WEATHER

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Weather

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Weather Instruments

For the Amateur

BY

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"Everywhere, skin deep below our boasted science, we are brought up short by mystery impalpable, and by adamantine gates of transcendental forces and incomprehensible laws, of which the Lord, who is both God and Man alone holds the key, and alone can break the seal."

—*Chas. Kingsley.*

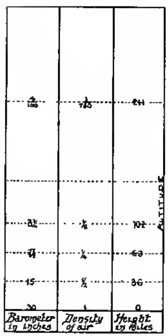
"Fair Weather After You"

—*Shakespeare.*

THE atmosphere surrounding the earth may be regarded as an "ocean" of air extending upward from the earth's surface. Obeying the law of gases it exerts, in all directions, a pressure varying according to the density of the air.

It is impossible to tell accurately to what height air extends. Formerly some authorities claimed eight miles, while others said forty to fifty miles.

The existence of an atmosphere at more than a hundred miles above the surface of the earth is revealed to us by the phenomenon of twilight and the luminosity of meteors and fireballs.



Decrease · of Density · and amount · of · air · with · Increase · of · Altitude

Should you measure off the "ocean of air" in layers of equal thickness, the top layer would naturally be lightest because it is not weighted down and compressed by any layers above. Each succeeding layer would increase in weight until the earth is reached. This layer is heaviest as it must support the entire volume of air above.

An altitude of 85,270 feet was registered at Uccle Observatory, Belgium, by 'balon-sondes' the pressure at this point being only 0.67 inch.

THE AIR AT GREAT HEIGHTS.

It is almost out of the question for man to ascend higher than five or six miles because of lack of air to breathe. At six miles it is too thin to supply a human being with the requisite oxygen for breathing.

At great heights the atmosphere becomes more and more attenuated, and thins out by insensible gradations into a perfect vacuum. There is no definite boundary immediately below which there is an atmosphere, and immediately above which there is none.

The pressure at an altitude of a few miles is very small, decreasing with increase in altitude, as the higher the ascent, the less air remains above.

PRESSURE OF THE ATMOSPHERE.

The air at sea level (weighted down by the air above it) exerts a pressure of about 14.7 pounds per square inch of surface. The pressure on a grown person (average 16 square feet) would be about 35,000 pounds. Were it not for the ease with which the air (under this pressure) penetrates the body, very slight changes in pressure would prove disastrous.

THE WEIGHT OF AIR IN POUNDS.

Like terrestrial solids and fluids, the atmosphere is held in place by the attraction of the earth. As the area of the earth's surface is one hundred and ninety-seven million square miles, or seven hundred and

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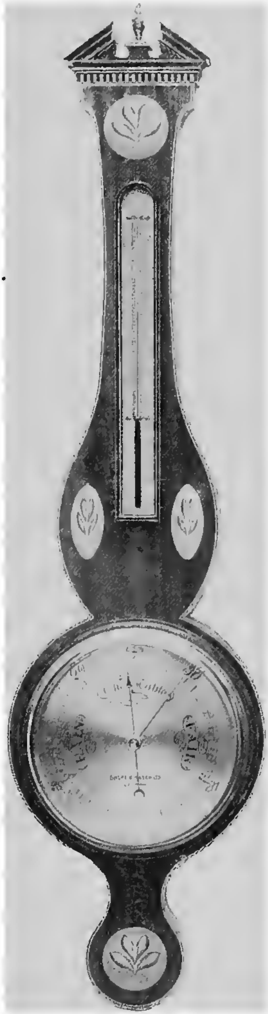
Generally speaking, the fall of one inch in the barometer indicates a rise of about 900 feet in the elevation:

917	feet	above	sea	level	the	barometer	falls	1 in.
1860	"	"	"	"	"	"	"	2 in.
2830	"	"	"	"	"	"	"	3 in.
3830	"	"	"	"	"	"	"	4 in.
4861	"	"	"	"	"	"	"	5 in.

ninety quadrillion inches, the total weight of the atmosphere is eleven and two-thirds quintillion pounds.

Of the enormity of these values, some idea may be obtained by instituting a few interesting comparisons. One million trains each composed of one million powerful locomotives would represent but the hundredth part of the weight of the atmosphere. A leaden ball equal in weight to the atmosphere would have a diameter of 60 miles.

This law (decrease of pressure) being known, its principle is used in measuring the height of hills and mountains by means of barometric observations at the two points.



THE ANEROID.

The word "Aneroid" is a Greek compound, expressing "without fluid," thus distinguishing this barometer from one which measures the pressure of the air by means of a mercury column.

The Aneroid is so arranged that the pressure of the air actuates the upper surface of a vacuum chamber, which is per-

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The average height of the barometer in England at sea level is 29.94 inches. The average height of the barometer in the United States at sea level is 29.92 inches.

fectly balanced between this pressure and a main spring.

The vertical action thus given to the vacuum chamber is multiplied and transmitted to an index hand moving over the dial, which has been graduated into divisions (inches and fractions of an inch) to agree with the scale of the mercurial barometer.

EARLY WEATHER RECORDS.

The earliest records of weather are found in mythical stories, some of which still survive. In England and Sweden "Noah's Ark" is still seen in the sky, while in Germany the "Sea Ship" still turns its head to the wind before the rain. In Scotland the "Wind Dog" and the "Boar's Head" are still the dread of the fisherman, while such names as "Goat's Hair" and "Mares' Tail" recall some of the shaggy monsters of antiquity.

It is said that some of the prognostics of the Greek "Diosemeia" (270 B. C.) are in current use at the present time, having been incorporated by Virgil in his Georgics and then translated into English.

OLD WEATHER PROVERBS.

The enormous extent to which such a foretelling has been carried on, is shown by the vast array of weather proverbs and adages handed down from the past, while the faultiness of their generalizations has been proved by the utter failure of most attempts at their verification. Among the most common of these wise sayings are those which assert a controlling influence of certain days over the weather for considerable periods to follow.

A cubic foot of dry air at 32° F. at sea level weighs 0.080728 lbs.

The most potent of these special days seems to have been sacred to some particular saint, and perhaps the most powerful of all in this respect was the far-famed St. Swithin, whose wonderful prowess as a rain-maker is shown in the verse:

"St. Swithin's day, if thou dost rain,
For forty days it will remain.
St. Swithin's day, if thou be fair,
For forty days 'twill rain nae mair."

A class of proverbs has to do with some supposed relation between one meteorological condition and another soon to follow, or of certain conditions existing at one time of day being indicative of immediate change. As an example of the first:

"A storm of hail
Brings frost in its tail."

Or:

"If the rain comes before the wind,
Lower your topsails and take them in;
If the wind comes before the rain,
Lower your top sails and hoist them again."

And:

"The rainbow in the morning
Is the shepherd's warning,
The rainbow at night
Is the shepherd's delight."

There are grounds for suspecting that the existence of many of the most "catchy" of all the proverbs is due to the tendency which existed a century or two ago, especially in England, where the crop of sayings seemed to be most prolific, of putting words together in such a way as to form rhyme, even at the expense of truth. A case in point, though not from weather

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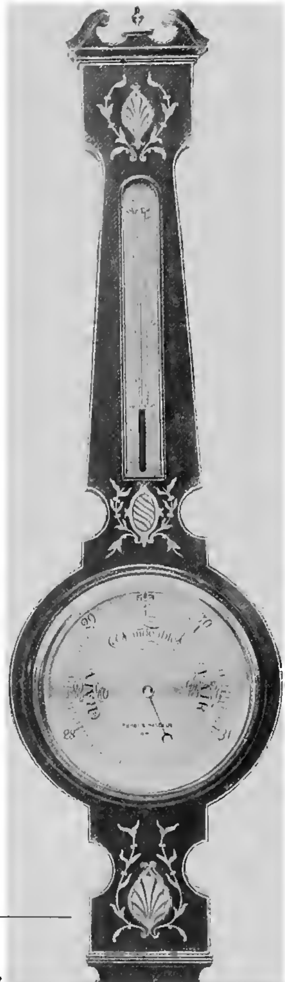
"Evening red and morning gray
Are sure signs of a pleasant day."

lore, is the epitaph upon a seventeenth century tombstone in an English country churchyard:

"Here lies the body of Thomas Woodhen,
The kindest of husbands and best of men."

Directly beneath is the explanation:

"His name was Woodcock but it wouldn't come in rhyme."



THE INFLUENCE OF WEATHER ON PEOPLE.

The records of the police courts of New York City, studied in connection with those of the Weather Bureau, show conclusively that not only on the hot day but during certain meteorological conditions, (unknown perhaps by name to the author of "Romeo and Juliet"), was the "mad blood stirring."*

Records of deportment in the public schools, of suicide, of death, of general health, and of the behavior of the insane similarly studied, show unmistakable evidence of a weather influence, and in spite of the fact that it seemed to Samuel Johnson a very sorry thing that "a being endowed with reason should resign his

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*** "I pray thee, good Mercutio, let's retire:
The day is hot; the Capulets abroad,
And if we meet, we shall not 'scape a brawl,
For now, these hot days, is the mad blood stirring."**

powers to the influence of the air, and live in dependence upon weather and wind," even the most phlegmatic of us must acknowledge the potency of the east wind and the leaden sky.

It was not until 1643, twenty-three years after the landing of the Pilgrims on Plymouth Rock, that Torricelli discovered the principle of the barometer. Torricelli's great teacher, Galileo, died without knowing why Nature, under certain conditions, abhors a vacuum; but he had discovered the principle of the thermometer. The data from the readings of these two instruments form the foundation of all meteorological science.

THE FIRST USE OF THE BAROMETER.

As soon as men began to observe the barometer attentively, they began gradually to recognize that the rising and falling of the barometer had an evident connection with the weather. It was the celebrated burgomaster, Otto von Guericke, of Magdeburg, who first used the barometer as a "weather glass." He applied, even then, to his water barometer the "weather scale," which is at present in such general use, on which the highest reading occurring at any place is designated as "fine weather," the lowest reading as "rain and wind," etc. The barometer as a weather glass has taken its course throughout the world, and is to-day used almost universally.

ROTARY MOTION OF STORMS.

About one hundred years after the invention of the barometer (1747), Benjamin Franklin divined that certain storms had a rotary motion and that they progressed in a northeasterly direction. Although his

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Lowest U. S. barometer reading was taken at Galveston, Texas, during the year of flood when the barometer reached 28.48 inches or nearly ¾ lb. per square inch below normal.

ideas in this respect were more important than his act of drawing the lightning from the clouds and identifying it with the electricity of the laboratory, his contemporaries thought little of his philosophy of storms. It remained for Redfield, Espy, Maury, Loomis and Abbe, one hundred years later, to gather the data and completely establish the truth of that which the great Franklin had dimly yet wonderfully outlined.

STUDY OF CONDITIONS AT GREAT ELEVATIONS.

We have at present no method by which we can forecast the weather with absolute certainty even for one day in advance, to say nothing of longer periods.

The Weather Bureau has established an Observatory at Mount Weather to study conditions of temperature, pressure, humidity and wind velocity and direction at great elevations to increase our knowledge of the laws governing the atmosphere, which should eventually enable our successors (if not ourselves) to add to the accuracy of weather forecasts and to make them for a longer period in advance.

A temperature of 111 degrees below zero was taken at St. Louis, Mo., at an altitude of 48,700 feet.

Hall Barometer

As one of the primary objects in view in establishing Mount Weather Observatory was to make a study of the relations existing between the various forms of solar radiation and terrestrial weather conditions, much attention had to be given to the instrumental equipment and to securing men to study the variation in the amount of heat energy given off by the sun from day to day and variation in the amount of heat absorbed by the atmosphere.

So important to the study of the sun is a continuous record of the magnetic variations that one of the first steps in the establishment of the Observatory was the installation of a magnetic plant consisting of the best modern instruments for the direct observation and for continuous registration of the variation in the magnetism of the earth.

Researches are also carried on to determine the existence and measure the extent of probable direct relation between meteorological disturbances and magnetic variations.

AT PRESENT WEATHER PREDICTIONS ARE MADE:

(*a*) From local observations and refer to the locality where made.

(*b*) From weather charts (covering an extended region) and refer to any region on the chart.

(*c*) From weather charts in connection with local observation and refer to the region where the local observations are made.

As storms usually occur where the air pressure is low, the aneroid not only determines the height of mountains but also forecasts the weather.

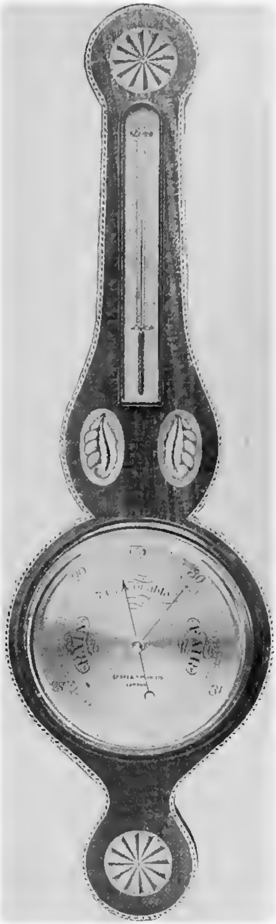
The sun setting after a fine day behind a heavy bank of clouds, with a falling barometer, is generally indicative of rain or snow, according to the season, either in the night or next morning.

"WEATHER" AND THE EFFECT OF THE SUN.

We speak of weather as meaning the atmospheric condition as shown by the meteorological element of a particular time, for a day, a season, or even a year. Climate is the aggregate of weather conditions.

The sun regulates our weather; it gives rise to winter and summer; by evaporation it raises the aqueous vapor into the air, and this vapor by cooling, produces clouds, rain, snowstorms and hail; it is the primary cause of the differences in atmospheric pressure, and in this way produces the winds.

This heating influence of the sun, as also its modifications by cloudiness, by the wind, by the change from day to night or from winter to summer, and by the properties of the earth's surface, which, consisting as it does of water and land either covered with vegetation or barren, has varying capacities for absorbing the sun's heat. This influence of the heat of the sun has been established with the most absolute certainty by the most exact observations.



Hall Barometer

The sun is the great source of light and heat, which is transmitted to the earth. It is 853,000 miles in diameter and spherical in shape.

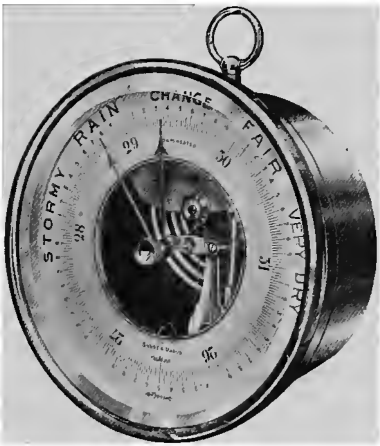
THE METEOROLOGICAL ELEMENTS.

The meteorological elements are the temperature, the barometric pressure, the humidity, precipitation, evaporation, the wind, the clouds and the electrical conditions of the air.

Aerial Meteors are winds, hurricanes, whirlwinds, etc.

Aqueous Meteors are fogs, clouds, rain, dew, snow, etc.

Luminous Meteors are lightning, the rainbow and the Aurora Borealis.



Metal Case Compensated Aneroid Barometer

HOW TO FORECAST.

To make a good forecast, it is essential that the observer take into consideration the direction and force of winds, appearance of the sky, humidity of the air and a comparison of the barometer reading with the indicated pressure for several days preceding.

An important fact, too often overlooked, is that the Aneroid *foretells*, rather than indicates weather that is present. The Aneroid generally indicates changes in weather 12 to 24 hours in advance.

After "setting" the barometer if the hands at the next observation coincide, the barometer is "station-

Wood Frame Aneroid Barometer

ary." If the blue hand has moved to the right, the barometer is "rising." If it has moved to the left, the barometer is "falling." The extent of the rise or fall being the distance (in fractions of an inch) between the two hands upon the dial.

The possibility is always for a continuation of existing weather unless some phenomenon presents itself which foretells a change.

A very low barometer is usually attendant upon stormy weather, with wind and rain at intervals, but the latter not necessarily in any great quantity. If the weather, notwithstanding a very low barometer, is fine and calm, it is not to be depended upon; a change may come on very suddenly.

EFFECT OF WIND.

The wind which causes the barometer to rise and fall, has more to do with the weather than the prevalence or deficiency of sunshine. The shifting of the wind is the most trustworthy of weather forecasts.

A rise in the barometer shows that heavier air is drifting to a place just before occupied by light air. As heavy air is air that has been condensed by cold, a rise in the barometer indicates a cold wind.

A fall in the barometer shows that light air is drifting to a place just before occupied by heavy air, or, in other words, a warm wind is blowing.

A falling barometer usually indicates a high or a low atmospheric pressure existing near at hand. The fall is then due to the gradual drifting up of the lighter air and the drifting away of the heavier air in the giddy whirl of some aerial conflict. A falling barometer shows that lighter pressures are approaching the station of the observer.

WEATHER WORDS ON ANEROID USELESS.

Whoever has provided himself with an instrument of this kind believes himself to be the possessor of a self-registering weather prophet, and is generally highly indignant if it rains when his barometer stands at "fine" or astonished if it is fine weather when the barometer says "rain."

The reading 29.5 (29½ inches) was at one time assumed to be the midway line separating "Fair" from "Rain" and was accordingly marked "Change." 30 inches was marked "Fair;" 31 inches, "Very Dry;" 28.5 inches, "Rain;" and 28 inches, "Stormy." A fixed standard was thus assumed for a condition of Nature that is literally as unstable as the wind. It was

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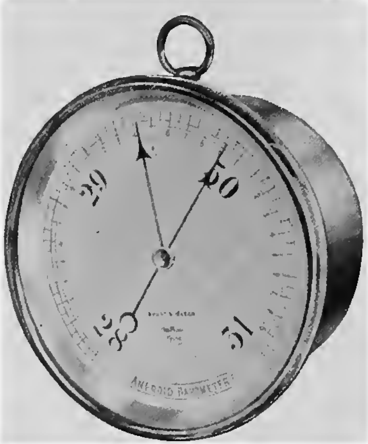
A sudden rise in the barometer is nearly as threatening as a sudden fall because it shows that the level is unsteady.

supposed that the instruments were to be used only in places about at the same level as the surface of the sea.



This is the ideal barometer, as the scale reads only from 28 to 31 inches, and has no weather words on it.

One thousand feet of altitude represents, roughly, an inch of pressure on the barometer. So that if two barometers were placed, one at sea level and the other at an altitude of 1,000 feet, the one at sea level might read "Fair," while the other, under practically similar meteorological conditions, would read "Rain."

Even at the sea level, if a barometer which has been standing at, say, 30.9 inches for some days, suddenly fell to 29.9 in 24 hours, it would give a positive indication of change, intimating the approach of strong wind

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ALTITUDE.

The scientific word for "height." The altitude of a cone or pyramid is the height of its vertex above the plane on which it stands. The altitude of a star is its height above the horizon. The altitude of a mountain or hill is its greatest height above sea level.

and probably rain, yet according to the dial, it would read "Fair." In a similar manner, if a barometer that had been standing at 28 inches for some days, rose in about 24 hours to 29 inches it would indicate the approach of a cold, dry wind although the dial would read "Rain."

It follows that these words on the dial have no significance but are simply relative.

SINGLE OBSERVATION USELESS.

A single observation of the barometer, without reference to the conditions prevailing at definite intervals preceding is liable to be misleading. The important thing to know is—Has the rise or fall been a gradual one or has it been rapid? If the barometer is stationary, how long has this condition existed? Weather prognostications from barometer observations are based on a knowledge of all these conditions, and never from a single observation.

RAPID CHANGES INDICATE.

A rapid fall or a rapid rise intimates that a strong wind is about to blow, and that this wind will bring with it a change in the weather. What the precise nature of the change is to be must, in the main, depend upon the direction from which the wind blows.

If an observer stands with the wind blowing on his back, the locality of low barometric pressure will be at his left and that of high barometric pressure at his right. With low pressure in the west and high pressure in the east, the wind will be from the south; but with low pressure in the east and high pressure in the west, the wind will be from the north.

When the glass falls low,
Prepare for a blow;
When it rises high,
Let all your kites fly.

The barometer rises for northerly wind (including from northwest, by the *north*, to eastward) for dry, or less wet weather, for less wind, or for more than one of these changes—except on a few occasions when rain, hail or snow comes from the northward with *strong* wind.

The barometer falls for southerly wind (including from southeast, by the *south*, to the westward), for wet weather, for stronger wind or for more than one of these changes—except on a few occasions when *moderate* wind with rain (or snow) comes from the northward.

The above applies to readings in the northern hemisphere. The readings in the southern hemisphere are practically the reverse of these.

For a change of wind towards northerly directions a thermometer falls.

For change of wind towards southerly directions a thermometer rises.

Moisture or dampness in the air (shown by a hygrometer) increases before rain, fog or dew.

GENERAL BAROMETER INDICATIONS.

A gradual but steady rise indicates settled fair weather.

A gradual but steady fall indicates unsettled or wet weather.

A very slow rise from a low point is usually associated with high winds and dry weather.

A rapid rise indicates clear weather with high winds.

A very slow fall from a high point is usually connected with wet and unpleasant weather without much wind.

A sudden fall indicates a sudden shower or high winds, or both.

When the barometer falls considerably without any particular change of weather, you may be certain that a violent storm is raging at a distance.

A stationary barometer indicates a continuance of existing conditions, but a slight tap on the barometer face will likely move the hand a trifle, indicating whether the tendency is to rise or fall.

In the warm months the winds are light and rather variable, and changes in direction have not the same importance as in the colder months. The rain of summer generally occurs in connection with thunderstorms; it will be found that these are most frequent from a certain direction and with the wind in a particular quarter.

Beyond the fact that more thunderstorms come from a westerly quarter than from any other direction, little can be said that will be of value in forecasting their approach by the direction of the surface winds only. The coming of a thunderstorm can generally be foretold a few hours in advance by the form and movement of the clouds.

STORMY WEATHER IN WINTER.

The signs of falling weather in the colder months are the formation of a high sheet cloud covering the whole sky, an increase in the temperature and moisture of the air, and the change of the wind to some easterly quarter. The precise direction that the wind takes, whether northeast, east or southeast, varies for different localities and the direction from which the storm is approaching.

In New England, the Middle States and the Ohio Valley, northeasterly winds precede storms that approach from the southwest, and southeasterly winds precede storms that approach by way of the Lake

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Rapid changes in the barometer indicate early and marked changes in the weather.

Region. On the Pacific coast southeasterly and southerly winds precede rain storms.

☞ In Wyoming and other Northwestern States the heavy snowstorms of winter and spring generally come from the north or northwest with a strong wind from the same direction. The direction of the wind depends very much on the position of traveling storms that pass across the country.

In every locality, there is one direction of cloud motion that betokens bad weather, and another, generally the opposite direction, which portends fine weather, etc. Weather rules relative to red morning and evening sky have been deduced.

