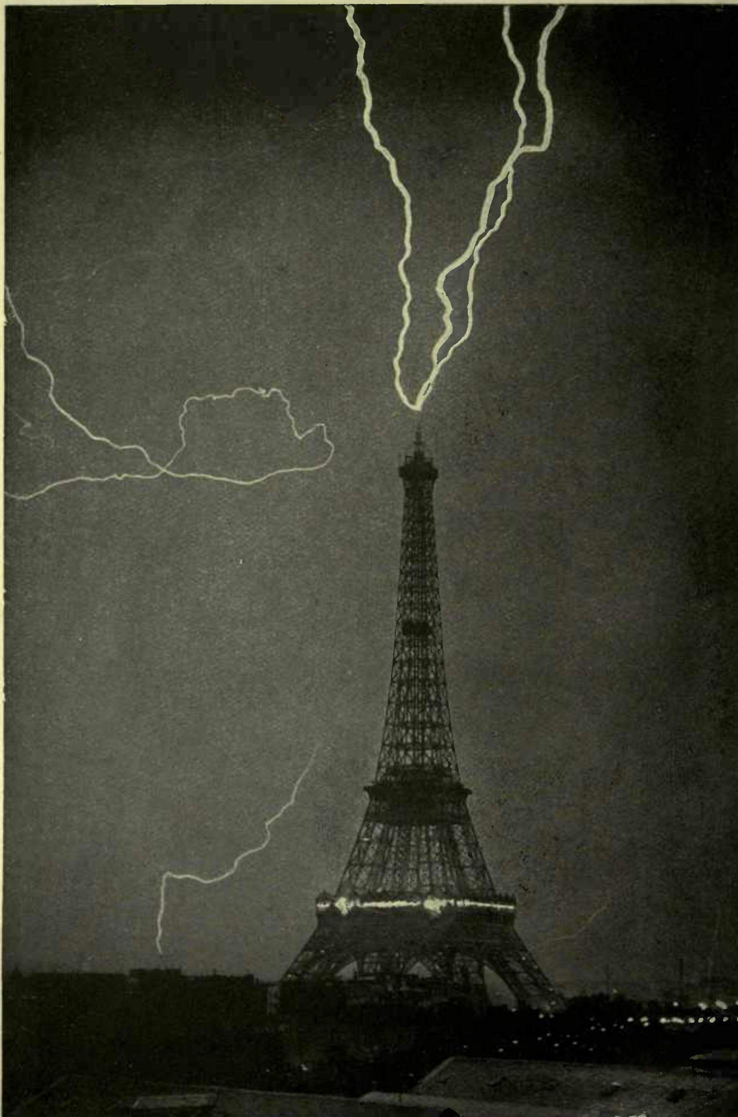

Lightning striking the Eiffel Tower, Paris, on June 3rd, 1902, at 9.20 p.m. By Mons. G. Loppé. Reproduced from Mons. Camille Flammarion's *Thunder and Lightning*, by permission of Messrs. Chatto & Windus.

[*Frontispiece.*

METEOROLOGY FOR ALL

BEING SOME WEATHER PROBLEMS EXPLAINED

BY

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"Weather Instruments and How to Use Them"
"Helps for the Practical Meteorologist"
Etc., Etc.

WITH AN INTRODUCTION

BY

M. DE CARLE S. SALTER

Superintendent of the British Rainfall Oganization

WITH NUMEROUS ILLUSTRATIONS

LONDON
WITHERBY & CO.
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1919

To

E.

F. H. N.

C.

Omne tulit punctum qui miscuit
utile dulci.

INTRODUCTION.

Mr. Horner has chosen a propitious moment for laying before the public a new work on Meteorology, and it is a pleasure to be privileged to write a few words by way of introduction. Meteorology to-day stands at the parting of the ways. By common consent one of the most ancient of the branches of natural philosophy which have gripped the imagination of mankind, it is nevertheless, as far as scientific development is concerned, of comparatively modern growth, and is still in a primitive stage relatively to many of the lines of scientific thought which have transformed the world of yesterday into that of to-day. After the great and far-reaching stimulus imparted by the introduction of maps of atmospheric pressure in the middle of the nineteenth century, meteorologists seemed for the most part to be content to rest on their oars and drift in the newly opened seas without making much definite way. This period of semi-stagnation was brought to an end when, no longer satisfied with the empirical methods which had for so long hampered progress, meteorologists began to set themselves the task of exploring the upper layers of the atmosphere in addition to the surface layer and applying to the data thus obtained the known laws of physics. That this stage of meteorology should have synchronized with the mechanical conquest of the air by the discovery of the art of flying was probably more than a mere coincidence, but this much at least is certain, that if aeronautics gave any necessary impulse to meteorology, meteorology will repay the debt a hundredfold in its service to aeronautics.

It is but a few years ago that the serious student of the weather often ploughed his lonely furrow only to feel that he served as a jest to his fellow-men. The "Clerk of the Weather," whoever that fictitious person may have been, was a sort of scientific Aunt Sally at whom the wag might fling his wit. But the War, sternly sorting out the true from the false, quickly made it apparent that the meteorologist had his place, and that no mean one, in the world of reality. The story of how the resources of meteorological science were mobilized and thrown into the common stock of service in the time of greatest need will some day be told. It is enough now to say that it played a great part in the successful prosecution of war on land, on sea and in air, and played that part with conspicuous success. And the war, and specially the development of aeronautics, which was its necessary concomitant, left to meteorology a rich harvest of new problems and of new possibilities. The world is at last awakening to the realization that meteorology is no idle pastime, but a very urgent necessity if the complete conquest of the air is to be achieved. It is for this reason that the science stands to-day on its trial ; either it must make good the promise which it has held forth or confess itself at fault.

If meteorology is essential to the aeronaut, its service in other economic fields is none the less very great. To the agriculturist, the traveller, the sailor, and perhaps more than all to the engineer, it is a highly important department of knowledge, and every year it becomes increasingly so. In many of its applications pure meteorology overlaps its twin science climatology, and the two are so intimately related that it is difficult for any text book to treat of the one without dealing also with the other.

The progress of climatology as a science has, however, been essentially different from that of meteorology. Whilst the latter has, as has been intimated, seemed to go forward with a series of impulses, the former, depending on another set of circumstances, has advanced rather by steady growth. Pure meteorology has by its nature to look to the few exceptionally gifted individuals who alone can disentangle and re-weave the intricate threads of imperfectly known natural laws at work in a free atmosphere. Climatology needs, it is true, the trained specialist to lead the way, but depends in a far greater measure than does meteorology upon the co-operation of thousands of helpers willing to work together for a common cause. Thanks to the organizing ability of a comparatively small number of men the contributions, sometimes humble, sometimes more ambitious, of the many, can be co-ordinated with a definite object. Perhaps no better example of this could be found than the single case of the study of the distribution of rainfall in the British Isles. The observation of rainfall is probably the most simple of all the requirements of climatology, but it is essential that such observations should be made simultaneously at a very large number of places and maintained regularly over a very long period. In Great Britain both these desiderata have been in a large measure satisfied, and there exists at the present time an army of more than five thousand observers of rainfall working with the most diverse objects in view, but on a practically uniform system, and thereby providing a mass of information from which it is possible to derive scientific generalizations of an extremely valuable nature. Although their numbers are not so large, a similar statement holds good in regard to the observers of other climatological elements, such as temperature and sunshine, and it is to this great band of devoted adherents of the science that

Mr. Horner's book will appeal. Whilst treating in a large measure with the actual processes which they carry out, it will give an additional interest to their work by showing how it is being applied and how far the fabric which all are helping to erect has been put together.

One word I would like to add. Meteorology, and even more, climatology, in so far as they depend upon the work of the observer, and they depend upon it in no small measure, demand a certain discipline. Individuality is an excellent thing in its right sphere, but for most of the purposes of our science uniformity of method is in a high degree essential. Those on whom it devolves to urge compliance with certain approved methods and the use of certain standardized instruments do so in no spirit of Prussianism, in pure love of imposing their will, but because they know from experience that in unity lies strength, whilst out of want of unity only confusion can come.

The workers for meteorological and climatological science are indeed many, for the subject makes a universal appeal; but there is room for many more, and I confidently hope that at the beginning of a new era of peace a great incentive will be given towards the strengthening of the corps of helpers who have done so much to give British contributions to climatology and meteorology a unique place in the world-wide advancement of scientific thought.

CARLE SALTER.

62, Camden Square, London, N.W.1.

15th August, 1919.

PREFACE.

THIS work is not intended as a text-book on Meteorology, but as a compendium of information about the WEATHER as it affects the daily life of *all* of us—whether man, woman, or child.

On the state of the weather depends, far more than many of us realise, our health, our ability to work, or even to enjoy ourselves. The day may appear fine, warm, sunny—in fact, everything that is desirable, but if the hygrometer proclaims that the state of air surrounding us is nearing saturation, we shall feel languid, and disinclined for any exertion.

Many invalids also are very susceptible to changes of barometric pressure and temperature, and a careful study of symptoms preceding and accompanying these mutations will well repay those who have charge of such patients.

To the gardener and agriculturist no words of mine are needed to emphasise the importance of a study of meteorology in relation to the welfare of growing crops; and the seafarer and aviator, who are also catered for in these pages, likewise need no admonition from me.

The individual I wish particularly to reach, and interest in the weather is the one (whether man or woman, old or young) who has never previously given a thought to the subject, except perhaps to consider the "weather" (in general terms) a nuisance!

The "style" of this work, which I have endeavoured to keep throughout is a popular one, but accuracy of detail has not been sacrificed in consequence.

* * * * *

I have to acknowledge my indebtedness for the numerous valuable illustrations to Capt. D. Wilson-

Barker, R.D., R.N.R.; The Royal Meteorological Society; The Meteorological Office; His Majesty's Stationery Office; Messrs. Negretti and Zambra; Messrs. Cassell & Co., Ltd.; Messrs. Longmans, Green & Co.; Mr. James J. Hicks; Messrs. Chatto & Windus; the Editor of the *Daily Telegraph*; Messrs. C. F. Casella & Co.; The U.S. Weather Bureau; and Mr. F. W. Sturt. I have also to thank the Editors of the *Journal* of the Royal Meteorological Society for quotations from papers, read before the Society, and must also acknowledge quotations from Mr. R. Inwards' valuable work—*Weather Lore*—and from my own articles in the *Nautical Magazine*, the *English Mechanic and World of Science* and *Air*, to the respective Editors of which journals I hereby tender my thanks. Also acknowledgment must be made to the Meteorological Office and United States Weather Bureau for excerpts from their publications; and finally to the Editors of *Symons's Meteorological Magazine* and *British Rainfall*, and to all those who helped in other ways.

Before concluding these brief remarks I must not forget also to thank Mr. Carle Salter, F. R. Met. Soc., Superintendent of The British Rainfall Organization, for so kindly writing an introduction to the work.

* * * * *

From first to last it has been a great pleasure to me to compile this work, and I can only hope that my readers will reap an equal amount of pleasure, besides gaining knowledge of a most fascinating subject.

D.W.H.

August, 1919.

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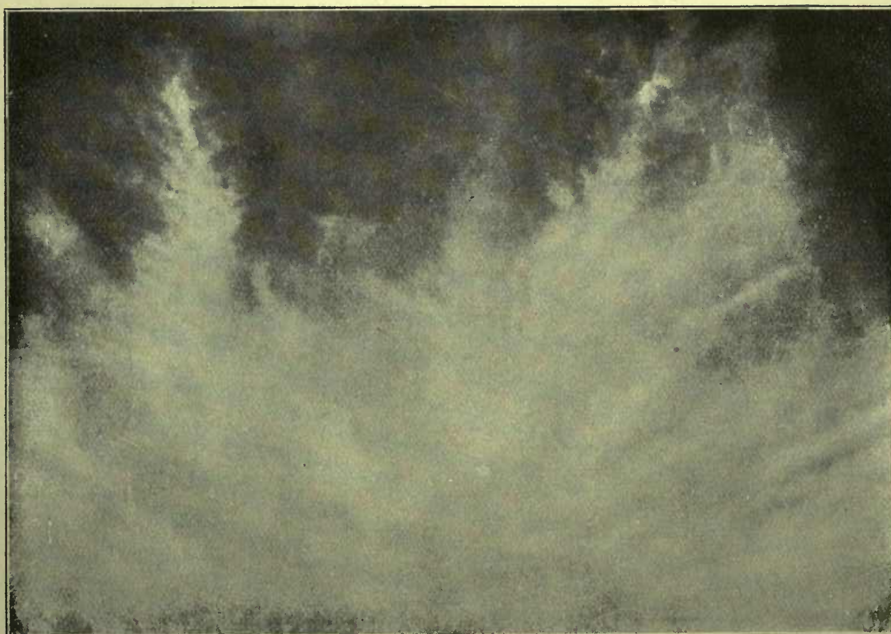

Cirrus.

Photo by Capt. D. Wilson-Barker.
Reproduced by permission from *Clouds and Weather Signs.*

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METEOROLOGY FOR ALL.

CHAPTER I.

CLOUDS AS WEATHER PROPHETS.

How many of us are there who could describe off-hand the species of cloud in the sky above us at a given moment, and, what is perhaps more to the point, deduce a reasonably correct forecast of coming weather from its aspect?

We will first take the "cirrus" cloud (abbreviation ci.) [Plate I]. The name, as is well known, comes from the Latin word *cirrus*, meaning a *hair*, though it would seem to the author that a "feather" would more aptly describe these clouds, as they resemble nothing so much as a quill pen with widely feathered ends. They are commonly known by the name of "mares' tails." They are the highest form of cloud known in our atmosphere, having been observed by Gay Lussac, in 1804, when in a balloon at an altitude of more than *four miles*, still far above him. This cloud is composed of minute ice particles, and it is to this and "cirro-stratus" (cir.-s.) that we owe the phenomena of halos, coloured parhelia (known to sailors as "wind-dogs"),* etc., which are attributed to the refraction of the sun's (or moon's) rays through prisms of ice.

The appearance of cirrus in a clear blue sky does not always portend bad weather. If the sky becomes only slightly flecked with feathers of this cloud which gradually melt away again it is a sign of long continued fine weather. If, on the contrary, it appears springing up from the horizon in long spirals like a bunch of quills with the feathered ends uppermost, and rooted in cirro-stratus below them, the whole mass thickening as time goes on, then it may be pretty safely assumed that a rain and wind-bearing depression is situated in that direction.

On the near approach of the disturbance, the encroaching cirrus and cirro-stratus clouds gradually co-mingle and presently cover the greater part of the sky. At first white, this pallium (known as "sheet-cloud") becomes greyer by slow degrees until it gradually resolves itself into "nimbus" (n.) or rain cloud. A few puffs of wind will now be felt—the "advance guard" of the coming storm, and presently detached portions of cloud of a blacker hue than the rest will appear beneath the generally grey canopy. These are "fracto-nimbus," or "flying scud," and when these appear it is time to consider the storm is upon us, as the rain and wind generally commence on their arrival. The approach and departure of cyclonic storms of this kind will be more fully described in a later chapter.

We now come to a consideration of "cirro-stratus," or "cirro-nebula," as it is sometimes called, *without* the admixture of pure cirrus. Now it must be remembered that although halos and mock-suns appearing

* There is no more sure precursor of a gale than the "wind-dog" or coloured parhelion.

in a conglomeration of cirrus and cirro-stratus as described above are sure signs of bad weather, we must not confuse them with similar optical phenomena appearing in a plain, thin, white sheet of cirro-stratus covering the whole of the sky to an even density. These may appear and disappear again in very fine weather, but mostly in the springtime in either hemisphere when the atmosphere is warming up after its winter chilling.

