for capacities, or the introduction of the air-trap to prevent deterioration. They are framed in wood, and are showy instruments. Their usual faults are either sluggishness from over contraction, or pumping from insufficient contraction. The scale-errors are sometimes of considerable magnitude, and differ in value at different parts of the scale; while the mercury itself is frequently impure, owing to oxidation or to the presence of moisture.

The cistern is made of box-wood with a flexible sheep-skin base, to which a lifting screw is attached. This arrangement is solely intended for making the instrument portable. It is covered by an outer brass casing. After fixing up such an instrument the brass casing should be unscrewed, and the flexible base of the cistern let down. Before changing the position of the instrument, or taking it down for carriage, the cistern should be screwed up so as to confine the mercury in a close space.

Verification of barometers.

Verification of Barometers.—To find the index correction for a Fortin's barometer, comparison with a standard, at any part of the scale at which the mercury may happen to be, is generally considered sufficient. It is a work of much more time to test the marine barometer, since it is necessary to find the correction for scale readings at each half inch throughout the range of atmospheric pressure to which it may be exposed; and it becomes necessary to have recourse to artificial means of changing the pressure of the atmosphere on the surface of the mercury in the cistern.

Kew method.

At Kew Observatory the barometers to be thus tested are placed, together with a standard, in an air-tight chamber, connected with an air pump, so that, by partially exhausting the air, they can be made to read much lower than the lowest pressure to which marine barometers are likely to be exposed; and by compressing the air they can be made to read higher than the mercury ever stands at the level of the sea. The tube of the standard with which they are compared is contracted similarly to that of the marine barometer, but a provision is made for adjusting the mercury in its cistern to the zero point. Glass windows are inserted in the upper part of the iron air-chamber, through which the scales of the barometers may be seen; but as the verniers cannot be moved in the usual way from outside the chamber, a provision is made for reading the height of the mercury, independently of the verniers attached to the scales of the respective barometers, by an instrument called a Cathetometer. At a distance of some five or six feet from the air-tight chamber a vertical scale is fixed. The divisions on the scale correspond exactly with those on the tube of the standard barometer. A vernier and telescope are made to slide on the scale by means of a rack and pinion. The telescope has two horizontal wires, one fixed, and the other moveable by a micrometer screw, so that the difference between the height of the column of mercury and the nearest division on the scale of the standard, and also of all the other barometers placed by the side of it for comparison, can be measured either with the vertical scale and vernier or with the micrometer wire. The means are thus possessed of testing barometers for index error in any part of the scale, through the whole range of atmospherical pressure to which they are likely to be exposed, and the usual practice is to test them at every half inch from 27·5 to 31 inches.

Defects of ordinary barometers.

In this way *ordinary* barometers of various constructions have been tested, and some found to read half an inch and more too high, while others read as much too low. In some cases those which were correct in one part of the scale were found to be several tenths of an inch wrong in other parts. In some the mercury would not descend lower than to about 29 inches, owing

to a very usual fault in the construction of many common barometers till lately in use,—*the cistern was not large enough* to hold the mercury which descended from the tube at the time of a *low atmospherical pressure.*

Syphon Barometers

Syphon barometers.

The tube of a barometer may be bent up at the open end in the shape of a syphon, with the short limb from six to eight inches long. This does away with the necessity for a cistern; for, when sufficient mercury is introduced into such a tube, the atmosphere supports the mercury in the long limb, which is closed at the top, by its pressure upon that in the short limb. As the barometrical column rises and falls, the mercury in the short limb falls and rises; therefore, provided the calibre of the upper part of the long limb be equal to that of the short limb, the distance between the upper and lower levels of the mercury is always the height of the barometric column. A scale of inches starting from a zero point taken near the bend of the tube, with verniers fitted to each limb, give the means of measuring the long and short columns. The difference of readings is the height of the barometer. Or, the zero point may be taken at some intermediate position, and the distances of the mercury levels being measured therefrom, upward and downward, their sum is the height of the barometer.

Mountain barometers.

This form of tube has been much used for mountain barometers; as, from the absence of a cistern, and the small quantity of mercury required, it makes a light and compact instrument. Instead of the top of the short limb being left entirely open, it is closed, and a small conical puncture is made at the side, which is bound round with cotton wool, so that the instrument may be inverted for travelling without any mercury escaping. The portion in the short limb is then loose in its part of the tube, but, as there is little of it, there is no danger of its breaking the tube by its momentum if ordinary care be taken in moving the instrument. The tube is contracted along the intermediate portion and round the bend, so that the mercury, filling it when inverted, is retained there while travelling.

As a standard station barometer the syphon tube is but little used, but it makes an excellent standard mountain instrument.

As the capillary action of the glass is considered to be the same at each of the mercury surfaces, no correction for capillarity is required. If, therefore, a correct scale of inches be applied, the instrument should have no errors; but practically this is hardly ever the case. The index error should be determined by comparison with an acknowledged standard barometer. The correction for temperature is applied, as for other barometers, according as the scale is brass or wood.

Wheel barometers.

The syphon tube is greatly used for the construction of the household weather glass known as the Wheel Barometer. In this instrument, the mercury in the short limb carries a float, to which a silk cord is attached, and carried over, and two or three times round, a fixed pulley, the other end being counterpoised, and kept in a guide tube to prevent its oscillating about. The axis of the pulley carries a pointer in front of a dial mounted on the wood frame of the instrument. As the barometer rises the float descends, and the cord drags the pointer to the right; as it falls the float rises and the counterpoise brings back the pointer to the left. The dial is graduated to correspond with the inches and divisions on an ordinary barometer, usually 28 to 31 inches. The arrangement gives a very open scale; for, although the actual movements of the mercury are only half of what they are in an ordinary barometer, yet the pointer, traversing a large arc, multiplies their linear extent. It will be apparent that as the mercury rises, say half an inch, in the long tube, the fall in the short limb being also half an inch, the length of the barometrical column has increased one inch; but for this increase of one inch there has only been movement through half an inch, and this is the amount of movement given to the pulley, and is shown on the dial as a change, say from 29 to 30 inches. The inertia arising from the weight of the float and the friction of the cord and pulley render the instrument at all times sluggish, but more especially so at the times of change from a falling to a rising barometer, and the converse.

Sluggishness of barometers. The most perfect barometer must always be a little behind the actual changes of atmospherical pressure, considered as pressure merely, because of the inertia to be overcome arising from the weight of the mercury and its friction against the glass tube. The mercury of a barometer is, moreover, virtually a body in motion, and must obey the law of inertia, which teaches that the motion will continue after the cause has ceased to produce it, until its energy is destroyed. Whenever, therefore, we seek to make the barometrical column perform work as in the wheel barometer, or in the registering barometers which act mechanically, we increase the inertia, and consequently render the instruments more sluggish than they otherwise would be. This circumstance has compelled meteorologists to resort to the photographic method of recording the height of the barometer as now perfected in the barograph used at the observatories of the Meteorological Committee. For a description of this instrument, see the Report of the Meteorological Committee for 1867.

Substitutes for Mercurial Barometers.

Aneroids, metallic barometers, and sympiesometers are useful as substitutes for the mercurial barometer as weather-glasses; but, as they cannot furnish observations of sufficient accuracy for scientific purposes, they need not be described in detail here.

The aneroid. The aneroid is an instrument which has come into extensive use, owing to its convenient size and its portability. These recommendations have at once secured its very general adoption.

It is especially suited for use on board small vessels, and also in lieu of the mountain barometer.

In the aneroid, atmospherical pressure is measured by its effect in altering the shape of a small, hermetically sealed, metallic box, from which almost all the air has been withdrawn, and which is kept from collapsing by a spring. The top of the box is corrugated.

When atmospherical pressure rises above the amount which was recorded when the instrument was made, the top is forced inwards, and *vice versâ* when pressure falls below that amount the top is forced outwards by the spring. These motions are transferred by a system of levers and springs to a hand which moves on a dial like that of a wheel barometer.

It is at once evident that the instrument must be graduated experimentally, as it cannot measure pressure absolutely, but only relatively to a mercurial barometer.

The instruments are very sensitive, but unfortunately it is found that they do not preserve their accuracy completely. If a table of corrections be determined for any aneroid, it will be found that after a time the instrument will have undergone some change, and that the values of the corrections require alteration, so that recomparison with a standard barometer is necessary. In every case of such comparison the readings of the mercurial barometer should be reduced to 32°. The principle of the metallic barometer is somewhat similar to that of the aneroid.

A most serious objection to the scientific utility of these instruments is their liability to injury owing to rust or to the alteration of force in the springs used in their construction.

The sympiesometer. In the sympiesometer atmospherical pressure is measured by the change of volume of a portion of air which is confined in the closed limb of a syphon tube by means of oil. Its principle is therefore somewhat similar to that of the aneroid. It is sensitive and is rather popular, but it has no claim to scientific accuracy whatever. It must be graduated experimentally, and before taking a reading the scale must be set to correspond with the temperature of the instrument, as shown by the attached thermometer. The oil which is contained in it is liable to undergo chemical changes which affect the accuracy and permanency of the readings.

As before stated, the aneroid is especially suitable for fishermen, pilots, or seafaring persons employed in boats or small coasting vessels, in which there is not space to suspend a barometer; and, of course, all that is stated in this manual regarding the barometer as a weather indicator, applies to it so far as a single observer is concerned. *For concerted observations mercurial barometers are indispensable.*

DIRECTIONS FOR USING THE "KEW" MARINE BAROMETER.

(See pp. 49–52.)

In handling barometers it should always be remembered that they are delicate and expensive instruments. The result of rough treatment is breakage; and for scientific purposes, observations from an instrument improperly repaired and not verified are useless.

The barometer should be fixed in a good light for observing, but out of the reach of sunshine or the occasional heat of a fire or lamp. The ill effects of artificial heat are, however, nearly completely obviated by taking a careful reading of the attached thermometer at the time of observation of the barometer. It should hang where it can swing freely, and be out of the reach of passengers or others passing near it, so as to be carefully protected from injury. The height of the cistern of the barometer above the level of the sea should be ascertained, and noted.