LOCAL SIGNS.

The rules that bad weather is expected when in any given locality the summit of a certain mountain is covered with a cap; that a small, "watery" halo around the moon indicates rain; that the weather will continue bad if, when the clouds break up, a second light covering of clouds is seen above them; that it will be fine weather if, after rainy weather, according to the locality, a certain wind sets in; that a slow breaking up of the clouds gives promise of fine weather, etc., all of these rules have been formulated from long-continued and accurate observation, and are exceedingly well adapted for *local* weather forecasts from one day to the next.

FORECASTING FROM COLOR OF CLOUDS.

Experienced observers also know from the color and nature of the clouds whether the prevailing weather will continue or will change and, by these delicate distinctions, generally acquire the reputation of being especially good weather prophets.

Should the barometer continue low when the sky becomes clear, expect more rain within 24 hours.

The Spider as a Barometer

THE spider is a good example of a living barometer. Every twenty-four hours he makes some alteration in his web to suit the weather. When a high wind or heavy rain threatens, he may be seen taking in sail, shortening the rope filaments that sustain the web structure. If the storm is to be unusually severe or of long duration, the ropes are strengthened as well as shortened.

On the contrary, when you see the spider running out the slender filaments, it is certain that calm, fine weather has set in, whose duration may be measured by their elongation. When the spider sits quiet and dull in the middle of its web, rain is not far off. If it be active, however, and continues so during a shower, then it will be of brief duration, and sunshine will follow. When you see the spiders coming out of the walls more freely than usual, you may be sure that rain is near.

THE FROG AS A BAROMETER.

A small green frog is found in Germany, which always comes out of the water when cold or wet weather is approaching. These frogs are caught and kept in glass jars furnished with a tiny ladder and half filled with water. The frog weather prophet sits high and dry on the top of his ladder for several hours before a storm, and climbs down to the bottom

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"Everything is lovely and the goose honks high."

when the weather is to be fair and clear. Other remarkable weather prophets are leeches.

About 1867 a new treatment of weather problems (known as the synoptic method weather charts) was introduced. Lines were drawn through all places where the barometer read 30; others through all places reading 29, etc. These were called "isobars" because they marked out lines of equal pressure. Dots drawn through places where the temperature was equal at the moment were called "isotherms" or lines of equal temperature.

Arrows marked velocity and direction of wind. Letters and symbols denoted appearance of sky, amount of clouds and occurrence rain or snow on Synoptic Chart.

WHEN THE CHARTS WERE EXAMINED IT WAS FOUND:

1. That in general the configuration of the isobars assumed one of seven well defined forms.

2. That, independent of the shape of the isobars, the wind always took a definite direction relative to the trend of those lines and the position of the nearest area of low pressure.

3. That the velocity of the wind was always nearly proportionate to the closeness of the isobars.

4. That the weather—that is, the kind of cloud, rain, fog, etc., at any point was related to the shape (not the closeness of the isobars), some shapes enclosing areas of fine, others of bad weather.

5. That the regions thus mapped out were constantly shifting their position so that changes of weather were caused by the drifting past of these areas of good or bad weather, just as on a small scale rain falls as a squall drives by.

The motion of these areas was found to follow certain laws, so that foretelling weather changes in advance became possible.

Birds fly high when the barometer is high—probably because the air is heavier and denser, therefore has more sustaining capacity.

6. That sometimes in the temperate zone and habitually in the tropics, rain fell without any appreciable change in the isobars, though the wind conformed to the general law of these lines.

So far the science rests on observation that such and such wind or weather comes with such a shape of isobars.

The same shape of isobars appear all over the world, but their motion and the details of weather are modified by numerous local, diurnal and annual variations which must be studied out.

Isobars represent the effect on our barometers of the movements of the air above us so that by means of isobars we trace the circulation and eddies of the atmosphere.

THE FIRST U. S. WEATHER BUREAU.

Although American scientists were the pioneers in discovering the rotary and progressive character of storms and in demonstrating the practicability of weather services, the United States was the fourth country to give legal autonomy to a weather service.

Congress authorized the first appropriation of $20,000 to inaugurate a tentative weather service in 1870. Gen. Albert J. Myer, to whom was assigned the Chiefship of the new Meteorological Service, doubtless had no conception of the future wonderful extension of the system that he was then authorized to begin.

STORM WARNING ON THE COAST.

Whether on the Atlantic, on the Pacific, or on the Lakes, there is either a full meteorological observatory or else a storm-warning display-man who attends to

If the barometer and thermometer both rise together, it is a very sure sign of coming fine weather.

the lighting of the danger lights on the storm-warning towers at night, to the display of danger flags by day, and to the distribution of storm-warning messages among vessel masters.

This system is so perfect that the Chief of the Weather Bureau, or the forecaster on duty at the Central Office, can dictate a "storm warning" and feel certain that inside of one hour a copy of the warning will be in the hands of every vessel master in every port of material size in the United States, provided that it is his desire that a complete distribution of the warning be made.

ADVANCE REPORTS OF STORMS REDUCE LOSS 75%.

The marine warnings of the service have been so well made that in over ten years no protracted storm has reached any point in the United States without the danger warnings being displayed well in advance. As a result of these warnings the loss of life and property has been reduced to a minimum, being doubtless not more than 25 per cent. of what it would have been without this extensive system.

When a marked cold wave develops in the northern plateau of the Rocky Mountains and, by its broad area and great barometric pressure, threatens to sweep southward and eastward with its icy blasts, the meteorological stations of the Bureau are ordered to take observations every few hours in the region immediately in advance of the cold area and to telegraph the same to headquarters.

By this means every phase of the development of the cold area is carefully watched, and when the danger is great each observatory in the threatened region

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It is estimated that 80 per cent. to 85 per cent. of weather predictions are successful.

becomes a distributing center, from which warnings are sent to those who have produce or perishable articles of manufacture that need protection against low temperatures.

Travelling Set

The United States Government spends $1,500,000 a year on its Weather Bureau, which is more money than the combined governments of Europe spend.

It is not uncommon for the Bureau to distribute 100,000 telegrams and messages inside of the space of one or two hours, so that nearly every city, village

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In England the observed range of the barometer is about 1.3 inches, or about 0.3 in. greater than in U. S.

and hamlet receives the information in time to profit thereby. What this means to the farmer and shipper is well illustrated by the fact that it was gathered from those personally interested, statements relative to the sweep of one cold wave, which showed that over $3,400,000 worth of property that would have been destroyed by the low temperatures was saved.

Even when severe storms are not imminent there is, in addition to the printing of the forecasts in the daily press, a daily distribution of 80,000 telegrams, maps and bulletins, that place the information in the hands of millions whose personal interests are materially affected by the weather.

FINE WORK OF WEATHER BUREAU.

Not a single storm has swept across the United States or up or down its coastline within many years that has not been foretold hours, and possibly days, in advance by the Weather Bureau. The same applies to cold waves and floods.

The time at the disposal of the forecast official of the Weather Bureau at the Central Office in Washington for the purpose of forecasting probable weather changes, cold waves and severe storms is about thirty minutes in the morning and forty at night. It is impossible in this short time to do more than express the character of the anticipated changes for each state or district east of the Rocky Mountains in any but the most general terms.

LOCAL FORECASTING.

The local or state forecast official, on the other hand, is concerned with but a single district. He is at liberty to amplify the national forecasts or to put

The principal maximum barometric pressure occurs before noon and the principal minimum after noon.

forth a statement of his own, in which the anticipated changes may be given in as much detail as the conditions seem to justify.

Persons who use the forecasts constantly should cultivate the habit of carefully noting the weather changes in their respective localities, especially the sequences in which such changes occur, for it is only by acquiring a knowledge of local weather signs that they can use government forecasts to the best advantage.

Hall Barometer

If the barometer falls gradually for several days during fine weather, expect considerable rain. If it keeps rising while the wet continues, the weather, after a day or two, will probably be fair for some time.

The barometer and wind indications of the United States are generally summarized in the following table of the U. S. Weather Bureau:

Barometer Reduced to Sea Level.	Wind Direction.	Character of Weather Indicated.
30.10 to 30.20 and steady	SW. to NW.	Fair with slight temperature changes for 1 to 2 days.
30.10 to 30.20 and rising rapidly	SW. to NW.	Fair followed within 2 days by warmer and rain.
30.10 to 30.20 and falling slowly	SW. to NW.	Warmer with rain in 24 to 36 hours.
30.10 to 30.20 and falling rapidly	SW. to NW.	Warmer with rain in 18 to 24 hours.
30.20 and above and stationary	SW. to NW.	Continued fair with no decided temperature change.
30.20 and above and falling slowly	SW. to NW.	Slowly rising temperature and fair for two days.
30.10 to 30.20 and falling slowly	S. to SE.	Rain within 24 hours.
30.10 to 30.20 and falling rapidly	S. to SE.	Wind increasing in force with rain within 12 to 24 hours.
30.10 to 30.20 and falling slowly	SE. to NE.	Rain in 12 to 18 hours.
30.10 to 30.20 and falling rapidly	SE. to NE.	Increasing wind with rain within 12 hours.
30.10 and above and falling slowly	E. to NE.	In summer, with light winds, rain may not fall for several days. In winter, rain within 24 hours.
30.10 and above and falling rapidly	E to NE.	In summer, rain probably within 12 to 24 hours. In winter, rain or snow, with increasing wind will often set in, when the barometer begins to fall and the wind sets in from the NE.
30 or below and falling slowly	SE. to NE.	Rain will continue 1 or 2 days.
30 or below and falling rapidly	SE. to NE.	Rain with high wind, followed within 24 hours by clearing and cooler.
30 or below and rising slowly	S. to SW.	Clearing within a few hours and continued fair for several days.
29.80 or below and falling rapidly	S. to E.	Severe storm of wind and rain or snow imminent, followed within 24 hours by clearing and colder.
29.80 or below and falling rapidly	E. to N.	Severe northeast gales and heavy rain or snow, followed in winter by a cold wave.
29.80 or below and rising rapidly	Going to W.	Clearing and colder.

Explanation of Weather Map

THE U. S. Weather Bureau makes telegraphic reports of the weather each day at 8 a. m. and 8 p. m., seventy-fifth meridian time. The reports consist of observations of the barometer and thermometer, the velocity and direction of the wind, amount, kind and direction of movement of clouds, and amount of rain or snow.

On the weather maps solid lines (isobars) are drawn through points that have the same atmospheric pressure, a line being drawn for each one-tenth of an inch in the height of the barometer. Dotted lines (isotherms) are drawn through points that have the same atmospheric temperature, a line being drawn for each ten degrees of temperature. Heavy dotted lines are sometimes used to enclose areas where decided changes in temperature have occurred during the preceding twenty-four hours. The direction of the wind at each station is indicated by an arrow that flies with the wind.

The state of the weather—clear, partly cloudy, cloudy, rain or snow, is indicated by symbols. Shaded areas are used to show areas within which precipitation in the form of rain or snow has occurred during the preceding twelve hours.

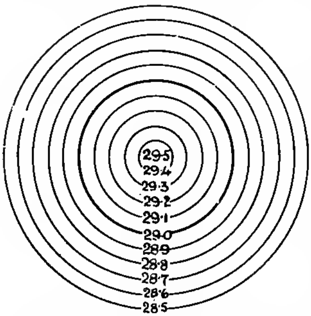
The rapidity of the storm's approach and its intensity will be indicated by the rate and amount of the fall in the barometer.

TABULAR DATA OF WEATHER MAPS.

The tabular data give details of maximum and minimum temperature and twenty-four hour temperature changes, wind velocities, and amount of precipitation during the preceding twenty-four hours. The text printed on the maps presents forecasts for the state and the station, and summarizes general and special meteorological features that are shown by the lines, symbols and tabulated data.

HOW "HIGHS" AND "LOWS" MOVE.

The centers of areas of low barometric pressure, or general storms, are indicated on the map by the word "Low," and the centers of areas of high barometric pressure by the word "High." The general movement of "Lows" and "Highs" in the United States is from west to east, and in their progression they are similar to a series of atmospheric waves, the crests of which are designated by the "Highs" and the troughs by the "Lows." These alternating "Highs" and "Lows" have an average easterly movement of about 600 to 700 miles a day. The "Lows" usually move in an easterly, or north of east, direction, and the "Highs" in an easterly, or south of east, direction.



Showing increase & decrease of Pressure.

In the tropics a rapid barometric fall is dangerous because, in a general way, it shows the observer is nearly in path of cyclone. Any fall of more than .02 is dangerous.

In advance of a "Low" the winds are southerly or easterly, and are, therefore, usually warmer. When the "Low" passes east of a place the wind shifts to westerly or northwesterly with lower temperature. The eastward advance of "Lows" is almost invariably preceded and attended by precipitation in the form of rain or snow, and their passage is usually followed by clearing weather.

The temperature on a given parallel west of a "Low" may be reasonably looked for on the same parallel to the east when the "Low" has passed, and when the night is clear and there is but little wind, frost is likely to occur along the north of an isotherm of 40°. A "Low" is generally followed by a "High," which in turn is followed by another "Low."

WHAT ISOTHERMS INDICATE.

When isotherms run nearly east and west no decided changes in temperature are likely to occur. When isotherms directly west of a place incline from northwest to southeast the temperature will rise; when from northwest to southwest, the temperature will fall.

Southerly to easterly winds prevail west of a nearly north and south line passing through the middle of a "High" and also east of a like line passing through the middle of a "Low." Northerly to westerly winds occur west of a nearly north and south line passing through the middle of a "Low," and also east of a similar line passing through the middle of a "High."

An absence of decided and energetic "Lows" and "Highs" indicates a continuance of existing weather

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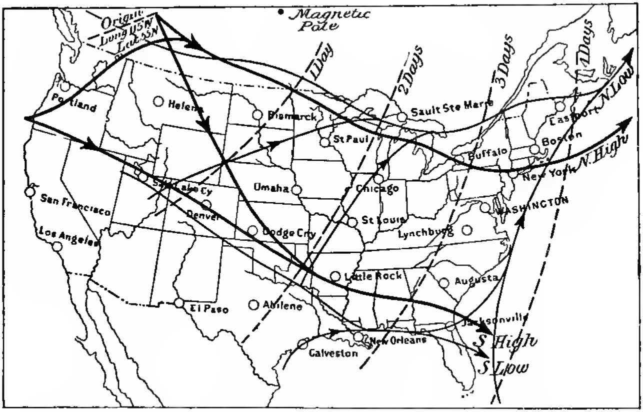
When the air becomes colder with a low barometer and a southwest wind, squalls from the northeast will certainly follow, and in winter it is nearly always accompanied by snow.

that will continue until later maps show a change, that usually appears in the west.

At first glance, weather maps look very confusing. The storms of the United States follow, however, year after year a series of tracks, not capricious, but related to each other by very well defined laws.



MEAN TRACKS AND AVERAGE DAILY MOVEMENT OF STORMS IN THE UNITED STATES.

The chart shows the general result of a study of tracks of storms in the United States. There are two sets of tracts running westerly and easterly, one set over the Northwestern boundary, the Lake Region, and the St. Lawrence Valley; the other set over the middle Rocky Mountain districts and the Gulf States. Each of these is double, with one for the "Highs" and one

When the wind sets in from points between east and northeast and the barometer falls steadily, a storm is approaching from the south or southwest. Its center will pass near or to the south or east of the observer within twelve to twenty-four hours, with wind shifting to northeast by way of north.

for the "Lows." There are lines crossing from one main track to another showing how storms pass from one to the other.

The transverse broken lines show the average daily movement. On the chart the heavy lines all belong to the tracks of the "Highs" and the lighter lines to the "Lows."

HOW "HIGHS" TRAVEL.

A "High" appearing on the California coast may cross the mountains near Salt Lake, and then pass directly over the belt of the Gulf States to the Florida coast; or it may then pass directly over the Florida coast; or it may move farther northward, cross the Rocky Mountains in the State of Washington, up the Columbia River Valley, then turn east, and finally reach the Gulf of St. Lawrence. The paths are determined by the laws of the general circulation of the atmosphere and the configuration of the North American Continent. This movement of the "Highs" from the middle Pacific coast to Florida or to the Gulf of St. Lawrence is confined to the summer half of the year—April to September, inclusive.

In the winter months, on the other hand, the source of the "Highs" is different, though they reach the same terminals.

TERMS USED IN FORECASTING.

"Fair Weather"—that is, the absence of rain or snow, is indicated by several terms. The first of these is the words themselves. It may be used singly or preceded by the word "generally." "Generally fair," as

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When the wind sets in from points south and southeast and the barometer falls steadily, it indicates a storm approaching from the west or northwest. Its center will pass near or north of the observer within twelve to twenty-four hours, with wind shifting to northwest, by way of southwest and west.

used by the forecast, is less positive than "fair" alone. It signifies that the probability of fair weather over the whole district and for the entire period is not so great as when "fair" alone is used.

PARTLY CLOUDY—RAIN—SNOW.

"Partly cloudy," is used when the indications favor clouds but no precipitation. "Threatening" is used when the weather will be overcast and gloomy, with the appearance of rain or snow at any moment, yet a measurable amount of precipitation is not anticipated.

A forecast of "rain" or "snow" may be expressed in various ways. In the late fall, early spring and the winter season it is most commonly indicated by the single word "rain" or "snow," when it is expected that the rain will continue for several hours. In other seasons of the year any one of the following terms, viz.: "local rain," "showers," and "thunderstorms," may be used.

Forecasts of local rains, showers or thunderstorms indicate that the conditions are favorable for the occurrence of precipitation in that district.

CLEARING.

"Clearing" is a word frequently used which carries a broader meaning than the word itself signifies, viz.: the occurrence of precipitation in the early part of the period; thus, "Clearing to-night" would indicate that rain or snow, whichever might be falling at the beginning of the period, would cease shortly thereafter and that the weather would be clear during the greater part of the time.

No rule can be laid down for forecasting even a single country. The details vary indefinitely and each observer must use his judgment.

Construction of the Aneroid Barometer Movement

"*A*" is a metal box or vacuum chamber consisting of two circular corrugated discs of thin German silver firmly soldered together at the edges (Fig. 2) and fastened to base plate, "*B*". When the air is exhausted the top and bottom discs close, as shown in Fig. 3.

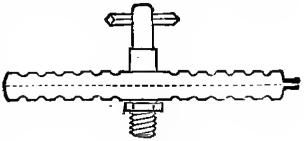


Fig. 2.

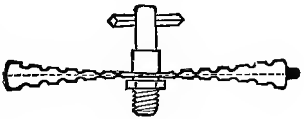
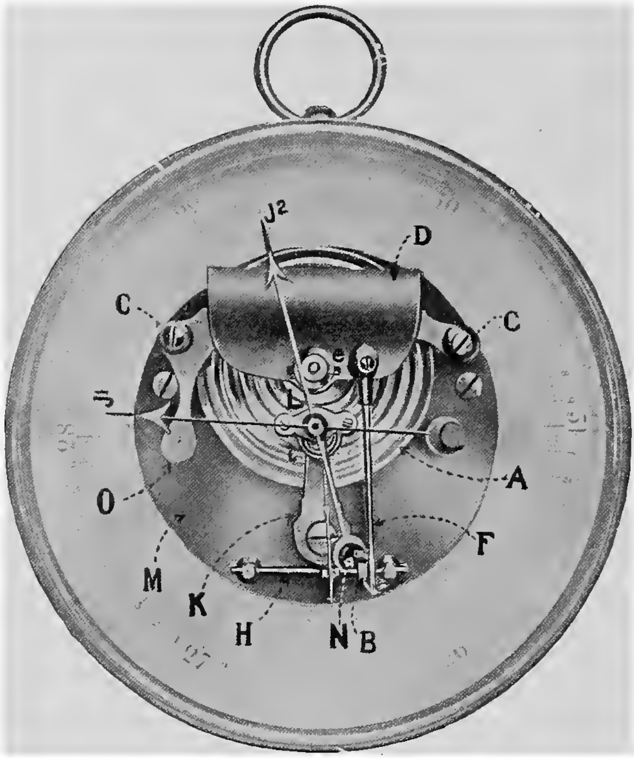


Fig. 3.

Spanning this chamber is the bridge "*O*" which is held from the plate by the finely pointed screws, "*C*," "*C*," these screws also being used to finely regulate the tension upon the chamber, "*A*." The knife edge, "*E*," is inserted in the post of the vacuum chamber (which passes through a hole in the spring, "*D*,") thus pulling the two corrugated discs of the vacuum chamber apart, leaving it in a poise with the atmosphere.

It is upon the movement of the vacuum chamber that the working of the barometer depends. An increase in pressure allows the vacuum to overcome the power of the spring, the action then being downwards; a decrease of air pressure producing the contrary result.

An accurate Aneroid will show the "altitude" of a table. If lifted from the floor to the top of a table it will register equal to 2 or 3 feet, according to the height of the table.



The lever "*F*," is fixed to the spring, "*D*," which (being in connection and working with the vacuum chamber as previously described) multiplies the movement considerably. The rod or main lever, "*F*," is connected to the lever, "*B*"; the lever, "*B*," is again connected to the lever, "*H*." To this a fine chain is attached which is wound upon the central pinion, "*L*," by the hair-spring, "*I*." The projecting arm, "*K*," (with the two small pillars and cross piece) supports the arbor and hair-spring. To the pin, "*L*," (which passes through the center of the hair-spring) is attached the hand, "*J*1," which indicates upon an accurately divided dial, the correct amount of barometric change.

The hand "*J*2," is the auxiliary C. & T. hand indicating sea level pressure.

The hand, "*J*3," is not connected with the movement but is set (by turning the milled head extending through the glass). As this hand remains stationary, a glance shows the movement of hand "*J*1."

Weather Barometers
For Use Above Sea Level

The pressure of the air is neither uniform or stationary, but it is different in different places and changes in many ways.

Firstly, it decreases as we ascend. At the sea-level the whole weight of the air above our heads is pressing mightily upon us, at a thousand feet there is not so much air above us and consequently the pressure is less.

The ideal barometer therefore is one that is easily adjusted so it will register at an elevation, the equivalent of the air pressure at the sea-level.

This is faithfully carried out in the barometer illustrated.

Inserted in the back of the instrument is a plate of about 2½ in. diameter divided from 0 to 3500 feet which revolves. Engraved on the case and pointing at the divided plate is an arrow. If the user is living at an altitude of 1000 feet above sea level all it is necessary to do is to turn the plate until the 1000 mark is against the arrow. The instrument will then register sea-level readings, which are the readings published daily on the weather maps. This plate will take care of all adjustments from 0 to 3500 feet above sea-level.