The next cloud to come under our notice is the "cirro-cumulus" (cir.-cu). These are small round clouds, generally appearing in masses, but sometimes in lines. They frequently resemble a flock of sheep lying down, and have also been likened to the markings on a mackerel, and hence have been called "mackerel sky," but they are really like bundles of wool more than anything else.

There is a saying about these clouds which the author believes is well known to sailors which runs thus :—

> "Mackerel sky;
> Not long wet, nor yet long dry,"

meaning, of course, that the ensuing weather will be showery, and this in the author's opinion is the correct interpretation to be placed upon them as a general rule. But there is a reservation. If we get these clouds in close array like a fleet of schooners before a following wind, then a gale may be expected within twelve hours. If they are in detached *masses* then showery weather may be expected as described above, but if in small detached *pieces*, with a tendency to disappear as they approach, they are indicative of fine weather. This cloud has also been named by the International Meteorological Committee "alto-cumulus," (a.-cu.).

"Strato-cumulus" (s.-cu.) is our next subject. Its more common name, "dry stratus," perhaps better describes it, as it frequently covers the whole sky for days together without producing rain, except on some occasions in the form of a very slight drizzle or mist. This is frequently met with in the English Channel, the North Sea, and the Bristol Channel and adjacent land areas, when northerly, north-easterly, or easterly winds prevail. Although essentially a winter cloud it is often present in the summer months on the southern coasts of the British Isles as was the case in 1913, when, although the weather was abnormally dry, yet the amount of sunshine was largely below the normal owing to the continued presence throughout the greater part of July and August of this "dry stratus." It can be distinguished from nimbus by its globular appearance and patches of blue sky appearing through it from time to time. This cloud is a "fine weather" phenomenon, and when it is present there need be no fear of gales of any severity, though a stiff breeze from the north-eastward may sometimes accompany it. In the old days of sailing ships it was these conditions that used frequently to keep homeward-bound vessels lying to at the mouth of the English Channel for days together almost within sight of home; for the "dry stratus" weather with the stiff "nor'-easter" is and always has been one of the most persistent weather conditions of "the Channel." The "sou'-wester" veers "nor'-west" and backs again, but your good "nor'-easter" is like the brook and "goes on for ever," or appears to do so at any rate!

The rain-cloud ("nimbus") has been mentioned before, and we will now pass on to the "cumulus" (cu.) or wool-pack clouds. Like all the other cloud forms with which we have been dealing, these are complex, and cannot be lightly dealt with in a few words. We have first the fine weather cumulus, those clouds that when seen upon a sea horizon in clear weather mean land somewhere in their neighbourhood. They are merely evaporation clouds formed over land surfaces by the heat of the sun drawing the moisture from the earth, and as it rises into the upper regions of the atmosphere it becomes condensed by the cold strata of air always present there, and thus appears as visible vapour, or what we call "cloud." It is useful as a weather prophet, as if it remains white and gradually fades away as the sun declines in power for the day it is a sign of fine weather. It is through this class of cloud that the phenomenon of "Jacob's ladder," or "the sun drawing water," is seen, although this is really typically a dry weather cloud. If this cloud is seen black in its lower portions with majestic white turrets on its upper parts then it is time to "look out for squalls!" These clouds, known as "cumulo-nimbus" (cu.-n.), rising in the form of mountains, etc., magnificent though they are to the eye of the observer, are productive of the most treacherous meteorological conditions; they are thunder clouds. They cannot be mistaken. They are white at the tops, taking the form of anvils and turrets, often veiled by stratus ("false cirrus"). Half way down they assume a dull coppery hue, whilst their bases are of inky blackness. They are the clouds also of the "black" and "white squalls" of tropical and semi-tropical regions. They are also responsible in equatorial regions for the diurnal thunderstorms which in some parts occur with such regularity; in Great Britian generally accompanying V-shaped "secondary," or thunderstorm depressions, and the general state of the atmosphere under these conditions is thoroughly unstable and unreliable.

We have now only to deal with the "stratus" (s.); the high or low fog cloud, to complete our list. This "cloud" is the one that produces the obnoxious "mixture" in the "Great Metropolis," and other large cities or towns, commonly known as "The London Particular," or "pea-souper," owing to its characteristic moisture holding the particles of smoke and soot from innumerable chimneys in suspension. It is difficult to say very much about fog, except that it is generally due to strata of air of different temperatures mixing or the sudden cooling of the atmosphere.

To amateur photographers, a very interesting and useful pastime is open for their leisure moments in taking photographs of clouds, and in doing so they may one day hit upon something that will be of real scientific value. The exposure for clouds with ordinary plates is about $\frac{1}{25}$ second, but of course varies with the lighting of the clouds. If a $\frac{1}{2}$-plate stand camera with pneumatic shutter is used, and we add to this the precaution of employing ortho-chromatic "backed" plates, very good results should be obtained.

Before leaving this interesting subject we must give the formula for taking regular cloud observations. The method employed is on an arbitrary scale of 0 (clear sky) to 10 (quite overcast), and 5 for a semi-clouded sky. If there is one cloud upon the horizon or in any part of the sky we put 1, and for a larger cloud or quantity of clouds 2, 3, or 4. Then over 5, we go 6, 7, 8 to 9, which last figure means almost overcast. Fog should be entered as "10F" as if there are no "Remarks" in our "log" to show what kind of weather it was at the time of the observation, the "F" removes all doubt. Further instructions on how to keep a "weather log" will be given in a later chapter.

In observing clouds the "black mirror," a small piece of clear glass with black paper pasted on the back, will be found useful, as the direct observation of very white clouds is trying to the eye.

In this connection it may be as well to observe that before photographing a cloud, or clouds, of this type

PLATE II.

Shower Cumulus.

Photo by D. W. Horner. Engraved by Cassell's Pictorial Agency.

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it would be advisable to obtain an idea of their outline by means of the "black mirror" or "nephoscope." This is also useful for determining the direction of movement of the upper clouds, whose gradual progress may in some cases be so slow as to be virtually imperceptible to ordinary direct visual observation.*

* The author is indebted for some of the illustrations of clouds in this book to Capt. D. Wilson-Barker, R.D., R.N.R., Past Pres. R. Met. Soc. Capt. Wilson-Barker's photographs of clouds have become "classics" of their kind, and every observer will do well to study them before attempting observations with a view to prognostication. For the rest of these I must refer the reader to Capt. Barker's "Clouds and Weather Signs" Witherby & Co.)

CHAPTER II.

SNOW AND LIGHTNING PHOTOGRAPHY.

In the last chapter we mentioned that amateur photographers would find an interesting pastime in taking pictures of clouds. Using similar photographic apparatus they can equally well devote their energies to snow, hail, hoar frost, or lightning.

The exposure for snow is the same as for light clouds, that is about $\frac{1}{25}$ second. Whenever possible snow should be photographed in bright sunshine, as, if a picture is taken on a cloudy day it will appear flat and dull.

One of the most difficult things to photograph is hoar frost, as it nearly always occurs on the branches of trees, where it is most picturesque, in a dense fog in the early morning, and we have to wait patiently till the fog clears and immediately take the picture or the warmth of the sun will melt the frost crystals.

Our next subject for the camera is hail. Although it is unusual it is by no means unknown for hailstones as large as hens' eggs, or even as large as oranges, to fall in the British Islands. A particular case was that at Richmond in Yorkshire on July 8th, 1893, when hailstones 6 to 7 inches in circumference fell. Photographs taken of them showed that the outer coating of the hailstones was of a white opaque character ; the next coating was clear ice ; followed by alternate coatings of opaque and clear ice. Some of the stones had nine separate coatings. It is not surprising that when such hailstones fall large quantities of glass are destroyed, vegetation damaged, corrugated iron and zinc perforated, and even birds and animals killed.

When photographing hailstones we must remember to place a penny or a foot-rule against the stones, otherwise we shall have nothing to show their actual size in the picture.

The most interesting, not to say exciting, work with the camera is taking pictures of lightning.

Owing to the intervention of photography the term "forked lightning" has been found to be quite erroneous, the impression of forked shape being simply due to an optical illusion brought about by the fact that the eye is unable to follow the rapid fluctuations in the more or less continuous stream of fire which goes to make up an ordinary lightning flash as revealed by the camera.

When we see lightning which appears to flicker, it means that several flashes were moving together along the same path. This fact was discovered by moving the camera to and fro during the most violent part of a thunderstorm.

Photographing lightning should only be essayed by those whose nerves are proof against sudden shocks. This being so we proceed as follows:—After dark when it is considered that a thunderstorm is approaching, place the camera on the window-sill, or covered balcony, or on a table inside the room at an open window. In either case it must be well protected from rain. If a stand camera is employed it should be removed from its tripod, as that will usually bring the lens too high for the aperture of an ordinary window when opened from the bottom.

Having placed the camera on the window-sill, or table, or some other firm support, we open the shutter and focus on a distant light. Then having wound film, or fixed dark slide with plate, according as we are using a hand or stand camera, we retire into the darkness of the room and await events. So soon as there is a good flash we close the shutter, and re-wind the film, or renew the plate as the case may be.

The chief difficulty is to select the right moment to take the best flash, but if we go to the expense of a pneumatic shutter with a fairly long tube, so that we may sit well back in the room with the bulb in our hand, we should achieve some very good results after a little practice.

Of course it is not to be expected that results as good as that seen in the frontispiece, of lightning striking the Eiffel Tower will be achieved all at once. In this, as in other things, patience and perseverance will be required.

CHAPTER III.

PHENOLOGICAL OBSERVATIONS.

THESE observations are of various natural phenomena, such as the first appearance or singing of birds; first appearance of insects; or the time of blossoming or budding of various trees.

No one should take up this subject unless they have plenty of spare time, some knowledge of botany, and country surroundings, as otherwise we may send in observations that may be entirely erroneous.

The Royal Meteorological Society issue a pamphlet giving hints as to the taking of these observations, and are glad to receive such from careful observers. The author is indebted to the Council of the Society for quotations made from this pamphlet in this chapter.

In the Botanical Section observations should be limited to wild plants and full grown trees. One special tree of each species should be selected, and the first budding reported each year. It is necessary always to note the budding of the *same tree*, and this should be one that through an average number of years has proved itself to be neither abnormally early nor late. For instance, the "Horse Chestnut" (*Æsculus hippocastanum*) is peculiar from the fact that two mature specimens may be standing next to one another in the same garden and yet differ by as much as a week or even more in coming into leaf; hence the necessity to keep to one tree in making our reports.

Then, again, there are the different forms of similar species. In the Oak family there is the English Oak (*Quercus robor*), whose spreading branches are well known in the English countryside, which is quite different from the Turkish, American, or French oak, the last-named retaining its leaves throughout the year.

The plants especially to be noted are given in the following list :—

Wood Anemone . .	(*Anemone nemorosa*).
Pilewort, or Lesser Celandine	(*Ranunculus ficaria*).
Marsh Marigold . .	(*Caltha palustris*).
Common Mallow . .	(*Malva sylvestris*).
Herb Robert . .	(*Geranium robertianum*).
Dutch Clover . .	(*Trifolium repens*).
Sloe, or Blackthorn . .	(*Prunus spinosa*).
Ivy . .	(*Hedera helix*).
Coltsfoot . . .	(*Tussilago farfara*).
Milfoil, or Yarrow . .	(*Achillea millefolium*)
Black Knapweed . .	(*Centaurea nigra*).
Harebell . .	(*Campanula rotundifolia*).
Greater Bindweed, or Wild Convolvulus . .	(*Convolvulvus sepium*).
Cowslip	(*Primula veris*).
Bluebell	(*Scilla nutans*).

INSECTS.

Cockchafer, or May Bug .	(*Melolontha vulgaris*).
Fern Chafer, or July Chafer .	(*Rhizotrogus solstitialis*).
Bloody-nose Beetle . .	(*Timarcha lævigata*).
Glow-worm . . .	(*Lampyris noctiluca*).
Honey Bee, or Common Hive Bee	(*Apis mellifica*).
Wasp	(*Vespa vulgaris*).
Large Garden White or Cabbage Butterfly .	(*Pieris brassicæ*).

Small Garden White or Cabbage Butterfly .	(*Pieris rapæ*).
Orange-tip Butterfly . .	(*Anthocharis cardamines*).
Meadow-brown Butterfly .	(*Epinephile Janira*).
St. Mark's Fly . . .	(*Bibio Marci*).

BIRDS.

Brown Owl . . .	(*Strix aluco*).
Flycatcher . . .	(*Muscicapa grisola*).
Song-Thrush . . .	(*Turdus musicus*).
Fieldfare	(*Turdus pilaris*).
Nightingale . . .	(*Daulias luscinia*).
Wheatear . . .	(*Saxicola œnanthe*).
Willow-Wren . . .	(*Phylloscopus trochilus*).
Chiffchaff . . .	(*Phylloscopus collybita*).
Sky-Lark	(*Alauda arvensis*).
Chaffinch	(*Fringilla cœlebs*)
Rook	(*Corvus frugilegus*).
Cuckoo	(*Cuculus canorus*).
Swallow, or Chimney Swallow	(*Hirundo rustica*).
House-Martin . . .	(*Hirundo urbica*).
Sand-Martin . . .	(*Hirundo riparia*).
Swift	(*Cypselus apus*).
Goatsucker, Nightjar, or Fern Owl . . .	(*Caprimulugus europæus.*)
Turtle-Dove . . .	(*Columba turtur*).
Partridge	(*Perdix cinerea*).
Woodcock . . .	(*Scolopax rusticola*).
Corncrake, or Land-Rail .	(*Crex pratensis*).

The fifteen specimens of flowers* are of special importance, and the list taken in conjunction with that of the insects and birds will be found long enough for the ordinary observer, those requiring a more ambitious

* Many more specimens of *wild flowers* are given in the pamphlet referred to.

list are referred to the pamphlet mentioned at the beginning of this chapter.

All desiring to take up this work should communicate with the Assistant Secretary of the Royal Meteorological Society (Mr. A. Hampton Brown) at 70, Victoria Street, London, S.W.1., who will supply the necessary information so as to enable observers to do work of real scientific value.

The object of the registration of Phenological observations by the Meteorological Society is to afford evidence of the control exerted by climate and weather over plants and animals, as shown by variation in the date of occurrence of yearly events in their lifetime, in different parts of England. The end in view can only be attained by accuracy in observation on the part of the recorders ; and therefore no doubtful entries should be admitted into the returns. To secure uniformity of method, which is of the utmost importance, strict attention should be paid to the rules and suggestions issued by the Society.

Should there be any doubt about one plant having been mistaken for another, a specimen should be sent to the Referee without delay, and he will inform the observer of the mistake (if any) while there is time to correct the record for the current season.

Birds mentioned in the list are chiefly birds of passage, and have been selected for ordinary observation. Any birds not included in the list which visit a district in unusual numbers or at a different time of year, should be noted and direction of flight recorded.

There is a tendency among novices in the study of bird life to confuse the song of the various genus of thrushes. For instance, the Song-Thrush (*Turdus musicus*) has a varied selection of musical notes, and a perceptible interval elapses before he repeats himself. The Mistle-Thrush, on the contrary, repeats its strain many times in succession in a highly staccato fashion.

Another member of the Thrush family, the Fieldfare (*Turdus pilaris*), chatters its peculiar note both when perched on a tree and when in flight.