Fixing up. A bracket and screws for suspending the barometer are in its box. Screw up the bracket where the barometer is to hang. Then lift the instrument carefully out of its box, bend back the hinged part of the suspension arm, and slip it into the bracket. (The holding screws should not be driven quite home until the instrument is in position.) The mercury will then fall gradually, and the instrument will usually be ready for observation in about an hour; but as local temperature affects the instrument slowly, it may be well not to record observations from it for some hours after first fixing it. In a well boiled tube, the mercury hangs adhesively sometimes, and will not quit the top of the tube. If, after an hour or so, the mercury has not descended to its proper level, tap the cistern end rather sharply with the finger, or make the instrument swing a little in its gimbals. This difficulty very rarely happens, and no precise mode of treatment can be laid down: the remedy lies much at the judgment of the observer, who should use such means as his discretion may lead him to deem best to cause the mercury to fall. The box should be safely stowed away.

Taking it down. Whenever it may be necessary to take down a barometer and stow it in its box, *the vernier should be brought down to the bottom of the scale.* Then, having lifted the instrument out of the bracket, place or hold it in an *inclined* position for a few minutes so as to allow the mercury to flow *very gently* up to the top of the glass tube. It should then be taken lengthwise and laid in its box. It is now portable, without any other adjustment whatever; and may be carried with the *cistern end upwards* or *lying flat*, but it must not be subjected to jars or concussions.

Packing it. Experience shows that it is advisable to give some directions as to packing barometers. The instrument having been taken down and placed in its box, as directed, should, if it is to be sent by rail or other conveyance, and is likely to be handled by persons unacquainted with its delicate and peculiar construction, be placed in a packing case with two or three inches of soft elastic packing all round it, as hay, straw, shavings, tow, or paper-cuttings. The lid of the case should *never be nailed down*, but always fastened with screws. The address label should be *pasted* (not nailed) on the end of the case which is next the cistern, or lower end of the barometer, and it should be marked "Glass and fragile instruments. Keep this box lying flat, or carry it this end upwards." Of course, if two or more barometers are packed together, the cisterns should all be placed at this marked end of the case. Barometers should be transmitted by passenger train, and, in short, always by whatever route or conveyance affords the most easy transit. Transhipment or change of conveyance should be avoided, if possible.

Barometer Vernier.

Principle of the vernier. In order to facilitate the taking of accurate readings of the height of the barometer, a small moveable scale, called a vernier, is attached to the instrument.

The general principle of this moveable dividing scale is that the total number of the smallest spaces or subdivisions of the vernier are made equal, taken together, to one less or more than that number of the smallest spaces in an equal length of the fixed scale. In standard barometers the twenty-five spaces in the vernier are equal to any twenty-four spaces of the scale, which are each half a tenth or five hundredths of an inch; therefore a space on the scale is larger than a space on the vernier by the twenty-fifth part of ·05, which is ·002 inch, consequently the vernier exhibits differences of ·002 of an inch.

Setting the vernier. The vernier is moved by a rack and pinion. Turn the milled-head of the pinion so as to bring the *lower* edge of the vernier exactly on a level with the top of the mercurial column. When set properly, the front edge of the vernier, the top of the mercury, and the back edge of the vernier should be in the line of sight, which line will thus just touch the *middle* and *uppermost* point of the column. Great care should be taken to acquire the habit of reading with the eye exactly on a level with the top of the mercury, that is with the line of sight at right angles to the scale.

A piece of white paper placed behind the tube, so as to reflect the light, assists in setting the vernier accurately. A small bull's-eye lamp held behind the instrument, so as to throw the light on the paper, enables the observer to get a correct reading at night. When observing the barometer, it should hang *freely*, not being inclined by holding or even by a touch; because any inclination will cause the column to rise in the tube.

The graduations of the scale and vernier are as follows:—

Every long line { cut on the barometer scale corresponds to - - }	a tenth	(·100)	of an inch.
„ short	five hundredths	(·050)	„
Every long line { cut on the vernier scale corresponds to - - }	one hundredth	(·010)	„
„ short	two thousandths	(·002)	„

Reading the barometer.

The mode of reading off may be learned from a study of the following diagrams, in which A B represents part of the scale, and C D the vernier, the lower edge D denoting the top of the mercurial column. The scale is readily understood; B is 29·000 inches; the first line above B is 29·050; the second line 29·100, and so on. The first thing is to note the scale line just below D, and the next is to find out the line of the vernier which is in one and the same direction with a line of the scale. In figure (1), the lower edge of the vernier, D, is represented in exact coincidence with scale line 29·5; the barometer therefore reads 29·500 inches. Studying it attentively in this position it will be perceived that the vernier line *a* is ·002 inch below the next line of the scale.

Fig. 1.

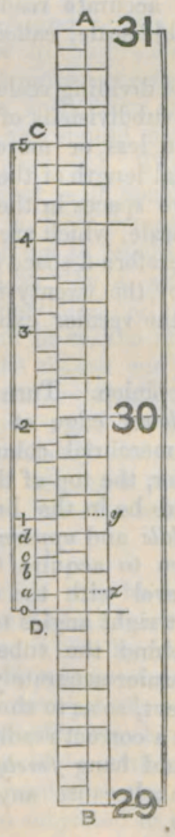
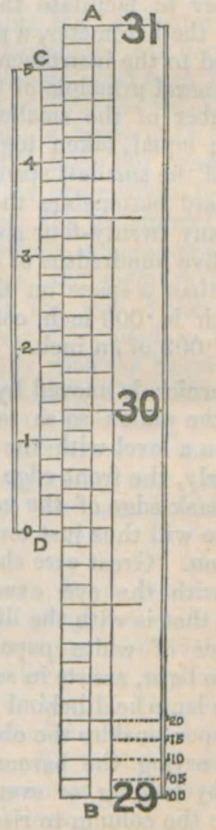


Fig. 2.



If, therefore, the vernier be moved so as to place *a* in a line with *z*, the edge D would read 29·502. In like manner it is seen that *b* is ·004 inch away from the line next above it *on the scale*; *c*, ·006 inch apart from that next above it; *d*, ·008 inch from that next above it; and 1, on the vernier, is ·010 below *y*. Hence, if 1 be moved into line with *y*, D would read 29·510. Thus the numbers 1, 2, 3, 4, 5, on the vernier, indicate hundredths, and the intermediate lines the even thousandths of an inch. Referring now to figure (2), the scale line just below D is 29·650. Looking carefully up the vernier, the third line above the figure 3 is seen to lie evenly with a line on the scale. The number 3 indicates ·030, and the third subdivision ·006; and thus we get—

Reading on scale -	-	29·650
Reading on vernier	- {	·030 ·006
Actual reading -	-	29·686 inches.

Sometimes two pairs of lines will appear to be coincident; in which case the intermediate thousandth of an inch should be set down as the reading. Thus, suppose the reading appears to be 29·684 or 29·686, the mean 29·685 should be adopted.

MANAGEMENT OF THERMOMETERS.

The thermometer has been described in general terms at page 9, and we shall now say a few words as to the method of using it.

It is not at all an easy matter to obtain a record of temperature which shall be altogether unexceptionable. If an open exposure is available, a louvre-boarded case, or screen, should be set up to contain the thermometers. There is a great difference of opinion among meteorologists as to the best form and size for such a screen. It would seem to be suitable for its purpose, if it afford perfect shelter from the sun's rays falling directly upon the instruments and allow free circulation of the air about them, keeping them at least three or four inches from the wall and from the sides and front of the screen itself. All thermometer stands which are entirely open on one side have two serious disadvantages; the thermometers are not sheltered from rain and snow, and constant care is required to turn the stand so as to keep the instruments always in the shade. This is more particularly necessary in high latitudes, as the sun rises and sets more on the polar side of the east and west points of the horizon than in the low latitudes.

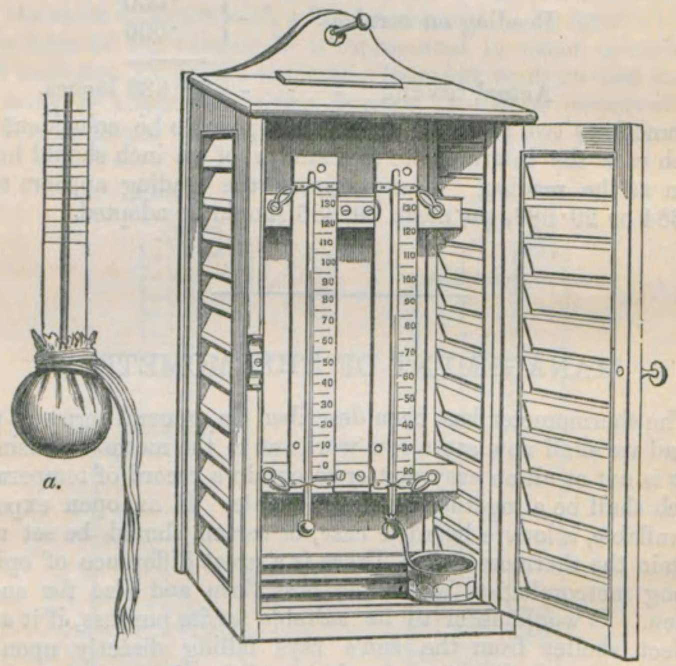
Thermometer screens.

Fig. 3, p. 60, shows the form of screen used for mounting the dry-bulb and wet-bulb thermometers on board ship, where it should be fixed in front of the poop or in any other available position, so as to be freely exposed to the external air. This form of screen has also been found to answer satisfactorily at land stations. It should be fixed about four feet from the ground, and face the north if possible.

Two thermometers should be fitted up in the vertical position in the screen, one to give the temperature of the air, and the other that of evaporation. They should be without cases or guards, near each other, but not within a less distance than two or three inches, and as free as possible from radiation from walls, heated ground or stones, and from draughts near windows of warm rooms and kitchen areas; and, on board ship, from cabins and engine rooms.

A piece of the finest muslin or cambric should be tied round the bulb of one thermometer, and a few threads of cotton wick

Fig. 3.



a.

passed round the glass stem close to the bulb (see *a*, fig 3), touching the muslin, and long enough to reach two or three inches below the lowest part of the bulb, should be carried down so as to dip into and remain in a small vessel of water. By this arrangement the water is slowly conducted, by capillary attraction, to the bulb and evaporated there. See fig. 3.

The cup, glass, or other small holder of water ought not to be under or too near the dry thermometer. This little reservoir should be on the off side of the wet thermometer, that is, as far as possible from the dry thermometer, which of course should not receive any moisture either from rain or otherwise. The water should be either distilled or rain water, or, if this be not procurable, the softest pure water which can be had, to avoid the inconvenience of the deposit of lime, &c. on the bulb. The water vessel

should be replenished *after*, or some little time *before*, observing; because observations are incorrect if made while the water is warmer than the air.