Occasionally (say once or twice a year) it is desirable to "check" the aneroid. The easiest way to do this is to consult the local Weather Bureau and obtain THE ACTUAL PRESSURE READING UNCORRECTED FOR ALTITUDE. Turn the plate in the back of the instrument until the "O" is coincident with the arrow head, and if the barometer agrees with the standard reading no alteration is necessary. If, however, it should be a little high or low, it can be set to agree by placing a screw-driver in the screw seen through the hole in the back of the case and when turned the hand on the dial will follow in the same direction. No greater correction than THREE TENTHS of an inch should be made by this method. If the instrument reads more than three tenths off the standard reading it should be put in competent hands for readjustment for occasionally dirt clogs some of the delicate working parts as in a clock.

The brass plate can then be revolved until the altitude of the town of observation is indicated against the arrow on the divided revolving plate. The instrument is then adjusted to a standard reading corrected for a difference in altitude between your city and the level of the sea.

Too much faith must not be put in the weather words. They are simply relative and it does not follow that any condition should follow that the indicating hand points to. On the re-arranged dial as supplied with these barometers, the weather words are arranged at AVERAGE readings, *i. e.*, at the point 29.72 inches the hand points to Rain—the average point at which rain occurs and the same applies to the "Change," "Fair" and "Very Dry" marks. It must be remembered that the weather is FORECASTED by an aneroid for probably twelve to twenty-four hours in advance and the readings do not indicate present conditions. The rapidity of a weather change and its intensity will be indicated by the rate and amount of movement of the hand.

The large figures on the dial represent inches of pressure. The small figures between represent tenths of inches. Each tenth of an inch is divided into fifths making each division value two one hundredths of an inch.

Another satisfactory solution is the C. & T. Patent Altitude Adjustment, which consists of an auxiliary hand of copper adjustably attached to the pressure hand and moving with it. While the pressure hand shows the actual atmospheric pressure at the altitude at which the aneroid is used, the copper hand may be so adjusted as to always show the corresponding sea-level pressure.

Aneroid Barometer with C. & T. Patent Altitude Adjustment

The illustration shows the hands set for an altitude of about 300 feet. The table on page 46 gives the amount to move the copper hand for various heights above sea-level.

LIST OF METEOROLOGICAL STATIONS UNITED STATES

STATION	Reference Plane above Mean Sea Level, Feet.	STATION	Reference Plane above Mean Sea Level, Feet.
Abilene, Tex.	1718.0	Cleveland, O.	594.3
Albany, N. Y.	18.2	Colorado Springs, Col.	5977.0
Alpena, Mich.	586.3	Columbia, Mo.	737.5
Amarillo, Tex.	3615.0	Columbus, Ohio	709.0
Astoria, Oreg.	18.9	Concordia, Kans.	1372.0
Atlanta, Ga.	1033.0	Corsicana, Tex.	427.5
Atlantic City, N. J.	8.3	Davenport, Iowa	536.4
Augusta, Ga.	100.4	Dayton, Wash.	1604.0
Baker City, Oreg.	3441.0	Deadwood, S. Dak.	4543.0
Baltimore, Md.	98.0	Denison, Tex.	747.8
Barnegat, N. J.	6.4	Denver, Colo.	5183.0
Binghamton, N. Y.	862.2	Des Moines, Iowa	799.0
Bismarck, N. Dak.	1670.0	Detroit, Mich.	584.8
Block Island, R. I.	16.4	Dodge, Kans.	2482.0
Boise, Idaho	2492.0	Dubuque, Iowa	643.0
Boston, Mass.	—5.0	Duluth, Minn.	601.0
Breckenridge, Minn.	962.0	Eagle, Alaska	575.0
Brownsville, Tex.	37.8	Eagle Pass, Tex.	692.9
Buffalo, N. Y.	575.8	Eastport, Me.	5.1
Burlington, Vt.	197.5	Elkins, W. Va.	1920.0
Cairo, Ill.	269.6	El Paso, Tex.	3692.0
Cape Henry, Va.	7.1	Erie, Pa.	572.9
Cape May, N. J.	6.4	Escanaba, Mich.	593.0
Carson City, Nev.	4660.0	Eureka, Cal.	25.7
Cedar City, Utah	5866.4	Evansville, Ind.	382.6
Cedar Keys, Fla.	6.5	Flagstaff, Ariz.	6886.0
Charlestown, S. C.	9.6	Fort Apache, Ariz.	5000.0
Charlotte, N. C.	725.0	Fort Bridger, Wyo.	6639.0
Chattanooga, Tenn.	630.6	Fort Canby, Wash.	192.0
Cheyenne, Wyo.	6054.0	Fort Custer, Mont.	3040.0
Chicago, Ill.	579.5	Fort Davis, Tex.	4923.3
Cienfuegos, Cuba, W. I.	15.5	Fort Gibson, Ind. T.	536.0
Cincinnati, O.	546.9	Fort Grant, Ariz.	4833.0

METEOROLOGICAL STATIONS —Continued

STATION	Reference Plane above Mean Sea Level, Feet.	STATION	Reference Plane above Mean Sea Level, Feet.
Fort Griffin, Tex	1270.0	Lansing, Mich	827.9
Fort Keogh, Mont	2367.0	Las Animas, Colo	3884.0
Fort Maginnis, Mont	4310.0	Leavenworth, Kans	737.5
Fort Smith, Ark	415.0	Lewiston, Idaho	737.8
Fort Stanton, N. Mex	6151.5	Lexington, Ky	965.5
Fort Stockton, Tex	3050.0	Lincoln, Nebr	1147.0
Fort Sully, S. Dak	1593.0	Little Rock, Ark	286.5
Fort Washakie, Wyo	5498.0	Los Angeles, Cal	255.6
Fort Worth, Tex	600.3	Louisville, Ky	456.5
Fresno, Cal	290.0	Lynchburg, Va	523.3
Galveston, Tex	5.6	Mackinaw City, Mich	582.0
Grand Haven, Mich	581.3	Macon, Ga	334.0
Grand Junction, Colo	4579.0	Manchester, N. H	180.8
Green Bay, Wis	587.3	Marquette, Mich	627.9
Hannibal, Mo	488.1	Memphis, Tenn	271.3
Harrisburg, Pa	317.0	Meriden, Miss	341.0
Havre, Mont	2483.0	Miles City, Mont	2355.0
Helena, Mont	3932.0	Milwaukee, Wis	586.2
Huron, S. Dak	1285.0	Montgomery, Ala	162.0
Idaho Falls, Idaho	4714.0	Montrose, Colo	5796.0
Independence, Cal	3721.0	Moorhead, Minn	909.0
Indianapolis, Ind	708.0	Morgantown, W. Va	789.6
Indianola, Tex	9.0	Mt. Tamalpais, Cal	2353.3
Jacksonville, Fla	7.5	Mt. Washington, N. H	6300.0
Jupiter, Fla	1.0	Nashville, Tenn	434.8
Kalispell, Mont	2949.0	New Haven, Conn	3.0
Kansas City, Mo	721.9	New London, Conn	23.1
Keeler, Cal	3607.0	New Orleans, La	8.5
Keokuk, Iowa	481.9	Newport, R. I	13.6
Knoxville, Tenn	806.6	New York, N. Y	37.4
La Crosse, Wis	678.5	Norfolk, Va	—1.4
Lamar, Mo	951.0	Northfield, Vt	739.0
Lander, Wyo	5368.6	North Platte, Nebr	2803.0

METEOROLOGICAL STATIONS —Continued

STATION.	Reference Plane above Mean Sea Level, Feet.	STATION.	Reference Plane above Mean Sea Level, Feet.
Oklahoma, Okla	1195.0	San Diego, Cal	5.8
Olympia, Wash	17.0	Sandusky, Ohio	572.9
Omaha, Nebr	1040.2	Sandy Hook, N. J	9.2
Oswego, N. Y	252.0	San Francisco, Cal	8.0
Palestine, Tex	494.7	San Luis Obispo, Cal	240.0
Parkersburg, W. Va	616.4	Santa Fe, N. Mex	6954.0
Pembina, N. Dak	798.4	Sault Ste. Marie, Mich	607.3
Pensacola, Fla	11.8	Savannah, Ga	41.7
Philadelphia, Pa	8.8	Seattle, Wash	22.3
Phoenix, Ariz	1084.0	Shreveport, La	187.2
Pierre, S. Dak	1441.4	Sioux City, Iowa	1107.0
Pike's Peak, Colo	14107.7	Sitka, Alaska	62.9
Pioche, Nev	6100.0	Southport, N. C	14.0
Pittsburg, Pa	697.0	Spokane, Wash	1010.0
Pocatello, Idaho	4466.9	Springfield, Ill	600.2
Poplar River, Mont	1955.0	Springfield, Mass	70.0
Port Angeles, Wash	11.3	Springfield, Mo	1348.0
Port Crescent, Wash	8.5	Tacoma, Wash	31.0
Port Eads, La	4.0	Tampa, Fla	—1.1
Port Huron, Mich	581.3	Tatoosh Island, Wash	162.0
Portland, Me	47.2	Thatchers Island, Mass	53.0
Portland, Oreg	8.2	Titusville, Fla	1.0
Prescott, Ariz	5320.0	Toledo, Ohio	572.8
Pueblo, Colo	4656.0	Tucson, Ariz	2389.0
Puerto Principe, Cuba, W. I	324.7	Umatilla, Oreg	297.0
Puntarasa, Fla	2.0	Unalaska, Alaska	8.0
Raleigh, N. C	317.0	Valentine, Nebr	2581.0
Rapid City, S. Dak	3175.0	Vicksburg, Miss	223.2
Red Bluff, Cal	306.0	Virginia City, Mont	5824.0
Richmond, Va	164.2	Visalia, Cal	325.1
Rio Grande City, Tex	200.0	Walla Walla, Wash	923.0
Rochester, N. Y	509.8	Washington, D. C	91.2
Roseberg, Oreg	482.0	Wichita, Kans	1300.0
Sacramento, Cal	2.0	Williston, N. Dak	1854.0
St. Louis, Mo	412.7	Wilmington, N. C	31.9
St. Michael's, Alaska	23.3	Winnemucca, Nev	4335.0
St. Paul, Minn	693.7	Woods Hole, Mass	4.0
St. Vincent, Minn	798.4	Yankton, S. Dak	1197.3
Salt Lake City, Utah	4268.0	Yuma, Ariz	140.5
San Antonio, Tex	683.0		

Table No. 2

For Aneroids with "C. & T." Adjustment

Table No. 2 gives the fraction of an inch, in which the copper hand should be moved to the right upon the dial for each successive thousand feet of elevation at which the Barometer will be used above sea level.

Above Sea Level.	Move Copper Hand to the Right.
500 feet	0.5 scale inches
1,000 "	1.1 " "
1,500 "	1.6 " "
2,000 "	2.2 " "
2,500 "	2.7 " "
3,000 "	3.2 " "
3,500 "	3.7 " "
4,000 "	4.2 " "

Cyclones

CYCLONES LOW.

AT times the barometric pressure over a part of a country is much below the average, sometimes as low as 29 inches or even less. In such cases the pressure increases in widening circles for a distance of several hundred miles from the place of lowest pressure.

A system of isobars of this kind is called a "Cyclone." It is usually accompanied by rain and high winds in the country over which it lies. The "Lows" are sometimes called storms. The center of the smallest isobar is called the storm center. When the shape of the isobar representing an area of low pressure are not rounding nearly circular, the area is called simply a "Low" or a "Depression."

CAUSES OF CYCLONES OR STORMS.

Cyclones are due primarily to the unequal heating and moisture, or cooling and drying, of the air over large regions of the earth's surface, disturbing the level of the surfaces of equal density. This results in a convectional ascensional movement of the lighter air near the ground and the coming down of heavier air from above to restore the equilibrium. The light air moves spirally inward and upward, and at a greater height flows outward to the sides. This flow is similar to that of water from a basin through a hole in the

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Rain falling at the rate of 0.02 inch per hour is considered light; at 0.05 inch heavy.

bottom. The motion from opposite sides gives rise to the rotation.

When the upward convection extends to a height at which the temperature is lowered by dynamic cooling below the temperature of the dew-point of the air, there is a condensation and cloud formation. When this occurs, the initial gyratory impulse of the air becomes of secondary consequence. The principal part in maintaining and extending the ascending motion is taken by the latent heat set free from the vapor. The cloud canopy in the daytime also increases the tendency of the air to ascend by transferring the point of application of the sun's heat from the ground to the top surface of the clouds at a height in the air.

DRY CYCLONE.

Convectional ascending motion in the air is going on at all times during the day, but for the most part is not sufficient to carry the air high enough to produce any great amount of condensation, sometimes on account of the feebleness of the ascensional force, and again because of the dryness of the air requiring ascent to a very great height to reduce it to the dew-point. This condition sometimes produces a dry cyclone of feeble action, with cloud formation only, and no rain. The decrease of pressure in a cyclone produced by rainfall alone in very slight. The centrifugal force developed by the gyration and the deflecting influence of the earth's rotation on the currents are the main causes of the production of low pressure at the centre of a cyclone.

ADJUSTMENT NECESSARY.

An aneroid barometer may be out of adjustment, so far as not agreeing with the reading of a mercurial

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On only a few occasions in any year will .10 be exceeded, though .20 has been recorded.

barometer, and still give accurate measurements of the amount of change in atmospheric pressure. It is more satisfactory to the observer, however, if his instrument be compared with a Standard Mercurial Barometer.

If they do not agree, the aneroid may be adjusted by turning the small adjusting screw until the indicating hand on the dial coincides with the height of the mercury column. It should however never be moved more than 0.3 inches.

The finest quality barometers require a slight adjustment at the end of say six months and then about once in nine months. After a time they become so nearly permanently accurate that they require no re-setting. The ordinary grade of instruments naturally require more frequent adjustment.

COMPENSATION OF ANEROIDS.

All fine quality aneroids are compensated to counteract the expansion and contraction of the metals, which alters the leverage of the mechanism, making the indications very inaccurate.

In compensating a barometer, it is necessary to make the lever "*F*" (See cut page 36) of a composite bar of two metals (steel and brass), the quantity of each being altered until it is correctly "compensated" for any change in temperature. This avoids the necessity of making allowances for temperature, which is necessary in reading a mercurial barometer.

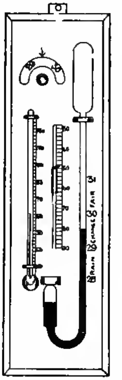
Fast rise after low,
Fortells stronger blow;
Long foretold, long last,
Short notice, soon past.

Approximate compensation for temperature can be made by leaving a small quantity of air in the vacuum chamber. When heated this increases its pressure upward and tends to offset the weakening effect upon the springs. This compensation alone is not sufficient. It is necessary to compensate the lever "*F*" as described.

ANEROIDS FOR MARINE USE.

The Aneroid Barometer is the best instrument that can be divised for marine use, not only on account of its extreme sensitiveness, but also because it is not affected by the motion of the vessel. It is now recognized as a necessity for the mariner and is made in many compact forms for use in yachts.

An important testimonial for their excellence for mariners was given in the generous action of the Life Boat Institution of Great Britain, when, in order to promote its use and prevent the loss of life amongst this fine class of fishermen, they offered to provide the master of any fishing smack with an aneroid at half price.


Sympiesometer

SYMPIESOMETER.

A barometer in which the atmospheric pressure is exerted directly on a short column of oil or similar liquid, causing compression of a portion of air or gas enclosed in the tube above the liquid; highly sensitive, but very liable to derangement and great inaccuracies.

Rainbow in morning,
Shepherds take warning;
Rainbow at night,
Shepherds' delight.

Watch and Pocket Aneroids

FOR the tourist, engineer and surveyor, the Aneroid Barometer is not only very interesting but also indispensable, as it measures, if properly used with great accuracy, the height of hills, mountains and gradients. There are many forms in use, but the regular watch or pocket style is the most popular.

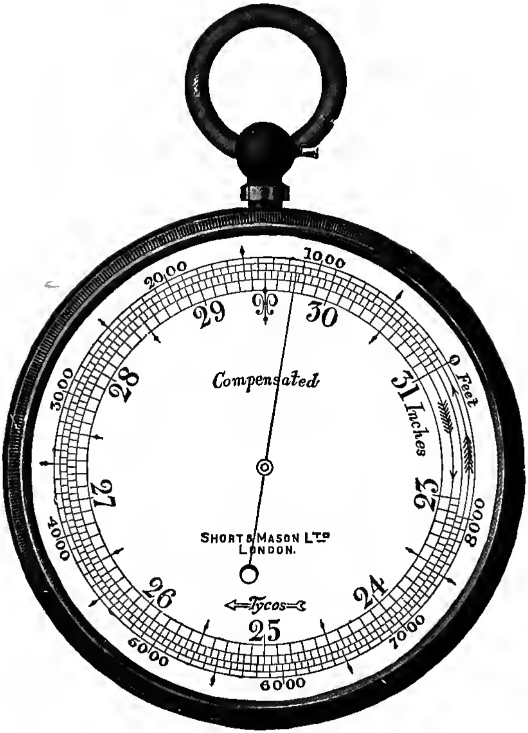
They are made with both fixed and revolving altitude scales.

Watch Aneroid with Altitude Scale

They will accurately register altitudes up to 20,000 feet. Those which register to 3,000 feet have the finest divisions, the value of each being but 10 feet. By sub-dividing, a careful observer can take even closer readings.

As the value of the altitude scale decreases, as the pressure lessens, the "O" of the altitude scale should always be exactly opposite 31 inches on the barometer dial before taking an altitude reading.

A red morn, that ever yet betoken
Wreck to the seamen, tempest to the field,
Sorrow to shepherd, woe unto the birds,
Gust and foul flaws to herdmen and herds.



Pocket Aneroid with Altitude Scale

For example, suppose the aneroid indicated a pressure of 27 inches. If we ascend a hill and the hand (due to decreasing pressure) moves to 22 inches, the correct method of determining the difference in altitude, would be as follows: Approximately the value of 27 inches (with the "O" feet at 31 inches) is

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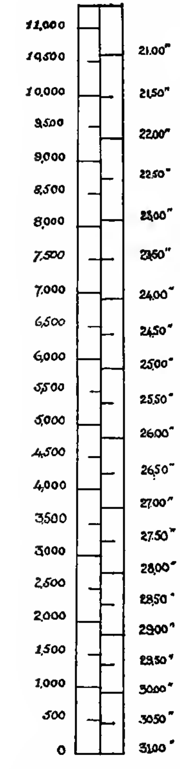
"Mackerel sky,
Twelve hours dry."

3,750 feet, while the value of 22 inches, under the same conditions, is 9,350 feet.



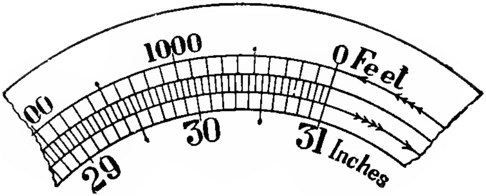
ALTITUDE SCALE — INCHES OF PRESSURE

	9,350′
	3,750′
Subtraction shows the difference in altitude to be.........	5,600′

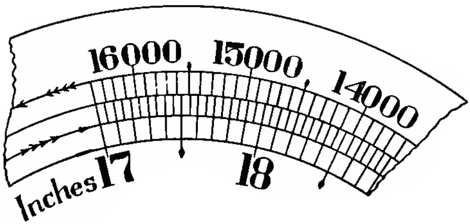
Now suppose the aneroid indicates a pressure of 27 inches, but instead of having the o feet at 31 inches (as we should) we move the milled ring so that the O feet is standing opposite 27 inches. If we then ascend the mountain until the hand reaches 22 inches, the altitude registered will be only 4,800 feet, or 800 feet in error.

The explanation is simple. As the air at sea-level is far heavier than at an altitude of a few thousand feet, it exerts a greater pressure. The graduations on the altitude scale of a watch or pocket aneroid gradually diminish in size. The first inch of pressure (from 31 inches to 30 inches) represents an ascent of about 900 feet, while an inch of pressure, say from 18 inches to 17 inches, represents about 1,570 feet.

When rainfall exceeds 2 inches a day or 10 inches a month, it is excessive.



30″ to 31″ represents 900 ft.



17″ to 18″ represents 1,580 ft.