One of the most elusive songsters is the Nightingale (*Daulias luscinia*), reports of whose song it is always necessary to take *cum grano salis*, for both the Song-Thrush and the Blackbird sing so late into the summer's evenings that not infrequently they are mistaken for the bird so beloved of poets. Certain it is that most of the stories we read in the newspapers about early Nightingales are pure fabrications made by people who are quite unable to differentiate between the varied songs of British birds.

The song of the Willow-Wren (*Phylloscopus trochilus*) somewhat resembles that of the Chaffinch (*Fringilla cœlebs*), but is not so loud or harsh. It is said that the Willow-Wren never arrives till the larches are green.

The two notes of the Chiffchaff (*Phylloscopus collybita*) are quite unmistakable, resembling the bird's English name as commonly written; it cannot be mistaken for anything else.

The bird most productive of mistakes is the Cuckoo (*Cuculus canorus*). Very frequently the first notes supposed to be heard are nothing more than some village school-boy imitating the bird's easily mimicked call. Even students of bird music are not immune from these errors, and an amusing story is told of two Professors of Ornithology who had each carefully learnt the Cuckoo's call in order to study their mode of life at close quarters. The scheme was that by means of repeating at intervals the bird's monotonous cry, they could approach its borrowed nest for the proposed observations. But it so happened that both the professors started their investigations on the same day from opposite sides of the same wood, with the result that, after a whole hour's prodigious "cuckooing," they came face to face, finding that the supposed bird which each had thought was answering him was the other professor!

It is a curious thing, but nevertheless true, that the Cuckoo does not frequent the woods in the West of England in such large numbers as in the Home Counties.

With regard to insects, the first appearance of each one should be recorded and also the period when it becomes common.

All observers, except skilled entomologists, should, if possible, forward to the Society with their reports, a specimen of each of the species referred to in the notes, to be submitted to the Referee for verification.

CHAPTER IV.

THE C.G.S. SYSTEM IN MODERN METEOROLOGY.*

As all the charts, and most of the tables, issued by the British Meteorological Office are now given in the C.G.S. system, a knowledge of this scheme of expressing meteorological data is desirable.

The barometer being the most important instrument, we will treat its readings first, and endeavour to show, in as plain language as is consistent with thoroughness of explanation, the exact relation between barometer readings in inches or centimetres with the " centibars " or " baromils " of the C.G.S. system.

To begin at the beginning. In case anyone should ask—which they might quite reasonably do—*Cui bono?* What is the use of worrying our heads with a new system of figures when the old ones did very well? I will give the answer as put forward in Major Gold's interesting paper, an answer which will, no doubt, appeal

* C.G.S. (centimetre-gramme-second) system. For most of the facts and figures anent barometer readings in this chapter I am indebted to a paper read before the Royal Meteorological Society on May 20th, 1914, by Lt.-Col. Ernest Gold, D.S.O., M.A., F.R.S., F.R.Met.Soc., entitled " Barometer Readings in Absolute Units and their Correction and Reduction." For the greater portion of the other figures I must acknowledge my indebtedness to the admirable comparison tables issued on a handy wall card by Messrs. Negretti & Zambra; and also to the *Seaman's Handbook*, issued by the Meteorological Office, London.

to those who, in a low latitude, have endeavoured to obtain a barometer reading in inches of mercury, and with a Fahrenheit scale thermometer attached, accurate in every little detail!

He remarks: "One of the absurdities of this (the inch-Fahrenheit) scale for barometers is that it is practically impossible to get a barometer actually under standard conditions. If the barometer is taken to latitude 45° and put in a cold room at temperature 32° F., then the mercury will be under standard conditions, but the scale will not; the scale will give values too high, because it must be brought to 62° F. before it reads correctly. If the baromil barometer, on the other hand, is put in such a cold room its readings (apart from index error) will give the correct values directly; the barometer will be under standard conditions, since the same temperature of 273° A. or 0° C. is standard for both mercury and scale."*

Having given a reason for the adoption of the system in question we will now proceed with our explanations.

As everyone knows, the column of mercury in the barometer tube is simply weighing the atmosphere. Almost any other liquid would do, except that the length of the column necessary makes them unwieldy, such as water or glycerine, hence the general adoption of mercury for convenience sake.

When barometers were first constructed it was deemed sufficiently accurate to take the length of a column of mercury as a unit of pressure, but as time went on many modifying factors were discovered. First, there was temperature, and then variation of gravity over the surface of the earth. Thus for scientific purposes an ideal column of mercury was always used, and was usually referred to as "reduced to 32° F., and latitude

* F.Fahrenheit, A.=absolute, and C.=centigrade.

45°." Therefore, from a scientific point of view, relinquishing the inch and millimetre is not new. Then we have a third modification, "reduction" of observations to sea level.

The C.G.S. units are multiples of the unit of pressure in the ordinary centimetre-gramme-second system. The unit of force is called the "dyne," and the unit of pressure defined as unit force per unit area is the dyne per square centimetre. The weight of a gramme is equal to a force of 981 dynes. If a column of water (= a gramme) one centimetre high is placed on a square centimetre it will cause a pressure of 981 dynes to the square centimetre, or nearly equal to one millibar.

The dyne per square centimetre is quite small, too slight to be measured with a mercurial barometer. It would take about seven of these small-pressure units to equal "Force 1" on the Beaufort scale of wind force. A wind equivalent to one dyne per square centimetre would scarcely be perceptible except to a most sensitive observer.

Notwithstanding this, however, there are many reasons for adopting this "dyne" as a base unit, and to quote Major Gold again: "It is the primary unit of pressure in the C.G.S. system, and as long ago as 1888 a committee of the British Association proposed the name 'barad' for it; at a congress of physicists in Paris in 1900 the name 'barye,' which had been proposed for one million dynes per square centimetre, was recommended for adoption as the fundamental unit to mean one dyne per square centimetre."

The unit of pressure generally adopted is the millibar (one-thousandth part of a bar). It is equal to the pressure of about .03 inch of mercury or by .75 millimetre. In round numbers it equals a pressure of ½ lb. to the square foot. Approximately it is equivalent to a wind force of 6 on a pressure plate.*

In using a barometer to measure the atmospheric pressure we measure a length in the first place, whether we use mercury, glycerine, or water.

In using millibars instead of inches—the latter being practically meaningless for they are not really "inches" at all—we do away with a great deal of unnecessary calculation in the reduction of barometric readings to sea level, for latitude, and all other corrections demanded of us by the Meteorological Office, if our readings are to be plotted on a synoptic weather map.

Having put before the reader the theory of the baromil barometer, we will now endeavour to show the easiest way to put its readings into practice.

To do this we will again draw from the "storehouse" of information on the subject given in Major Gold's paper—"Barometer Readings in Absolute Units"—from which we have previously quoted.

It appears that it occurred to the author that, instead of having a separate table for latitude correction, it would be far easier if an automatic correction of the readings of the attached thermometer were provided by means of a movable scale which could be set to the correct latitude each time the barometer was read. The latitude scale is given from 0° to 90°. This range could, if necessary, be curtailed by ¼ as it is unusual for ships to sail north or south of latitude 60°.

* A "bar" is equivalent to a pressure of 14.5 lbs. to the square inch, this being the ordinary atmospheric pressure at sea level, and the "millibar" is approximately one-thousandth part of it, the "centibar" being, of course, one-hundredth part of a "bar." To give the pressure in centibars or millibars mercurial barometers must be corrected for temperature and altitude. A good aneroid requires no such correction, but this form of instrument is objected to by the Meteorological Office, as it has a varying index error of its own, causing confusion in making amps.

To quote from the paper again the author says: "It would probably be best to have no scale engraved upon the stem of the thermometer except a prominent mark for freezing point and marks for every 5°. The reading would be taken from the movable scale. In the figure the scale is set so that the latitude mark 57° 10′ comes opposite the zero mark; readings on the scale then give the corrected values of the temperature of the attached thermometer to allow for the effect of latitude; the reading in the figure is 283.4°.

"If the reading were taken from a fixed scale with no allowance for latitude, it would be 290° A. The difference 6.6° multiplied by .163 gives the value of the gravity correction for Aberdeen for 1000 bm., viz., 1.07 bm.

"This value 283° is used with a table showing the ordinary corrections for temperature; the corresponding reading in baromils gives the correction necessary to reduce the reading of the barometer to millibars assuming there is no index error."

The correction of the barometer reading for temperature increases by about .163 bm. for each degree *absolute*; for degrees *Fahrenheit*, .091 bm. As attached thermometers are not used for temperatures, but merely to correct barometer readings, it is an advantage to have such a thermometer so graduated that it will give the corrections direct in baromils.

In this "ideal" thermometer the divisions would be about 10 per cent. farther apart than in Fahrenheit degrees. It would be specially useful for a barometer at sea, because by an adjustment of the thermometer scale all the corrections would be read directly from the instrument. In this diagram the altitude scale is movable relative to the scale of latitude, while the whole of the latitude and ideal scales for attached thermometer is movable up and down the thermometer itself. The thermometer is fixed to the frame of the barometer, on which is engraved the arrow on the right. To take a reading the height scale is pushed up or down till—o—comes opposite the latitude of the place of observation. Then the whole piece is moved until the figure denoting the height of the barometer cistern above mean sea level in metres comes opposite the arrow. The thermometer reading is then taken from the ideal scale, which gives the correction for temperature, gravity, and altitude combined for a pressure of 1000 mb. This is the theory of the method. In practice Mr. Whipple has pointed out that fixing the latitude may simplify matters, the ideal and height scales being moved together.

Mercurial barometers fitted with scales of baromils are now manufactured by Messrs. Negretti & Zambra, of London, to the order of the Meteorological Office. There have been two or three different types made, but all achieving the same result.

The portion of this chapter treating of the barometer would be incomplete without the inclusion of some correction and comparison tables which are essential until the use of barometers with the movable scales becomes general, which, of course, cannot be accomplished until a considerable time has elapsed.

Table I.—Showing the correction to be applied to readings of the barometer at station level to reduce them to mean sea level.

Temperature of air 260° A. (8.6° F.), pressure 1000 mb.

For a dry-bulb temperature of 285° A. (53.8° F.) the correction for a height of 10 metres is 1.198 mb., and for heights between 0 and 15 metres the correction may be taken to be proportional to this.

Table II.—For correcting the readings of mercury barometers on account of the variation of gravity with latitude.

From latitude 0° to 45° the amounts given are to be *subtracted*.

From 45° to 90° they are to be *added*.

TABLE I

Height in Metres.	Correction in Millibars.	Height in Metres.	Correction in Millibars.	Height in Metres.	Correction in Millibars.	Height in Metres.	Correction in Millibars.
10	1.313	40	5.26	70	9.23	100	13.21
11	1.44	41	5.39	71	9.36	101	13.34
12	1.58	42	5.52	72	9.49	102	13.47
13	1.71	43	5.66	73	9.63	103	13.61
14	1.84	44	5.79	74	9.76	104	13.74
15	1.97	45	5.92	75	9.89	105	13.87
16	2.10	46	6.05	76	10.02	106	14.00
17	2.23	47	6.19	77	10.16	107	14.14
18	2.36	48	6.32	78	10.29	108	14.27
19	2.50	49	6.45	79	10.42	109	14.40
20	2.63	50	6.58	80	10.55	110	14.54
21	2.76	51	6.71	81	10.69	111	14.67
22	2.89	52	6.84	82	10.82	112	14.80
23	3.02	53	6.98	83	10.95	113	14.94
24	3.15	54	7.11	84	11.08	114	15.07
25	3.28	55	7.24	85	11.22	115	15.20
26	3.41	56	7.37	86	11.35	116	15.33
27	3.55	57	7.51	87	11.48	117	15.47
28	3.68	58	7.64	88	11.61	118	15.60
29	3.81	59	7.77	89	11.75	119	15.73
30	3.94	60	7.90	90	11.88	120	15.87
31	4.07	61	8.04	91	12.01	121	16.00
32	4.20	62	8.17	92	12.14	122	16.13
33	4.34	63	8.30	93	12.28	123	16.27
34	4.47	64	8.43	94	12.41	124	16.40
35	4.60	65	8.57	95	12.54	125	16.53
36	4.73	66	8.70	96	12.67	126	16.66
37	4.86	67	8.83	97	12.81	127	16.80
38	4.99	68	8.96	98	12.94	128	16.93
39	5.13	69	9.10	99	13.08	129	17.07
40	5.26	70	9.23	100	13.21	130	17.20

The correction for altitude for a pressure at station-level of 1000 mb. has been calculated to .01 mb. for each metre up to 130m., and is given in Table I. The corrections for pressures on either side of 1000 mb. are easily found by means of this table by adding or subtracting 10%, 20%, etc., of the values.

Correction for gravity is given to .01 mb. for each degree of latitude for a pressure of 1000 mb. in Table II. The values for index error will be found on the Kew certificate given with the barometer.

TABLE II.

Lat. N. or S.	Corrections at 1000 mb.	Lat. N. or S.	Lat. N. or S.	Corrections at 1000 mb.	Lat. N. or S.
°	Baromils.	°	°	Baromils.	°
0	2.59	90	23	1.80	67
1	2.59	89	24	1.73	66
2	2.58	88	25	1.66	65
3	2.58	87	26	1.59	64
4	2.56	86	27	1.52	63
5	2.55	85	28	1.45	62
6	2.53	84	29	1.37	61
7	2.51	83	30	1.30	60
8	2.49	82	31	1.22	59
9	2.46	81	32	1.14	58
10	2.43	80	33	1.05	57
11	2.40	79	34	0.97	56
12	2.37	78	35	0.89	55
13	2.33	77	36	0.80	54
14	2.29	76	37	0.71	53
15	2.24	75	38	0.63	52
16	2.20	74	39	0.54	51
17	2.15	73	40	0.45	50
18	2.10	72	41	0.36	49
19	2.04	71	42	0.27	48
20	1.98	70	43	0.18	47
21	1.92	69	44	0.09	46
22	1.86	68	45	0.00	45

A pressure of 1000 millibars is equivalent to 29.52 inches of mercury, or 750 millimetres.

Normal pressure at sea level varies from about 925 mb. (27.3 in.) to 1053.5 mb. (31.11 in.).

Perhaps we should call this *abnormal*, for these are extremes. Normally the barometer does not fall frequently below 970 mb. (28.64 in.) or rise above 1040 mb. (30.7 in.). The following table is compiled with the aid of the *Seaman's Handbook*, and Messrs. Negretti & Zambra's Comparison Card.

BAROMETER.			THERMOMETER.			ANEMOMETER.	
Millibars.	Mm.	In.	Cent. °	Absol. °	FAHR. °	Metres per sec.	Miles per hour.
1053.1	789.9	31.1	50	323	122.2	45	102
1032.8	774.7	30.5	40	313	104.1	40	90
1015.9	762.0	30.0	30	303	86.0	35	78½
999.0	749.3	29.5	20	293	68.2	30	67½
982.0	736.6	29.0	10	283	50.0	25	56
965.1	723.9	28.5	0	273	32.0	20	44¾
948.2	711.2	28.0	−10	263	14.1	15	33½
931.5	697.4	27.5	−15	258	5.0	10	22½
914.6	685.0	27.0				5	11¼

Space will not permit further elaboration of the scheme, but enough has been written to show the reason for the new scales, and also to correct and convert readings of a "baromil" barometer, and also to convert the various temperature scales the one into the other and metres per second of wind veloçity into miles per hour.