The muslin and wick should be well washed before being applied, and occasionally while in use. They should be changed once or twice a month, or even oftener, according to the quality of the muslin, &c., and the exposure to *dust* or *blacks*. Accuracy depends much on the care taken for cleanliness, and for a proper supply of fresh water. The temperature of evaporation is a very important observation, and therefore especial care should be taken to make it correctly.

In our climate the usual difference between the readings of the dry and wet bulb thermometers ranges from 0 to 12 degrees in *outer* air.

When the wet bulb is frozen it should be wetted, by means of a camel-hair brush or a feather, with some cold water taken from under ice, care being taken to raise its temperature as little as possible. After waiting a few minutes, the moisture will first freeze, then cool down to the temperature of the air, and finally the thermometer will fall a trifle lower than the dry one, and then the temperature of evaporation may be noted. It is only when there is absolutely no water, either fluid or frozen, upon the bulb that it fails in cold weather; and, allowing for the error of the instrument, it can only read higher than the dry-bulb when the water is warmer than the air, which it never should be for the purpose of a correct observation.

APPENDIX I.

TELEGRAPHIC WEATHER INTELLIGENCE.

The Meteorological Office issues to ports or fishing stations notice of serious atmospherical disturbance on or near the coasts of the British Islands.

Signal.

The fact of such notice having been received at any station is made known by the use of a drum, which is hoisted on the receipt of the message, and remains hoisted for the space of 36 hours and no longer.

The Drum (or cylinder) has the appearance of a large black square seen from any point of view when suspended.

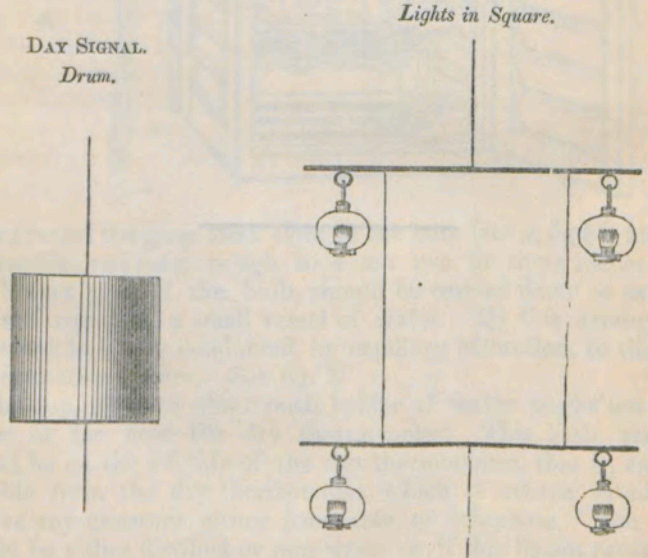
At dusk, a night signal should be hoisted, consisting of four lanterns hung on a square frame.

Lanterns will be supplied by the Committee of the Meteorological Office to any station, approved of by the Board of Trade where the cost of oil, &c. will be defrayed by the local authorities.

Cautionary Signals.

Night Signal.
Lights in Square.

Day Signal.
Drum.



Four lanterns will be sufficient with two yards, each 4ft. long.

These signals may be made with any lanterns, showing either white or any colour. Red is most eligible, and is used at the station supplied by the Meteorological Office. Lamps are preferable to candles. The halyards should be good rope, and protected from chafing. The lanterns should hang at least three feet apart.

Meaning of Signal.

The hoisting of the Drum does not imply *any prophecy of wind or weather;* it is only intended to convey information that there is an atmospherical disturbance somewhere, which may possibly reach the place where the signal is hoisted, and the knowledge of which is likely to be of use to the mariners and fishermen of that part of the coast. Its meaning is "Look out; bad weather "*may* be approaching you." At most stations a telegram stating the nature of the disturbance is posted up where the drum is hoisted.

It must be remembered that only the greater and more general disturbances of the atmosphere can be made known by this method. Local changes of less extent may be indicated to observers by their own instruments and by locally accredited signs of the weather. A regular study of the Weather Reports published in the London daily papers, especially in the Shipping and Mercantile Gazette, will also be found very useful as showing what weather has been prevalent at other stations.

Supply of Weather Intelligence.

A copy of the Daily Report will be supplied by post, free of cost, to any port the authorities of which apply for it, and will undertake to exhibit it to the public as soon as it is received.

If a port requires occasional telegraphic intelligence, the authorities can obtain any information which reaches the Meteorological Office, if they will state the precise nature of the information required, and undertake to bear half the cost of transmission of the messages.

Such messages would be issued soon after 11 a.m. each day.

APPENDIX II.

EXPLANATION OF THE TABLES.

TABLE I. contains the correction to be applied to the readings of barometers mounted in *brass* frames, in order to reduce them to the normal temperature, 32° F. It is taken from the "*Admiralty Manual of Scientific Enquiry*," and has been computed from the following formula given by Schumacher—

$$\text{Correction} = -h\,\frac{m\,(t-32) - s\,(t-62)}{1 + m\,(t-32)}$$

in which

h = height of the barometer,

t = temperature of attached thermometer,

m = expansion of mercury for 1° F., taken as ·0001001 of its length at 32°,

s = expansion of the substance of which the scale is made, for brass it is taken as ·00001041 of its length at 32° F., the standard temperature for the scale being 62° F.

TABLE II. is for reducing to the sea-level observations of the barometer made at any height not exceeding 500 feet. It has been abridged, by Mr. Simmonds' permission, from that given in his "*Meteorological Tables*."* It is given for two pressures at the lower station, namely, 30 and 27 inches. For intermediate pressures, the correction may be obtained by simple proportion.

For heights exceeding those given in the Table, the value, at the sea-level, of a barometer reading at a station, the height of which is known, may be calculated from the following formula:—

$$\text{Log}\,\frac{h}{h'} = f \div \left\{60159\left(1+\frac{t+t'-64}{900}\right)\left(1+\cdot 00268\cos 2\,l\right)\left(1+\frac{f+52251}{20886861}+\frac{h}{10443430}\right)\right\}$$

From a table of common logarithms, the natural number corresponding to $\log\frac{h}{h'}$ is found; or, $\frac{h}{h'} = n$,

And $h = n\,h'$.

In this formula—

h and h' = barometer reduced to 32° F. at the lower and upper stations respectively,

t and t' = the temperature of the air at the respective stations,

f = elevation of upper station in feet,

l = latitude of the place.

In the last factor of the divisor an approximate value must be used for h.

* Meteorological Tables by G. H. Simmonds. Williams & Strahan, London.

The above formula is merely an inversion of the well-known formula given by Laplace in his *Mécanique Céleste*, for finding the difference of elevation between any two places by means of the barometer, which, adapted to Fahrenheit's thermometer and English feet and inches, is,—

$$f = 60159\log\frac{h}{h'}\left(1+\frac{t+t'-64}{900}\right)\left(1+\cdot 00268\cos 2\,l\right)\left(1+\frac{f+52251}{20886861}+\frac{h}{10443430}\right)$$

In the last factor an approximate value must be used for f.

TABLE III. is for converting the reading from barometers having millimetre scales into inches, and *vice versâ*. It is computed from Captain Kater's determination of the length of the French metre in English inches (*see* Phil. Trans. for 1818, p. 109), viz., 1 metre at 32° F. = 39·37079 inches at 62° F.

Before using this Table, the barometer observations must be reduced to the normal temperature of 32° F., as per Table I., if the scale be English; but if it be a French scale, the French Table for the purpose must be employed, for which see Guyot's "Tables —Meteorological and Physical," published by the Smithsonian Institution.

TABLE IV. is to facilitate the conversion of readings of thermometers graduated according to either Fahrenheit, Celsius, or Reaumur, into equivalents of the others.

TABLE I.—Correction to be applied to Barometers with *Brass Scales*, extending from the Cistern to the top of the Mercurial Column, to reduce the observation to 32° Fahrenheit.