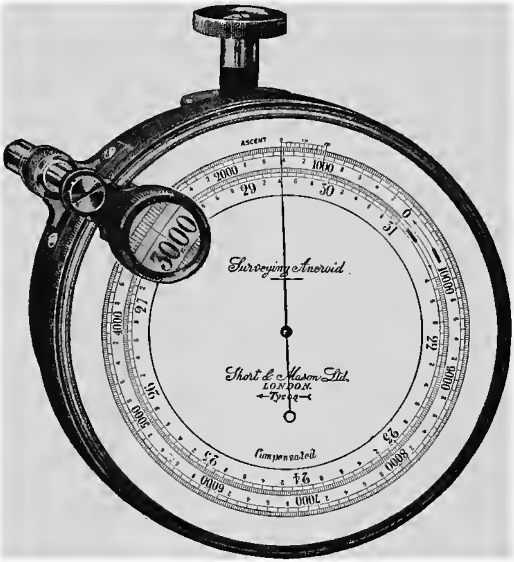
The following table of altitudes (by Professor Airey, Astronomer Royal of England) has been adopted as a standard:

AIREY'S ALTITUDE TABLE

Aneroid or Corrected Barometer	Height in Feet	Aneroid or Corrected Barometer	Height in Feet	Aneroid or Corrected Barometer	Height in Feet	Aneroid or Corrected Barometer	Height in Feet	Aneroid or Corrected Barometer	Height in Feet
in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.
31.00	0	28.28	2500	25.80	5000	23.54	7500	21.47	10000
30.94	50	28.23	2550	25.75	5050	23.50	7550	21.44	10050
30.88	100	28.18	2600	25.71	5100	23.45	7600	21.40	10100
30.83	150	28.12	2650	25.66	5150	23.41	7650	21.36	10150
30.77	200	28.07	2700	25.61	5200	23.37	7700	21.32	10200
30.71	250	28.02	2750	25.56	5250	23.32	7750	21.28	10250
30.66	300	27.97	2800	25.52	5300	23.28	7800	21.24	10300
30.60	350	27.92	2850	25.47	5350	23.24	7850	21.20	10350
30.54	400	27.87	2900	25.42	5400	23.20	7900	21.16	10400
30.49	450	27.82	2950	25.38	5450	23.15	7950	21.12	10450
30.43	500	27.76	3000	25.33	5500	23.11	8000	21.08	10500
30.38	550	27.71	3050	25.28	5550	23.07	8050	21.05	10550
30.32	600	27.66	3100	25.24	5600	23.03	8100	21.01	10600
30.26	650	27.61	3150	25.19	5650	22.98	8150	20.97	10650
30.21	700	27.56	3200	25.15	5700	22.94	8200	20.93	10700
30.15	750	27.51	3250	25.10	5750	22.90	8250	20.89	10750
30.10	800	27.46	3300	25.05	5800	22.86	8300	20.85	10800
30.04	850	27.41	3350	25.01	5850	22.82	8350	20.82	10850
29.99	900	27.36	3400	24.96	5900	22.77	8400	20.78	10900
29.93	950	27.31	3450	24.92	5950	22.73	8450	20.74	10950
29.88	1000	27.26	3500	24.87	6000	22.69	8500	20.70	11000
29.82	1050	27.21	3550	24.82	6050	22.65	8550	20.66	11050
29.77	1100	27.16	3600	24.78	6100	22.61	8600	20.63	11100
29.71	1150	27.11	3650	24.73	6150	22.57	8650	20.59	11150
29.66	1200	27.06	3700	24.69	6200	22.52	8700	20.55	11200
29.61	1250	27.01	3750	24.64	6250	22.48	8750	20.51	11250
29.55	1300	26.96	3800	24.60	6300	22.44	8800	20.47	11300
29.50	1350	26.91	3850	24.55	6350	22.40	8850	20.44	11350
29.44	1400	26.86	3900	24.51	6400	22.36	8900	20.40	11400
29.39	1450	26.81	3950	24.46	6450	22.32	8950	20.36	11450
29.34	1500	26.76	4000	24.42	6500	22.28	9000	20.32	11500
29.28	1550	26.72	4050	24.37	6550	22.24	9050	20.29	11550
29.23	1600	26.67	4100	24.33	6600	22.20	9100	20.25	11600
29.17	1650	26.62	4150	24.28	6650	22.16	9150	20.21	11650
29.12	1700	26.57	4200	24.24	6700	22.11	9200	20.18	11700
29.07	1750	26.52	4250	24.20	6750	22.07	9250	20.14	11750
29.01	1800	26.47	4300	24.15	6800	22.03	9300	20.10	11800
28.96	1850	26.42	4350	24.11	6850	21.99	9350	20.07	11850
28.91	1900	26.37	4400	24.06	6900	21.95	9400	20.03	11900
28.86	1950	26.33	4450	24.02	6950	21.91	9450	19.99	11950
28.80	2000	26.28	4500	23.97	7000	21.87	9500	19.95	12000
28.75	2050	26.23	4550	23.93	7050	21.83	9550	19.241	13000
28.70	2100	26.18	4600	23.89	7100	21.79	9600	18.548	14000
28.64	2150	26.13	4650	23.84	7150	21.75	9650	17.880	15000
28.59	2200	26.09	4700	23.80	7200	21.71	9700	17.235	16000
28.54	2250	26.04	4750	23.76	7250	21.67	9750	16.615	17000
28.49	2300	25.99	4800	23.71	7300	21.63	9800	16.016	18000
28.43	2350	25.94	4850	23.67	7350	21.59	9850	15.439	19000
28.38	2400	25.89	4900	23.62	7400	21.55	9900	14.883	20000
28.33	2450	25.85	4950	23.58	7450	21.51	9950		

SURVEYING ANEROIDS.

For very accurate altitude measurements, larger aneroids (3″ or 5″ in diameter) are generally used, as a small movement of the indicating hand can be



Surveying Aneroid Barometer

more readily detected. Greater accuracy in the movement can be also attained than is possible in the small Aneroid, which is of necessity crowded.

SCALE DIVISIONS.

On watch and pocket aneroids, the divisions of the pressure scale are equal, while the divisions of the altitude scale gradually diminish. The surveying aneroid scale reverses this arrangement, the divisions

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Meteors on entering the gaseous envelope of the earth are set afire by friction.

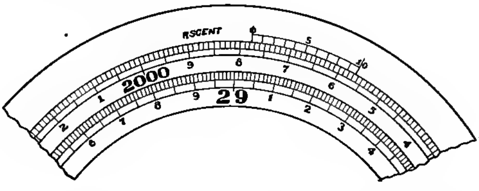
of the altitude being equal, while the pressure scale divisions diminish.

By having an equally divided altitude scale, it is practical to sub-divide (by means of the vernier applied to the altitude scale), which would not be possible were the scale unequal in value.

In the larger surveying aneroids, it is possible to take readings showing differences of single feet.

THE VERNIER.

The vernier is a device by means of which each graduation can be sub-divided into decimal quantities. It was invented by one Peter Vernier of Brussels in the year 1631. It consists of a small scale moved by a rackwork adjustment, attached to the milled knob at the top of barometer case.



If an aneroid scale is divided into ten-feet divisions, the vernier will be divided into ten divisions to exactly cover twenty-one divisions on the altitude scale. It is therefore possible for only one line on the vernier to coincide with any line on the altitude scale. If the second line on the scale coincides with a line on the altitude scale, it indicates that the odd number of feet to be added to the reading of the aneroid (as shown by the altitude scale) is two feet. If the third coincides, three feet should be added, and so on.

If an aneroid is divided into 20-feet divisions, the vernier sub-divides them into two-feet divisions; if fifty feet, it sub-divides into five feet. A small magnifying glass revolves around the case facilitating rapid accurate readings.

For example, if an aneroid (ten-feet divisions) reads a few feet over 1,770, adjust the "O" of the vernier scale directly under the hand. Only one graduation of the vernier scale can coincide with a graduation on the altitude scale. The seventh vernier graduation coinciding, the odd number of feet to add is seven (See illustration page 57.)

It is very essential that absolute accuracy be obtained on surveys, and the mode of procedure is as follows: Where a survey (which may take a consid-

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Barometric gradient means the degree or steepness of the slope of sobaric surfaces.

erable time) is taking place, two aneroids are employed. One is placed at the lower station (with an observer to record at stated intervals any change which takes place in the atmospheric pressure), the other being carried by the person making the ascent.

When the survey is completed, the indicated changes at the lower station are added to or deducted from the observed readings of the aneroid used in the ascent and corrections made accordingly. (See p. 53.)

Aneroids are compensated (see p. 49) but, as the atmosphere is affected by change in temperature the following rule for correction should be applied to the table of altitudes (which assumes a mean atmospheric temperature of 50° F.).

RULE FOR CORRECTION FOR TEMPERATURE.

Add together the temperature of the upper and lower stations. If this sum (in degrees) is greater than 100° F., increase the height by 1–1000th part for every degree in excess of 100°. If the sum be lower than 100°, diminish the height by 1–1000th part.

For example: the reading of the barometer at the lower station is 30.146—500 feet altitude.

Lower Station	30.146	500 feet
Upper "	21.019	10,500 feet
Reading by the scale......		10,000 feet
Temperature at lower station		60° F.
Temperature at upper station		30° F.
Total		90° F.

Evening red,
And morning gray;
Two sure signs
Of one fine day.

The total being less than 100°, the deduction would be 10 feet, therefore 10°×10 feet=100, deducted from reading of 10,000 feet equals correct height 9,900 feet.

Surveying aneroids should always be read in a horizontal position, as there is quite an appreciable amount of difference between the reading of an aneroid when held horizontally and when held vertically.

Surveying aneroids are made in ranges from 3,000 feet to 25,000 feet.

HYPSOMETERS.

From the connection between the boiling point of water and the atmospheric pressure, the height of mountains can be measured by the thermo-barometer.

Suppose, for example, it is found that water boils on the summit of a mountain at 90° C. and at its base 98° C. Since a liquor boils when its vapor pressure is equal to the atmospheric pressure, it is only necessary (in order to ascertain the atmospheric pressure at the top and the bottom of a mountain) to refer to a table giving corresponding temperatures and vapor pressures. By the aid of this table, the thermometer gives the same information as the barometer. An ascent of 1080 feet produces a diminution of 1° C. in the boiling point.

CONSTRUCTION OF HYPSOMETERS.

Instruments (hypsometers) used for this purpose, consist of a small metallic vessel for boiling water, fitted with a very delicate thermometer graduated from 80° C. to 100° C. only. As each degree thus

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In very high altitudes, they say it is impossible to boil eggs (hard) unless the cover of the kettle is weighted down so that the pressure of steam will allow higher temperature than is possible in an open vessel.

occupies a considerable space on the scale (the 1-10ths and even the 1-100ths of a degree being estimable) it is possible to determine the height of a place to within about ten feet.

AN EXPERIMENT—BOILING.

An interesting experiment on the effect of pressure on the boiling point is the following: Boil some water in a flask; while boiling is going on, cork the flask and remove the source of heat; when the glass vessel has somewhat cooled down, squeeze a sponge saturated with cold water over the flask, and boiling will be seen to recommence. This is owing to the fact that the sudden application of the cold water outside condenses the vapor above the hot water within, and thus considerably reduces the pressure above it, so that bubbles of vapor can be again formed in the liquid, and boiling is renewed.

On Mount Blanc water boils at 183.2 degrees F.
On Mount Quito water boils at 194 degrees F.

Barographs

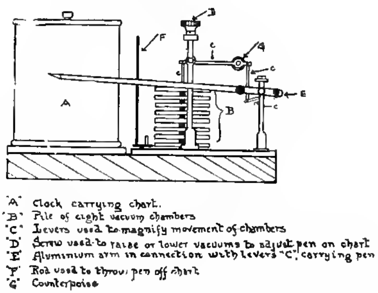
(Or Stormographs)

BAROGRAPHS (or stormographs) are aneroids arranged to record upon a chart the atmospheric changes, the amount of rise and fall and the time such changes occur.

The mechanism consists of a "pile" or series of vacuum chambers, seven or eight in number, each secured to the one above and below, making a movement of the whole seven or eight times as sensitive as a single chamber.

The movement of these chambers is still further greatly magnified and transmitted to the aluminum recording arm carrying the pen, by a series of connecting levers. This pen records the changes in pressure on a chart which encircles the drum containing the clock movement.

BAROGRAPH



A week's record can be obtained on the chart, as the clock revolves once in that time. As the top of the chart is divided into seven spaces, (the seven days of the week), and sub-divided to spaces representing two

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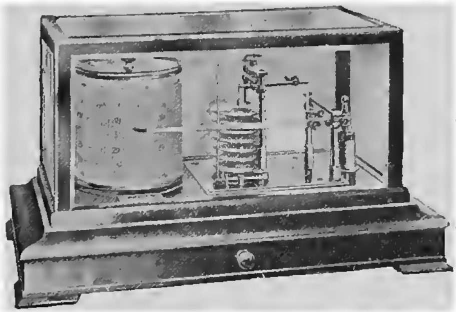
A Barogram is the record made by a Barograph.

hours each, it is possible to tell at what time of any day, atmospheric conditions undergo a change.

While the ranges of charts vary, the one universally used shows pressure from 28″ to 31″, the value of each division on the chart being .05 inches.



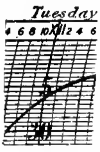
ADJUSTMENT OF BAROGRAPHS.

Barographs should be adjusted (to read with a standard barometer) by turning the small milled head screw, directly over the bridge spanning the vacuums. The pen will rise or fall, dependent on the direction the screw is turned.

The compensation for temperature is accomplished by leaving a sufficient quantity of air (ascertained by experiment when instrument is made) in the vacuum chambers so that the tendency of the barometer to register too low (on account of the weakening of the springs, the expansion of the levers and other parts) due to a rise in temperature, is counteracted by the increased pressure of air in the vacuum cells.

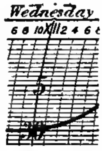
An evening grey,
And a morning red;
Will send the shepherd
Wet to bed.

The instrument should, however, be kept in as uniform a temperature as possible.



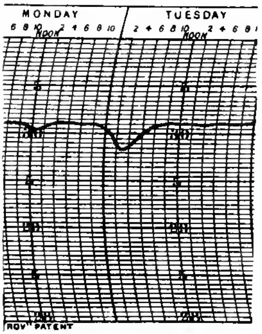
Convex.

With a rising recording barometer the trace of the pen is convex for a decreasing rate and concave for an increasing one. The reverse is true of a falling barometer. If fall is steady the line will be straight diagonally.



Concave

This cut illustrates one advantage of the barograph. Two observations of an aneroid were made (at 10 p. m. and 8 a. m., respectively) both showing a reading of 30.10 in., which would indicate a "stationary" barometer with a continuance of present weather. A glance at the barograph record shows a rapid fall and rise between 10 p. m. and 8 a. m., which indicates a short but severe storm due at about 11 a. m.

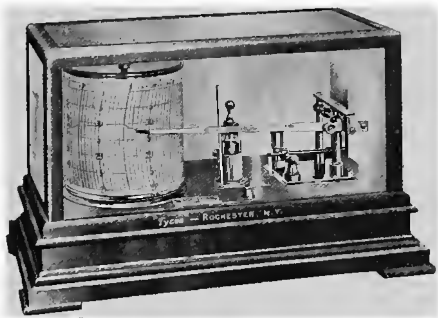


Speaking of a certain "delicate" barogram, Hon. Ralph Abercromby, F. R. Met. Soc., London, says:

> "A case of this sort shows, more than any other, the superior value of a continuous trace over an intermittent barograph, for though the latter permits the tabulation of hourly values, they entirely lose all chance of following these minute alterations of pressure which are often accompanied by great changes of weather."

In winter heavy rain is indicated by a decrease of pressure and an increase in temperature.

In weather prognostication a single observation of the Barometer is of little or no value, and while frequent observations will, if recorded, convey the desired information provided changes in atmospheric



Simplified Barograph

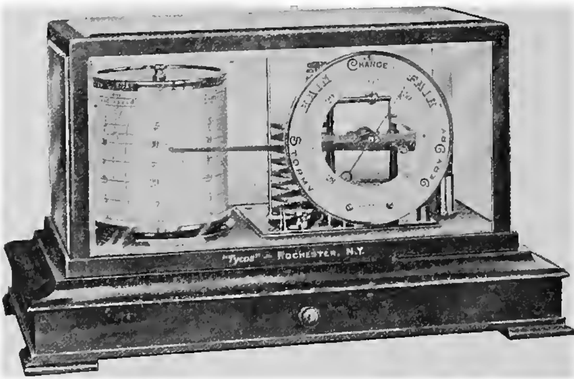
pressure are gradual, yet when sudden changes occur between observations such records will be missing and probably lead to a misinterpretation of "weather signs."

The Barograph is a most reliable form of Barometer in indicating the present-time atmospheric pressure, but its special value lies in the continuous hourly record which it creates, of every fluctuation in pressure for seven consecutive days, showing not only the extent of the various changes, but also the time of their occurrence.

Franklin ascribed the dry fog met with in London to the large quantities of coal tar and paraffin vapor sent into the atmosphere, which condense on the particles of fog, preventing their evaporation.

USE OF BAROGRAPHS AT SEA.

Barographs are invaluable for mariners, as they are not affected by the roll and motion of a vessel at sea. Here it is important to know not only the amount of rise or fall but also whether rapid or slow, as winds and seas depend upon these conditions. In all well appointed vessels it is now recognized as a necessity.



Barograph with Dial

An interesting attachment is made for recording barometers, in the shape of an auxiliary dial. Its hand is actuated by the same movement as the barograph, and therefore registers the same as the pen upon the chart. Instead of complicating the barograph the advantage to the lay user is obvious, as the present barometer readings are more readily determined by reference to the dial.

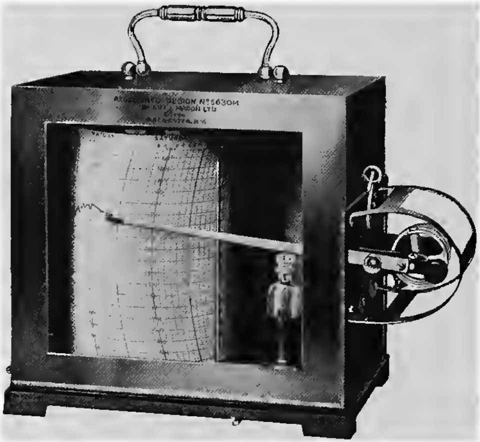
Thermograph or Recording Thermometer

Experiments have been made with many different types of recording thermometers, some depending upon a metallic spirit tube for their movement, others on a bi-metallic bar. As the latter style is more accurate, durable and constant in its action, it has been adopted as a standard by the best makers.

DEFECTS OF SPIRIT TUBE THERMOGRAPHS.

In the "spirit tube" thermograph the constant exposure to the air corrodes the metal, causing it to become more or less porous and leaky, making the instrument highly inaccurate. The mechanism also necessitates a series of levers, magnifying the movement of the tube. The "pins" which fasten these levers often become rusted causing the instrument to register even more inaccurately.

The thermograph now most generally used has a spiral coil of two different metals (brazed together) with the pen arm fixed directly to the coil. The expansion and contraction of the spiral coil causes the pen arm to move up and down, recording the temperature on the chart. It is three times as sensitive as a very sensitive mercurial thermometer.



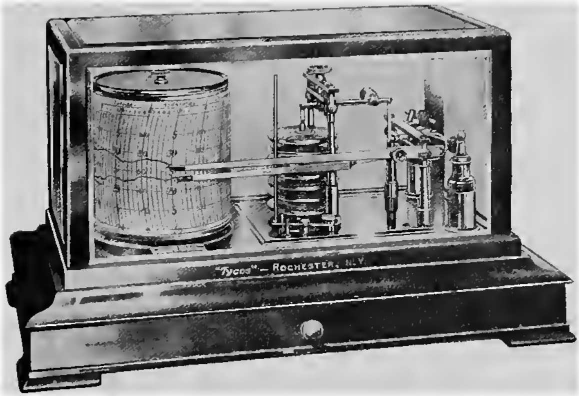
Metal Case Thermograph

USE OF THERMOGRAPHS.

Accurate thermographs are an absolute necessity in ship's stores, refrigerators, ice plants, railroads and fruit vans, as in such places the question is not so much "What *is* the temperature?" as "What *has been* the temperature?"

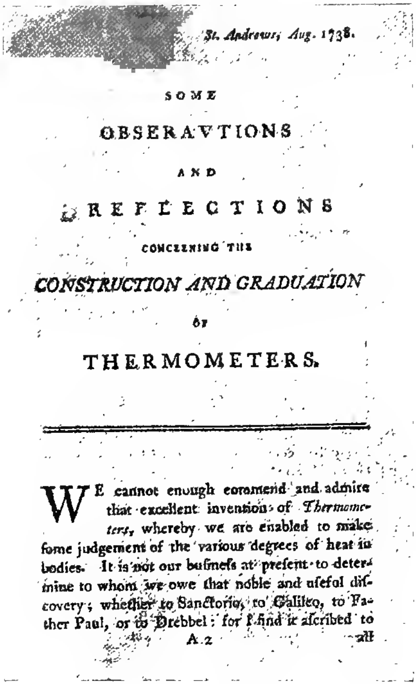
Where a uniform temperature of say 40° is necessary, a thermometer at the time of inspection may show 40° but it does not tell if the temperature has been above or below 40° in the past two, four, six or eight hours. The thermograph keeps a time record of all fluctuations in temperature, any alteration on the chart being easily detected.

Thermogram is the record made by a Thermograph.



COMBINED THERMOGRAPH AND BAROGRAPH.

A recent improvement has been introduced into recording instruments by combining the barograph and thermograph in the same instrument. The records are given on the same chart but in different colored inks to prevent confusion.



St. Andrews, Aug. 1738.

SOME

OBSERAVTIONS

AND

REFLECTIONS

CONCERNING THE

CONSTRUCTION AND GRADUATION

OF

THERMOMETERS.

WE cannot enough commend and admire that excellent invention of *Thermometers*, whereby we are enabled to make ſome judgement of the various degrees of heat in bodies. It is not our buſineſs at preſent to determine to whom we owe that noble and uſeful diſcovery; whether to Sanctorio, to Galileo, to Father Paul, or to Drebbel: for I find it aſcribed to

A 2 all

Above, we show a halftone of the title page of a book on Thermometry written in 1738 by Bernardinus Teleius.

There are some very interesting facts in this old book, which, if space permitted, we would like to reproduce.

In certain locations in the interior of Australia, the temperature frequently drops 60 to 70 degrees in a few hours.

OLD IDEAS OF POINTING TUBES.

At one time, the bright minds of Europe decided that the freezing point of liquors varied to such an extent that it could not be used as a test point, suggesting taking the temperature

> "In a cave cut straight into the bottom of a cliff fronting the sea to the depth of 130 feet with 80 feet of earth above it."

Speaking of this, our author says:

> "But with Dr. Hale's leave, this degree of temperature I do not think a very convenient term for universal construction of thermometers. Everybody cannot go to Mr. Boyle's grotto; and it is but few who can have an opportunity of making observations and adjusting thermometers in the cave of the 'Parisian Observatory.'"

Other quotations are:

> "Fahrenheit actually found that water was capable of a greater or less degree of heat in boiling, according to the greater or less weight of the atmosphere.
>
> "And some have suspected that water freezes at different degrees of heat in different seasons, countries and climates. And Dr. Cyrilli's observations would seem to confirm it. At Naples he found water to freeze when his thermometer was 10 degrees above the freezing point, as it had been constructed in England (while this difference in the freezing point was supposed to be due to 'some saline additional mixture from the air, it was probably due to inaccurate thermometer)'."

He says of Sir Isaac Newton:

> "He carried everything he meddled with beyond what anybody had done before him and generally with a greater than ordinary exactness and precision."

A change of 60 degrees F. in 24 hours has been observed in the United States but twice from 1880 to 1890.

He then goes on speaking of the scale laid out by Newton having test points at freezing water, the heat of the human body, boiling water and melting tin. saying:

> "I wish the world would have received this or any other determined scale for adjusting their thermometers, but I suppose they might be apprehensive of some inconveniences in this scheme."

Speaking of the bulbs of Thermometers which were then made about 4 inches in diameter, he says:

> "I find them to quabrate very ill together, just I suppose from that cause of the different sizes of their bulbs * * * small bulbs and small tubes are (notwithstanding the imaginary faults and difficulties stated against them by Mr. De Reaumur) vastly more convenient and may be constructed sufficiently accurate."

Speaking of the faults of various liquids to be used in Thermometers, he says:

> "We have, it seems, nothing left but quicksilver. This is a very movable and ticklish fluid; it both heats and cools faster than any liquor we know of or have had occasion to try.
>
> "It is said that they were first contrived by that curious mathematician Olaus Roemer. Mr. Fahrenheit in Amsterdam and other workmen in that country manufactured very many of them, and that in a portable and mighty convenient form for many purposes, making them very final and enclosing the tube in another glass hermetically sealed."

The lowest temperature in United States—63 degrees below zero—Poplar River, Mont., January, 1885.

CALIBRATION.

> "Indeed in all this we have supposed the bore of the tube to be perfectly cylindrical, which cannot always be obtained. But though it be tapering or somewhat unequal, it is easy to manage the matter, by making a small portion of the quicksilver, as much, for example, as fills up a half, or, if you please, a whole inch, slide backward and forward in the tube; and by this means to find the proportions of all its inequalities and from them to adjust your division to a scale of the most perfect equality."