The advantage of the *absolute* scale for thermometers is undoubtedly the absence of the necessity of plus or minus signs no matter how low the temperature. This was the "weak" point of the otherwise "perfect" centigrade scale, as directly temperatures of "below freezing" had to be registered the minus sign had to be used (thus − 2° C.). Careless observers frequently forgot the minus sign and so "upset the whole bag of tricks," so to speak! The absolute scale eliminates this trouble, and as the degrees are exactly the same as the centigrade in "length" conversion is easy, but the writer expects, all the same, that it will be a long time before the ordinary individual understands anything but degrees Fahrenheit !*

* All the tables except the last are published by kind permission of the Royal Meteorological Society, from whose *Journal* they are. reproduced, illustrating Major Gold's paper mentioned *ante*. The diagrams mentioned on p. 21 appeared in the original paper.

CHAPTER V.

BAROMETERS AND THEIR USES.

As is well known, the principle of the mercurial barometer is that at sea-level normal atmospheric pressure will support a column of mercury of about 30 inches in length, declining 1/10 of an inch for every 90 feet we rise above that level.

The Standard Mercurial Barometer for use on land is the Fortin (Fig. 1)*.

This instrument has a flexible base to the cistern which contains the mercury, and before a reading is taken we must adjust this with great nicety.

The thermometer which will be found fixed to the case of the barometer (known as the "attached thermometer") should be read first as it is liable to be influenced by the warmth from our body. Then the mercury in the cistern at the base of the barometer should be adjusted by means of the screw underneath in such manner that the tip of the ivory pin (called the *fiducial point*) should just touch the surface of the mercury. Then the barometer tube should be gently tapped to prevent any mercury adhering to the glass; after this the *vernier* or reading scale should be set so that the two lower edges come level with the apex, or extreme top of the mercurial column. By this means we are able to read off the barometer scale to thousandths of an inch. (The Vernier is shown in Fig. 2.)*

* Fig. 1 is lent by Mr. F. W. Sturt; 3, 7 and 8 are from blocks lent by Mr. James J. Hicks; 2 by permission of the Royal Meteorological Society.

The reading having been taken it should be corrected for sea-level and temperature according to instructions given at the end of this chapter.

Of course it will be understood that the barometer just described would only be used where great accuracy is desired. For ordinary use some of the barometers described later in this chapter are much more suitable, as they are more easy to read by the uninitiated.

The most usual form of mercurial barometer for use at sea is the "Marine Barometer" which is an adaptation of that known as the "Kew" pattern. (Fig. 3)*.

As will be seen, it is mounted on a brass arm with a gimbal ring to counteract the motion of the ship so that the instrument may always remain in an upright position.

In case the movement of the vessel should cause the mercury column to oscillate, the bore of the tube is contracted near the cistern, so making the action of the mercurial column slower and steadier.

There is also an arrangement which prevents any air rising into the barometer tube and so spoiling the "Torricellian vacuum," as the space between the top of the tube and the apex of the mercury is called, as if there is the slightest amount of air there the readings will be entirely incorrect. The iron cistern must not be touched or tampered with in any way or the readings will no longer be accurate.

The method of reading this barometer is the same as the "Fortin," or standard barometer, with one important exception. The cistern is *rigid* in the marine barometer and there is no necessity for adjustment. Indeed, as we have said just above, any unscrewing would put it out of order. The barometer tube may

* All the illustrations of instruments, except where otherwise mentioned, in this book, are kindly lent by Messrs. Negretti & Zambra, of London, by whose permission they are here reproduced.

FIG. I.—STANDARD "FORTIN" BAROMETER. Reproduced by permission of Mr. F. W. Sturt, Tunbridge Wells.
FIG. 3.—Kew Pattern Marine Barometer.
FIG. 4.—Interior Mechanism of Aneroid.

FIG. I.

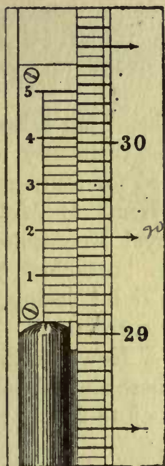


FIG. 2.
Vernier or
Reading Scale.

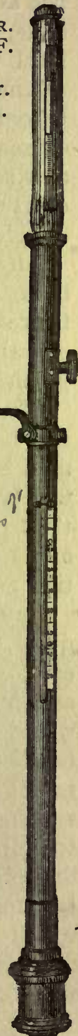


FIG. 3.

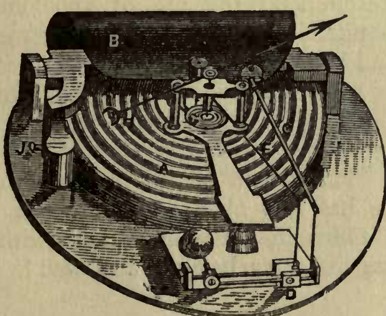


FIG. 4.

be gently tapped in calm weather in case any mercury has adhered to the glass ; then the *vernier*, or reading scale, should be set so that the two lower edges come level with the apex or extreme top of the mercurial column. By this means we are able to read off the barometer direct to $\frac{2}{1000}$ (.002) of an inch, and by estimation to $\frac{1}{1000}$ (.001) of an inch, thus :—*9th February*, 9 *a.m.*, *bar.* 30.128 *inches*, these figures being of course an extract from an imaginary "log," or "register."

After the reading has been taken the observer must, if he wishes to be scientifically accurate, correct the figures he has obtained for temperature error by means of tables given in *Hints to Meteorological Observers*, published by the Royal Meteorological Society.

The reading of the "attached thermometer," which will be found on the outer casing of the barometer, is used in making these corrections. The "index errors" will be found on the "Kew Certificate" supplied with the barometer, and these should be added or subtracted as the case may be, before finally entering the observation as quite correct.

Any other class of mercurial barometer would be quite useless at sea, and for those who only wish to employ the "glass" for forecasting the weather, without aspiring to higher scientific attainments, the author would recommend the use of an "aneroid." They can be obtained more cheaply than the mercurial instruments and have the great advantage of easy portability and freedom from accident. It seems almost impossible to put an aneroid barometer out of order, unless by dropping it one breaks the vacuum box or the spring balance. The author has in his possession an aneroid which he has had about twenty years. It has been dropped twice in travelling about with him, but is still doing its duty bravely and well!

PLATE III.

Cumulo-Stratus at sunset.

Photo by D. W. Horner. Engraved by Cassell's Pictorial Agency.

To face p. 30.]

The author is aware that many meteorologists do not agree with him in regard to the immunity from getting out of order of the aneroid barometer. Some look upon them as unreliable instruments, and so they are for *accurate comparisons* of observations as the high and low readings are apt to be exaggerated, but we are at present only dealing with cases where the observations are for our own immediate personal use. Of course, if we are going to take part in any co-operative scheme of weather observation for synoptic chart work or for reporting to the Meteorological Office, or other scientific association, it must always be remembered that the "Fortin" or "Kew" barometer previously described is an *absolute necessity*, as readings from no other instrument will be accepted.

But to return to our "aneroid."

As is well known, the principle of the aneroid barometer is a vacuum box, and spring and a piece of chain by means of which the movements of the air are carried from the vacuum box to an indicator by a compensated lever which shows the variations of atmospheric pressure very plainly on a clearly graduated dial. A reference to Fig. 4 will show the interior mechanism of the aneroid more thoroughly than any written description.

One of the most suitable forms of this class of instrument for ship-board use is the "Fisherman's Aneroid Barometer" (Fig. 5), constructed by Messrs. Negretti & Zambra to meet the decision of the Committee of the Royal National Lifeboat Institution to supply a reliable aneroid of a size available for use on board small fishing smacks and coasting vessels, in which it would be impossible to use a mercurial barometer.

It is also quite suitable for larger vessels where the marine barometer is either impracticable or unnecessary. It has none of those misleading words around its dial which are worse than useless in foretelling the weather, such as " rain," " set fair," etc., but instead has Admiral Fitzroy's rules for predicting the weather. It is equally to be recommended for use by observers on land, and is indeed of all-round utility.

It is an " aneroid " of great accuracy and the only word retained is " CHANGE," because it has been found by careful observation that the weather actually does change when the indicator reaches that point (29.50 inches = 999 mb.). The other words are more often than not wrong and therefore worse than useless, and have been omitted on this barometer, which has been specially designed for the use of seamen, and others.

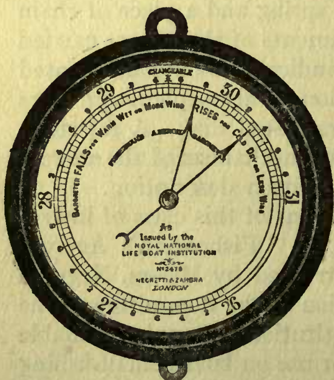


FIG. 5.
Fisherman's Aneroid Barometer.

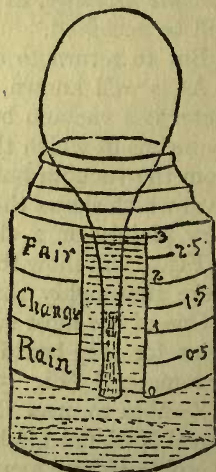


FIG. 6.
Old English Weather Glass.

A case in point has recently come under the notice of the author. After a long spell of dry weather, with the " glass " standing at or above 30 inches (1015.9 mb.), the aneroid barometer fell slowly to "CHANGE." Sure enough a great "change" followed, rain falling every day after, what is known to meteorologists as "an absolute drought" being succeeded by a "rainspell."

A useful adjunct to the aneroid would be a contrivance as illustrated in Fig. 6, which for want of a better name we will call "The Old English Barometer," as a specimen could be found at one time in many cottage homes throughout the length and breadth of England. Its construction is very simple, being a Florentine flask inverted in a 3 lb. jam jar, the jar being filled with water up to the neck. To preserve the freshness of the water the author places a piece of charcoal in it, when it will keep quite good indefinitely. The use of this instrument (if we may dignify it by such a high-sounding name) is to act as a "check" on the barometer. For instance, in winter we have our aneroid falling for wet and stormy weather, but our "Old English Weather Glass" refuses to accompany it in its decline. The conclusions to be drawn from this state of things are that it will more probably snow than rain. On the contrary, if both fall together warm rain with S. Wly. gales (speaking from a North Temperate Region viewpoint) will most probably follow. On the other hand, in summer a rise of both barometers will presage dry but cool weather, whereas if our "O.E.B." lags behind the aneroid, heat may be expected. If the water barometer persistently remains low in hot weather, with the aneroid indicator fairly high, but "jumpy," then thunderstorms are in the neighbourhood, and a look-out should be kept for "line squalls," which frequently occur without any great fall in the aneroid, but the "needle" of the barometer behaves in a very unsteady manner.

It must be pointed out that for use on board ship the "Old English Weather Glass" should be firmly clamped to a shelf swung on gimbals to take the motion of the ship, or its existence will end suddenly in disaster and "smithereens." Even avoiding this, unless the contrivance swings easily, the water would splash out where the flask meets the jar.

There was once a man who was the proud possessor of a barometer of the old-fashioned "wheel" pattern. The much-prized instrument had persisted for days in pointing to "set fair," the while it poured with rain! So at last, getting out of all patience with it, he took and threw it out in the garden, exclaiming—"There, you stupid thing! *Now* will you say it's fair?" The "moral" of this tale is that it was *not* the barometer that was stupid, but its possessor; because the "glass" will frequently remain high whilst it rains, especially in a "secondary" depression, showing generally a lengthy spell of fine weather to come. Had not the meaningless words "set fair" appeared on the dial this barometric tragedy would not have happened! It must always be remembered that it is not the point where the mercury, or, in the case of an aneroid, the indicator, happens to be at a given moment that foretells the weather, but the movement either up or down. To take a concrete case. We will imagine that the barometer is standing at 30.51 inches, which is a high reading, equivalent to the words "set fair," or even "very dry" on some barometers; then the mercury begins to fall and in a few hours is down to 30.01 inches—a fall of half an inch. A strong wind or gale will probably spring up, accompanied by a good deal of rain, though the "glass" has still only fallen as low as "fair." Then we may have the barometer down to 29.43 ("rain"),* but it is quite steady or maybe it is rising. With these conditions

* On some barometer dials the word "change" appears about this place.

we may have (for a time at least) very fine weather. This shows the utter uselessness of the words mentioned. Therefore note the figures on the barometer dial, and see which way the indicator moves, and if there be words, just ignore them.

As a general rule a falling barometer indicates bad weather and a rising one the opposite, but, as we have already pointed out, there are exceptions to this rule as to every other, and one exception is the case of severe thunder squalls, where the barometer will frequently rise rather sharply just before the storm. It is supposed that this may be due to the electrical tension in the atmosphere, as, so soon as the storm breaks, the mercury falls again. An aneroid under these circumstances will sometimes behave in a most erratic manner, the needle fluctuating up and down as the electrical disturbance approaches.

The following is a specimen "weather log," or "meteorological register."

Date.	At 9 a.m.					At 9 p.m.						
July, 1918.	Aneroid Baro-meter.	Therms.		Wind.		Aneroid Baro-meter.	Therms.		Wind.		Temperature.	
		Dry Bulb.	Wet Bulb.	Direc-tion.	Frc.		Dry Bulb.	Wet Bulb.	Direc-tion.	Frc.	Maxi-mum.	Mini-mum.
	in.	°	°		0-12	in.	°	°		0-12	°	°
1	30.00	63	60	Z	0	30.01	57	53	W.	1	77	52
2	.08	59	56	N.W.	1	.23	62	59	N.E.	3	69	49
3	.34	57	55	N.E.	0	.34	56	54	N.W.	0	73	46
4	.35	63	61	E.	0	.28	60	58	N.	0	77	47
5	.20	66	60	W.N.W.	2	.12	53	49	W.	1	71	54
6	.05	62	58	W.N.W.	2	30.10	54	52	W.	0	75	53
7	30.05	63	58	W.	1	29.95	58	56	S.W.	0	75	52
8	29.75	65	62	S.W.	0	29.64	52	50	W.S.W.	4	73	52

Z = CALM. If dry and wet bulb read *alike* enter "SAT." in wet bulb column instead of figures, showing that the air is *saturated*.

In the barometer column it is not necessary to repeat the whole numbers of inches each day, but only when the reading changes from 29 to 30 or 30 to 29 and so on.

The force of the wind varies on the Beaufort Scale from 0 = calm to 12 = hurricane.*

The method of using the instruments to foretell coming changes of weather is simple ; Admiral Fitzroy's words regarding the barometer hold good to this day :—

Long foretold, long last,
Short notice, soon past.

Also—

First rise after low
Foretells stronger blow.

If we see the barometer falling day after day and the weather still continues fair, a long spell of bad weather may be anticipated when the change does come. On the contrary, if the barometer falls rapidly and the weather breaks at once, the change will only be a temporary one, and fair weather will soon return. The converse is also true, a slow rise being far more likely to be followed by continued fine weather than a sudden one. Taking the second axiom ; after a S.Wly. gale, with sharply falling barometer, the glass will commence to rise rapidly and this is accompanied by the " stronger blow " from the N.Ww'd, the gale with rising glass being often more violent than that which accompanied the fall. A good hint for forecasting a renewal of bad weather during unsettled conditions is as follows, and it points out a fact which is frequently overlooked.

After a spell of rain, or rain and wind, the barometer is rising and has every appearance of continuing to do so, but shortly before midnight the rise is suddenly checked, though, tap the instrument as we may,† we cannot persuade the indicator to fall or " go back," as it is frequently called. Nevertheless, that " check "

* The Beaufort Scale is given in full in Chapter X.