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

TABLE I.—*continued.*

Temp.	INCHES.															Temp.
	24·0	24.5	25·0	25·5	26·0	26·5	27·0	27·5	28·0	28·5	29·0	29·5	30·0	30·5	31·0	
°	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	°
51	·048	·049	·050	·051	·052	·053	·054	·055	·056	·057	·058	·059	·060	·061	·062	51
52	·050	·052	·053	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	·064	·065	52
53	·053	·054	·055	·056	·057	·058	·059	·060	·061	·063	·064	·065	·066	·067	·068	53
54	·055	·056	·057	·058	·059	·060	·062	·063	·064	·065	·066	·067	·068	·070	·071	54
55	·057	·058	·059	·060	·062	·063	·064	·065	·066	·068	·069	·070	·071	·072	·073	55
56	·059	·060	·061	·063	·064	·065	·066	·068	·069	·070	·071	·073	·074	·075	·076	56
57	·061	·062	·064	·065	·066	·068	·069	·070	·071	·073	·074	·075	·076	·078	·079	57
58	·063	·065	·066	·067	·069	·070	·071	·073	·074	·075	·077	·078	·079	·081	·082	58
59	·065	·067	·068	·070	·071	·072	·074	·075	·076	·078	·079	·080	·082	·083	·085	59
60	·068	·069	·070	·072	·073	·075	·076	·077	·079	·080	·082	·083	·085	·086	·087	60
61	·070	·071	·073	·074	·075	·077	·078	·080	·081	·083	·084	·086	·087	·089	·090	61
62	·072	·073	·075	·076	·078	·079	·081	·082	·084	·085	·087	·088	·090	·091	·093	62
63	·074	·076	·077	·079	·080	·082	·083	·085	·086	·088	·089	·091	·093	·094	·096	63
64	·076	·078	·079	·081	·082	·084	·086	·087	·089	·090	·092	·094	·095	·097	·098	64
65	·078	·080	·082	·083	·085	·086	·088	·090	·091	·093	·095	·096	·098	·100	·101	65
66	·080	·082	·084	·085	·087	·089	·090	·092	·094	·096	·097	·099	·101	·102	·104	66
67	·083	·084	·086	·088	·089	·091	·093	·095	·096	·098	·100	·102	·103	·105	·107	67
68	·085	·086	·088	·090	·092	·094	·095	·097	·099	·101	·102	·104	·106	·108	·109	68
69	·087	·089	·090	·092	·094	·096	·098	·100	·101	·103	·105	·107	·109	·110	·112	69
70	·089	·091	·093	·095	·096	·098	·100	·102	·104	·106	·108	·109	·111	·113	·115	70
71	·091	·093	·095	·097	·099	·101	·102	·104	·106	·108	·110	·112	·114	·116	·118	71
72	·093	·095	·097	·099	·101	·103	·105	·107	·109	·111	·113	·115	·117	·119	·120	72
73	·095	·097	·099	·101	·103	·105	·107	·109	·111	·113	·115	·117	·119	·121	·123	73
74	·097	·099	·102	·104	·106	·108	·110	·112	·114	·116	·118	·120	·122	·124	·126	74
75	.100	·102	·104	·106	·108	·110	·112	·114	·116	·118	·120	·122	·125	·127	·129	75
76	·102	·104	·106	·108	·110	·112	·114	·117	·119	·121	·123	·125	·127	·129	·131	76
77	·104	·106	·108	·110	·112	·115	·117	·119	·121	·123	·126	·128	·130	·132	·134	77
78	·106	·108	·110	·113	·115	·117	·119	·122	·124	·126	·128	·130	·133	·135	·137	78
79	·108	·110	·113	·115	·117	·119	·122	·124	·126	·128	·131	·133	·135	·137	·140	79
80	·110	·113	·115	·117	·119	·122	·124	·126	·129	·131	·133	·136	·138	·140	·143	80
81	·112	·115	·117	·119	·122	·124	·126	·129	·131	·134	·136	·138	·141	·143	·145	81
82	·114	·117	·119	·122	·124	·126	·129	·131	·134	·136	·138	·141	·143	·146	·148	82
83	·117	·119	·121	·124	·126	·129	·131	·134	·136	·139	·141	·143	·146	·148	·151	83
84	·119	·121	·124	·126	·129	·131	·134	·136	·139	·141	·144	·146	·149	·151	·154	84
85	·121	·123	·126	·128	·131	·133	·136	·139	·141	·144	·146	·149	·151	·154	·156	85
86	·123	·126	·128	·131	·133	·136	·138	·141	·144	·146	·149	·151	·154	·156	·159	86
87	·125	·128	·130	·133	·136	·138	·141	·143	·146	·149	·151	·154	·157	·159	·162	87
88	·127	·130	·133	·135	·138	·141	·143	·146	·149	·151	·154	·157	·159	·162	·165	88
89	·129	·132	·135	·137	·140	·143	·146	·148	·151	·154	·156	·159	·162	·165	·167	89
90	·131	·134	·137	·140	·142	·145	·148	·151	·153	·156	·159	·162	·164	·167	·170	90
91	·134	·136	·139	·142	·145	·148	·150	·153	·156	·159	·162	·165	·167	·170	·173	91
92	·136	·139	·141	·144	·147	·150	·153	·156	·158	·161	·164	·167	·170	·172	·175	92
93	.138	·141	·144	·147	·149	·152	·155	·158	·161	·164	·167	·170	·172	·175	·178	93
94	·140	·143	·146	·149	·152	·155	·157	·161	·163	·166	·169	·172	·175	·177	·180	94
95	·142	·145	·148	·151	·154	·157	·160	·163	·166	·169	·172	·175	·178	·180	·183	95
96	·144	·147	·150	·153	·156	·159	·162	·165	·168	·171	·174	·178	·181	·183	·186	96
97	·146	·149	·152	·156	·159	·162	·165	·168	·171	·174	·177	·180	·183	·186	·189	67
98	·148	·152	·155	·158	·161	·164	·167	·170	·173	·176	·179	·183	·186	·188	·191	98
99	·151	·154	·157	·160	·163	·166	·169	·173	·176	·179	·182	·185	·188	·191	·194	99
100	·153	·156	·159	·162	·165	·169	·172	·175	·178	·181	·184	·188	·191	·194	·197	100

Table II.—For reducing Observations of the Barometer to Sea-level.
(Barometrical Reading at Sea-level = 30 inches.)

Height in Feet.	Temperature—Degrees Fahr. —20	—10	0	+10	+20	+30	+40	+50	+60	+70	+80	+90	Height in Feet.
	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	
10	·013	·013	·012	·012	·012	·012	·011	·011	·011	·011	·010	·010	10
20	·026	·025	·025	·024	·024	·023	·023	·022	·022	·021	·021	·021	20
30	·039	·038	·037	·036	·035	·035	·034	·033	·033	·032	·031	·031	30
40	·051	·050	·049	·048	·047	·046	·045	·044	·043	·043	·042	·041	40
50	·064	·063	·061	·060	·059	·058	·056	·055	·054	·053	·052	·051	50
60	·077	·075	·074	·072	·071	·069	·068	·066	·065	·064	·063	·062	60
70	·090	·088	·086	·084	·082	·081	·079	·077	·076	·075	·073	·072	70
80	·103	·100	·098	·096	·094	·092	·090	·089	·087	·085	·084	·082	80
90	·116	·113	·110	·108	·106	·104	·102	·100	·098	·096	·094	·092	90
100	·128	·125	·123	·120	·118	·115	·113	·111	·109	·106	·104	·103	100
110	·141	·138	·135	·132	·129	·127	·124	·122	·119	·117	·115	·113	110
120	·154	·151	·147	·144	·141	·138	·135	·133	·130	·128	·125	·123	120
130	·167	·163	·159	·156	·153	·150	·147	·144	·141	·138	·136	·133	130
140	·180	·176	·172	·168	·165	·161	·158	·155	·152	·149	·146	·144	140
150	·192	·188	·184	·180	·176	·173	·169	·166	·163	·160	·157	·154	150
160	·205	·201	·196	·192	·188	·184	·180	·177	·173	·170	·167	·164	160
170	·218	·213	·208	·204	·200	·196	·192	·188	·184	·181	·177	·174	170
180	·231	·226	·221	·216	·211	·207	·203	·199	·195	·191	·188	·184	180
190	·243	·238	·233	·228	·223	·218	·214	·210	·206	·202	·198	·195	190
200	·256	·250	·245	·240	·235	·230	·225	·221	·217	·213	·209	·205	200
210	·269	·263	·257	·252	·246	·241	·237	·232	·227	·223	·219	·215	210
220	·282	·275	·269	·264	·258	·253	·248	·243	·238	·234	·229	·225	220
230	·294	·288	·282	·276	·270	·264	·259	·254	·249	·244	·240	·235	230
240	·307	·300	·294	·288	·282	·276	·270	·265	·260	·255	·250	·246	240
250	·320	·313	·306	·299	·293	·287	·281	·276	·271	·266	·261	·256	250
260	·333	·325	·318	·311	·305	·299	·293	·287	·281	·276	·271	·266	260
270	·345	·338	·330	·323	·317	·310	304	·298	·292	·287	·281	·276	270
280	·358	·350	·343	·335	·328	·322	·315	·309	·303	·297	·292	·286	280
290	·371	·363	·355	·347	·340	·333	·326	·320	·314	·308	·302	·297	290
300	·384	·375	·367	·359	·352	·344	·338	·331	·324	·318	·312	·307	300
310	·396	·387	·379	·371	·363	·356	·349	·342	·335	·329	·323	·817	310
320	·409	·400	·391	·383	·375	·367	·360	·353	·346	·339	·333	·327	320
330	·422	·412	·403	·395	·387	·379	·371	·364	·357	·350	·343	·337	330
340	·434	·425	·416	·407	·398	·390	·382	·375	·367	·361	·354	·347	340
350	·447	·437	·428	·419	·410	·401	·393	·386	·378	·371	·364	·358	350
360	·460	·450	·440	·430	·421	·413	·405	·397	·389	·382	·375	·368	360
370	·472	·462	·452	·442	·433	·424	·416	·408	·400	·392	·385	·378	370
380	·485	·474	·464	·454	·445	·436	·427	·418	·410	·403	·395	·388	380
390	·498	·487	·476	·466	·456	·447	·438	·429	·421	·413	·406	·398	390
400	·511	·499	·488	·478	·468	·458	·449	·440	·432	·424	·416	·408	400
410	·523	·512	·500	·490	·480	·470	·460	·451	·443	·434	·426	·418	410
420	·536	·524	·513	·502	·491	·481	·472	·462	·453	·445	·437	·429	420
430	·549	·536	·525	·514	·503	·492	·483	·473	·464	·455	·447	·439	430
440	·561	·549	·537	·525	·514	·504	·494	·484	·475	·466	·457	·449	440
450	·574	·561	·549	·537	·526	·515	·505	·495	·485	·476	·467	·459	450
460	·587	·574	·561	·549	·538	·527	·516	·506	·496	·487	·478	·469	460
470	·599	·586	·573	·561	·549	·538	·527	·517	·507	·497	·488	·479	470
480	·612	·598	·585	·573	·561	·549	·538	·528	·518	·508	·498	·489	480
490	·624	·611	·597	·585	·572	·561	·549	·539	·528	·518	·509	·499	490
500	·637	·623	·609	·596	·584	·572	·561	·550	·539	·529	·519	·510	500

Corrections for intermediate readings are obtained by

Table II.—*continued.*
(Barometrical Reading at Sea-level = 27 inches.)