Of a method of a scientist in marking as a test point the heat of a summer day, he says:

> "This, indeed, is a very incongruous way of graduating thermometers, as the great heat of the summer sun is such an indefinite degree of heat in different days, years, climates, etc."

St. Andrews, 1738-'39.

An

ESSAY

towards a

NATURAL AND EXPERIMENTAL HISTORY

of the

Various Degrees of HEAT in BODIES.

1. Of the way of computing the different degrees of heat.

Many of the ancients had strange notions of the nature of heat. They supposed it in different subjects to differ in kind as well as quantity. They talked very magnificently of the Celestial Heat, as differing much

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The highest temperature registered in the United States was at Death Valley, Cal., June 30th, July 1st and 2nd, 1891, when thermometer reached 122 degrees F.

in its nature from the heats commonly produced on our earth. And these, too, they thought to be of quite different natures in the different bodies wherein they are lodged. The heat of the fire or of hot water, or of fermenting substances, they thought of a lower kind, and altogether distinct from the heat of animals. And this, too, they distinguished into the natural and preternatural, or morbid, as sorts of heat quite different from one another. And those, too, they reckoned of different natures in the different species of animals. Doctrines and ways of speaking of this sort, set up by their peripatetic school, and too much adopted by Galen and the Physicians after him, continued long in the world; and were also countenanced by the chemists, these *philosophi per ignem*, who professed and valued themselves on a more than ordinary knowledge of the secrets and operations of heat.

EXCESSIVE HEAT IN YE OLDE TYME.

Much has been said of the scorching and intolerable heat of the sun in the torrid zone. We have many strange stories of extraordinary summer heats, as great tracts of land, houses, etc., set on fire, stones heated so as to melt lead, etc. These indeed seem extravagant. But the German annals preserve the memory of an excessively hot summer in 1230, when they roasted eggs in the sand heated by the sun. And I have been told that in Egypt, by no means the hottest country in the world, they can often on the tops of their houses roast their eggs at the sun. And to harden the white of an egg I find the heat of about graduation 156 to be necessary. In the year 1705 the summer was very warm. At Montpelier one day the sun was so hot as to raise the quicksilver in M. Amonton's Thermometer to the mark of boiling water itself, which is our graduation 212.

Thermometers

THEIR INVENTION, STYLES, EVOLUTION AND MANUFACTURE.

It has taken many centuries to perfect that simple yet wonderful instrument—the thermometer—used for the measurement of temperature. Many people are credited with its invention, Drebbel (a Hollander) being referred to more than any, but to Galileo Galilei the laurels are handed. It seems that about 1592 he "invented" the thermometer described as "a glass containing air and water to indicate changes and differences in temperature." This was perfected more or less by the Grand Duke of Tuscany, Ferdinand the Second, about 1610.

Drebbel's Thermometer
1592

They seem to have been made first at the glass works in Murano (near Venice) of a glass tube, the width of a finger, to which was fixed a bulb with a capacity of three or four ordinary drinking glasses.

Fahrenheit may be said to have made one of the greatest discoveries in relation to the subject when he learned that water always freezes at the same temperature (see footnote).

Increasing the pressure on water 1 atmosphere (14.7 lbs.) lowers the freezing point .0075 C.

In 1714 he devised a scale for which the fixed points were determined by the ordinary heat of a healthy human body and the degree of cold generated by a mixture of ice and sal-ammoniac or common salt. The thermometer on which this scale was used was followed, a few years later, by a mercurial one constructed with regard to a belief, then held by certain learned men, that water would always boil at the same temperature; and it was by means of experiments made with this instrument that Fahrenheit was able to declare that atmospheric pressure governs the boiling point of water.

THE FIRST THERMOMETER WITH SEALED TUBE.

About 1650, a most important and radical change was made by Ferdinand the Second, who manufactured a thermometer tube of the present form, filling it to a certain height with colored alcohol. He then closed the tube, hermetically sealed it and graduated the degrees upon the stem of the tube.


Kircher's Thermometer. 1643

This was after Torricelli had invented the barometer or demonstrated the weight of the air, and was the first thermometer made to work independent of the atmospheric pressure.

The thermometers of Florence became famous throughout Europe, as did Torricelli's barometer and a hygrometer invented by Ferdinand the Second. A number of meteorological stations were established by

The highest known average monthly temperature ever observed is that of 102 degrees F. for July at Death Valley, California. The lowest ia –60 degrees F. for January at Werchojansk, Siberia.

him in Florence, Pisa, Bologna, Milan, Warsaw, Parma and Innsbruck, where observations were made with these instruments several times daily.

Robert Hooke and Hon. Robert Boyle, of the "Royal Society" in London, were the first to realize the necessity of having a standard scale. About 1662, Hooke, placing his instrument in freezing distilled water, marked "zero" at the top of the column of spirit after immersion of the bulb. Soon after, he suggested that the second point should be the boiling point of water, but this does not seem to have been adopted at that time.

Mersenne's Thermometer
1644

SUGGESTED "TEST" POINTS.

Delance suggested that the freezing point of water should be marked "cold" (—10°), the melting point of butter "hot" (10°) and the space midway between "temperate" (0°) with ten divisions between each.

FIRST USE OF MERCURY IN THERMOMETERS.

Athanasius Kircher was the first to use mercury in thermometers, about 1641, but Fahrenheit was the first to construct mercury thermometers with reliable scales (1714). His scale (with Centigrade and Reaumur) is used as a standard throughout the world to this day.


Sanctorius Thermometer,
1646

Delance once remarked that "curious people use mercury in thermometers."

ANCIENT SCALES ON THERMOMETERS.

Thermometers for special uses were first manufactured in 1726 by Fowler, of London, mostly for use in hothouses. They ranged in length from one to four feet, being graduated only to 90°.

THE REAUMUR SCALE.

Reaumur, a Frenchman (about 1730), brought to public notice his new scale, in which he made "0°" the freezing point of water and 80° the boiling point, but his scale has never enjoyed such public favor as Fahrenheit's.

THE CELSIUS SCALE.

Anders Celsius, in 1742, proposed a new scale with the boiling point of water at "0°" and with melting ice at "100°." The Centigrade scale is the result, but the two points were reversed by Christin (Lyons, France) in 1743.

From this time on, as science has advanced, the thermometer has been perfected into a most scientific instrument.

TO CONVERT ONE SCALE TO ANOTHER.

To convert Centigrade degrees into degrees of Fahrenheit, multiply by 9, divide the product by 5 and add 32.

To convert Fahrenheit degrees into degrees of Centigrade subtract 32, multiply by 5 and divide by 9.

To convert Reaumur degrees into degrees of Fahrenheit, multiply by 9, divide by 4 and add 32.

To convert Fahrenheit degrees into degrees of Reaumur, subtract 32, multiply by 4 and divide by 9.

To convert Reaumur degrees into degrees of Centigrade, multiply by 5 and divide by 4.

When the same amount of heat falls on land and water surfaces, the temperature of the land is raised nearly twice as many degrees as the water.

To convert Centigrade degrees into degrees of Reaumur, multiply by 4 and divide by 5.

C.	Water freezes at 0° Water boils at 100°	F.	Water freezes at 32° Water boils at 212°

R.	Water freezes at 0° Water boils at 80°

THE MAKING OF THERMOMETERS.

Everyone is familiar with the thermometer for registering air temperature, but few realize how much care must be exercised in its manufacture.

Inspecting the Canes

The glass tubes are drawn to great lengths, frequently exceeding 300 feet. These lengths are cut into pieces ("canes") four feet long. Each piece is carefully examined, when all except four or five nearly perfect canes are destroyed because of defects. The more particular the manufacturer, the greater the cost of the finished thermometers.

THE BORE OF TUBE.

In some thermometers the bore is much finer than the diameter of a hair, the capacity of the bulb being 1000 times as great as the capacity of the bore.

Graduating Scales

The bore looks much larger than it is on account of the magnifying lens front.

The "canes" are cut twice the length of thermometer tubes desired. One of the pieces is held in the flame of a blow pipe at the point where it is to be severed. When sufficiently heated, it is withdrawn and pulled apart, making two tubes, each sealed at one end. The sealed end is heated, being withdrawn from the flame at the proper moment, when a bulb is formed by blowing through the open end of the bulb. The bulb is turned round and round in the flame and (by blowing at the open end of the tube) is gradually increased in size. The process is repeated until the bulb is the exact size desired. Glass is such a poor conductor of heat that the workman can hold the tube within about an inch of the red-hot portion.

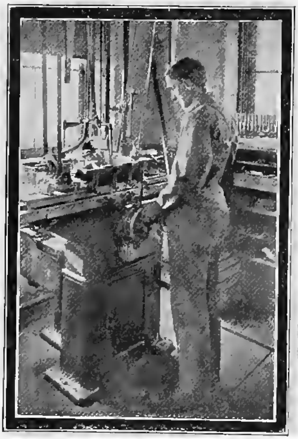
Joining the Bulb

The average temperature of the air in England is about 50 degrees. The average temperature of the air in the United States is about 52.4 degrees.

BLOWING THE BULB.

Blowing the bulb is a very delicate operation, as on its exactness depends the control of the rise of the mercury in the tiny bore. For an open range thermometer a small column and a large bulb is necessary, while for a close range instrument, a large column and a small bulb will produce the slight movement required.

Blowing the Bulb



In another department, the bulb is heated in the flame of a Bunsen burner to expand the air it contains. The tube is then inverted in a vessel containing mercury. As the expanded air in the bulb cools, it contracts, forming a partial vacuum, which draws the mercury into the tube. Several repetitions of this process finally fill the bulb and tube to the proper point.

The same weight of water requires about 32 times as much heat as mercury to produce the same elevation of temperature.

ROASTING THE TUBES.

The filled tubes are then "roasted" to expel every particle of moisture. This is done by placing them in heated sand for the necessary time, depending on the amount of humidity in the air when tubes are made.

The bulb is then held over a gas flame until the mercury in it boils, thus driving out the balance of the air, when the tube is again thrust into the vessel of mercury and the bulb completely filled. As soon as the bulb has cooled thoroughly it is plunged in cracked ice to drive the mercury to a low point, where it will be out of the way. The flame is blown across the tube at a point near the top where it is desired to cut it off, and the tube is brought to a red heat and is drawn out until it is very thin, but still contains a minute hole at the center. The bulb is once more heated until the mercury completely fills the tube and a small portion of it escapes, all the air originally in the tube and bulb being thus displaced. The top is then securely sealed and a "hook" drawn by which to secure the tube to the back of the scale.

After being "pointed," the tube is laid on a blank strip of metal, which is to become the scale for this particular tube, and the test points are transferred to the blank scale. The graduating machine can then be set to cut the space between any two of the points into exact sub-divisions, varying from a few to a hundred to the inch.

WHY SCALES ARE NUMBERED.

Each scale is then given a serial number, corresponding to the number of the particular tube to which it belongs.

A white frost never lasts more than three days; a long frost is a black frost.

In the manufacturing process they now separate, coming together (when completed) to be assembled. Seldom, if ever, will two thermometer tubes fit one scale. For example, tube No. 10,000 must be mounted on scale No. 10,000 or the finished thermometer would be inaccurate.

When a tube is broken in the course of manufacture, the corresponding scale must be "scrapped," as it would fit no other tube.

REASONS FOR INACCURACY.

The scientific reason for inaccuracy in thermometers is unevenness of calibre in the tubes, caused by some imperfection in drawing the latter. It will be readily understood that if the bore is wider at one point than at another, the mercury will, with an equal increment of heat or cold, rise or fall a shorter distance at the wider than at the narrower portion, thus giving an apparent rise or fall of temperature less than the true one.

This difficulty may be avoided by a process known as calibration, which is as simple as it is correct in its results. Enough mercury is placed in the column to fill a certain portion of it, say two inches; and this space is carefully divided into a large number of degrees. The mercury is then passed along the tube until the lower end is exactly at the point previously occupied by the upper end; it is very carefully measured, and if its length differs to any appreciable extent from that shown in the former position, the tube is rejected as irregular in bore.

This test is made through every portion of the tube; and to be absolutely reliable, it should be made

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After his return from the Arctic regions, Sir Leopold McClintock said: "The atmosphere changes were indicated first by the Aneroid, next by the Sympiesometer and last by the mercurial barometer."

in both directions, as the surface of the mercury is slightly convex in passing upward and slightly concave in passing downward.

SCALES.

The scales finished in silver have black graduations and figures for contrast, while scales that are oxidized have white figures and graduations.

The same general process is used in manufacturing all thermometers, but of course the best glass and the most careful workmen are employed in making the standard grades and more time is spent in testing, graduating and re-testing to insure greater accuracy.

SEASONING.

After being sealed, but before being tested, the "standard" tubes are "seasoned" by being placed in a vault for from twelve to twenty-four months. This is necessary, as many thermometers are rendered more or less faulty by molecular changes in the bulbs after the instruments have been finally tested.

After glass has been heated to the temperature it is in blowing the bulbs, it resumes its minimum bulk gradually, the length of time (that must elapse before shrinkage entirely ceases) varying according to the relative proportions of lead, soda and silica used in the manufacture of the glass. For this reason the bulbs for fine instruments, after being filled and sealed, should be kept from one to two years before being scaled.

Enameled glass shrinks more than plain; hence many of the finest instruments have plain glass bulbs sealed to enameled tubes.

As spirit boils at 173 degrees F., mercury is always used for high temperatures. It boils at 675 F. in atmosphere, but, under pressure, will register much higher (according to pressure used).

If manufacturers slight the seasoning process, it saves tieing up a large amount of money, reducing the cost of production correspondingly, but naturally produces an instrument that will prove inferior after a certain time.

VARIATION IN THERMOMETER BORE.

Examining the Bore

Seldom, if ever, will two canes have the same size bore. As it is impossible to make tools or gauges to determine the comparative size of the bulb (to the bore) the workman must depend entirely upon his judgment and years of practice.

SPIRIT THERMOMETERS.

The method of making an alcohol or spirit thermometer differs in one important particular from that just described for the mercurial instrument. In the latter case the air and moisture are exhausted (as nearly as possible) from the tube and bulb before the tube is closed; but when alcohol is used it is necessary to have the tube full of air above the fluid before the sealing takes place. The reason for this is obvious, when it is remembered that alcohol is naturally volatile and would be wholly unreliable in its movements if placed in a vacuum. After the bulb and part of the tube has been filled with spirits by the same method as that pursued with mercury (heat, of course, being used with great caution), the fluid is drawn down as far as possible by the application of artificial cold, and the top is sealed while the tube is full of air.

Various fluids have been and are still used for making thermometers, the chief of which is ether, sulphuric acid, alcohol and mercury, the last two being now most extenaively favored.

TEST POINTS.

All thermometer scales are determined by the standard hydrogen thermometer. The first step in scale making is to place upon the tube the "test points."

Melting Ice Test

The tube is placed vertically in melting ice to obtain the freezing point (32° F.). At the end of about half an hour, the tube is raised until the top of the mercury is seen, at which point the tube is marked.

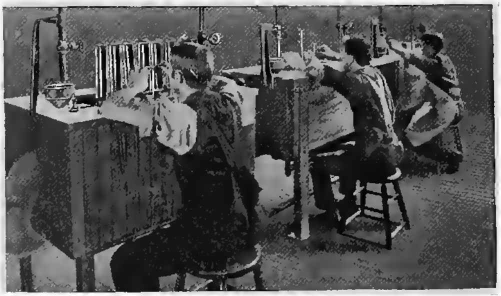
The tube is then placed in a bath in which the water is kept at a constant temperature (according to an absolute standard) of 62° F., at which point the tube is marked.

This process is repeated at 92° when the tube is ready for mounting on the finished scale.

To have an absolutely accurate test, the water in all baths must be kept in perfect circulation (an electrically driven agitator is usually used), so that the temperature in every part will be the same.

TESTS ON OTHER THERMOMETERS.

These tests are for the most ordinary kind of thermometers, the test points varying according to the character or grade of the instrument. Incubator ther-



Pointing Tubes

mometers are tested 90-100-110, clinicals at 95-100-105-110, while thermometers for other purposes have other test points.

DEFECTS IN THERMOMETERS.

The greater number of defects in ordinary commercial thermometers result from improper or careless construction, the chief errors being usually made in testing, or "pointing" and scaling. Quick and decisive tests of thermometers can only be made by comparison with a standard instrument under water, for currents of air, radiation, reflection, and varying degrees of sensitiveness due to different sizes and thicknesses of bulbs, render it impossible to make prompt and definite comparisons in the open air. In some

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As mercury freezes at –38.02 F., spirit thermometers are used to register low temperatures.

factories, where very cheap instruments are made, the work of pointing is so carelessly done that the water in which the tests are made is often allowed to fall quite a few degrees below the proper temperature before the workman restores it by adding hot water.

If all thermometer tubes could be made with the same size bore—

If all could be made with the same capacity bulb—

If all could be made without taking into account the personal equation of the workman—

Then, and then only, could the operation of thermometer manufacture be made mechanical.

PRICE VS. QUALITY.

There are thermometers and thermometers. The price is not to be determined by the cost of the small piece of glass and the small amount of mercury entering into its construction any more than the value of a fine microscopic lens is to be determined by the cost of the sand (and other materials which are fused to make the glass) from which the lens is ground.

It is claimed, and apparently with good reason, that metallic thermometers (while correct in theory and very ingenious) are impractical. Their action depends upon the difference in expansibility of two strips of different metals (as steel and brass), the flat sides of which are soldered together. After a while these metals become "set," when the registration is anything but accurate. If the manufacturers would (or could afford to) use Invar Steel and fine quality brass and then have all the work done by hand (as in the case of thermographs), permanent accuracy would result, but the cost would be prohibitive.

Absolute zero is −459.4 F. Above this temperature everything scientifically contains heat.

AN EXPERIMENT—BOILING.

At a barometric pressure of 29.92 *pure* water boils at 212° F. Water freed from air (by ebullition) may be raised to over 230° F. without boiling, and if covered with a layer of oil, may be raised to 248° F. without boiling, but above this temperature it suddenly begins to boil, and with almost explosive violence.

AN EXPERIMENT—FREEZING.

The freezing point of pure water can be diminished by several degrees if the water is previously freed from air by boiling and is then kept in a perfectly still place. It may be cooled to 25° F. without freezing. When slightly agitated the liquid (or a part of it) at once solidifies.

Sea water freezes at about 26°, the ice being quite pure.

Note—Manufacturing thermometers for high temperatures (750 degrees to 1,000 degrees F.) requires more than ordinary skill and care.

They cannot be sufficiently "seasoned" by storing, but must be heated for at least 75 hours to a temperature 100 degrees F. beyond the maximum point at which the finished thermometer can ever be used.

It is possible to maintain this high temperature night and day for 75 hours (with approximately no fluctuation) only through the aid of very finely built and controlled electric ovens.

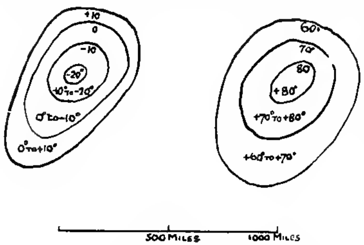
Thermometers In Meteorological Work

THERMOMETERS are quite as necessary as barometers and are considered just as important.

Care must be exercised in selecting proper exposure, the thermometer being hung where the air can circulate very freely around it. It is well to provide shelter from the direct rays and also from radiated heat of the sun. Errors (sometimes due to improper exposure) result in very misleading results.

DAILY MAXIMUM AND MINIMUM.

The maximum temperature of the 24 hours is reached about 3 or 4 p. m., after the sun has attained its greatest altitude, when the amount of radiated heat from the earth just equals the amount received from the sun.



Areas · of · low · and · high · Temperature.

The minimum temperature occurs at or just a few minutes before sunrise.

The temperature irregularly but gradually decreases or increases in all directions from a central more or less limited

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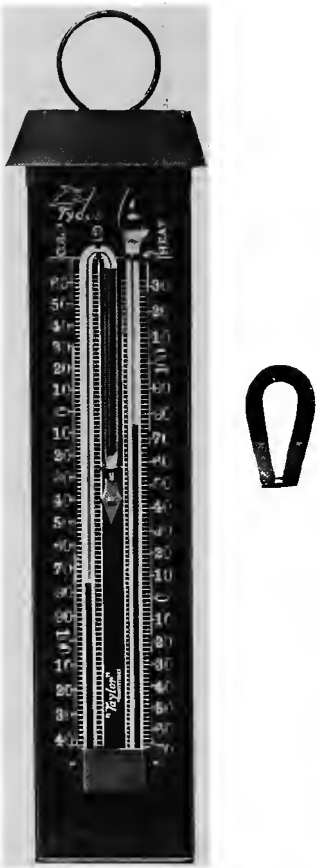
Our earth in its revolution around the sun intercepts less than one-half of one-billionth of the heat sent off by the sun.

area of high or low temperature. (See drawing on preceding page.)



During the day, the ground receives from the sun more heat than it radiates into space. The reverse is the case during the night.

It is necessary in meteorological observations, to know the highest temperature of the day and the lowest temperature of the night. Ordinary thermometers could only give these indications by a continuous observation, which would be impractical.

The Thermograph (see p. 67) is of course the ideal instrument, as it gives all fluctuations and the time of their occurrence, but a maximum and minimum thermometer will give the extremes. The mercury pushes ahead of it an index (see cut). When the mercury recedes, the index remains at the highest point. In the left hand tube this is the lowest, while in the right hand tube it is the highest degree of heat reached.

The Eastern Hemisphere is 2° F. warmer than the Western, due to the greater amount of land 80° E long. and 100° E. long. from Greenwich.

HOW WATER FREEZES.

Water contracts when its temperature sinks to about 25° F., but from this point (although the cooling continues) it expands to the freezing point so that 25° represents the point of greatest contraction.

In winter, the water at the surface of a lake becomes cooled and sinks to the bottom and a continual series of currents go on until the whole has a temperature of about 25° F.

The cooling on the surface still continues, but water expands about 10% at the moment of solidifying and, in consequence, floats on the surface of the water. Were it not for this, a lake would freeze solid. The ice which forms protects the water below, the lower portions of which remain at a temperature of about 25° F.

EFFECT OF CLOUDY SKY.

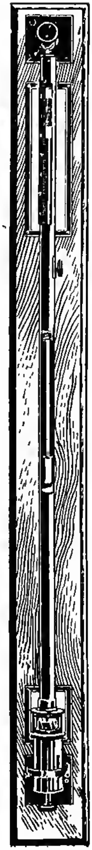
In some winters it has been found that the rivers have not frozen, the sky having been cloudy, although the thermometer had been for several days below 25° F., while rivers freeze at higher temperatures when the sky is clear.

DEPTH OF THE SEA.