† The aneroid barometer should always be gently tapped with the knuckles before reading, thus overcoming the inertia of the indicator and so getting a correct observation.

is more often than not (especially if it occurs between 29.70 ins. and 30.00 ins.) the first sign of the approach of a new depression bringing more wind and rain.

Fig. 7 shows a pocket aneroid barometer which can be used either for foretelling the weather or for taking medium altitudes. Of course, if it is to be used as a weather-glass it must not be carried in the pocket, for even walking upstairs will cause a sensitive aneroid to

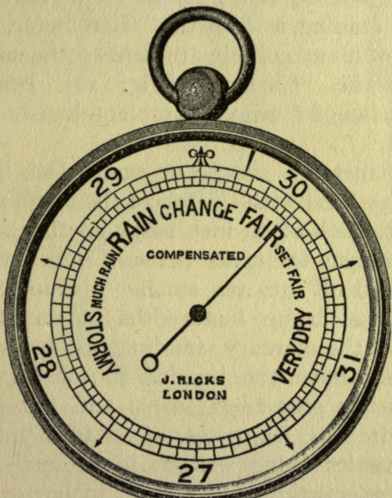


FIG. 7.
Pocket Aneroid, with Weather Indications.

fall slightly owing to the difference in air pressure in the upper or lower portion of a house. To predict the weather from it we must hang it on a nail on the wall.

The most suitable instrument for carrying in the pocket is the aneroid shown in Fig. 8, which is compensated for temperature and has an altitude scale up to fifteen thousand feet. This is useful for mountaineering; for aviation purposes a similar instrument can be had, graduated up to 30,000 ft.

The next illustration, Fig. 9, shows Messrs. Negretti & Zambra's "Land Barometer," which may be adapted to any altitude by setting the scale. It has a scale in inches, millimetres and millibars* of the C.G.S. system. For those who prefer a Mercurial Barometer, but do not wish to go to the expense or trouble of reading a "Fortin" Barometer, they have the choice of many good instruments; the one generally known as the "Fitzroy" (Fig. 10), being named after the famous admiral meteorologist, is one of the best.

This barometer is simple to read. One has only to bring the eye level with the top of the mercury and note the nearest tenth of an inch mark on the scale. Then we must imagine the space between each "tenth" line to be marked off into ten smaller divisions, or "hundredth" lines, being hundredths of an inch. Now, say we have the mercury standing just below the third tenth mark above the line of 30 inches. We have thus 30 inches *plus* two tenths, and (by estimation) seven hundredths, *i.e.*, $30\frac{27}{100}$ of an inch but, meteorological statistics being written in decimals, we write down our observation thus: 30.27 inches.

In Chapter XV. will be explained the mechanism of the old-fashioned wheel barometer.

The advantage of the aneroid over the mercury barometer is that it can be carried about in any position without putting it out of order.

We must mention the *Barograph*, or self-recording aneroid barometer (Fig. 11).

* The centibars and millibars are on the outer circle of the dial, next come inches, and on the inner circle millimetres. For *land* use there is no better instrument, and an adaptation for *sea* purposes has also been made.

FIG. 8.—Mountaineer's Aneroid, with Altitude Scale.
FIG. 9.—Messrs. Negretti and Zambra's Land Barometer
FIG. 10.—Fitzroy Barometer.

FIG. 8.

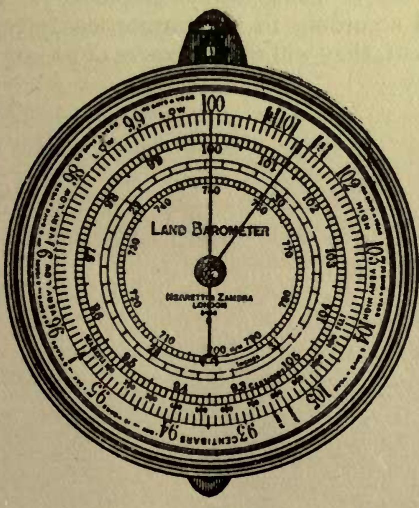


FIG. 9.

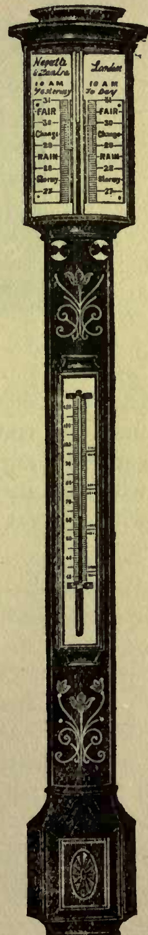


FIG. 10.

These are useful in that they continuously keep a record of the movements of air-pressure when the observer is absent and show the rate at which a depression

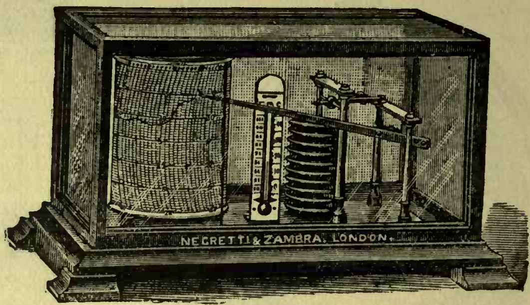


FIG. 11.
Self-recording Barograph.

may be coming on or going away graphically. If carefully adjusted according to the instructions given with each instrument, they will show changes of pressure with a great nicety.

Corrections for Mercurial Barometers.

The correction for bringing a barometer reading to mean sea-level may be calculated by the following formula :

$$\frac{bf}{29{\cdot}1(836 + t + t') - \frac{1}{2}f};$$

b being the barometer reading corrected for index error and reduced to 32°F. ; *f* the height in feet of the cistern of the barometer above M.S.L. ; *t* representing the dry bulb temperature at our station and *t'* that at sea-level. It may be assumed that these temperatures are identical.

We will suppose that the barometer reading is 30.135 ; the attached thermometer 53°, index error + .023, height above sea-level 150ft., dry bulb temperature 46° ; then we find the reduced readings of barometric pressure in the following manner :—

Reading of Barometer	30.135in.
Index Error	+ 00.023
Pressure at Temp. 53°	30.158
Correction for Temp. ..	− 00.066
Pressure at Temp. 32° F. ..	30.092
Correction for Height	+ 00.155
Reading reduced to 32° F. sea level	30.247

For the necessary correction tables the reader is referred to "Hints to Meteorological Observers," issued by The Royal Meteorological Society at 1*s*. 6*d*., and published by Messrs. Stanford, London.

CHAPTER VI.

THERMOMETERS AND HYGROMETERS, AND THEIR USES.

NEXT in importance to the barometer comes the *thermometer*. If space is limited, as it mostly is in the smaller class of house, the author would recommend the following procedure :—

Find a sheltered spot, as much free from the effects of sun and wind as possible, and yet exposed to the free passage of air. Then mount firmly and securely on the wall-boarding of the space selected the following instruments :—A good Six's maximum and minimum thermometer (Fig. 12) and a polymeter (Fig. 13). The reason why these two rather unusual instruments are recommended is that they both hang upright and take very little space, and yet we can obtain a large amount of information from these two small instruments; indeed they are a veritable *multum in parvo*.

A good plan is to place these two instruments on boards outside a *north* window, on either side, in such a way that they can be read with the window open or closed.

From the Six's thermometer we can obtain the highest and lowest temperatures during the past 24 hours, and as the indexes that show the highest and lowest points reached cannot be moved except with a magnet, with which it is necessary to " set " the thermometer twice a day, there is no fear of an index being misplaced. This shows us the highest and lowest

" shade " temperatures in the air during the preceding 24 hours. It must be fixed in such a position that under no circumstances whatever can direct sunlight fall upon it.* It must also be set perfectly upright,

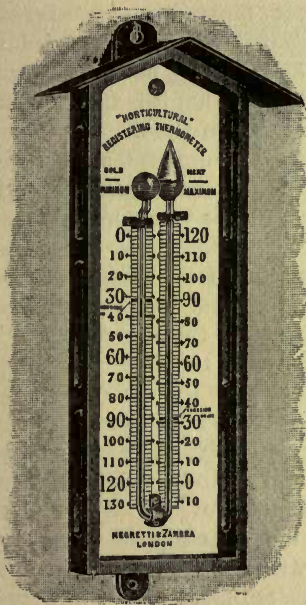


FIG. 12.
Six's Maximum and
Minimum Thermometer.

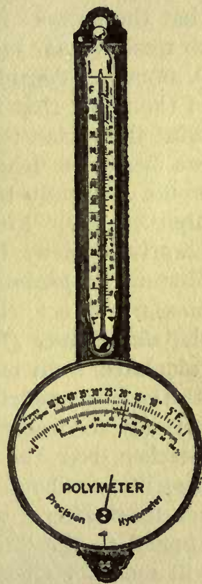


FIG. 13.
Polymeter.

as in the illustration, and firmly attached to its support, as if there be room for movement of any sort the indexes may be shaken down and the readings vitiated.

* This is true of all thermometers, *none* being suitable for exposure to the sun except the black or bright bulb in vacuo. Also all instruments should be firmly fixed to the wall or a strong stand to avoid vibration.

The movement of the mercurial column moves the steel indexes to the point of highest and lowest temperature, where they remain until re-set by a magnet after the reading has been taken. The best time for all observations of these instruments would be 9 a.m. and 9 p.m. "railway" time. It must be remembered that the *bottom* of the "pin" or "index" is the point to read, *not the top*, a mistake made by many novices. A moment's consideration will show that it is the portion of the index that has been resting on the mercury that must show what the maximum or minimum temperature has been, the length of the pin or index being added would naturally make the reading several degrees too high or low. From Lambrecht's Polymeter (a comparatively new, but very useful, invention) we can obtain the *present temperature* of the air, the *relative humidity* direct without calculation, the *dew-point*, and the *elastic force of aqueous vapour*; the last two being calculated from tables supplied with the instrument.* As the hygrometric part is actuated by a hair, there is nothing to freeze, which is an advantage in frosty weather over the dry and wet bulb to be presently described. Should the indicator of the Polymeter get fixed after a while a spot of machine oil carefully applied to the "bearings," without touching the hair, will soon set all right again. Supplied with the Polymeter for a small extra charge is a perforated zinc case with glass front. This will be found a great protection to the instrument, but the author found that in windy weather the glass in the front of the case, being loose in its groove, rattled in an annoying manner. To obviate this defect he cut two thin strips of indiarubber and wedged them in between the glass and the frame at top and bottom, which was found quite satisfactory.

* Mason's Hygrometer can be used either in conjunction with or instead of the Polymeter.

The dry and wet bulb (*the Psychrometer*, commonly called "Mason's Hygrometer") is the most usual form of hygrometer in use (Fig. 14). It consists of two thermometers, the one having the bulb wrapped up in

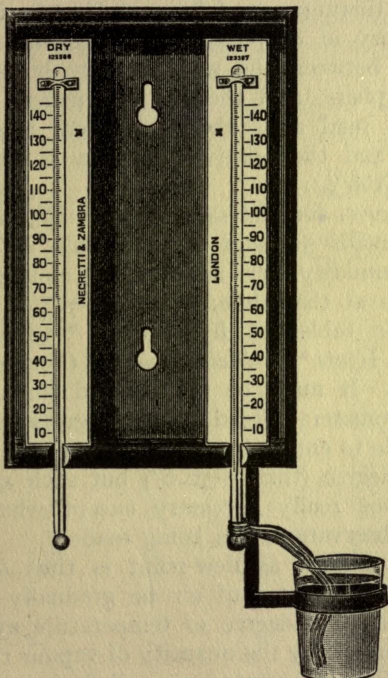


FIG. 14.
Mason's Hygrometer (dry and wet bulb.)

muslin, and the other being used as an ordinary thermometer. From the muslin covered bulb of the "wet bulb" thermometer there run a few pieces of darning cotton (generally about eight strands) and the ends of these are led into a receptacle of distilled or rain-water (if ordinary water is used the muslin, etc., soon becomes clogged with deposits), then owing to *capillarity* the water flows up the darning cotton and keeps the muslin moist. As the moisture evaporates from the surface of the muslin, heat is made latent, and the wet bulb thermometer falls according to the amount and rapidity of evaporation. Hence the greater the difference between the wet and dry bulbs the *drier* the atmosphere, and the less the *wetter*, until when they both read alike the atmosphere is said to be *saturated*, and the relative humidity is one hundred per cent. (100%).

If, however, for the sake of example, we find the dry bulb reads 52° and the wet bulb 48°, then the relative humidity, or amount of moisture in the atmosphere at that time, would be 74%.

Glaisher's tables of hygrometric * values will be found in *Hints to Meteorological Observers*, before mentioned. It must be remembered that the better class thermometers all read to *single* degrees and therefore it is possible to enter observations from such to a tenth (.1) of a degree (thus :—52.8°) but such accuracy of detail is not really necessary except where strictly scientific observations are being made.

What is known as dew-point is thus defined by Glaisher : "If a mass of air be gradually cooled, it will descend to a degree of temperature at which it will be saturated by the quantity of vapour then mixed with it. This temperature is called the dew-point."

To find the dew-point we have to make use of a table of factors given below ; the method of using these factors is as follows :—

From the dry bulb reading subtract that of the wet bulb, multiply the difference between them by the factor corresponding to the dry bulb reading and sub-

* From the Greek: 'υγρός, damp, and μέτρον, a measure.

tract the product from the dry bulb reading. The result is the dew-point, or the point to which temperature will have to fall before dew is formed. For example :—

Dry bulb=53° Wet bulb=49°.

Then—

53−49=4×2.00 (the factor corresponding to 53°)=8.
53− 8=45°= the dew-point temperature required.

TABLE 1.

GLAISHER'S FACTORS.

Reading of the Dry Bulb Thermometer.	Factor.	Reading of the Dry Bulb Thermometer.	Factor.	Reading of the Dry Bulb Thermometer.	Factor.
°		°		°	
20	8.14	44	2.18	68	1.79
21	7.88	45	2.16	69	1.78
22	7.60	46	2.14	70	1.77
23	7.28	47	2.12	71	1.76
24	6.92	48	2.10	72	1.75
25	6.53	49	2.08	73	1.74
26	6.08	50	2.06	74	1.73
27	5.61	51	2.04	75	1.72
28	5.12	52	2.02	76	1.71
29	4.63	53	2.00	77	1.70
30	4.15	54	1.98	78	1.69
31	3.70	55	1.96	79	1.69
32	3.32	56	1.94	80	1.68
33	3.01	57	1.92	81	1.68
34	2.77	58	1.90	82	1.67
35	2.60	59	1.89	83	1.67
36	2.50	60	1.88	84	1.66
37	2.42	61	1.87	85	1.65
38	2.36	62	1.86	86	1.65
39	2.32	63	1.85	87	1.64
40	2.29	64	1.83	88	1.64
41	2.26	65	1.82	89	1.63
42	2.23	66	1.81	90	1.63
43	2.20	67	1.80	91	1.62

As the late Dr. Buchan observed, " It indicates the point near which the descent of the temperature of the air during the night will be arrested. Thus, then, the dew-point determines the minimum temperature of the night."

When the dew-point is reached, dew is deposited and latent heat is given off, causing a rise of temperature.

Table II.—Tension or Elastic Force of Aqueous Vapour in Inches of Mercury for Every Degree of Temperature from 0° to 95° F.