Height in Feet.	Temperature—Degrees Fahr. —20	—10	0	+10	+20	+30	+40	+50	+60	+70	+80	+90	Height in Feet.
	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	+ IN.	
10	·012	·011	·011	·011	·011	·010	·010	·010	·010	·010	·009	·009	10
20	·023	·023	·022	·022	·021	·021	·020	·020	·020	·019	·019	·018	20
30	·035	·034	·033	·032	·032	·031	·031	·030	·029	·029	·028	·028	30
40	·046	·045	·044	·043	·042	·041	·041	·040	·039	·038	·038	·037	40
50	·058	·056	·055	·054	·053	·052	·051	·050	·049	·048	·047	·046	50
60	·069	·068	·066	·065	·064	·062	·061	·060	·059	·058	·056	·055	60
70	·081	·079	·077	·076	·074	·073	·071	·070	·068	·067	·066	·065	70
80	·092	·090	·088	·086	·085	·083	·081	·080	·078	·077	·075	·074	80
90	·104	·102	·099	·097	·095	·093	·091	·090	·088	·086	·085	·083	90
100	·115	·113	·110	·108	·106	·104	·102	·100	·098	·096	·094	·092	100
110	·127	·124	·121	·119	·116	·114	·112	·110	·107	·105	·103	·102	110
120	·138	·135	·132	·130	·127	·124	·122	·119	·117	·115	·113	·111	120
130	·150	·147	·143	·140	·137	·135	·132	·129	·127	·124	·122	·120	130
140	·161	·158	·154	·151	·148	·145	·142	·139	·136	·134	·132	·129	140
150	·173	·169	·165	·162	·159	·155	·152	·149	·146	·144	·141	·138	150
160	·184	·180	·176	·173	·169	·166	·162	·159	·156	·153	·150	·148	160
170	·196	·192	·187	·183	·180	·176	·172	·169	·166	·163	·160	·157	170
180	·207	·203	·198	·194	·190	·186	·183	·179	·175	·172	·169	·166	180
190	·219	·214	·209	·205	·201	·197	·193	·189	·185	·182	·178	·175	190
200	·230	·225	·220	·216	·211	·207	·203	·199	·195	·191	·188	·184	200
210	·242	·237	·231	·226	·222	·217	·213	·209	·205	·201	·197	·193	210
220	·253	·248	·242	·237	·232	·227	·223	·219	·214	·210	·206	·203	220
230	·265	·259	·253	·248	·243	·238	·233	·228	·224	·220	·216	·212	230
240	·276	·270	·264	·259	·253	·248	·243	·238	·234	·229	·225	·221	240
250	·288	·281	·275	·269	·264	·258	·253	·248	·243	·239	·234	·230	250
260	·299	·293	·286	·280	·274	·269	·263	·258	·253	·248	·244	·239	260
270	·311	·304	·297	·291	·285	·279	·273	·268	·263	·258	·253	·248	270
280	·322	·315	·308	·302	·295	·289	·283	·278	·272	·267	·262	·258	280
290	·334	·326	·319	·312	·306	·299	·293	·288	·282	·277	·272	·267	290
300	·345	·337	·330	·323	·316	·310	·303	·298	·292	·286	·281	·276	300
310	·356	·349	·341	·334	·327	·320	·314	·307	·302	·296	·290	·285	310
320	·368	·360	·352	·344	·337	·330	·324	·317	·311	·305	·300	·294	320
330	·379	·371	·363	·355	·348	·341	·334	·327	·321	·315	·309	·303	330
340	·391	·382	·374	·366	·358	·351	·344	·337	·331	·324	·318	·312	340
350	·402	·393	·385	·376	·369	·361	·354	·347	·340	·334	·328	·322	350
360	·414	·404	·396	·387	·379	·371	·364	·357	·350	·343	·337	·331	360
370	·425	·415	·406	·398	·389	·382	·374	·367	·360	·353	·346	·340	370
380	·436	·427	·417	·408	·400	·392	·384	·376	·369	·362	·355	·349	380
390	·448	·438	·428	·419	·410	·402	·394	·386	·379	·372	·365	·358	390
400	·459	·449	·439	·430	·421	·412	·404	·396	·388	·381	·374	·367	400
410	·471	·460	·450	·440	·431	·422	·414	·406	·398	·391	·383	·376	410
420	·482	·471	·461	·451	·442	·433	·424	·416	·408	·400	·393	·385	420
430	·493	·482	·472	·462	·452	·443	·434	·425	·417	·409	·402	·395	430
440	·505	·493	·483	·472	·463	·453	·444	·435	·427	·419	·411	·404	440
450	·516	·505	·494	·483	·473	·463	·454	·445	·437	·428	·420	·413	450
460	·527	·516	·505	·494	·483	·474	·464	·455	·446	·438	·430	·422	460
470	·539	·527	·515	·504	·494	·484	·474	·465	·456	·447	·439	·431	470
480	·550	·538	·526	·515	·504	·494	·484	·475	·465	·457	·448	·440	480
490	·562	·549	·537	·526	·515	·504	·494	·484	·475	·466	·457	·449	490
500	·573	·560	·548	·536	·525	·514	·504	·494	·485	·475	·467	·458	500

proportion between the two parts of this Table.

TABLE III.

COMPARISON of the METRIC and ENGLISH BAROMETER SCALES.
(1 Metre = 39·37079 Inches.)

Millimetres.	Tenths of a Millimetre. 0	1	2	3	4	5	6	7	8	9
	English Inches.									
705	27·756	27·760	27·764	27·768	27·772	27·776	27·780	27·784	27·788	27·792
6	·796	·800	·804	·808	·812	·815	·819	·823	·827	·831
7	·835	·839	·843	·847	·851	·855	·859	·863	·867	·871
8	·875	·878	·882	·886	·890	·894	·898	·902	·906	·910
9	27·914	27·918	27·922	27·926	27·930	27·934	27·938	27·941	27·945	27·949
710	27·953	27·957	27·961	27·965	27·969	27·973	27·977	27·981	27·985	27·989
1	27·993	27·997	28·001	28·004	28·008	28·012	28·016	28·020	28·024	28·028
2	28·032	28·036	·040	·044	·048	·052	·056	·060	·063	·067
3	·071	·075	·079	·083	·087	·091	·095	·099	·103	·107
4	28·111	28·115	28·119	28·123	28·126	28·130	28·134	28·138	28·142	28·146
715	28·150	28·154	28·158	28·162	28·166	28·170	28·174	28·178	28·182	28·186
6	·189	·193	·197	·201	·205	·209	·213	·217	·221	·225
7	·229	·233	·237	·241	·245	·249	·252	·256	·260	·264
8	·268	·272	·276	·280	·284	·288	·292	·296	·300	·304
9	28·308	28·312	28·315	28·319	28·323	28·327	28·331	28·335	28·339	28·343
720	28·347	28·351	28·355	28·359	28·363	28·367	28·371	28·375	28·378	28·382
1	·386	·390	·394	·398	·402	·406	·410	·414	·418	·422
2	·426	·430	·434	·438	·441	·445	·449	·453	·457	·461
3	·465	·469	·473	·477	·481	·485	·489	·493	·497	·501
4	28·504	28·508	28·512	28·516	28·520	28·524	28·528	28·532	28·536	28·540
725	28·544	28·548	28·552	28·556	28·560	28·564	28·567	28·571	28·575	28·579
6	·583	·587	·591	·595	·599	·603	·607	·611	·615	·619
7	·623	·627	·630	·634	·638	·642	·646	·650	·654	·658
8	·662	·666	·670	·674	·678	·682	·686	·689	·693	·697
9	28·701	28·705	28·709	28·713	28·717	28·721	28·725	28·729	28·733	28·737
730	28·741	28·745	28·749	28·752	28·756	28·760	28·764	28·768	28·772	28·776
1	·780	·784	·788	·792	·796	·800	·804	·808	·812	·815
2	·819	·823	·827	·831	·835	·839	·843	·847	·851	·855
3	·859	·863	·867	·871	·875	·878	·882	·886	·890	·894
4	28·898	28·902	28·906	28·910	28·914	28·918	28·922	28·926	28·930	28·934
735	28·938	28·941	28·945	28·949	28·953	28·957	28·961	28·965	28·969	28·973
6	28·977	28·981	28·985	28·989	28·993	28·997	29·001	29·004	29·008	29·012
7	29·016	29·020	29·024	29·028	29·032	29·036	·040	·044	·048	·052
8	·056	·060	·064	·067	·071	·075	·079	·083	·087	·091
9	29·095	29·099	29·103	29·107	29·111	29·115	29·119	29·123	29·127	29·130
740	29·134	29·138	29·142	29·146	29·150	29·154	29·158	29·162	29·166	29·170
1	·174	·178	·182	·186	·190	·193	·197	·201	·205	·209
2	·213	·217	·221	·225	·229	·233	·237	·241	·245	·249
3	·252	·256	·260	·264	·268	·272	·276	·280	·284	·288
4	29·292	29·296	29·300	29·304	29·308	29·312	29·315	29·319	29·323	29·327

TABLE III.—*continued.*

COMPARISON of the METRIC and ENGLISH BAROMETER SCALES.
(1 Metre = 39·37079 Inches).

Millimetres.	Tenths of a Millimetre. 0	1	2	3	4	5	6	7	8	9
	English Inches.									
745	29·331	29·335	29·339	29·343	29·347	29·351	29·355	29·359	29·363	29·367
6	·371	·375	·378	·382	·386	·390	·394	·398	·402	·406
7	·410	·414	·418	·422	·426	·430	·434	·438	·441	·445
8	·449	·453	·457	·461	·465	·469	·473	·477	·481	·485
9	29·489	29·493	29·497	29·501	29·504	29·508	29·512	29·516	29·520	29·524
750	29·528	29·532	29·536	29·540	29·544	29·548	29·552	29·556	29·560	29·564
1	·567	·571	·575	·579	·583	·587	·591	·595	·599	·603
2	·607	·611	·615	·619	·623	·627	·630	·634	·638	·642
3	·646	·650	·654	·658	·662	·666	·670	·674	·678	·682
4	29·686	29·690	29·693	29·697	29·701	29·705	29·709	29·713	29·717	29·721
755	29·725	29·729	29·733	29·737	29·741	29·745	29·749	29·753	29·756	29·760
6	·764	·768	·772	·776	·780	·784	·788	·792	·796	·800
7	·804	·808	·812	·815	·819	·823	·827	·831	·835	·839
8	·843	·847	·851	·855	·859	·863	·867	·871	·875	·878
9	29·882	29·886	29·890	29·894	29·898	29·902	29·906	29·910	29·914	29·918
760	29·922	29·926	29·930	29·934	29·938	29·941	29·945	29·949	29·953	29·957
1	29·961	29·965	29·969	29·973	29·977	29·981	29·985	29·989	29·993	29·997
2	30·001	30·004	30·008	32·012	30·016	30·020	30·024	30·028	30·032	30·036
3	·040	·044	·048	·052	·056	·060	·064	·067	·071	·075
4	30·079	30·083	30·087	30·091	30·095	30·099	30·103	30·107	30·111	30·115
765	30·119	30·123	30·127	30·130	30·134	30·138	30·142	30·146	30·150	30·154
6	·158	·162	·166	·170	·174	·178	·182	·186	·190	·193
7	·197	·201	·205	·209	·213	·217	·221	·225	·229	·233
8	·237	·241	·245	·249	·253	·256	·260	·264	·268	·272
9	30·276	30·280	30·284	30·288	30·292	30·296	30·300	30·304	30·308	30·312
770	30·316	30·319	30·323	30·327	30·331	30·335	30·339	30·343	30·347	30·351
1	·355	·359	·363	·367	·371	·375	·379	·382	·386	·390
2	·394	·398	·402	·406	·410	·414	·418	·422	·426	·430
3	·434	·438	·441	·445	·449	·453	·457	·461	·465	·469
4	30·473	30·477	30·481	30·485	30·489	30·493	30·497	30·501	30·504	30·508
775	30·512	30·516	30·520	30·524	30·528	30·532	30·536	30·540	30·544	30·548
6	·552	·556	·560	·564	·567	·571	·575	·579	·583	·587
7	·591	·595	·599	·603	·607	·611	·615	·619	·623	·627
8	·630	·634	·638	·642	·646	·650	·654	·658	·662	·666
9	30·670	30·674	30·678	30·682	30·686	30·690	30·693	30·697	30·701	30·705
780	30·709	30·713	30·717	30·721	30·725	30·729	30·733	30·737	30·741	30·745
1	·749	·753	·756	·760	·764	·768	·772	·776	·780	·784
2	·788	·792	·796	·800	·804	·808	·812	·816	·819	·823
3	·827	·831	·835	·839	·843	·847	·851	·855	·859	·863
4	·867	·871	·875	·879	·882	·886	·890	·894	·898	·902
785	30·906	30·910	30·914	30·918	30·922	30·926	30·930	30·934	30·938	30·942

Parts.