The depth of the open sea is very variable; the lead generally reaches the bottom at about 300 to 450 yards, in the ocean it is usually 1,300 yards, and instances are known where the bottom has not been reached at 4,500 yards. It has been computed that the total mass of the water does not exceed that of a liquid layer surrounding the earth with a depth of about 1,100 yards.

An isothermal line is a line every point of which has the same temperature.

Mercurial Barometers



THE Mercurial Barometer of to-day is essentially the same as originally invented by Torricelli in 1643.

It consists of a straight glass tube, 32 or 33 inches long, filled with mercury. The tube is inverted with the open end in a cup of mercury, the column falls until counterbalanced by the weight of the surrounding atmosphere pressing upon the surface of the mercury in the cistern.

In other words, were it possible to weigh a column of air (of the same diameter as the bore of the barometer tube) extending from the surface of the mercury in the cistern to the top of the atmosphere, the weight would be the same as that of the mercury contained in the tube above the surface of the mercury in the cistern.

Hence, any change in atmospheric pressure produces an alteration in the height of the mercurial column in the tube. It only remains, therefore, to devise some method of measuring the height of the column to determine the varying conditions of atmospheric pressure.

It is almost impossible to safely ship Mercurial Barometers (no matter how carefully packed) on account of the weight of the mercury.

Humidity

WHEN you say "humidity" people shrug their shoulders and look for something more interesting, not realizing that without moisture in the air there would be no life—that the lack of humidity causes discomfort, ill health, catarrhs, colds, and other diseases of the mucous membrane—that by having proper humidity in the houses in winter they could save 12½ per cent. of the total cost of heating.

Many people have the idea that colds are taken (in winter) by the sudden change in temperature in stepping out of doors, but as a matter of fact the change in humidity is much more liable to cause disease. You can better realize this if you will but consider that in buildings heated with steam and hot water, with an average temperature of 72°, the relative humidity averages 28 per cent.

UNHEALTHY INDOOR ATMOSPHERE.

In the most arid regions of the world, only, is a humidity as low as 30 per cent. found. Imagine what parching and blindness this causes; what thirst and what dryness of the tissues in those lonely wastes—and this is just the "climate" we live in all winter.

When 50% humidity is spoken of it means that half as much moisture is present, as would be necessary for the saturation of the vapor under the existing conditions of temperature and pressure.

Stepping from this atmosphere to an outside humidity of about 70 per cent., is it any wonder that such a sharp and violent change is productive of harm, particularly to the delicate mucous membrane of the upper air passages? The pneumonia period is the season of artificial heat in living rooms. This artificial heat (especially if a hot air heater is used) is dry enough to work nervous irritation to the person compelled to breathe it.

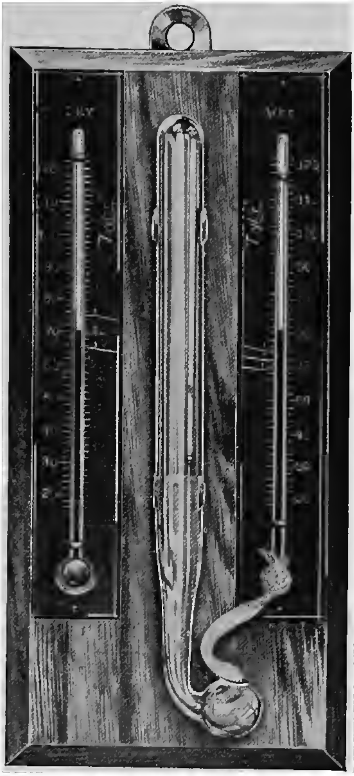
Hygrometer

THE PROPER HUMIDITY.

Dr. Henry Mitchell Smith, M. D., in his book on "*Indoor Humidity*," says: "It was most interesting and instructive to find that on the perfect days in May and early June, with all the windows open admitting freely the outdoor air, a thermometer stood at 65 to 68 degrees and the hygrometer registered about 60 per cent. relative humidity."

If a room at 68° is not warm enough for any healthy person it is because the humidity is too low, and

The Zuni Indians in New Mexico said: "When the locks of the Navajos grow damp in the scalp house, surely it will rain."



Ordinary Grade, Tube Not Insulated

water should be evaporated to bring the moisture up to the right degree. In other words, water instead of coal should be used to make rooms comfortable when the temperature has reached 68°.

Humidity causes the temperature, as shown by the thermometer, to vary as much as 45° from the temperature as felt by your body. If it were not for the moisture in the air it would be too cold to live in.

The reason for this is that if the air is dry the heat goes through it without warming it. If the air is moist, it stops the radiated heat and warms it, so that humidity becomes Nature's great bed blanket. If the air lacks moisture, it lacks its clothing quality, so that we are obliged to heat our living rooms warmer, in order to feel comfortable. The dry air allows too

If every particle of moisture in the air were precipitated it would cover the entire globe to a depth of less than four inches.

much radiation from the body and too rapid evaporation makes us feel cold.

WHY WIND COOLS.

The cooling effect produced by a wind or draught does not necessarily arise from the wind being cooler, for it may, as shown by the thermometer, be actually warmer, but arises from the rapid evaporation it causes from the surface of the skin.

Authorities agree that if we were to stop having our "climate" indoors (in winter), the dryest climate known, and kept it at a humidity of 65, we would be comfortable at 65 to 68 temperature, save money and avoid sickness. Certainly the subject deserves consideration.

Water-vapor in some shape forms, as it were, a blanket for the earth and saves it from being burned up and frozen alternately.

HUMIDITY TERMS.

The three terms used in referring to the moisture in the atmosphere are: Absolute humidity, relative humidity and dew point.

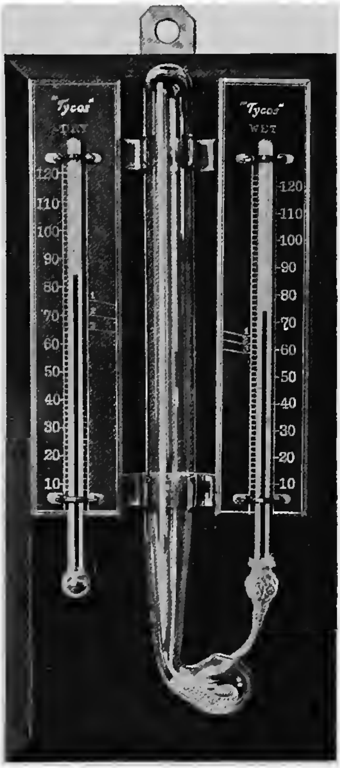
The amount of water-vapor in the air (when expressed in the number of grains per cubic foot of air) is called the absolute humidity; when expressed in the form of a percentage, it is called relative humidity.

The relative humidity depends chiefly on the temperature of the air. If we make moist air colder, we shall increase its relative humidity without increasing its absolute humidity. If it is cooled sufficiently, its relative humidity will become 100 per cent., which is saturation.

Sounds travel far when the humidity is high.

The dew point is that temperature of the air at which its invisible moisture begins to condense into visible water drops.

THE HYGROMETER.



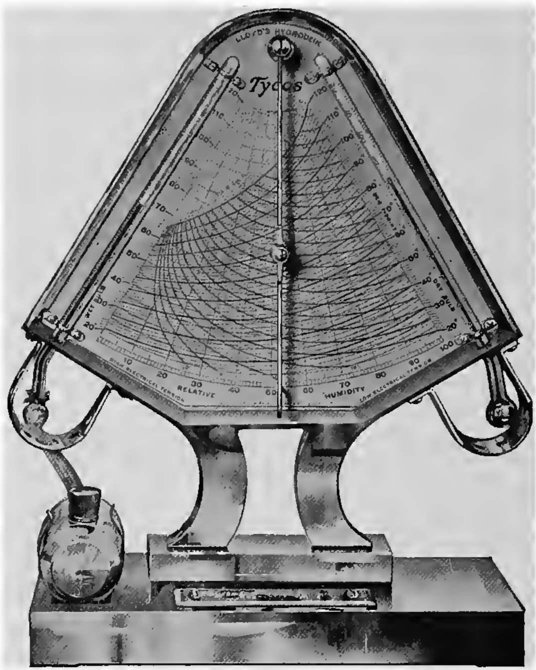
Better Grade, with Insulated Tube

The Hygrometer is an instrument devised to determine the percentage of moisture in the air. It consists of two thermometers, the bulb of one exposed to the air while the bulb of the other is constantly wet, being covered with silk cord or wick immersed in water. As evaporation causes a loss of heat, the wet bulb thermometer will read lower than the dry, providing there is any degree of dryness in the air.

The more rapid the evaporation, the greater the cooling; hence the greater the difference between the readings of the two thermometers. If the air is fully saturated, both thermometers will read alike, as there can then be no evaporation.

The region of least relative humidity is Southwest Arizona, where it averages but 40 per cent., as against 60 to 80 per cent. in other sections.

The Hygrodeik



The Hygrodeik is an improved form of hygrometer, being portable, easy to read and very accurate.

The wet and dry bulb thermometers are mounted on the edges of a chart plotted from new and corrected tables prepared under the direction of the Weather Bureau. At the top of the chart is a swinging index, to which is fitted a sliding pointer.

HOW TO READ.

All that is necessary to take a reading is to swing the index to the wet bulb side of the chart and slide the pointer either up or down the index arm until it points to the same degree of temperature on the chart that the wet bulb does on its tube. Swing the arm towards the dry bulb and note where the pointer intersects the line, curving downwards from the reading of the dry bulb thermometer.

At this intersection the index hand will point to the relative humidity on the scale at the bottom of the chart.

Example: Should the temperature of the wet bulb be 60° and the dry bulb 70°, the hand will indicate a relative humidity of 55° when the pointer rests on the intersecting lines of 60° and 70°.

After the first observation, it is very easy to find the "dew point."

Observe the intersection as above and follow the curved line (passing through it, which runs from the top downward to the right) to the point of contact with the dry bulb scale. The degree (53) at this point on that scale is the dew point required. The figure at the upper end of this line will give the Absolute Humidity or the amount of water in grains (4.5 grains) per cubic foot of air.

THE "SLING" PSYCHROMETER OR HYGROMETER.

The Sling Psychrometer was designed for the purpose of obtaining quick and more accurate results than are possible with the stationary wet and dry bulb instruments. The original design has been improved upon by doing away with the link connection between

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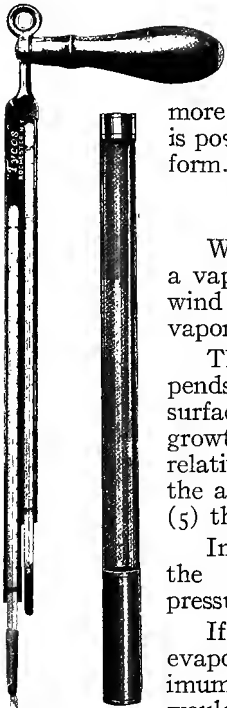
About one-half of the entire quantity of moisture in the air is contained in the first seven thousand feet from the earth.



the thermometer back and the handle. The improved form lessens the liability to breakage in swinging and enables the user to more quickly obtain the readings than is possible on the less rigid, link handle form.

EVAPORATION.

Water, when evaporated, becomes a vapor, which is transferred by the wind to regions where there is less vapor.

The rapidity of evaporation depends on whether (1) it is free water surface, wet ground or vegetable growth, (2) the temperature, (3) the relative amount of water already in the air, (4) the motion of the air and (5) the atmospheric pressure.

Increase of temperature accelerates the evaporation by increasing the pressure of the vapor.

If air were freed from moisture, evaporation would reach its maximum. If air is saturated, there would be no evaporation.

Circulation increases evaporation, as, if the atmosphere were not renewed, the air surrounding the liquid would soon become saturated when evaporation would cease.

The amount of evaporation from plants (transpiration) is enormous, being five times as much as from water and twelve times as much as from ordinary land.

The relative humidity within a forest exceeds that of the open by 2 to 4 per cent.

Clouds

"So foul a sky clears not without a storm."
—SHAKESPEARE.

IT is a trite saying that "clouds are the storm signals of the sky." Even the amateur, by watching the clouds scudding or drifting miles above, can often make a pretty sure guess of coming weather.

FORMATION OF CLOUDS.

When aqueous vapor (rising from a vessel of boiling water) diffuses in the colder air, it condenses, forming a sort of a cloud.

Clouds form, first, through the direct cooling of the moist air by contact with colder bodies or through loss of the heat by radiation. Second, when ascending air currents are present and the moist air thus expands (due to diminishing pressure) and cools. Third, the formation of clouds by mixture of air of different temperatures and humidities. If a current of water-saturated air meets a current of cold air also saturated, the air acquires the mean temperature of the two, but can retain only a portion of the vapor in invisible form, so that a cloud or mist is formed.

HOW FOGS DIFFER FROM CLOUDS.

Some clouds differ from fogs only in their elevation from the earth. A fog, resting on the top of a

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As clouds contain more dust than the surrounding air, it is thought that the dust within them is drawn up from the earth's surface.

mountain, is called a cloud. A cloud, resting on the surface of the earth, is called a fog.

When clouds form over a region in which the air is nearly saturated, the globules of water (forming the clouds) unite and descend through the moist air underneath, falling as rain (if above 32°).

Precipitation occurs when moist air is cooled below the dew point. This may take the form of rain, snow, hail, dew or frost.

The amount of precipitation in the course of a year averages greatest at a distance of a few degrees from the equator, decreasing slightly towards the poles.

> The sun sets weeping in the lowly west,
> Witnessing storms to come, woe, and unrest.

Since the colors and duration of twilight, especially at evening, depends upon the amount of condensed vapor which the atmosphere contains, these appearances should afford some indications of the weather which may be expected.

The following are some of the rules which are relied upon by seamen:

When after sunset the western sky is of a whitish yellow, and this tint extends a great height, it is probable that it will rain during the night or next day. Gaudy or unusual hues, with hard, definitely outlined clouds, foretell rain and probable wind.

HOW THE SUN FORETELLS STORMS.

If the sun before setting appears diffuse and of a brilliant white, it foretells storm. If it sets in a sky

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The effect of clouds is to prevent the minimum temperature from becoming as low as it would under a clear sky, because the radiation of heat from the earth is hindered.

slightly purple, the atmosphere near the zenith being of a bright blue, we may rely upon fine weather.

> Above the rest, the sun who never lies,
> Foretells the change of weather in the skies;
> For if he rise unwilling to his race,
> Clouds on his brow and spots upon his face,
> Or if through mists he shoots his sullen beams,
> Frugal of light in loose and straggling streams,
> Suspect a drizzling day and southern rain,
> Fatal to fruits, and flocks, and promised grain.

Nearly every class of clouds attains a loftier altitude between the hours of 4 and 8 p. m. than at any other part of the day, whereas between noon and 4 o'clock they fall a trifle below the average.

In velocity, conspicuous variations are attributable to a change of season. Stratus, for instance, floats along at a mean rate of thirteen miles an hour in warm weather, but accelerates its speed to twenty-four miles an hour in cold. The tops of Cumuli travel thirty-four miles an hour in summer and forty-seven miles an hour in winter.

HIGH SPEED OF CLOUDS.

The average for Cirrus in the former season is sixty-seven miles and in the latter seventy-eight. But in March, 1897, the maximum velocity observed was 187 miles, while in the previous December Cirrus was seen moving at a rate of over 200 miles an hour! Nice weather to get caught in with a flying machine! Prof. Bigelow says it looks as though the greatest speeds were realized at an elevation of seven or seven and a half miles, and from that level up to ten miles there was a slight falling off. But further observation is required to verify that inference.

Ordinarily the height of clouds varies from 1300-1500 yards in winter to 3300-4300 yards in summer.

CLOUDS.

Soft looking or delicate clouds foretell fine weather, with moderate or high breezes.

Hard-edged clouds, wind.

A dark, gloomy, blue sky, windy but light.

A bright blue sky indicates fine weather.

A bright yellow sky at sunset presages wind; pale yellow, wet.

By the prevalence and kind of red or yellow, or other tints, the coming weather may be foretold.

Generally the softer look, the less wind (perhaps more rain) may be expected, and the harder, more "greasy," rolled, tufted, or ragged, the stronger the coming wind will prove.

Small, inky-looking clouds foretell rain.

Light scud clouds driving across heavy masses show wind and rain, but if alone, may indicate wind only.

High upper clouds crossing the sun, moon or stars, in a direction different from that of the lower clouds, or the wind field below, foretell a change of wind toward that direction.

THE SKY.

Whether clear or cloudy, a rosy sky at sunset presages fine weather.

A sickly-looking, greenish hue, wind and rain.

A dark (or Indian) red, rain.

A red sky in the morning, considerable wind or rain.

Clouds have been observed within 230 yards of the ground.

A gray sky in the morning, fine weather.

A high dawn, look out for wind.

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.

PROGNOSTICATIONS.

After fine weather, the first signs in the sky of a coming change are usually light streaks, curls, wisps, or mottled patches of white, distant clouds, which increase and are followed by an overcasting of murky vapor that grows into cloudiness. This appearance more or less 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 weather will prove.

Light, delicate, quiet tints of color, with soft, undefined form of clouds, indicate and accompany fine weather, but unusual or gaudy hues, with hard, definitely outlined clouds, foretell rain, and probably strong wind.

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.

Dew is an indication of fine weather; so is fog; neither of these two formations occur under an overcast sky, or when there is much wind; one sees fog

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Rainfall diminishes with the height of a station above sea level at a rate of 3 or 4 per cent. for each 100 feet increase of altitude.

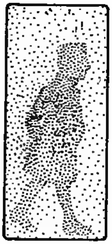
occasionally rolled away, as it were, by wind, but seldom or never formed while it is blowing.

Remarkable clearness of atmosphere near the horizon, distant objects, such as hills, unusually visible 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.

Much refraction is a sign of easterly wind, veering southward.

Rainfall decreases both in quantity and frequency as the distance increases from the sea.

Fogs and Their Cause



THE vapor in the atmosphere is quite transparent, but when, from any cause, the air becomes cooled below the dew point, a portion of its vapor is precipitated in the form of drops of water (extremely minute), which affects the transparency of the air, forming a fog if near the surface of the earth, or a cloud if in the upper regions of the atmosphere.

The chief cause of fogs is that the moist soil is at a higher temperature than the air. The vapor which ascends reaches its point of saturation, condenses, becoming visible. Fogs are also caused when a current of hot and moist air passes over a river at a lower temperature.

The diameter of the smallest *visible* particles of fog has been estimated at 1–180th inch. When the diameter of the particles becomes equal to 1–80th inch, they fall with an appreciable velocity and are called raindrops.

On the Atlantic Ocean, from 30° to 35° north latitude, fogs are almost unknown.

The Gulf Stream is caused by the warm waters of the tropics being continually pushed by the trade winds into the Gulf of Mexico. Seeking an outlet, they pour eastward through the Florida Straits (forming a stream 32 miles wide) which ends at the Great Bahama Bank. Here it spreads to 50 miles, continuing as far as the capes of Chesapeake. It then spreads (like a fan) over the North Atlantic. "To suppose it could possibly affect the climate of the North Atlantic Coast is an obvious absurdity."

Fogs never form when the air is very dry, and therefore are never known in deserts.

On the northern side of the Gulf Stream they are of common occurrence, but most prevalent in summer, when the "Banks" are enveloped in fog nearly half the time.

DRY FOG.

The vapor which causes these fogs is furnished by the warm air of the Gulf Stream being condensed by the cold air of the banks, the contrast of temperature being most sudden. During the month of July the water on the banks frequently has a temperature of 45° F., while within a distance of less than 300 miles the Gulf Stream has a temperature of 78° F.

Franklin ascribed the *dry fog* met with in London to the large quantities of coal tar and paraffin vapor sent into the atmosphere, which condense on the particles of fog, preventing their evaporation.

The particles of fog are sustained in the air in the same manner as a cloud of dust. A cloud of dust remains for a long time suspended in the air, although each particle may consist of matter 2,000 times as dense as the air in which it floats. When the air is perfectly tranquil these particles do indeed fall, but they descend so slowly that their motion is only perceptible after the lapse of a considerable interval of time.

HAIL.

When raindrops become frozen in their passage through the air they fall as hail. They may be frozen on their downward passage, but it is generally believed that they are frozen by first being carried (by vertical air currents) upwards where the temperature

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The size of hail varies from 1-10th of an inch or less to more than four inches in diameter.

of the air is below freezing, and that they have not sufficient time to melt before reaching the earth.

The following is an extract from the "Memoirs of Benvenuto Cellini of a terrible hailstorm in Lyon in 1544. He writes of the storm "The hail at length rose to the size of lemons . . . at about half a mile's distance all the trees were broken down, and all the cattle were deprived of life; we likewise found a great many shepherds killed; and we saw hailstones which a man would have found it a difficult matter to have grasped in both hands."

SLEET.

Sleet is solidified water consisting of small icy needles pressed together. Its formation is ascribed to the sudden congelation of the minute globules of the clouds in an agitated atmosphere.

DUST STORMS AND RED RAIN.

A dust-fall on a large scale occurred in May and August, 1883, when an enormous quantity of dust was hurled into the air during the Krakatoa eruption, being collected at various distances, the greatest being more than 1,100 miles from the seat of the disturbance. The tremendous height to which the finer particles of dust were thrown, coupled with the movement of the air and this great distance from the earth's surface, were responsible for the magnificent colored sunsets which were observed nearly all over the world.

On March 10th, 1901 (accompanying a depression traveling from Algeria to Pomerania), there occurred

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The maximum amount of rainfall a day is sometimes enormous. On one occasion in Japan 29.5 inches of rain fell in 24 hours, and in India 39.5 inches fell in 24 hours. This is as much as would fall in a favorably situated region in a cold temperature climate in a year.

a sirocco with red dust in the morning in Sicily, in the afternoon in southern Italy; on March 11th, there fell red and yellow dust generally with snow northward in Brandenburg and Pomerania.

ON MARCH 20TH, PROF. RUCKER SAYS:

"At 7:30 this morning the sky was copper colored, and it was evident that another fall of dust was taking place. The sirocco had been blowing for two days and it was raining slightly. The sky ceased to be copper colored about 8 or 8:15 a. m."

Under these circumstances he measured the dust that accumulated on various flat surfaces during the hour. The average, 0.00135, or about five and one-half tons per square mile, gives a fair idea of the density of the dust in the region of Taormina.

As regards the total amount of dust that fell to the surface, rough estimates indicated that the weight of it would amount to about 1,800,000 tons, two-thirds of which were deposited to the south of the Alps.

The dust was examined by Prof. Perhanz, both microscopically and chemically, and was found to be perfectly similar to the sands of the Desert of Sahara.

The facts collected have led the investigators to form a very concrete survey of the whole phenomenon, tracing the origin of the dust to dust-storms that occurred on March 8th, 9th and 10th in the desert El Erg, situated in the southern part of Algeria, which carried the dust and transported it northward.