Temp.	Tension.	Temp.	Tension.	Temp.	Tension.	Temp.	Tension.
°		°		°		°	
0	.044	24	.129	48	.335	72	.785
1	.046	25	.135	49	.348	73	.812
2	.048	26	.141	50	.361	74	.840
3	.050	27	.147	51	.374	75	.868
4	.052	28	.153	52	.388	76	.897
5	.054	29	.160	53	.403	77	.927
6	.057	30	.167	54	.418	78	.958
7	.060	31	.174	55	.433	79	.990
8	.062	32	.181	56	.449	80	1.023
9	.065	33	.188	57	.465	81	1.057
10	.068	34	.196	58	.482	82	1.092
11	.071	35	.204	59	.500	83	1.128
12	.074	36	.212	60	.518	84	1.165
13	.078	37	.220	61	.537	85	1.203
14	.082	38	.229	62	.556	86	1.242
15	.086	39	.238	63	.576	87	1.282
16	.090	40	.247	64	.596	88	1.323
17	.094	41	.257	65	.617	89	1.366
18	.098	42	.267	66	.639	90	1.410
19	.103	43	.277	67	.661	91	1.455
20	.108	44	.288	68	.684	92	1.501
21	.113	45	.299	69	.708	93	1.548
22	.118	46	.311	70	.733	94	1.596
23	.123	47	.323	71	.759	95	1.646

So soon as the air is again cooled down to the dew-point by radiation the same process is gone through again, the air temperature remaining in the neighbourhood of the dew-point throughout the night as long as the sky remains clear and the air calm.

Having found the dew-point it is possible to deduce the relative humidity (percentage of saturation), if we have a table of tension or elastic force of aqueous vapour at normal temperature.

Referring to Table II. (Tension of Aqueous Vapour) we find that with a dry bulb temperature of 53° the tension is .403 inch, while that of our dew-point temperature of 45° is .299 inch, therefore if the air was saturated the tension would be .403 inch, but as it is only .299 inch, we find the relative humidity by simple proportion, 100 representing saturation; 0 dry air, and x the relative humidity, thus: .403 : .299 : : 100 : x=74.2 per cent.

Then by subtracting the dew-point temperature tension equivalent from that of the dry bulb we can obtain the force of evaporation. Thus: .403 — .299 =.104 inch.

Various methods have been tried to produce a psychrometer which would give the dew-point, or relative humidity, direct without reference to Glaisher's Tables. Two of the best of these are Messrs. Negretti & Zambra's horticultural hygrometer and percentage hygrometer (Figs. 15 and 16).

We have already seen that the dew-point determines the minimum temperature of the night, and if this is below the freezing point it is only reasonable to assume that there will be a frost before the morning. This is one of the uses of the dew-point, for we may have a temperature as high as 60°, but if the wet bulb be 44° (or less) the dew-point will be below freezing.

If then instead of the ordinary dry and wet bulb we have this horticultural hygrometer we shall not have to look up complicated tables, but by merely turning a cylinder between the two thermometers we get the required result at a glance. As late in the evening as possible note the dry bulb reading, also that of the wet bulb, and the difference between the two. Turn the cylinder until the line and figure representing the difference between is at the *right hand side* of the opening, look down the scale on that side and the wet bulb reading will fall opposite one of three sections of the cylinder. Suppose the dry bulb reads 41° and the wet 36°, the difference is 5°, the 5 line along the right edge of the opening and 36° comes opposite the *black* section. Now as *white* section means no frost ; *shaded*

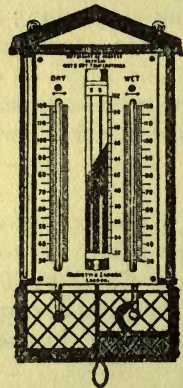


FIG. 15.
Horticultural Hygrometer.

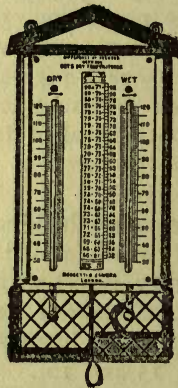


FIG. 16.
Percentage Hygrometer.

—frost doubtful ; *black*—frost highly probable ; the example we have taken shows that a frost is almost certain.

We have already described the uses of relative humidity, hence we need not enlarge upon the handiness of the percentage hygrometer. The observation of this instrument should be taken as with an ordinary psychrometer at a fixed hour (say 9 a.m. each day) note the dry bulb reading, then that of the wet bulb and difference between the two.

Turn the cylinder by means of the handle until the line and figure representing this difference is at the *right hand side* of the opening. Look down the scale on this side and the wet bulb reading will be opposite a set of figures showing the percentage of moisture in the atmosphere. For instance, dry bulb 61°, wet bulb 56°, difference 5°, the 5 line along the right edge of the opening 56° comes opposite 72%, the relative humidity required.

Observations of relative humidity, whether obtained from the psychrometer or directly from the polymeter, are useful on an occasion such as the following. In fine, sunny weather, the barometer steady or rising, and no signs of a change except perhaps a wisp of cirrus cloud flecking a blue sky, the humidity will suddenly increase perhaps 20 or 30 per cent.

Some little time later the barometer will begin to fall and bad weather will set in within from 6 to 12 hours of the first indication of the hygrometer.

Rising dew-point foretells warmer and damper weather, and falling, cooler and drier weather. A dew-point of 62.5° F. or more indicates that stormy weather may be expected within 24 hours.

It must not be forgotten whether we use the psychrometer or polymeter we must be careful to fix them in such a position that the sun's rays never fall directly upon them.

If we make use of the *polymeter* for our observations of the hygrometrical condition of the atmosphere, the following notes will be found useful.

In the thermometer which will be found above the dial we shall find various figures from which may be calculated the tension or elastic force of aqueous vapour. Water, like steam, has a certain weight and the weight of saturated air is given in grammes per cubic meter. The maximum contents can be read on the *right hand* *side* of the scale opposite degrees of temperature. The scale is marked in millimetres, but grammes may be read instead, as each millimetre of air pressure equals one gramme of water vapour per cubic metre.

A certain amount of vapour causes a certain amount of pressure; the maximum contents equal the maximum vapour pressure which is given directly opposite the temperature; for instance, temp. 43° F.=7 millimetres of water vapour pressure; at a temperature of 79.5° =25mm. or 59°=12½mm.

To find the dew-point we subtract the number of degrees indicated by the correct position of the forked hand from the air temperature shown by the thermometer. This important factor can also be deduced by calculation from the relative humidity and the maximum vapour pressure. Multiply the maximum vapour pressure by the present relative humidity; this is divided by 100 and the result is the maximum vapour pressure of the dew-point or *absolute humidity*. If the same is looked up on the right side thermometer scale at height of temperature the dew-point is found. For example, R.H. 57%, temp. 62° F.=14mm. v.p. the absolute humidity $= \frac{14 \times 57}{100} = 7{\cdot}98$ or 8 millimetres. Opposite 8 mm. on the v.p. scale dew-point 46.5° is found.

When the instrument has been securely fixed up, the whole length of the hair must be carefully moistened with rain or distilled water applied very gently by means of a camel-hair brush, pigeon feather, or a sprayer, care being taken that the hairs hang freely and do not stick to the metal parts, 15 minutes later the hair must be moistened again. The index hand must now show 95% on the lower scale, this equalling 100% for damp, foggy or wet weather; if it does not show this adjust by turning screw at top of instrument until the hand stands at 95%. On the dial will be found two sets of figures, the highest, called the "number of degrees," serves to ascertain the dew-point with a forked index hand. At a temperature of 32° F. the prong on the right has to be used; at 50° the longest one; at 68° the middle one and so on. The lower set of figures shows the relative humidity or moisture of the air in percentages, 100% equalling saturation.

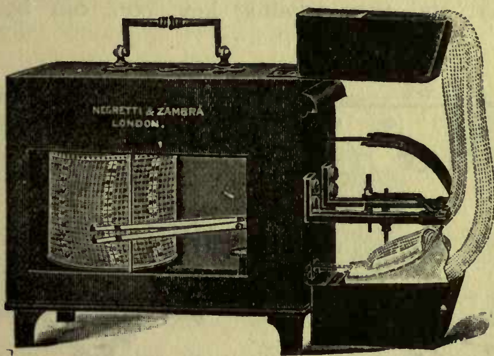


FIG. 17.
Self-recording Hygrometer actuated by wet and dry bulb.

Fig. 17 shows a recording hygrometer actuated by an enclosed wet and dry bulb; two indicators record on a chart graduated in degrees Fahrenheit, and the indicator arms are prevented from fouling one another by being set 10° apart, this difference being taken into consideration when reading the chart. As this piece of mechanism is rather complicated, a short description of how to set it in action will not be out of place.

First remove the pen from the chart by means of lever. There are two types of clock-work, both running for eight days.* In type I. (*see* Fig. 17a) remove lid from brass cylinder containing clock-work and unscrew milled head inside top of cylinder, when the latter can be taken off its spindle. The clock is wound by turning the fixed key from right to left, taking care to leave it in a position not interfering with replacing of milled head. The regulator is close by. In type II. (*see* Fig. 17b) remove lid from brass cylinder, press nut inside cylinder well down, and give it a half turn to the left, until it is free from spindle. We now remove cylinder, and then winding key, etc., can be seen.

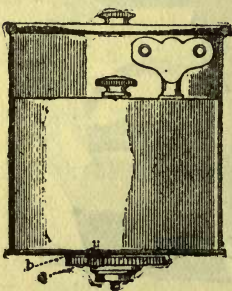


FIG. 17 (*a*).—Type I.

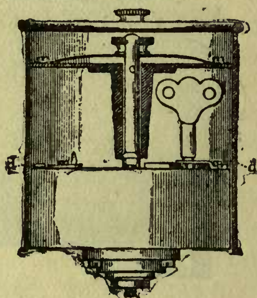


FIG. 17 (*b*).—Type II.

When replacing cylinder on spindle press down brass nut and keep on turning till it catches. When the clock is wound up it sometimes happens that it will not start by itself; a small bent lever has therefore been placed on the top plate for the purpose of starting. A quick movement of the lever from side to side is necessary, but care must be taken to finally leave it

* This type of clock-work is now supplied with the majority of self-recording instruments made by Messrs. Negretti & Zambra, so that this description suffices for all such apparatus mentioned in this work, including the Hyetograph, p. 82.

at one side or the other, or it will interfere with the escapement wheel.

The following remarks apply to *both types*. Draw out the brass band which holds the chart in position; remove old and replace with a new one on the cylinder, putting it back on its spindle. The cylinder can now be moved either way, turning until the correct day and hour on the chart are brought under the point of the pen. Then fill the pen with a special ink supplied for the purpose, and to make sure that it will flow freely, draw a needle *very gently* along the slot which runs from the bottom of the pen up to the point. Replace pen on chart and move gently up and down the paper till it marks clearly; if pen presses too heavily or too lightly on the chart pressure can be adjusted by means of milled head on lever arm. Of course, the wet bulb has to be kept moistened in exactly the same way as in an ordinary psychrometer.

In Fig. 18 we have a *Hygrograph*. This instrument, instead of being dependent on a wet and dry bulb combination, is actuated by a bundle of human hairs whose length varies according to the moisture or dryness of the surrounding air. The chart, instead of being graduated in degrees of temperature, is ruled in percentages of moisture from O (absolute dryness) to 100 (complete saturation). The principle which actuates the pen is similar to that of the polymeter, the clockwork part being the same as that already described.

Fig. 19 shows a self-recording thermometer which, of course, would not be necessary in conjunction with the wet and dry bulb thermometer, but if we use the hygrograph it would be advisable to supplement its records in this way.

It will be seen from the foregoing remarks that all hygrometrical observations, whether taken by direct or indirect methods, are finally expressed in percentages of saturation for relative humidity; in degrees Fahrenheit, Centigrade, or Absolute, for dew-point; and in inches of mercury or millibars for tension of vapour (Absolute humidity).

To sum up, then, the principle of the wet bulb is *capillarity*, and the water is drawn up to the bulb of the thermometer from the receptacle in exactly the same way as oil flows up a lamp-wick to feed the flame. The direct-reading hygrometers depend on the differing length of either a bunch of human hairs or a piece of catgut.

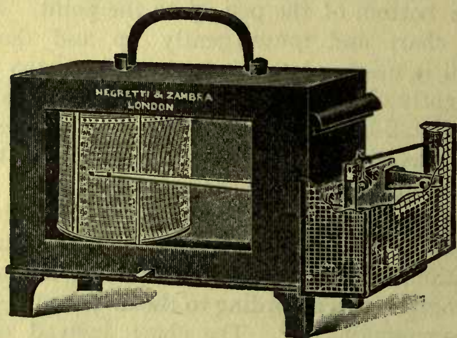


FIG. 18.
Hygrograph.

There are, of course, other direct-reading hygrometers besides those described, but they have, for the greater part, become obsolete for general use and have been relegated to the laboratory.

In connection with condensation, which is intimately related to hygrometry, the author recalls the following story, which was frequently related by a learned friend of his at various scientific meetings to illustrate a point. A certain colonel in India, more learned in military than scientific matters, was sitting one night in his tent fuming with the heat, notwithstanding the continual working of the *punkah,* when he suddenly noticed that the glass of iced brandy and water standing beside him was surrounded by a pool of water on the table. Thinking that he had put the glass down with too great force and so cracked it, he tasted the liquid on the table and then exclaimed, "By Jove! that's funny; the water's come through the tumbler, but not the brandy!" Of course, the true explanation of the phenomenon is that the temperature of the iced brandy and water, being so very much lower than that of the air in the tent, had condensed the moisture in the atmosphere

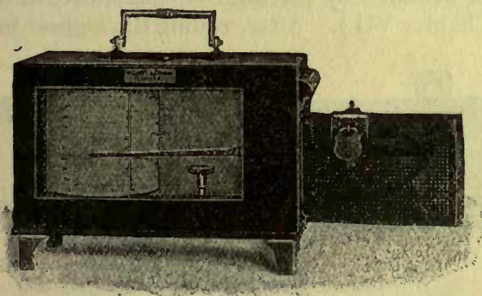


FIG. 19.
Self-recording Thermometer

to such an extent on the outside of the tumbler that it had run down and made a pool on the table which the colonel had mistaken for a portion of his beverage!

We next come to the *maximum* and *minimum* thermometers (Standard Pattern) for land and sea use. These thermometers *must* be used if our observations are to be sent to the Meteorological Office, as readings from a Six's, or Dimenuon thermometer are not accepted.

The Standard Maximum Thermometer* for land use consists of a tube of mercury fitted on an opal glass

* Messrs. Negretti & Zambra's patent.

scale (Fig. 20). Above the top of the mercury column the tube is quite free from air, and in the bend just above the bulb is inserted, and fixed with the blowpipe, a small piece of solid glass enamel which acts as a valve, mercury being able to pass when expanded by heat, but not to return on reduction of temperature. In this way the top of the mercury column shows the maximum temperature during the previous twenty-four hours.

This thermometer should be fixed horizontally in the shade with air freely surrounding it. This can be best attained by placing the instrument in a screen (*vide* Chapter VII.). After reading the highest tempera-

FIG. 20.
Standard Maximum Thermometer.

ture from the end of the mercury column furthest from the bulb, we swing the thermometer, bulb downwards, with a gentle, pendulous motion, until the column is continuous throughout. It then shows the present temperature and can be placed in position ready for the next observation. This is the only maximum thermometer that will not get out of order.

The construction and use of Rutherford's Spirit Minimum Thermometer (Fig. 21) is practically the same as the minimum thermometer for sea use presently to be described and is set in the same way.

If our observations were to be taken at sea, instead of on land, the ordinary standard type of maximum thermometer would not register correctly, owing to the motion of the ship, therefore Messrs. Negretti & Zambra have constructed an instrument on the principle of the *inverted* maximum thermometer.