Mill.	Inch.
1	0·0394
2	·0787
3	·1181
4	·1575
5	·1968
6	·2362
7	·2756
8	·3149
9	·3543
10	·3937

TABLE III.—*continued.*

COMPARISON of the ENGLISH and METRIC BAROMETER SCALES.

English Inches and Tenths.	Hundredths of an Inch.									
	0	1	2	3	4	5	6	7	8	9
27·0	685·79	686·04	686·30	686·55	686·80	687·06	687·31	687·57	687·82	688·07
·1	688·33	688·58	688·84	689·09	689·34	689·60	689·85	690·11	690·36	690·61
·2	690·87	691·12	691·38	691·63	691·88	692·14	692·39	692·65	692·90	693·15
·3	693·41	693·66	693·92	694·17	694·42	694·68	694·93	695·19	695·44	695·69
·4	695·95	696·20	696·46	696·71	696·96	697·22	697·47	697·73	697·98	698·23
·5	698·49	698·74	699·00	699·25	699·50	699·76	700·01	700·27	700·52	700·77
·6	701·03	701·28	701·54	701·79	702·04	702·30	702·55	702·81	703·06	703·31
·7	703·57	703·82	704·08	704·33	704·58	704·84	705·09	705·35	705·60	705·85
·8	706·11	706·36	706·62	706·87	707·12	707·38	707·63	707·89	708·14	708·39
·9	708·65	708·90	709·16	709·41	709·66	709·92	710·17	710·43	710·68	710·93
28·0	711·19	711·44	711·70	711·95	712·20	712·46	712·71	712·97	713·22	713·47
·1	713·73	713·98	714·24	714·49	714·74	715·00	715·25	715·51	715·76	716·01
·2	716·27	716·52	716·78	717·03	717·28	717·54	717·79	718·04	718·30	718·55
·3	718·81	719·06	719·31	719·57	719·82	720·08	720·33	720·58	720·84	721·09
·4	721·35	721·60	721·85	722·11	722·36	722·62	722·87	723·12	723·38	723·63
·5	723·89	724·14	724·39	724·65	724·90	725·16	725·41	725·66	725·92	726·17
·6	726·43	726·68	726·93	727·19	727·44	727·70	727·95	728·20	728·46	728·71
·7	728·97	729·22	729·47	729·73	729·98	730·24	730·49	730·74	731·00	731·25
·8	731·51	731·76	732·01	732·27	732·52	732·78	733·03	733·28	733·54	732·79
·9	734·05	734·30	734·55	734·81	735·06	735·32	735·57	735·82	736·08	736·33
29·0	736·59	736·84	737·09	737·35	737·60	737·86	738·11	738·36	738·62	738·87
·1	739·13	739·38	739·63	739·89	740·14	740·40	740·65	740·90	741·16	741·41
·2	741·67	741·92	742·17	742·43	742·68	742·94	743·19	743·44	743·70	743·95
·3	744·21	744·46	744·71	744·97	745·22	745·48	745·73	745·98	746·24	746·49
·4	746·75	747·00	747·25	747·51	747·76	748·02	748·27	748·52	748·78	749·03
·5	749·29	749·54	749·79	750·05	750·30	750·56	750·81	751·06	751·32	751·57
·6	751·83	752·08	752·33	752·59	752·84	753·10	753·35	753·60	753·86	754·11
·7	754·37	754·62	754·87	755·13	755·38	755·64	755·89	756·14	756·40	756·65
·8	756·91	757·16	757·41	757·67	757·92	758·18	758·43	758·68	758·94	759·19
·9	759·45	759·70	759·95	760·21	760·46	760·72	760·97	761·22	761·48	761·73

TABLE III.—*continued.*

COMPARISON of the ENGLISH and METRIC BAROMETER SCALES.

English Inches and Tenths.	Hundredths of an Inch.									
	0	1	2	3	4	5	6	7	8	9
30·0	761·99	762·24	762·49	762·75	763·00	763·26	763·51	763·76	764·02	764·27
·1	764·53	764·78	765·03	765·29	765·54	765·80	766·05	766·30	766·56	766·81
·2	767·07	767·32	767·57	767·83	768·08	768·34	768·59	768·84	769·10	769·35
·3	769·61	769·86	770·11	770·37	770·62	770·88	771·13	771·38	771·64	771·89
·4	772·15	772·40	772·65	772·91	773·16	773·42	773·67	773·92	774·18	774·43
·5	774·69	774·94	775·19	775·45	775·70	775·96	776·21	776·46	776·72	776·97
·6	777·23	777·48	777·73	777·99	778·24	778·50	778·75	779·00	779·26	779·51
·7	779·77	780.02	780·27	780·53	780·78	781·04	781·29	781·54	781·80	782·05
·8	782·31	782·56	782·81	783·07	783·32	783·58	783·83	784·08	784·34	784·59
·9	784·85	785·10	785·35	785·61	785·86	786·12	786·37	786·62	786·88	787·13
31·0	787·39	787·64	787·89	788·15	788·40	788·66	788·91	789·16	789·42	789·67
·1	789·93	790·18	790·43	790·69	790·94	791·20	791·45	791·70	791·96	792·21
·2	792·47	792·72	792·97	793·23	793·48	793·74	793·99	794·24	794·50	794·75
·3	795·01	795·26	795·51	795·77	796·02	796·28	796·53	796·78	797·04	797·29
·4	797·55	797·80	798·05	798·31	798·56	798·82	799·07	799·32	799·58	799·83

Inch.	Mill.
1	25·400
2	50·799
3	76·199
4	101·598
5	126·998
6	152·397
7	177·797
8	203·196
9	228·596
10	253·995

Thousandths of an Inch.								
1	2	3	4	5	6	7	8	9
0·03	0·05	0·08	0·10	0·13	0·15	0·18	0·20	0·23

TABLE IV.

Comparison of Thermometers graduated according to the Fahrenheit, Centigrade, and Reaumur Scales.

FAHRENHEIT.

Fahrenheit.	Centigrade.	Reaumur.	Fahrenheit.	Centigrade.	Reaumur.
1°	−17·2°	−13·8°	51°	10·6°	8·4°
2	16·7	13·3	52	11·1	8·9
3	16·1	12·9	53	11·7	9·3
4	15·6	12·4	54	12·2	9·8
5	15·0	12·0	55	12·8	10·2
6	14·4	11·6	56	13·3	10·7
7	13·9	11·1	57	13·9	11·1
8	13·3	10·7	58	14·4	11·6
9	12·8	10·2	59	15·0	12·0
10	12·2	9·8	60	15·6	12·4
11	−11·7	− 9·3	61	16·1	12·9
12	11·1	8·9	62	16·7	13·3
13	10·6	8·4	63	17·2	13·8
14	10·0	8·0	64	17·8	14·2
15	9·4	7·6	65	18·3	14·7
16	8·9	7·1	66	18·9	15·1
17	8·3	6·7	67	19·4	15·6
18	7·8	6·2	68	20·0	16·0
19	7·2	5·8	69	20·6	16·4
20	6·7	5·3	70	21·1	16·9
21	− 6·1	− 4·9	71	21·7	17·3
22	5·6	4·4	72	22·2	17·8
23	5·0	4·0	73	22·8	18·2
24	4·4	3·6	74	23·3	18·7
25	3·9	3·1	75	23·9	19·1
26	3·3	2·7	76	24·4	19·6
27	2·8	2·2	77	25·0	20·0
28	2·2	1·8	78	25·6	20·4
29	1·7	1·3	79	26·1	20·9
30	1·1	0·9	80	26·7	21·3
31	− 0·6	− 0·4	81	27·2	21·8
32	0·0	0·0	82	27·8	22·2
33	+ 0·6	+ 0·4	83	28·3	22·7
34	1·1	0·9	84	28·9	23·1
35	1·7	1·3	85	29·4	23·6
36	2·2	1·8	86	30·0	24·0
37	2·8	2·2	87	30·6	24·4
38	3·3	2·7	88	31·1	24·9
39	3·9	3·1	89	31·7	25·3
40	4·4	3·6	90	32·2	25·8
41	+ 5·0	+ 4·0	91	32·8	26·2
42	5·6	4·4	92	33·3	26·7
43	6·1	4·9	93	33·9	27·1
44	6·7	5·3	94	34·4	27·6
45	7·2	5·8	95	35·0	28·0
46	7·8	6·2	96	35·6	28·4
47	8·3	6·7	97	36·1	28·9
48	8·9	7·1	98	36·7	29·3
49	9·4	7·6	99	37·2	29·8
50	+10·0	+ 8·0	100	37·8	30·2

CENTIGRADE.

Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.
−17°	1·4°	−13·6°	11°	51·8°	8·8°
16	3·2	12·8	12	53·6	9·6
15	5·0	12·0	13	55·4	10·4
14	6·8	11·2	14	57·2	11·2
13	8·6	10·4	15	59·0	12·0
12	10·4	9·6	16	60·8	12·8
11	12·2	8·8	17	62·6	13·6
−10	14·0	− 8·0	18	64·4	14·4
9	15·8	7·2	19	66·2	15·2
8	17·6	6·4	20	68·0	16·0
7	19·4	5·6	21	69·8	16·8
6	21·2	4·8	22	71·6	17·6
5	23·0	4·0	23	73·4	18·4
4	24·8	3·2	24	75·2	19·2
3	26·6	2·4	25	77·0	20·0
2	28·4	1·6	26	78·8	20·8
− 1	30·2	− 0·8	27	80·6	21·6
0	32·0	0·0	28	82·4	22·4
+ 1	33·8	+ 0·8	29	84·2	23·2
2	35·6	1·6	30	86·0	24·0
3	37·4	2·4	31	87·8	24·8
4	39·2	3·2	32	89·6	25·6
5	41·0	4·0	33	91·4	26·4
6	42·8	4·8	34	93·2	27·2
7	44·6	5·6	35	95·0	28·0
8	46·4	6·4	36	96·8	28·8
9	48·2	7·2	37	98·6	29·6
+10	50·0	+ 8·0	38	100·4	30·4

REAUMUR.