This dust began to fall at Algiers and Tunis in the dry state on the night of the 9th. The subsequent falls gradually took place northward, first Sicily, then Italy, the Alps, Austro-Hungary, Germany, Denmark and European Russia, practically in the order named, coming in for their share. In Sicily and Italy the dust was noticed to have fallen even without the aid of rain, but in the other countries it was only detected during and after showers.

Not only did the dust-fall occur in these countries in the sequence mentioned, but the quantity that fell became gradually less the more north the places were situated, and the fineness of the dust, as shown by the analyses, increased at the same time.

In January or February, 1890, the steamship "Queensmore," arriving at Baltimore from England, reported red rain and red dust off the coast of Newfoundland. It would be very remarkable if this was Sahara dust.

Formation of Snow, Dew and Frost

MINUTE ice crystals form when condensation takes place at a temperature below the freezing point. Snow flakes are produced by the union of these crystals. While the formation of snow flakes in the upper air necessitates freezing, they frequently reach the earth when the temperature of the lower air is considerably above the freezing point (32° F.). This is because they fall rapidly without melting to any extent.

DEW.

When the temperature of the earth's surface falls below the dew point of the air, the latter deposits on the cooled surface part of its vapor in the form of small water drops, which we know as "dew drops."

On account of the rapid cooling (by radiation), especially on clear nights, the temperature of the ground and other solid substances becomes colder than that of the air above, and the "dew point" or even "frost point" are reached by the ground and the adjacent layer of air, while the temperature of the air (at a height of a few feet from the ground) is several degrees warmer.

FROST.

As before stated, the atmosphere of the earth always contains more or less moisture in an invisible

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Frost suddenly following heavy rain seldom lasts.

form. When at a considerable elevation above the earth, this moisture is condensed and clouds are formed; when the process of condensation is more active and the temperature of the air is above freezing, rain falls; and when the temperature of the air is below freezing, snow is produced.

When the moisture of the air in immediate contact with the earth is condensed at temperatures above freezing, dew is formed; when at temperatures below freezing, frost is deposited.

WHAT FROST IS.

Frost is, therefore, the moisture of the air condensed at freezing temperatures (32° F.) upon plants and other objects near the surface of the earth.

In the process of frost formation, the temperature of the air a few feet above the earth is commonly several degrees above freezing. The surfaces upon which frost is deposited must, however, possess freezing temperatures.

The manner in which frost is deposited on plants and other objects is very similar to that observed when the air moisture of a room is frozen and deposited upon window glass, the temperature of which has been reduced to freezing by the out-of-doors cold.

WHEN TO EXPECT FROST.

With other atmospheric conditions favorable, frost may be expected when temperature, as reported by the Weather Bureau, falls to a point 8° to 10° above the freezing point. While the surfaces upon which frost is deposited must possess freezing temperature, the temperature of the air a few feet above the

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When the frost gets into the air (air becomes dull) it will rain.
When the temperature is at 32° F., rain and hail often fall together.

surfaces may be several degrees above freezing; and it is the temperature of the air, in some instances many feet above the ground, that is given by the Weather Bureau observations.

CLEAR.

Another atmospheric condition favorable for the occurrence of frost is a clear, cloudless and comparatively calm night. The presence of cloud retards radiation or loss of heat from plants; the cloud acts as a screen in preventing the heat collected from the sun's rays during the day from escaping into the upper air.

When clouds are not present, and a withdrawal of the sun's rays causes a rapid cooling of the air at moderate elevations, the warmer air which collects near the surface of the earth during the day rises, and the cooler upper air, owing to its greater density or weight, settles to the earth.

CALM.

Calm or comparatively still air is a condition which favors the formation of frost. On windy nights the air is disturbed and is not permitted to arrange itself in layers according to its density, with the densest and coldest air near the surface of the earth, but is kept mixed by the wind.

RAINBOWS.

Rainbows are produced by the refraction of the sun's rays by means of the rain drops in the air. The center of the bow is opposite the sun. Rainbows are most frequent in local showers in which the sun suddenly breaks through the clouds at the edge.

Rainbow in morning shows that shower is west of us and that we will probably get it. Rainbow in the evening shows that shower is east of us and is passing off.

Lightning and Thunder

THE atmosphere contains free electricity which is always positive in clear, but sometimes negative in cloudy weather.

> "The occurrence of negative electricity is a certain indication that within a distance of forty miles, it either rains, snows or hails."—Palmieri.

The electricity of the air is carried by the vapor particles. If 1,000 particles unite to make a droplet, the quantity of electricity it contains will be 1,000 times as great as in the small one; therefore, the potential will be 100 times as great. Instead of 1,000 vapor particles uniting to make a droplet, it usually takes billions.

The spark (lightning) shooting from electrically charged clouds sometimes extends four to five miles in length. The duration of flash varies from 1-300th of a second to a second.

The reason lightning passes through the air in an irregular direction is probably due to the resistance of the air by the passage of a strong discharge, the spark taking the direction of least resistance.

The ground (by the induction of the electricity from the cloud) becomes charged with contrary electricity. When the tendency of the two electricities to

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In a vacuum, electricity passes in a straight line.

combine exceeds the resistance of the air, the electric discharge strikes between a thunder cloud and the ground.

Men and animals (like the ground) are sometimes charged with the opposite electricity to that of the thunder cloud. When the lightning is discharged (even at a distance) the bodies revert rapidly from the electric to the natural state, causing a concussion (called a return shock) which has often proved fatal.

Lightning usually strikes the tallest and best conducting objects. After the passage of lightning a peculiar odor is frequently produced, due to the formation of ozone.

HEIGHT OF THUNDER CLOUDS.

Thunder clouds are sometimes limited to a height of 3-25ths of a mile from the earth and sometimes they rise to a height of over a mile.

Observers on the summits of hills less than a quarter of a mile in height report having seen thunder showers below them, while they were enjoying a cloudless sky. On the other hand, on the Cordilleras Mountains, a violent thunderstorm was experienced at the peak, which has an altitude of 15,970 feet.

DIFFERENT FORMS OF LIGHTNING.

Streak Lightning—A plain, broad, smooth streak or flash of lightning.

Sinuous Lightning—A flash following some general direction, but the line is sinuous, bending from side to side. This is the most common type.

If lightning is at a distance of 15 miles, thunder will not be heard.

Ramified Lightning—Part of the flash appears to branch off from the main stem like the branches of a tree from the trunk; but whether these branches issue from the trunk or unite with it, is unknown.

Meandering Lightning—Flash appears to wander without any definite course and forms irregular loops.

Beaded Lightning—A series of bright beads of light appear along the white streaks of lightning.

Dark Flashes—These have been photographed, but, as well as the others, are not really understood.

Heat lightning is ascribed to distant lightning flashes, which are below the horizon, but illuminate the higher strata of clouds, so that their brightness is visible at great distances. They produce no sound, probably in consequence of the fact that they are so far off that the rolling of thunder cannot reach the ear of the observer.

THUNDER.

The occurrence of lightning and thunder is practically simultaneous, but an interval of several seconds elapses before the thunder is heard. Sounds travel 1,120 feet a second, so that it is easy to calculate the distance of a storm by counting the seconds and multiplying by 1,120. To reduce to miles divide by 5,280. (Allow one mile for every five seconds for approximate estimate).

WHY IT THUNDERS.

The noise of the thunder arises in some such manner as the crack of a whip or the report of a cannon. The lightning compresses the surrounding air. This

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A summer thunderstorm which does not much depress the barometer will be very local and of slight consequence.

compressed air rushes in to fill the partial vacuum forming in turn a partial vacuum, making the wave motion, which produces the sound.

Suspend an electric bell from inside the glass dome of a vacuum apparatus. You will hear the ringing of the bell distinctly, but as the air is gradually exhausted from the dome, the sound continues to diminish until it ceases when there is no air left to vibrate. If a gun were discharged in a perfect vacuum, no report would be heard.

Thunder "rolls" because lightning is a series of discharges, each of which gives rise to a particular sound. Also because of the reflection from the ground, from clouds and from layers of air of different densities.

FREQUENCY OF THUNDER STORMS.

Thunderstorms occur oftenest in the summer months, more frequently in the afternoon. They are preceded by a decrease in air pressure and relative humidity and an increase in temperature. When storms burst, the pressure and humidity increase rapidly and the thermometer falls. At the end of the storm the pressure and humidity is at the maximum while the temperature is at its minimum.

WHEN THUNDER IS HEARD.

The first thunder in a storm is heard before the thunder cloud reaches the zenith (the point directly overhead), the first rains commencing after it. The interval between the rain and thunder varies from a few minutes to about half an hour. About five minutes after the rain begins there comes from the west

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When the sun in the morning is breaking through the clouds and scorching, a thunderstorm follows in the afternoon.

or northwest a brisk wind which suddenly increases in violence, becoming a "squall." This wind dies down after the rain has begun.

The heaviest rain in the storm varies; at times it occurs at the beginning and sometimes during the latter part of the storm.

Some few minutes after the rainstorm has begun the lightning occurs, when the thunder is invariably loudest.

There are three kinds of thunderstorms: heat, winter and cyclonic.

Heat storms are due to the unstable condition of the lower air, due to local heating. They need for their development a moist, quiet air, warmed by the sun's rays.

CYCLONIC STORMS.

Cyclonic storms are the result of well developed areas of low atmospheric pressure. They become in some extreme cases, tornadoes.

TORNADOES.

Tornadoes are caused by local differences in temperature, the air having become abnormally heated over a central area, causing a difference in pressure between the air of the inner region and that which surrounds it.

From this, a flow of air rises spirally, increasing in velocity* as it approaches the center. This velocity varies from 7 to 100 miles an hour, 44 miles being considered an average. They usually come from the southwest, moving in the direction of the northeast.

Winter storms occur most frequently at night, especially in high latitudes, being more frequent near the coast.

WHY TORNADOES ARE DESTRUCTIVE.

The normal air pressure is about 14.7 pounds a square inch and if the pressure is reduced one-quarter of this amount in the center of a tornado it is lessened about 3.7 pounds per square inch, or 533 pounds a square foot.

Therefore, if a tornado passes over a building (where the normal pressure on the inner and outer walls is an average of 2,117 pounds per square foot) the pressure on the outside of the walls is suddenly reduced to about 533 pounds per square foot the result will be in the nature of an explosion, as the outer wall cannot support the pressure from the inside.

Rainfall

A PITCHER of ice water on a hot summer day is not a bad sort of hygrometer. The pitcher is naturally cooler than the surrounding air, and consequently some of the water-vapor in the air is condensed and collects on the outside of the pitcher. It will be remembered that water-vapor changes to the liquid state when the air is cooled below a certain point. The principle illustrated by the pitcher of ice water is repeated on a grand scale in nature every time rain or snow falls.

The capacity of air to retain moisture, or the quantity of moisture which a given volume of air will hold, increases with increased temperature until saturation is obtained. It follows that with a reduction of temperature (from whatever cause) precipitation must take place from the inability of the air to sustain the amount of aqueous vapor it has absorbed, the result being rain.

Rain, briefly speaking, is caused by the chilling of the air which contains a certain amount of moisture. This chilling may take place either through the rise of the air into higher and colder levels, through its contact with a colder surface; or from its meeting a colder current of air.

Little globules form and fall by gravitation, forming into larger drops as one united with another. This

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Among the Chassia Hills, in India, the average rainfall is over 470 inches.

increase of weight causes them to descend more rapidly, overtaking other drops. The greater the height of clouds, the larger the rain drops will be when they reach the earth.

Rain is often caused by the rushing of air from a low-land up over a mountain; some of the heaviest rainfalls take place on mountains near the sea. The air over the ocean gets thoroughly soaked with vapor, which while warm it can carry. Then it suddenly comes up against a mountain range and has to pour upwards, losing heat as it does so; becoming fast colder, it can no longer contain its surplus of hidden moisture.

SEA WINDS BRING RAIN.

When wind which blows over water first reaches land, rain will be precipitated.

In Ceylon the rainy seasons on the two sides of the island occur in different months, which depend on the time each coast is exposed to the prevailing monsoon. ("Monsoon" is derived from Arabic word for "season.")

Along the Atlantic coast of the United States, rain occurs most frequently with the wind from the north-east. Throughout most of the interior of the United States, the principal part of the rain comes with a westerly wind. In central Europe, about three-fourths of all the rain occurs with a westerly wind.

In England, if a mountain under about 1,500 feet obstructs the prevailing westerly wind, the greatest amount of rain will fall on the east side of the range, the condensed vapor being blown over the top of the hill. If the range is higher, the rain clouds cannot blow over, and the rain falls on the west side.

In some regions of India the total yearly rainfall is but 4 inches.

CLOUDBURSTS.

Cloudbursts are sudden and excessive downpours of rain, which have been kept from falling by the ascending air current until a large amount of water has been accumulated.

TEMPERATURE AND HUMIDITY INDICATE RAIN.

There is an increase in temperature and humidity of the air before rain. It does not follow, however, that every increase in humidity at the earth's surface indicates rain. In the coast districts, an increase in humidity may result from the wind shifting to blow temporarily from over the water, and a temporary increase is sometimes due to fog.

Ignoring purely local and temporary conditions, it may be assumed that, as a rule, general rains are preceded twelve to twenty-four hours by an increase in atmospheric moisture.

The rain winds of the United States are from the oceans and the Gulf.

RAIN GAUGES (PLUVIOMETERS).

The amount of rainfall is measured on the basis of the depth of water which would accumulate on a level surface if all of it remained as it fell without loss by evaporation or otherwise. Snow, hail, etc., are measured both on the basis of the actual depth of the precipitation, and (more accurately) by melting the snow or hail, obtaining the equivalent depth in water.

There are many gauges other than those illustrated, the most important being the "stick" gauge, which accurately measures (by means of a divided stick or rule) the depth of water in the "receiver."

A gallon of rain weighs ten pounds, and if spread out in a layer one inch thick will cover an area of two

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If the sun sets in dark, heavy clouds, expect rain next day.

square feet. An inch of rainfall gives 100 tons of water to the acre, or 60,000 tons a square mile, yet in Khase Hills in Bengal, India, the rainfall exceeds 600 inches yearly—the greatest in the world.

ELECTRICAL RAIN GAUGES.

The "Electrical Tipping Bucket" rain gauge has a small bucket below the funnel, which "tips" after having received 1–100th of an inch of rain. The amount of rainfall is measured by the number of "tips," which is electrically recorded any reasonable distance away.

Then there is the "Weighing Gauge," an instrument devised for weighing the amount of rain or snow fall. This is probably one of the most accurate styles, as no loss occurs from evaporation or melting if snow is measured.

TO MEASURE SNOW.

To measure the fall of snow, select a place where the snow has not drifted, invert the funnel of the gauge, pressing it through the snow to the ground, then give the funnel a sharp turn and it will lift up the snow in its circumference.

It is necessary to reduce snow to a liquid condition for accurate measurement, the simplest method being to add a known volume of water, sufficient to reduce it to a state of "slush."

The graduated measuring glass should be held so that the surface of the water is level to obtain a true reading.

Fig. 1

ZERO SETTING REGISTERING GAUGE

Fig. 1 shows the type of rain gauge known as the "Zero Setting Registering Gauge." It is made on the tilting bucket principle, the rain falling through the opening in the top (8″×8″), passing through a small pipe and falling into the tilting bucket. When a given amount of rain has fallen (0.01″) the weight of this rain causes the bucket to tilt over on the laden side, discharging the rain into a receiver. The tilting of the bucket operates a mechanical arrangement by which the hand is made to register the amount fallen.

The large outer dial registers the fall in single 1-100ths of an inch, one complete revolution showing a fall of one inch. The smaller hand in the second dial

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There is an increase in rainfall up to an altitude of about 4,000 feet. It decreases above this point.

notes the number of revolutions of the large hand, registering up to twelve inches. The illustration shows the gauge reading at 13-100ths of an inch.

Fig. 2

THE HOWARD RAIN GAUGE

Fig. 2, known as the "Howard Rain Gauge," consists of a 5″ metal funnel fitted into a glass bottle to receive the rain. When a reading is to be taken, the rain is poured from the bottle into a graduated glass jar which is divided in 0.01 inch graduations.

During a rain on the sea there falls on the surface a coating of fresh water which does not immediately sink to the bottom.

Fig. 3

THE BRITISH ASSOCIATION GAUGE

The "British Association Gauge" (Fig. 3) consists of a metal cylinder with a 5″ funnel, which conducts the rain into a removable metal receiver, where it can be readily measured without disturbing the gauge.

The heaviest annual rainfall of any place on the globe is on the Khasi Hills, in Bengal, where it is 600 inches, of which 500 inches falls in seven months.

Fig. 4

THE GLAISHERS

The "Glaishers" (Fig. 4) is probably the rain gauge most generally used. The chance of evaporation is reduced to a minimum by making, at the end of the funnel, a tube ending in a curve. In this curve is retained a certain amount of water already contained in the gauge. If this gauge is sunk in the ground to within 8 inches of the top, no evaporation will take place, even in the warmest seasons.

EXPOSURE OF GAUGES.

The exposure of rain gauges is a very important matter, as it is very necessary that they be placed where they will get proper exposure. Within a few

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yards of each other, two rain gauges may show a difference of 20% in the rainfall during a heavy rainstorm.

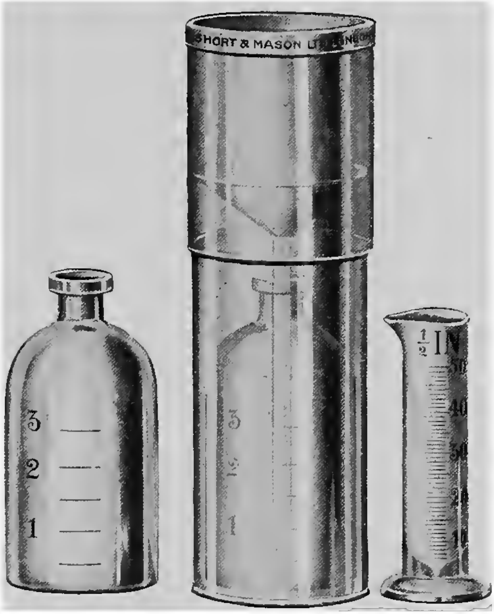

Fig. 5

OFFICIAL BRITISH PATTERN RAIN-GAUGE

Copper case with brass rimmed funnel 5 inches in diameter, inside bottle of white glass. Camden pattern jar.

The wind is the most serious obstacle in collecting the true amount of precipitation. The stronger the wind, the greater the difference. In blowing against the gauge, the eddies of wind formed at the top and

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In the extreme northwest corner of the United States the most rain falls.

about the mouth carry away rain (and especially snow) so that too little is caught. Snow is often blown out of a deep gauge after becoming lodged there. In a high location, eddies of wind (produced by walls or buildings) divert rain that would otherwise fall into the gauge. A gauge on a plot of ground with a fence three feet high around it (at a distance of three feet) will collect, roughly, 6% more rain than without the fence. These differences are entirely due to the wind currents.

A gauge near the edge of a building collects less rainfall than one in the center of a roof. In the center of a flat roof (at least 60 feet square) the rainfall collected does not materially differ from that collected on the ground. Rain gauges should not be exposed on roofs unless better exposure is unobtainable, when the center of a flat, unobstructed roof should be selected.

A position in an open lot, unobstructed by large trees, buildings or fences is preferable. Low bushes, fences or walls in the vicinity of a gauge are, however, beneficial to break the force of the wind, but they must be at a distance of not less than the height of the object.

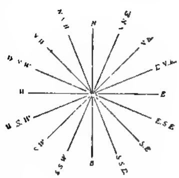
Wind Pressure

"*Many can brook the weather that love not the wind.*"

—SHAKESPEARE.

WINDS are currents of air. The direction of the wind is designated by the point of the horizon *from* which it blows.

There are eight principal directions in which they blow, *i. e.*, N., N. E., E., S. E., S., S. W., W., N. W. Mariners further divide the distances between each of these eight directions into four others, making thirty-two in all, called "points" or " rhumbs. " A figure of thirty-two rhumbs on a circle in the form of a star is known as the mariners' card. In meteorological work, sixteen divisions are used.



There would be a continual calm (air at rest) were it not for the unequal distribution of heat. There is a tendency towards a permanent interchange of air between the equatorial and polar regions due to the difference in temperature.

Winds are produced as a result of a difference in temperature between adjacent countries. If the tem-

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The least rainfall in the United States is in the southwestern part of Arizona.

perature of a certain place increases, the air becomes heated and, as it expands, rises towards the higher regions. There it flows from hot to cold countries.

In certain regions in the open ocean where the greatest heat and cold do not alter their relative positions, the wind blows always in the same direction.

At the same time the equilibrium is disturbed at the surface of the earth as the barometric pressure in the colder parts is greater than that in the warmer, which produces a current from the high to the low barometric pressure. Two distinct winds are therefore produced—the upper one *from* and the lower one *towards* the heated region.

FROM GREATEST TO LEAST PRESSURE.

Unequal atmospheric pressure tends to throw the air drift from the region of greatest pressure to regions of least pressure. The light air is driven up towards the clouds and above. It then flows over and back to fill up the space before occupied by the heavier air.

SEA WIND.

Along the seashore in midsummer, the wind blows from the sea to the land during the hottest part of the day. At night the direction of the wind is reversed.

During the day the land retains the heat at its surface, while the sea diffuses it. The air on land consequently expands and becomes light. The heavier air over the cool sea, not being warmed and expanded to the same extent, presses with its greater weight in upon that resting over the land.

After the setting of the sun, the land dissipates the heat much more rapidly than does the sea, so that

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The barometer falls lower for high winds than for heavy rain.

in a comparatively short time the land is cooler than the water. The air over the land thus becoming the colder, the pressure is seaward. This of course does not apply to all localities.

DIFFERENT KINDS OF WINDS.

In a similar manner, mountain breezes are caused by heating and cooling of the hills and valleys.

Avalanche wind is the rush of air produced in front of a landslide.

Volcanic wind is the outrush of air with volcanic eruptions.

A "squall" is a local rush of air to restore the normal condition when disturbed by local causes.

A "monsoon" blows in one direction for six months and in another for the next six months.

The "simoon" is a hot wind which blows over the deserts of Asia and Africa. It is known under the name of "sirocco" when blowing over the Sahara.

The reason the velocity of wind is less on land than on water is that on land the wind is continually retarded by obstacles and has the very great friction against the earth.

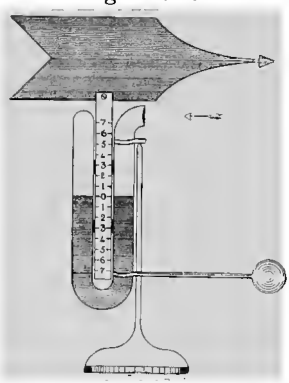
THE FORCE OF WIND PER SQUARE FOOT.