This thermometer is suspended with bulb uppermost. As the temperature rises the mercury in the bulb passes a constriction just below it, and falls to the end of the tube. The stem of the thermometer is therefore filled with mercury up to the correct temperature. To anyone who has been accustomed to an ordinary thermometer, this, of course, has a distinctly "up-side-down" appearance, but one soon becomes used to it and in practice it is very reliable.

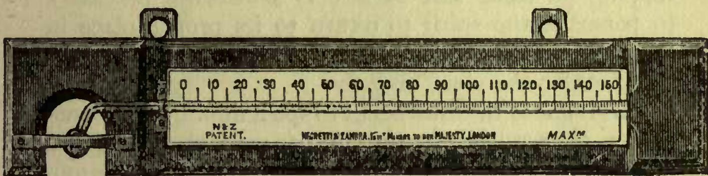


Fig. 21.
Rutherford's Spirit Minimum Thermometer.

The author knows of* a set of twelve of these thermometers, that are "set" by clockwork to "go off" every hour, so that one is able to obtain the temperature at every hour of the night or day without any need for the attendance of the observer. This thermometer is set by gently shaking it with the bulb downwards, when the thermometer is again ready for use when hung upright.

The minimum thermometer is hung horizontally, and is similar in principle to "Rutherford's Spirit Minimum." There is a steel index, or pin, floating

* At the Headquarters of the *British Rainfall Organization*, Camden Square, London N.W.1.

in the coloured spirit, which though pulled backwards towards the bulb with fall of temperature, remains at the lowest point reached when temperature rises again, thus marking the minimum temperature. This instrument is re-set by lowering the end farthest from the bulb, and allowing the index to slide gently up to the end of the column of spirit. If the pin is sent down the tube with a "bang," it is apt to force its way through the end of the column and so spoil the thermometer. Should some of the spirit collect at the top of the tube, shake carefully with the bulb of the instrument downwards until the vagrant piece becomes reconnected with the main column. A gentle tapping on some soft surface is sometimes necessary to persuade the spirit to return to its proper place in the tube, but if this is resorted to great care must be exercised or the glass may fly.

This is one of the drawbacks to spirit minimum thermometers, the tendency for the spirit to work up in detached pieces to the top of the tube and so make the thermometer read *too low*. Hence a watch must always be kept for such a contingency.

Returning to our observation on land the next most important instrument is the Terrestrial Radiation Thermometer, which is used for taking the lowest temperature "on the grass," as it is called (Fig. 22). It is really a Standard Minimum Thermometer having the degrees and figures etched on the glass tube and protected by a hermetically sealed glass sheath. The pattern shown is that adopted by the Meteorological Office. It should be laid on short grass and surrounded by a low wire fence not more than six inches high to prevent damage through being inadvertently trodden upon. It is set in the same way as the Standard Minimum Thermometer.

If we wish to take the highest temperature "in the sun " we must use a Solar Radiation Thermometer with a blackened bulb, the whole thermometer being

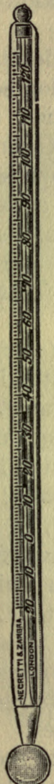


FIG. 22.
Terrestrial
Radiation
Thermometer.

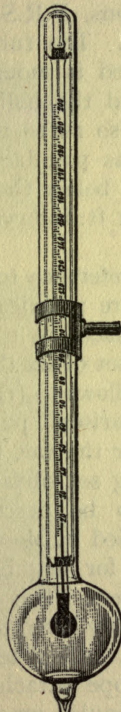


FIG. 23.
Solar
Radiation
Thermometer.

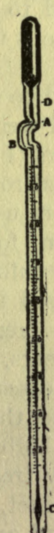


FIG. 26.
Deep
Sea
Thermometer.

enclosed in a vacuum jacket so that it indicates the actual temperature of the sun's rays, without being affected by local breezes or currents of air. This instrument must be mounted on a post 4 ft. from the ground with its bulb pointing due south. Its action is similar to the Standard Maximum. (Fig. 23).

Fig. 24 shows an Earth Thermometer devised by the late Mr. G. J. Symons, F.R.S., and adopted by the Meteorological Office. The tube on which the scale and figures are etched is mounted in a hermetically sealed glass tube, and the bulb is surrounded with a non-conductive wax so as to make the action of the instrument as slow as possible. The bulb should be arranged to be 1 ft. below the ground, and, if more than one is used, at 1 ft. intervals up to 6, 12, or even 20 ft.

It will be seen on reference to Fig. 14 (*ante*) that the dry and wet bulbs are practically two standard thermometers (Fig. 25) placed in a special frame. Indeed it is usual to have a set of six thermometers as Fig. 25, which are used as follows :—(1) As *the* standard thermometer for comparison purposes only; (2) for the dry bulb; (3) for the wet bulb; (4), (5), and (6), being used for taking sea-surface temperatures in the manner presently to be described. In this set of instruments, as supplied by Messrs. Negretti & Zambra, copper cases, frame for dry bulb, etc., are supplied with the thermometers. The method of setting up the wet bulb has already been touched upon, so that we will now treat of sea-surface temperatures.

A bucket, with rope attached, should be heaved overboard and then hauled up on deck quickly, immersing one of the standard thermometers in the water immediately. Leave it in the water from three to five minutes, then take the thermometer out of the bucket, and read at once. All sea temperatures *near the surface* are taken in this way. These observations are not only made at sea, but may be taken from a pier-head, and are indeed both useful and interesting to observers residing near the sea-shore.

Deep-sea thermometry is another matter altogether, and will be now explained, the next subject in our

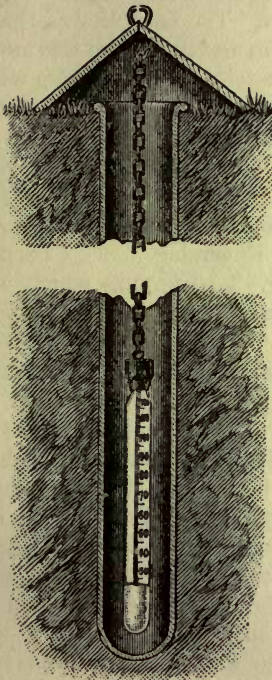


FIG. 24.
Earth
Thermometer.

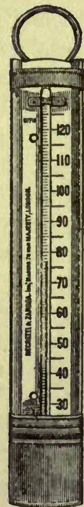


FIG 25.
Standard
Thermometer.

series on instruments being the construction and use of the "Deep Sea Thermometer."

In this connection it is interesting to note, especially in view of the recent tragic death of Sir John Murray, the instigator of the *Challenger* expedition, that it was during the soundings taken in the course of that investigation of ocean depths that such objections were found to the then style of deep-sea thermometer that Messrs. Negretti & Zambra used every effort to overcome these defects. The trouble was that with an ordinary Six's maximum and minimum thermometer, enclosed in a case to resist water-pressure, which is practically of what the old style instrument consisted, one did not obtain the temperature of the sea at the *lowest* point touched at any *particular* spot desired, but at *some* place on the way up or down where the water was colder or warmer. Therefore in 1878 they produced the original "Reversing" or "Turnover," "Deep Sea Thermometer."* (Fig. 26,) which is on a similar principle to the maximum thermometer recently mentioned, and may be briefly thus described. It will be seen from the figure that there is a minute contraction of the bore of the tube at (*A*). Below this is a small reservoir (*B*), and at the bottom of the tube is a cavity (*C*) which allows the expansion of mercury when the bulb is being carried bulb downwards. It has sometimes occurred that the weight of the mercury in the bulb through a shock has forced a small portion beyond the contraction, therefore another fine contraction (*D*) has been added in the bore of the tube. When the thermometer is in use it is placed bulb downwards, and the mercury rises and falls in the same way as in an ordinary thermometer. When the moment arrives at which it is desired to take the temperature the thermometer is allowed to swing upside down, the bulb then being uppermost. The mercurial column divides at (*A*) and falls by its own weight to the bottom of the tube, indicating on the

* The principle of this instrument is similar to that of the Standard Maximum Thermometer for use at sea.

PLATE IV.

Cumulus.

Photo by Capt. D. Wilson-Barker.
Reproduced by permission from *Clouds and Weather Signs.*

To face p. 64.]

graduated scale, which reads upwards from (*C*), the actual temperature at the moment of reversal. Should the temperature increase between this time and the moment of observation, this will make absolutely no difference to the column, because any mercury which may escape the contraction (*A*) falls into the reservoir (*B*).

It being necessary to protect the thermometer from the pressure of the water at great depths, the expedient adopted is to place it entirely in a shield of glass hermetically sealed. This case must, of course, be strong, but need not be exhausted of air. It renders the enclosed thermometer, however, more difficult to be affected by changes of temperature, and will make its action slow. To counteract this "sluggishness," some mercury is introduced into that portion of the shield surrounding the bulb, and this acts as a conductor of heat or cold from the outside. These thermometers are graduated on the stem and for ordinary purposes they range from — 2° to +25° C. in .2° C. (This is equivalent to 28.4° F. to 77° F., or 271° to 298° *absolute*.*)

It is necessary to employ some contrivance for turning over or reversing the thermometer at the required depth, and a simple and efficient method where the depths are not too great has been found to be a hollow wooden frame loaded with shot, free to move from end to end, and sufficient to render the instrument just vertically buoyant in sea water.

In using this, a cord is rove through the hole in the frame nearest the bulb, and the instrument is fastened by this cord to the sounding line. On its way down the bulb of the thermometer will be pulled downwards (Fig. 27), and on being pulled up will reverse itself

* The new *absolute* thermometer scale has been explained in Chapter IV., pp. 17, *et seq.*

(Fig. 28) owing to the resistance of the water, and consequent displacement of the centre of gravity.

The chief objection to this method is that when sounding in ocean deeps a check upon the line caused by the motion of the ship due to the heave of the sea

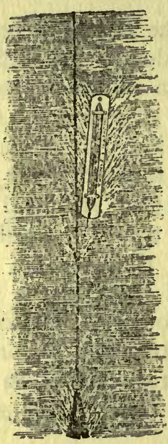


Fig. 27.
Reversing Thermometer.

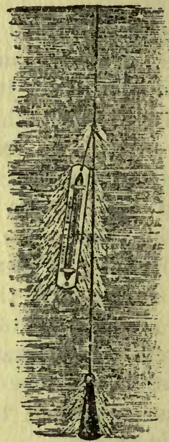


Fig. 28.
Reversing Thermometer.

may make it turn over and register prematurely. Therefore, for soundings to great depths, Messrs. Negretti & Zambra constructed, from suggestions kindly furnished by Admiral Magnaghi, of the Royal Italian Navy, the apparatus illustrated in Fig. 29. In this instrument the thermometer is fixed in a hollow metal tube which is itself placed in a specially constructed frame. The thermometer is fixed in such a way that it is held bulb downwards by a pin at the top of the case. This pin is in direct connection with a fan, which while the instrument is descending remains stationary. Immediately upon the apparatus being stopped, and the drawing up motion commenced, the fan revolves and the thermometer is released, falling over and recording the temperature at once. A pin then automatically holds it in place until drawn up and read.

Fig. 30 shows a similar instrument invented by Dr. H. R. Mill, the late director of *The British Rainfall*

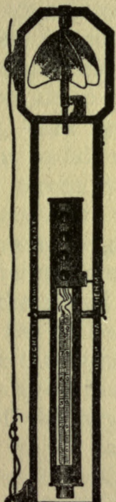


FIG. 29.
"Magnaghi"
Deep Sea
Thermometer.

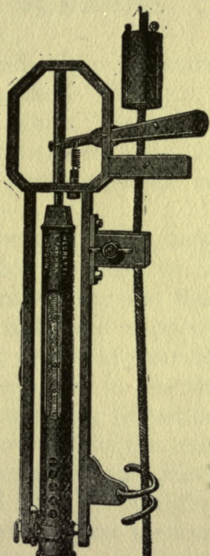


FIG. 30.
"Scottish" pattern
Deep Sea
Thermometer.

Organization, when he was working in connection with the geographical and hydrographical survey of the Scottish lakes. This apparatus is equally in favour with the "Magnaghi." The chief difference, as will be seen from the illustrations, is that the release of the thermometer, instead of being caused by a revolving fan, is effected by a weight, sometimes called a "messenger," which, travelling at any given moment down the sounding line, depresses a lever, and so reverses the instrument.

All these deep-sea thermometers stand a pressure of 450 atmospheres, or 3 tons to the square inch.

* The tables and some of the formulæ are from *Moore's Meteorology* (Rebman); other formulæ from Messrs. Negretti & Zambra's descriptive leaflets.

CHAPTER VII.

THERMOMETER SCREENS.

THE screen usually employed by meteorological observers is known as the "Stevenson" (Fig. 31) which is a contrivance of "Louvre blinds" which, whilst allowing air to pass freely around the enclosed thermometers, does not permit the smallest direct ray of sunlight to fall upon them.*

This screen is erected on four posts at a height of four feet from the ground which is taken to be the "breathing height" of an average man, and therefore the thermometers arranged inside are supposed to show the actual temperature or degree of heat or cold which has to be endured by the "man in the street."

That this is not always the case may be verified by anyone living in a large town who will take the temperature of the dry-bulb thermometer in the Stevenson Screen in his back garden, and then go straight to a thermometer exposed outside an optician's shop in a street of the town. If this is done on a hot summer's afternoon it will be found that the "street" thermometer will read several degrees higher than the "screen" one. This is due to the heat of the sun being reflected from the pavement. On a winter afternoon the contrary would probably be the case owing to the draught between the houses.

The object, however, of using the screen is to obtain uniformity, and, having put up our screen at the height

* This screen should be fixed with its door facing *due north*.

mentioned, we must arrange the thermometers in it as shown in the illustration. That is we place the dry and wet bulb thermometers at the back of the screen, and in front, one above the other, we fix the standard maximum and minimum thermometers already mentioned in chapter VI., pp. 58 and 59.

Should we not wish to go to the expense of the Stevenson Screen there are three ways in which we can find a substitute.

If we are going to send our observations to the Meteorological Office the only other screen permissible is the adaptation of the "Glaisher" (Fig. 32) fixed to a wall facing due north.* It will be seen that in this form of screen the dry-and-wet bulbs are placed to the right, the maximum and minimum thermometers being fixed to the left of the board.

This screen has the advantage of cheapness, but has the counteracting disadvantage that, whereas with the "Stevenson" it can be placed anywhere in our garden with an open position and we can lock up our thermometers quite safe from interference, in the wall screen we have to carefully select a wall or wall-boarding or situation for a stand with a north aspect, and our thermometers are always liable to interference or damage by mischievous persons.

The second way to obtain a cheaper form of thermometer exposure is to fix them on boards outside a north window, as mentioned in chapter VI. Figs. 33 and 34 show such window thermometers which should be placed at an angle of 45° to the plane of the window. The advantage of this method is that observations can be taken at any time of the day or night in any weather

* This may also be fixed to a "stand" if preferred, but of course the instruments must face *north*. This is not the *true* "Glaisher" screen, which is too complicated in its manipulation for the ordinary observer, requiring constant attention to turn it round away from the sun.

without the inconvenience of going outside. If we decide, however, to have our instruments at the window, the best thermometers for the purpose will be a good

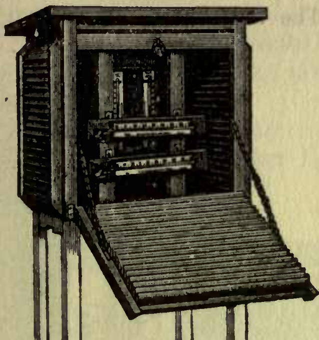


FIG. 31.