Reaumur.	Fahrenheit.	Centigrade.	Reaumur.	Fahrenheit.	Centigrade.
−14°	0·5°	−17·5°	9°	52·3°	11·3°
13	2·8	16·3	10	54·5	12·5
12	5·0	15·0	11	56·8	13·8
11	7·3	13·8	12	59·0	15·0
−10	9·5	−12·5	13	61·3	16·3
9	11·8	11·3	14	63·5	17·5
8	14·0	10·0	15	65·8	18·8
7	16·3	8·8	16	68·0	20·0
6	18·5	7·5	17	70·3	21·3
5	20·8	6·3	18	72·5	22·5
4	23·0	5·0	19	74·8	23·8
3	25·3	3·8	20	77·0	25·0
2	27·5	2.5	21	79·3	26·3
− 1	29·8	− 1·3	22	81·5	27·5
0	32·0	0·0	23	83·8	28·8
+ 1	34·3	+ 1·3	24	86·0	30·0
2	36·5	2·5	25	88·3	31·3
3	38·8	3·8	26	90·5	32·5
4	41·0	5·0	27	92·8	33·8
5	43·3	6·3	28	95·0	35·0
6	45·5	7·5	29	97·3	36·3
7	47·8	8·8	30	99·5	37·5
+ 8	50·0	+10·0	31	101·8	38·8

Decimal Parts of a Degree.

Centigrade Scale compared with Fahrenheit and Reaumur.			Fahrenheit Scale compared with Centigrade and Reaumur.			Reaumur Scale compared with Centigrade and Fahrenheit.		
Cent.	Fah.	Reaum.	Fah.	Cent.	Reaum.	Reaum.	Cent.	Fah.
0·1°	0·18°	0·08°	0·1°	0·06°	0·04°	0·1°	0·13°	0·22°
·2	·36	·16	·2	·11	·09	·2	·25	·45
·3	·54	·24	·3	·17	·13	·3	·38	·67
·4	·72	·32	·4	·22	·18	·4	·50	0·90
·5	0·90	·40	·5	·28	·22	·5	·63	1·12
·6	1·08	·48	·6	·33	·27	·6	·75	·35
·7	·26	·56	·7	·39	·31	·7	0·88	·57
·8	·44	·64	·8	·44	·36	·8	1·00	1·80
0·9	1·62	·72	0·9	·50	·40	0·9	·13	2·02
1·0	1·80	0·80	1·0	0·56	0·44	1·0	1·25	2·25

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Pl 1

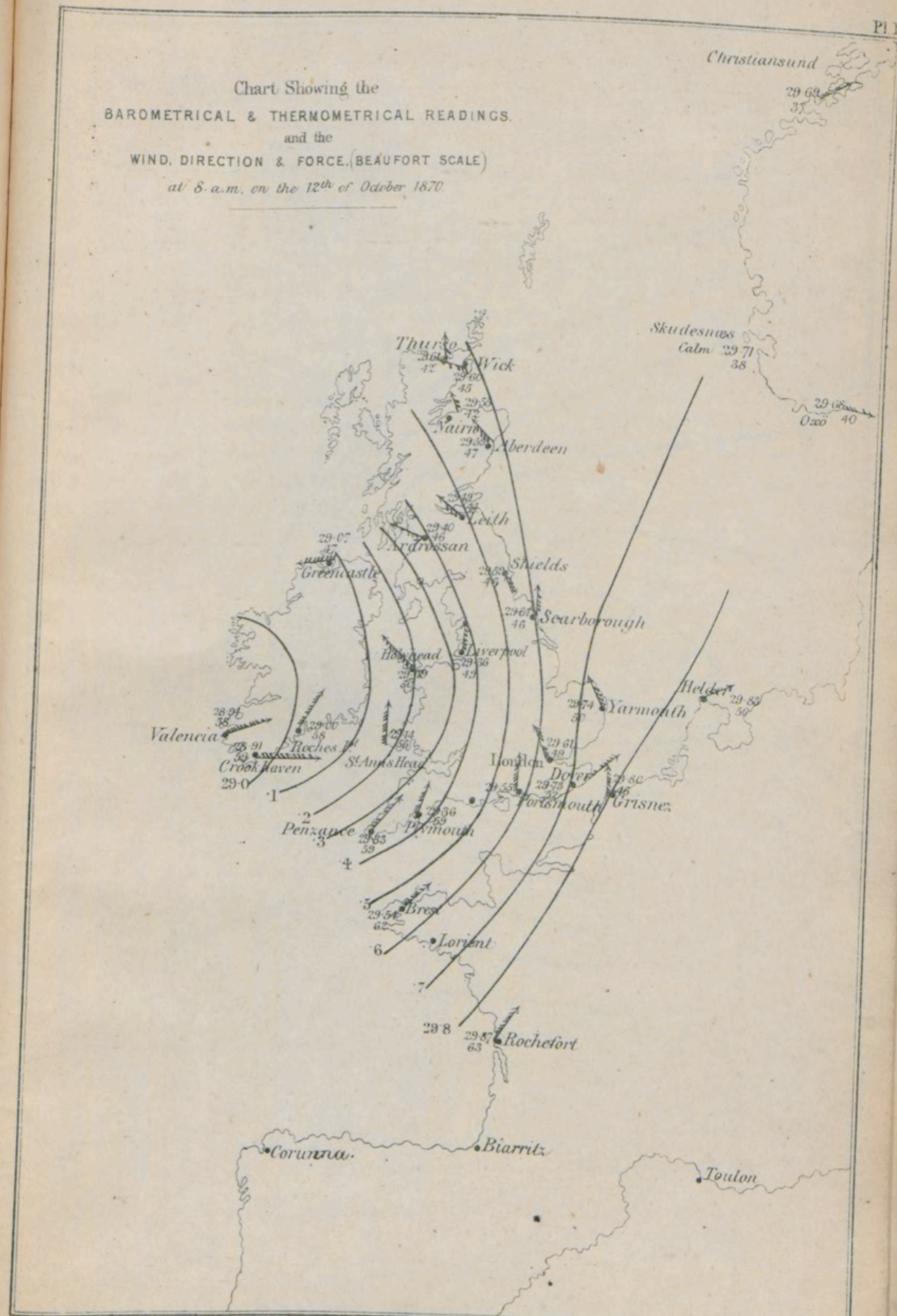


Chart Showing the
BAROMETRICAL & THERMOMETRICAL READINGS
and the
WIND, DIRECTION & FORCE. (BEAUFORT SCALE)
at 8. a.m. on the 12th of October 1870.

Vincent Brooks Day & Son Lith.