Miles.	Force, Lbs.	Oz.	Miles.	Force, Lbs.
3		¾	50	13
18	1¼		75	28
35	6		90	40

Periodic winds are those which blow regularly in the same direction at the same seasons and at the same hours of the day.

The velocity of the wind is determined by the use of an instrument called the anemometer.

Among the earliest of many different forms of wind gauges, was one invented by Dr. Lind. This consisted of a glass syphon tube, half filled with water, one end bent outwards at right angles. The apparatus is supported on a vane so that the wind blows in the open end of the tube, forcing the water higher into the opposite end of the tube, which is closed. This is graduated with the zero point at the level of the water.



Lind's Anemometer

ROBINSON'S ANEMOMETER.

The type illustrated Fig. 1 (invented by Dr. Robinson, of Armagh, in 1846, and known as Robinson's Anemometer) has become the standard pattern. It consists of four arms, revolving horizontally. At the end of each is fitted a hemispherical cup, three inches in diameter. These vanes are connected to the mechanism by a steel rod through the central pillar of the instrument.

The dials of Robinson's Anemometer register 500 miles, showing the velocity of the air. As the hands can be readily set to zero, it obviates the necessity of taking a reading before each observation.

Regular winds are those which blow all the year through in a virtually constant direction.

A useful improvement is an attachment of a weather vane, with magnetic direction points, by means of which the direction of the wind can be obtained as well as the velocity.

Another recent improvement (ball bearings on the central shaft) reduces the friction and wear to a minimum.

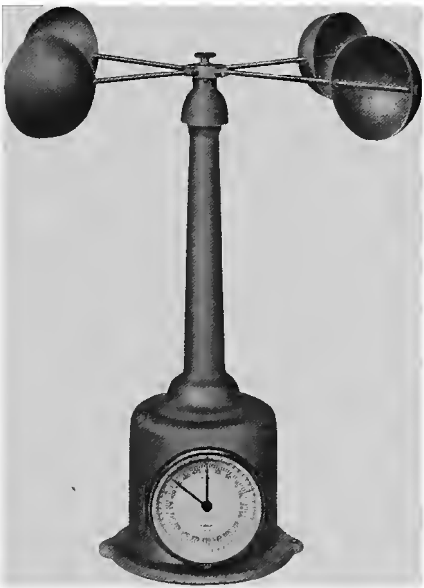


Fig. 1. Robinson's Anemometer

Another style, known as the "Birams" (Fig. 2) is used in registering and regulating the velocity of currents of air in mines, tunnels and sewers, also for

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

ventilation of public buildings, schools, etc. It records velocities up to about 3,000 feet per minute; beyond this, it is liable to derangement.

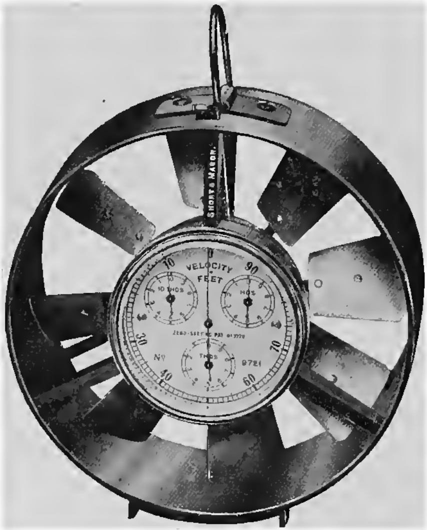


Fig. 2

This anemometer has a circular brass collar about two inches deep, in the center of which is a very delicately poised fan wheel extending from the center outwards. The revolutions of this vane or fan wheel are recorded on a dial in the center of the instrument.

Some instruments have dials capable of taking readings to 1,000 feet, others to 10,000,000 feet, but the latter are not generally used.

An excessive monthly rainfall of nearly 42 inches occurred in Northern California and one of 37 inches in Louisiana.

Fig. 3

Fig. 3 shows an "airmeter"—an instrument arranged so that the dial is at right angles to the fan wheel. It is used for the registration of currents of air (in pressure and velocity) in mines, tunnels, sewers, and the ventilators, etc., of public buildings.

This form of instrument is supplied with a universal jointed socket holder, which enables the operator to hold it by means of a staff at any angle.

A disconnector projecting from the band of the instrument serves to throw the mechanism out of gear, and arrest its action when required.

The most recent and valuable addition to airmeters is a patent zero setting attachment, a patented plan by which all the indices can be set to zero, or the starting point, at the will of the user.

In using instruments of this character, great care should be exercised, as the slightest bend in the vane or vane arm will make the reading inaccurate.

The following table may be found useful in determining the effect of recorded winds.

Name.	Miles per hour.	Apparent effect.
Calm	0	No visible horizontal motion to inanimate matter.
Light	1 to 2	Causes smoke to move from the vertical.
Gentle	3 to 5	Moves leaves of trees.
Fresh	6 to 14	Moves small branches of trees and blows up dust.
Brisk	15 to 24	Good sailing breeze, makes whitecaps.
High	25 to 39	Sways trees and breaks small branches.
Gale	40 to 59	Dangerous for sailing vessels.
Storm	60 to 79	Prostrates exposed trees and frail houses.
Hurricane	80 upwards	Prostrates everything.

Feet per minute	Miles per hour	Pressure in lbs. per square foot	Feet per minute	Miles per hour	Pressure in lbs. per square foot
20	.227	.0002	1,500	17.405	1.4375
30	.340	.0006	2,000	22.727	2.5553
40	.454	.0010	2,500	28 407	3.9918
50	.568	.0016	3,000	34.090	5.7500
60	.681	.0023	3,500	39.772	7.8255
70	.795	.0031	4,000	45.454	10.2202
80	.909	.0041	4,500	51.131	12.9375
90	1.022	.0051	5,000	56.818	15.9709
100	1.136	.0063	5,500	62.499	19.2982
150	1.704	.0143	6,000	68.181	22.9954
200	2.272	.0255	6,500	73.861	26.9764
300	3.409	.0575	7,000	79.545	31.3020
400	4.545	.1021	7,500	85.225	35.9375
500	5.681	.1596	8,000	90.909	40.8868
600	6.818	.2300	8,500	96.589	46.1554
700	7.954	.3125	9,000	102.272	51.7500
800	9.090	.4087	9,500	107.952	57.7447
900	10 227	.5175	10,000	113.636	63.8837
1,000	11 363	.6384			

An anemogram is the record as taken by a recording anemometer.

VELOCITY OF AIR.

To determine the velocity of air in an opening, it is necessary to take a number of readings in different positions. Add the readings and divide by the number taken. The result will be an average velocity in lineal feet. Allowances must then be made for frictional and momentum errors, as provided for on correction chart. Multiply the number of feet recorded by the area of the opening to obtain the number of cubic feet of air passing through the opening per unit of measured time.

As an example, suppose an average of 100 feet of air is registered in one minute in an opening 6×3. Then—$1/8$ square feet $\times$ $100/1 = 100/8$, or $12\frac{1}{2}$ cubic feet per minute.

This reading having been taken at 100 feet per minute, to find the velocity of air in the passage we proceed as follows: 100 divided by 88 equals 1.136 miles per hour, as being 1/60th of a mile.

FORCE OF AIR.

To ascertain the force of the air current, multiply the square of velocity of the air in feet per second by .0023.

Compasses

GEOGRAPHICAL meridian of a place is the imaginary plane passing through this place and through the two terrestrial poles, and the meridian is the outline of this plane upon the surface of the globe.

The magnetic meridian is the vertical plane passing at this place through the two poles of a compass needle.

The magnetic meridian does not coincide with the geographical meridian and the angle which exists between these two meridians is called declination, or variation of the magnetic needle.

In certain parts of the earth the two meridians coincide. This "line of no variation" is called the "Agnoic line." Such a line cuts the east of South America near Cape Hatteras, and traverses Hudson's Bay. Thence it passes through the arctic regions, entering the Old World east of the White Sea, traverses the Caspian, cuts the east of Arabia, turns then towards Australia, and passes across the Atlantic circle to complete the circuit.

There are places where the declination of the compass changes most rapidly. The most remarkable of these is the coast of Newfoundland, the Gulf of St.

Natural iron magnets are exceedingly rare, but a large quantity of magnetic iron is found in Sweden and the states of New York and New Jersey.

Lawrence, the seaboard of North America and the English Channel and its approaches.

The magnetism of the earth is subject (within certain limitations) to almost continual changes, both in direction and intensity. The magnetic needle is hardly ever absolutely stationary, but exhibits almost continually very minute variations.

TRUE NORTH AND SOUTH.

The earth being a magnet, a free needle at any place should assume a definite direction, but it does not follow that this direction must be true north and south, as the magnetic poles of the earth do not naturally coincide with the geographical poles.

If a compass be at a place in the same meridian with the two poles, the needle will point to true north. But if the magnetic pole lie either west or east of the meridian of the given place, the north end of the needle will deviate either east or west of the true north, and the declination (or variation of the needle) will thus be shown in degrees.

CHANGE IN COMPASS VARIATION.

In the region between San Francisco and Honolulu recent charts gave systematically too small a value of easterly variation (magnetic declination), so that the compass actually pointed 1° to 2° farther east than shown by the charts used in directing the course of a vessel between these ports. Since the distance is about 2,000 miles, and assuming an average systematic error of but 1°, it might transpire during a cloudy or foggy passage, when no sun or stars would be visible and

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The end of the needle pointing south contains northern magnetism because (according to the law of magnetism) like poles repel, while unlike poles attract.

sole dependence would have to be put upon the compass and the log, that the vessel at the end of her 2,000 mile voyage would find herself too far north by about 1-60th of the distance traveled (roughly, 35 miles).

CHANGES IN DECLINATION OF COMPASS.

Illustrations of the difference in magnetic variations are well shown by the following: In London, in 1576, the declination was 11°, 15′ east of true north. Eighty years later, it pointed due north, and in 1760, there is a record of it pointing 19°, 13′ west of north. The westerly declination attained its maximum about 1819, when its reading was 24°, 40′. Since then the needle has been traveling slightly eastward, the present annual rate of decrease being more than 8′. In 1904, it was 16°, 15′

THE DIP OF THE COMPASS.

If we imagine the earth as a huge round magnet (with the north and south poles opposite one another) and hold a magnetic needle which is accurately balanced (at the equator of that sphere), it will not only point north and south but assume a perfectly horizontal position. If it is moved nearer to the north end of the sphere, that end of the needle will dip, and the same thing takes place if it is held towards the south. At either pole it would point to the earth (at an angle of 90° F.). This is called the inclination or dip of the compass.

Robert Normas is credited with the discovery of the dip of the compass as far back as 1576.

Between 5 and 7:30 a. m. the positive electricity is at its minimum.

It reaches its first maximum about 9:30 a. m., when it again decreases—from 2:30 to 4:30. It increases, reaching its second maximum from 6:30 to 9:30.

WHERE MAGNETISM IS GREATEST.

By counting the vibrations of a delicate dipping needle, it will be found that the strength of the earth's magnetism increases as we go from the equator towards either of the poles.

COMPASSES.

A compass is probably best described as a magnetized needle pivoted upon its center to swing freely

Fig. 1

Lightning often reverses the poles of compass needles.

on a hardened point, used to indicate the magnetic meridian and, by the means of a graduated dial or circle, the azimuths of bearing of objects from this meridian.

EARLY COMPASSES.

It is difficult to determine who first put magnetism to practical use, but the early Chinese appear to have been acquainted with the polarity property of loadstone (magnetic iron ore) and used it as a compass by floating it in water upon a piece of cork.

INVENTED.

Flavio Goija, of Amalfi (early part of the fourteenth century) is said to have been the first to have invented the magnetic needle.

Dr. Gilbert (1600) states that the compass was brought to Italy from China by Marco Polo about 1295. There is evidence of its having been used in France about the year 1150, in Syria about the same period and in Norway previous to 1266.

There are many kinds of compasses, each adapted for a certain purpose when used by surveyors, huntsmen, mariners and for the military, *et al.*

PRISMATIC COMPASS.

The prismatic compass (Fig. 1) is used for surveying, more especially for military purposes. It consists of a brass box about 3 inches in diameter. Upon the pivot is balanced the magnetic needle, to the top of which is fixed a card correctly divided into degrees.

In the best quality compasses, a divided aluminum ring is substituted in place of the card dial, as it makes a far more satisfactory instrument and less liable to derangement.

The greatest amount of electricity is observed when harometric pressure is highest.

OBSERVATION OF ANGLES.

As horizontal angles can be observed with great rapidity, it is a very valuable instrument to the military surveyor, who can make observations (holding the compass in his hands) with all the accuracy necessary for an observation or sketch; to obtain absolute accuracy the use of a tripod stand is necessary.

METHOD OF USING COMPASS FIG. I.

The sight vane and prism box must be turned up so that the instrument appears as illustrated, then set or hold the instrument as nearly horizontal as possible so that the dial may revolve freely. The divisions on the dial can be finely focused by either raising or lowering the prism box in its socket.

Look at the object being sighted (through the slit in the prism box) until the metal line in the sight vane cuts through the object. Then, by looking through the prism box at the dial, a certain number can be read. That degree number is the magnetic bearing of the object from the point of observation. Should the observer wish to take an angle from that object to another repeat the operation by sighting the second object (being careful to revolve the compass box on its center), and after *that* reading has been noted, the value of the angle is the difference between the two readings taken.

If the first reading were 249°, 30′, and the second reading 319°, 30′, the value of the angle would be 70°.

AZIMUTH SHADES AND MIRROR ATTACHMENTS.

For the purpose of taking the bearing of objects considerable above or below the level of the observer, mirrors and sun glasses ("azimuth shades and mirror

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The blue of the sky is attributable to the reflection of sunshine from minute particles of dust in the air.

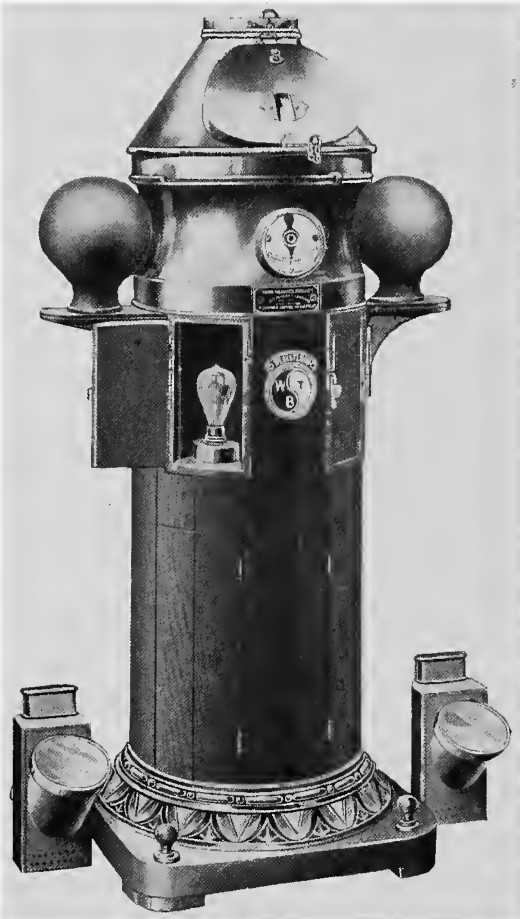

Fig. 2.

Lord Kelvin's Standard Compass

attachments") are applied to a certain type of prismatic compasses.

The mirror slides up and down the sight vane with sufficient friction to remain at any desired part of the vane. It can be put on with its face either above or below the horizontal plane of the eye. If the instrument is used for obtaining the magnetic azimuth of the sun, the dark glasses must be placed between the sun's image and the eye.

SHIPS' COMPASSES.

The ship compass, which Sir Wm. Thompson (Lord Kelvin) invented (Fig. 2), has been taken as the standard for the marine world.

The mariner's compass consists of a copper or brass bowl, hemispherical in shape, into which is mounted a compass card fitted upon a delicate point, the dial revolving upon an agate cap to insure its working easily.

As the roll and pitch of a vessel would be liable to unsettle the ordinary compasses, these bowls are usually filled with some alcoholic liquid to keep the card steady.

CONSTRUCTION.

The bowls of the compasses are supported in a ring by two pivots projecting from the opposite sides of the box. This ring is swung by two pivots at right angles to the first. This arrangement (called "gimballing") keeps the pivot of the compass always vertical, the bowl being weighted at the bottom, so that its center of gravity is considerably below the points of suspension. The dial card (with its attachments) is constructed as light as possible to make the compass very sensitive.

The Peruvians, in order to preserve the shoots of young plants from freezing, light great fires, the smoke of which, producing an artificial cloud, hinders the cooling produced by radiation.

It consists of a thin aluminum circular rim, attached by silk strings to a small aluminum disc, in the center of which is an agate cap. To the strings is gummed a thin paper annulus, on which is marked the points of the compass. The pivot upon which this dial rests is made of platinum-iridium, to insure hardness and freedom from oxidization.

There are eight magnets (about as thick as knitting needles, and from two to three inches long), placed symmetrically on each side of the center. These lie in a plane about 1⅛ inches below the card, being supported from the aluminum ring by silk strings. Since the weight of the card (magnets and all) is not more than 11½ grams, and since the needles are some way below the point of suspension, the card remains horizontal even when there is considerable tendency of the needles to dip.

The bowl of Lord Kelvin's compass has a compartment at its base, partially filled with castor oil to prevent oscillations.

A MAGNETIC EXPERIMENT.

To induce a small amount of natural magnetism into a bar of soft iron (such as an ordinary poker), tie a silk string around the center, holding it so that it points due north and south at the proper angle of dip. By lightly tapping the iron with a piece of metal, the molecules will arrange themselves by the induction of natural magnetism which is constantly passing around us. It will not retain its power for any length of time and will lose it instantly if dropped or put into a fire

SHIPS ARE MAGNETS.

In this manner, ships become huge magnets, as the hammering of plates, rivets, etc., in the construction

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In some parts of the world nearly all the moisture which the earth ever receives comes in the form of dew. This is particularly true of some parts of Egypt and Arabia.

induces natural magnetism. A great amount of it is generally lost on the first voyage, due to the buffeting of the waves and the vibration of the machinery and engines. The magnetism which is left is called *permanent* magnetism, as it undergoes very little subsequent loss of power.

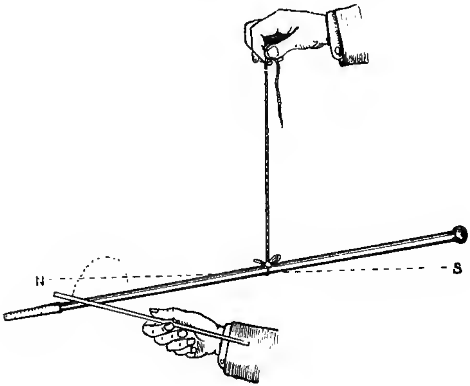

Fig. 3
Magnetizing a Bar of Iron

WHY SHIPS ARE "SWUNG."

Before leaving port, ships are "swung" for the adjustment of the compass to compensate for the local attraction of iron and steel in the ship. A sufficient number of hard steel magnets are then placed in the binnacle (under the compass) in such a manner as to exactly counterbalance the permanent magnetism of the ship. Other influences are corrected by a bar of soft iron (Flinders Bar) placed immediately forward or abaft the binnacle. It must be of the proper length

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A fall of one foot of snow may be roughly taken as equal to an inch of rain.

to produce exact compensation when its upper end is on a level with the needles of the compass.

HOW SHIPS ARE SWUNG.

The process consists in observing the direction of the Standard Compass on board the vessel, as the ship's head points N., N.E., E., S.E., etc., and comparing it with that of an undisturbed compass on shore. In this way the error of the compass on each point is ascertained, and from it the table of errors is drawn off.

By examining this table, the navigating officer ascertains how much of the errors are due to the permanent magnetism in the ship, and how much to temporary induction in the vertical and horizontal iron.

METHODS OF COMPENSATION.

These several errors are compensated for, first, by permanent magnets in the binnacle; second, by the Flinders Bar; third, by the port or starboard iron spheres.

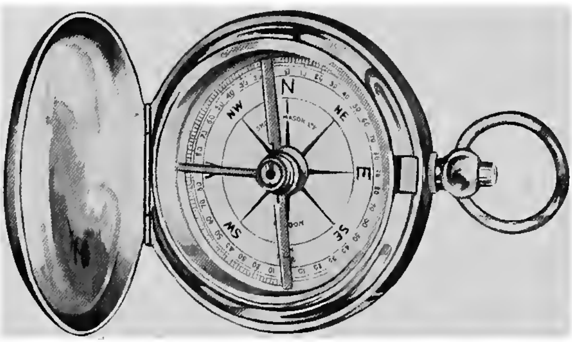

Fig. 4

Many types of compasses are used by travelers, tourists and sportsmen, the most popular styles being mounted in hunter watch cases (Fig. 4) or contained in brass boxes with lifting covers (Fig. 5). Most of

Fig. 5.

these have the dial (fixed in the base of the compass) graduated 0° to 90° between N. and E., E. and S., S. and W., and W. and N. The "bar needle," which is usually employed in these compasses, has a jeweled center, the whole revolving upon a delicate steel point.

PROTECTION OF JEWELS.

An automatic stop is fitted to the better styles, the spring of the lid, when closed, coming in contact with a lifter, which "throws" the needle and jewel cap off the point, preventing friction and wear.

In August, 1851, hailstones weighing 18 ounces—diameter 4 inches, circumference 12½ inches—fell in New Hampshire. Hailstones weighing 16 ounces fell in Pittsburgh.

Fig. 6. Luminous Dial Compass.

Fig. 6 illustrates a luminous dial compass, which has great advantage over the ordinary kind, as by exposure to daylight, the dial becomes luminous (can be seen throughout the night). In the lid is inserted a small glass having a vertical line etched upon it. By means of the small sight hole in the ring or bow of the compass and the line on the glass, it is quite a simple matter to readily ascertain the magnetic direction of any place.

MILITARY MARCHING.

In military marching, all magnetic directions are given from 0° to 360°, counting from right to left.

It is necessary that all military compasses, having fixed dials of degrees, should be figured from right to left and all compasses having movable or floating dials of degrees should be figured from left to right. This will be apparent by the following examples:

TO SET A FIXED DIAL COMPASS.

To set a compass (having fixed dial) to a given magnetic bearing, say 45°, the compass should be turned until the magnetic needle stands directly over the point at 45°, and the march made in the direction of the north point on the dial.

Fig. 7. Compass with Floating Dial

TO SET A FLOATING DIAL COMPASS

To set a compass (having a floating dial of degrees) to the same magnetic bearing, the compass should be turned until the central or luminous line in the lid of the compass is directly over the point at 45°, and the march made in the direction of the central line in lid of the case.

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