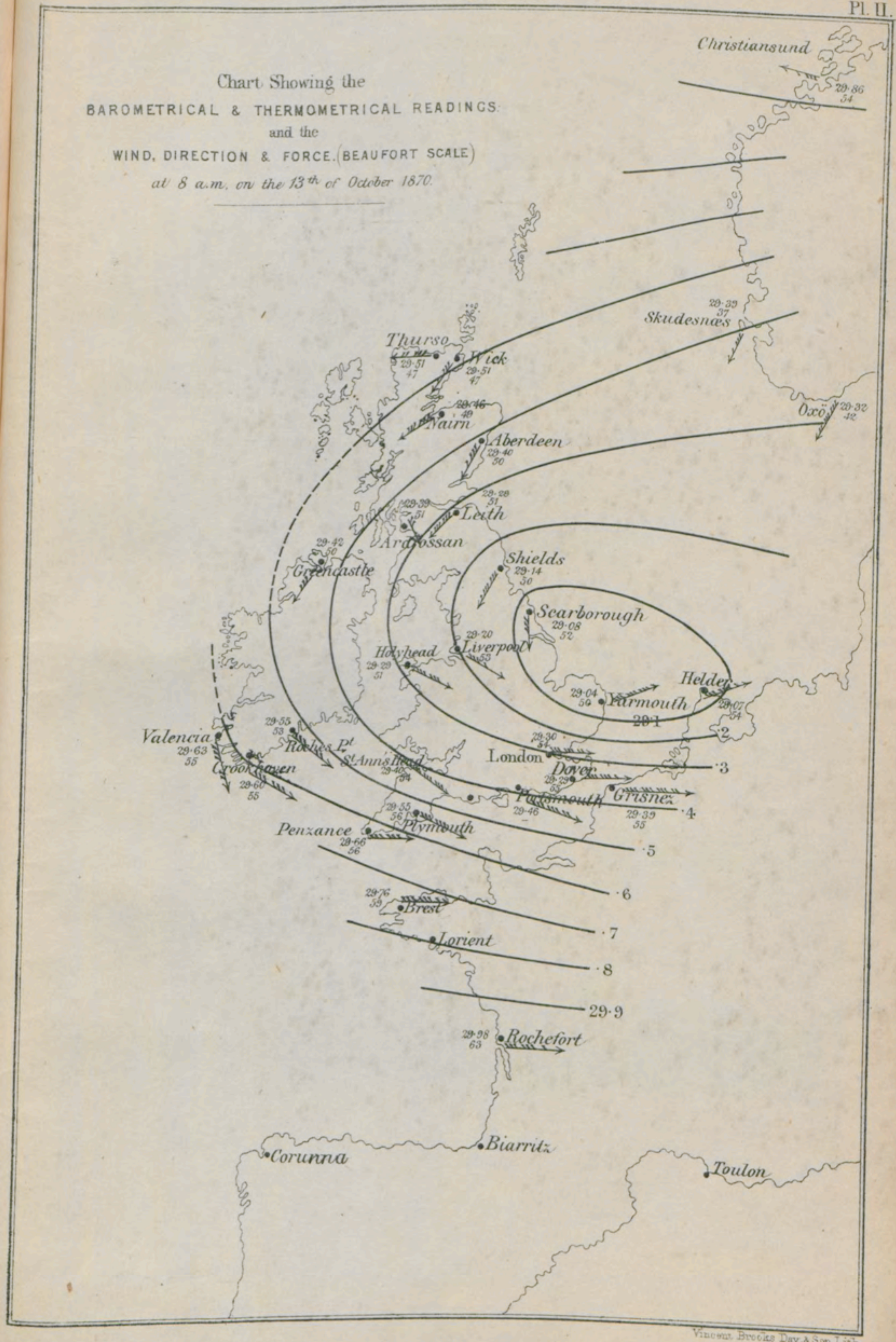
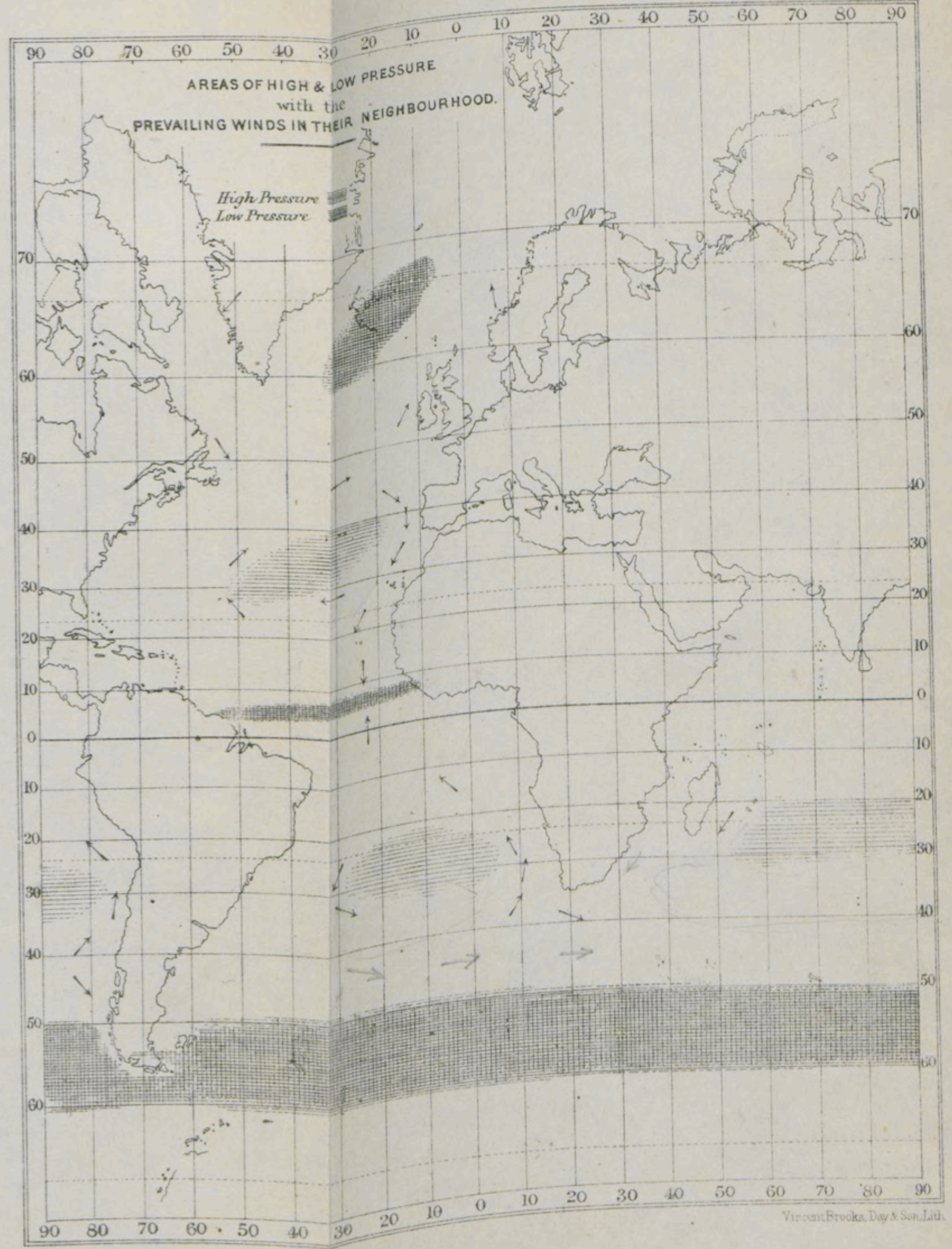


Chart Showing the
BAROMETRICAL & THERMOMETRICAL READINGS
and the
WIND, DIRECTION & FORCE. (BEAUFORT SCALE)
at 8 a.m. on the 13th of October 1870.

Vincent Brooks Day & Son Lith.

Pl. III.



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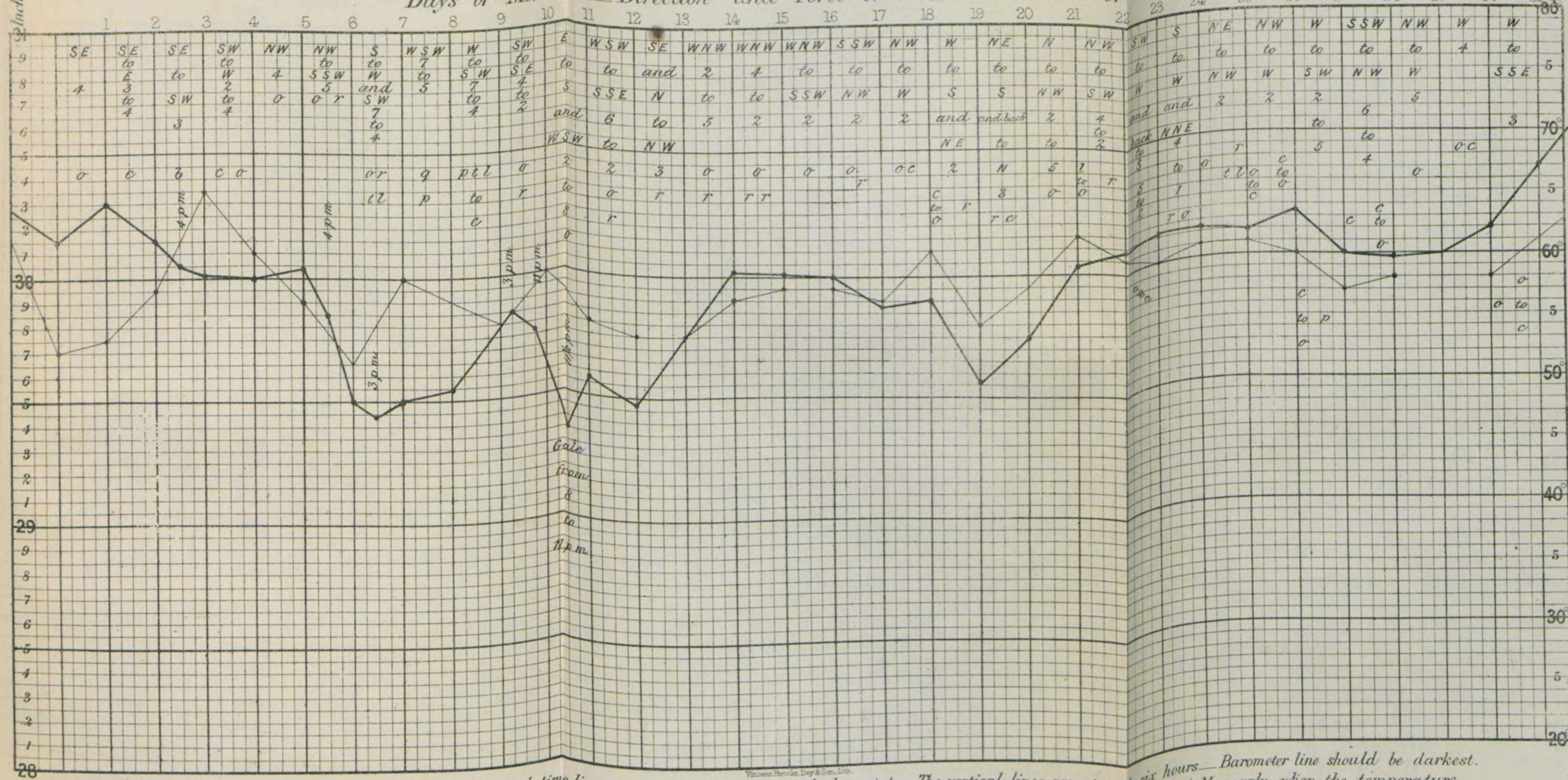
FISHERY OR COAST DIAGRAM.

Barometer and Thermometer at London *Month* June *Year* 1863.

Days of Month — Direction and Force of Wind — Initials of Weather.



Notes: *Mark the points at which height (by side scale) and time lines cross. Draw a line through the points. The vertical lines are at each six hours — Barometer line should be darkest.*
First days are of previous month, for reference, in judging of weather; in order to foretell its character. Time lines or day figures are at 8 A.M. nearly — when the temperature is about the mean or average of night and day.
Intermediate, or alternate lines are for degrees of thermometer, or half tenths of Inches.
The angles made by the drawn lines with those of the form are very useful aids in foretelling weather: especially with exact squares — such as the above, without thermometer lines between.
N. B. This paper should be held on a board by an edge above and below — each end being free — for reading or to hold while shifting.

LIST OF PUBLICATIONS, &c.

ISSUED UNDER

THE AUTHORITY OF THE METEOROLOGICAL COMMITTEE.

OFFICIAL.

No. 1. Report for 1867. Presented to Parliament. 1*s.*

2. Instructions for Meteorological Telegraphy.

3. Fishery Barometer Manual. 6*d.*

4. Charts of Surface Temperature, South Atlantic Ocean. 2*s.* 6*d.*

5. Report for 1868. Presented to Parliament. 5*d.*

6. Report for 1869. Presented to Parliament. 10*d.*

7. Quarterly Weather Report, 1869. Parts I.—IV. Price 5*s.* each. [Published by Stanford, Charing Cross.]

8. Barometer Manual. 1*s.*

NON-OFFICIAL.

No. 1. Report to the Committee on the Connexion between Strong Winds and Barometrical Differences.—By Robert H. Scott, Director of the Office. 6*d.*

2. Report to the Committee on the Meteorology of the North Atlantic.—By Captain H. Toynbee, Marine Superintendent. 1*s.*

3. Report to the Committee on the Use of Isobaric Curves.—By Captain H. Toynbee, Marine Superintendent. 1*s.*