FIG. 31.—Stevenson Screen.
FIG. 32.—Wall Thermometer Screen.
FIG. 33.—Six's Thermometer.
Suitable for placing at window.

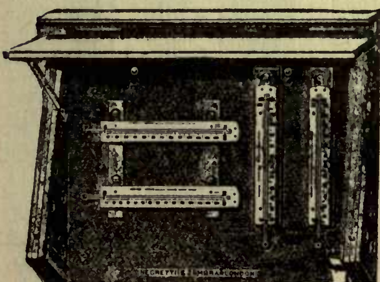


FIG. 32.

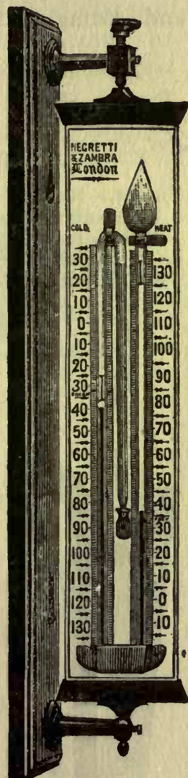


FIG. 33.

"Six's" and a Mason's Hygrometer or Polymeter, according to fancy, as mentioned at the beginning of chapter VI.

Should we be of a mechanical turn of mind the third way to avoid expense is to make the screen ourselves.

To make a "Stevenson" we require some Venetian blind-laths, 3 by 2 inch quartering, some floor-boards and slating battens. The floor-boards will form the

FIG. 34.—Plain Thermometer for Window use.

FIG. 35.—Negretti & Zambra's Horticultural Thermometer for Garden use.

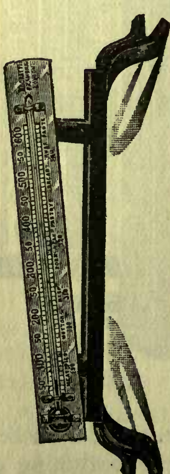


FIG. 34.

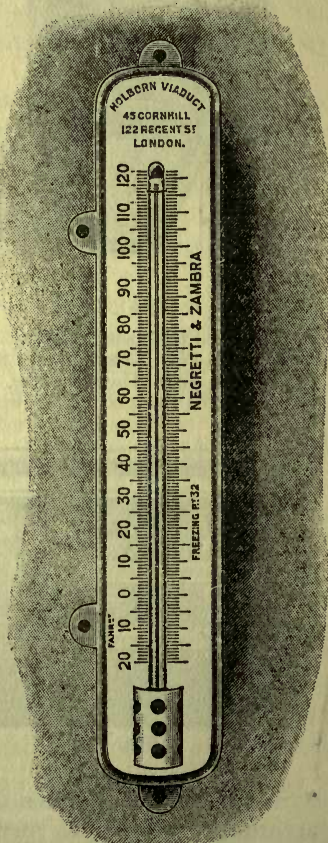


FIG. 35.

top and bottom of the screen; the battens, with the blind-laths let in to the openings between, will form the sides, whilst the legs can be manufactured from the quartering. In setting up the screen we must remember to sink the legs quite three feet into the ground, the part to be beneath the earth should be well tarred, the rest of the contrivance being given two coats of good white oil paint.

A "Gardener's Thermometer Screen," to hold the Horticultural Spirit Minimum Thermometer, shown in

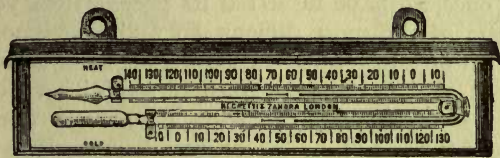


FIG. 36.
Dimenuon Thermometer.

Fig. 35, or, if we wish to know both the highest and lowest temperature, the Dimenuon Thermometer (Fig. 36) can be made from two upright battens, 3 to 4 feet high, and a cross-piece at the top about 2 feet in length, with two hooks to suspend the instrument upon, and having a piece of weather-boarding over to protect from sun and rain. If this contrivance is protected by a "fence" of wire netting from the depredations of cats or dogs, it will be found quite sufficient for garden purposes.

CHAPTER VIII.

RAINGAUGES AND HOW TO USE THEM.

ALTHOUGH the raingauge, or *pluviometer*, is one of the easiest of meteorological instruments to manage when once we have mastered its peculiarities, yet it is also one of the most difficult to find accommodation for in an ordinary back garden. This is on account of the fact that it must be fixed in a position that, no matter how strongly the wind may blow from any quarter, there will be no obstructions such as trees, bushes, walls, etc., which may prevent the gauge catching the proper amount of rain. The same defect is brought about by a too bleak exposure, so we must endeavour to attain the "happy medium." Also the gauge should be fixed on perfectly level ground at one foot above its surface ; never on a terrace or on the side of a hill.

We will suppose, however, that a suitable position has been found. We must next decide what kind of gauge we are going to employ. The most usual form, and the one recommended by the British Rainfall Organization, is the "Snowdon" pattern 5-inch copper gauge (Fig. 37). This gauge, if used with care, will practically last a lifetime, and, owing to the deep funnel, snow cannot drift, nor hail jump, out after once it is in.

The same class of gauge can be had more cheaply made in zinc or galvanised iron, but after a while they start to corrode or rust unless kept painted every year. so that the copper gauge pays better in the long run.

The Meteorological Office have adopted a raingauge with a funnel 8 inches in diameter (Fig. 38), the reason given for using the larger size is that it is easier to keep quite level, and also that it gives a larger volume of water and therefore there is less possibility of mistakes being made in the readings. Certainly in the larger size gauge there may be less difficulty in deciding the exact

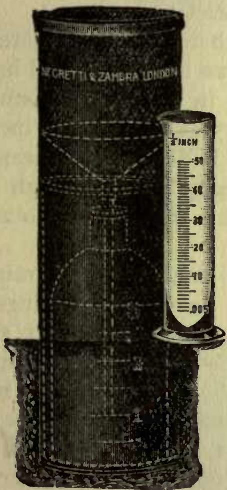


FIG. 37.
" Snowdon "
Rain Gauge,
with Measure Glass.

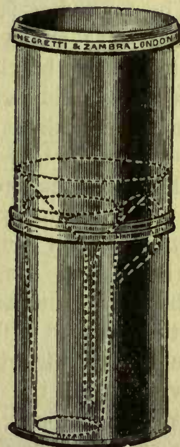


FIG. 38.
" Meteorological
Office "
Raingauge.

middle of the *meniscus**. This is also assisted by the use of the " Camden " measure glass (Fig. 39). The late Mr. G. J. Symons, F.R.S., the founder of the British Rainfall Organization, in a series of experiments with raingauges of different sizes (Fig. 40), came to the

* Apparent double surface of water as seen in measure glass.

conclusion that the 5-inch gave virtually the same results as the 8-inch.

The amateur observer then, unless sending readings of his gauge to the Meteorological Office, had best adopt the 5-inch pattern of gauge. This latter type of gauge is not only recommended by The British Rainfall Organization, of which Mr. Carle Salter is superintendent,* but also by The Royal Meteorological Society and by The Scottish Meteorological Society.

The Snowdon Raingauge with a funnel diameter of 5 inches (12.7 centimetres) has an inner can, and inside that a glass bottle graduated in half inches, and a measure-glass showing from 0.005 inch up to 0.50 inches, being half an inch of rainfall. If desired the measure-glass can be graduated in millimetres, though the author does not recommend this method of notation for the following reasons.

It has been the custom in England since rainfall statistics were commenced to take the readings in inches and hundredths, and, as we will presently show that inches and millimetres can never be strictly comparable, the taking of rainfall in the latter notation must inevitably in the course of time alter the apparent aggregate amount of rainfall at any given place. In any case we should make up our minds whether we are going to measure rainfall in inches or millimetres, and when we have decided adhere to the one method only.

To illustrate our point we will show that to convert inches to millimetres *exactly* is impossible, because a millimetre is equal to 0.03937 inch, and it would be impracticable to use this unwieldy fraction for ordinary

* The British Rainfall Organization is now affiliated with The Meteorological Office, with Mr. Salter as Superintendent. We do not wish to convey the idea of any divergence of opinion between The Meteorological Office and the other Organizations, readings from the 5in. being acceptable equally with the 8in. by all.

purposes. Therefore it is usual to assume that 1 mm. is equal to 0.04 in., and calculate accordingly. In the course of time this small error must multiply into many

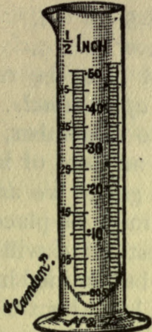


FIG. 39.
"Camden"
Measure Glass.

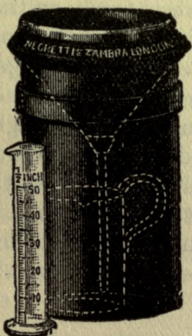


FIG. 40.
"Glaisher"
Raingauge.

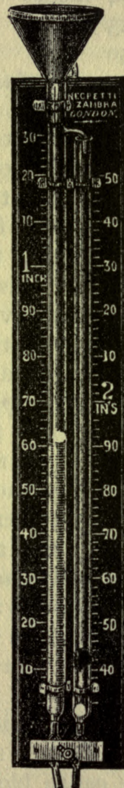


FIG. 41.
Symons' "Storm"
Raingauge.

inches of precipitation; of course, this residual error only arises when each daily reading is converted and that is why we do not recommend such conversion. However, it may help observers to memorize the following "rule-of-thumb" points. Roughly :—

0.04 inches	......	1.0 millimetres.
0.25 „	......	6.5 „
0.50 „	......	13.0 „

and so on, *ad infinitum*, but it must be remembered that these figures are only *approximate*. An inch (26 mm.) of rain, it is useful to remember, is equal to 100.993 (roughly 101) tons on an acre of land.

Having selected the kind of gauge we are going to use and the spot to fix it up, it must be placed firmly in the ground so that the strongest wind will be unable to overturn it. This object can be attained in two ways.

We can either have three iron legs about 6 inches long attached to the bottom of the gauge (in some good-class gauges there are slots provided at the sides, and wooden legs are supplied to fit ; ready for use). These legs must be sunk into the ground in such a manner that the base of the raingauge rests firmly on the ground.

The second method is to dig out a hole, and having lined it with cement-concrete, fix the gauge exactly in the hole. The author prefers the first method, as should the instrument get out of the straight it can easily be levelled up again by adjusting the legs according to the reading of a spirit-level placed across the funnel top, whereas if the alignment becomes upset with the other method the whole concrete foundation has to be readjusted. Official Meteorologists prefer the second method as there is said to be less likelihood of leakage or of the gauge blowing over.

Now having placed our raingauge in position we must proceed to learn how to take readings from it.

It will be remembered that the measure-glass holds exactly half an inch, shown as fifty hundredths (0.50) of an inch, each small mark being one hundredth of an inch (0.01 in.). When we measure the rain, should we find it up to 34 of these marks in the glass we put down 0.34 in our register.* Should the rainfall be only up to one of the marks, we put it down as " .01 in." (one hundredth of an inch), and so on†. If the rainfall is over the glass full, we must remember that we have .50 in. already in hand, and whatever is over we add to this .50. Suppose it is .32, then .50+.32=.82 in. If we have over two glasses full, then the rain is over an inch, and suppose we have two glasses full and .17 over, then it will be .50+.50+.17=1.17 in. (i.e., one inch and seventeen-hundredths). Do not forget, after making these experiments, to empty the gauge ready for the first real fall of rain.

Those who do not understand this system of decimal notation need not trouble about it. They can simply put down the numbers, remembering when adding them up that every 100 marks an inch of rainfall.

A raingauge should always be capable of holding at least 4 inches, as falls to that amount may take place in the British Isles at any time, and it is even well to have the outer case watertight, so that if the inner receptacle should leak or overflow the amount will not be lost.

Some people may think that this is an unnecessary precaution, but to those we would point out that there

* The British Rainfall Organization deprecates the use of a *cypher* before the decimal point, preferring .34 to 0.34, but this is a matter for personal preference, and the author uses each method alternately, often finding it easier to add up columns of figures with the cypher than without, the eye following the *noughts* better than the blank spaces.

† These small falls of .01in. are very important as a fall of .01in. in 24 hours constitutes what is known as a " rain day." Some observers advocate a fall of not less than .04in. (1mm.) being called a " wet day," but this system is not yet in general use.—D.W.H.

have been two cases of widespread falls of *over four inches* in 24 hours, within recent years.

The first of these was the remarkable rain storm in East Anglia of August 25–26th, 1912, when amounts up to 8 inches were recorded over a large area of Norfolk and Suffolk. The second instance was on June 28th, 1917, where in a considerable district around Bruton in Somerset from 8½ to 9½ inches of rain fell in the 24 hours, doing considerable damage.*

Therefore to avoid the disappointment of finding our records spoiled by the gauge overflowing we should be sure that the outer casing of our gauge is quite sound and will hold water up to ten inches.

One of the most difficult forms of precipitation to measure is snow, for if it is accompanied by any wind it drifts about to such an extent that as much may be blown out of the funnel as originally went in. The Snowdon gauge is intended to obviate this possibility so far as may be, but even with that instrument we are not perfectly sure that we have got the true amount of rainfall from what is actually caught in the funnel.

To measure snow we proceed in the following manner. We remove the funnel and bottle or inner can from the raingauge, and, setting them at a little distance from the fire, let the snow slowly melt into the receptacle and then measure the resulting rain-water in the usual way. Another method is to measure a certain quantity of warm (*not hot*) water in the measure-glass, say half an inch for the sake of convenience, and then pour that carefully over the snow in the funnel so that it and the warm water run together into the bottle or can. We then measure the water, subtracting

* *British Rainfall*, 1912, p. 28, "The Great Rain Storm of August 25–26, 1912."

B.R., 1917, p. 22, "The Great Rain Storm of June 28, 1917."

PLATE V.

Singular case of three fireballs descending on the lightning conductor above the Palais Royal Power Station in Paris.

From sketch by Mons. H. Rudaux. Reproduced by permission of Messrs. Chatto & Windus, from *Thunder and Lightning.*

To face p. 80.]

the amount of water we have added, and the remainder is the amount of rainfall due to the snow.

There is an objection to both these methods. In the first, if it is still snowing at the time of observation, we may lose some precipitation while we are melting the snow; on the other hand amateurs have been known when using the second method to forget to subtract the amount of water added, thus spoiling the entire observation.

If we can afford it, it is always well to have, as well as the ordinary gauge, a self recording raingauge of some sort.

The cheapest form of this instrument is the Symons' "Storm" Raingauge. This instrument was originally constructed by Mr. G. J. Symons as a convenient means for observing the rate of rainfall minute by minute, without either measuring or going out of doors. It is not a standard instrument, and is simply intended for the use of those amateurs who cannot afford an expensive instrument of the Hyetograph type. An inch of rain is represented by about 24 inches on the tube; therefore, as each tenth of an inch is about 3 inches long, the water can be seen gradually rising in the tube as the rain continues, and the quantity in any interval, however short, may be easily noted. In order to facilitate reading at a distance, floats are placed in each tube, and these being white while the board is black are clearly visible at a distance. If the rain fills the tube up to the top line, viz., 1.3 inches, it then flows into the second, and that float begins to rise until 2.5 inches of rain have fallen. The chief advantage of this "Storm" gauge, to the ordinary amateur, is that there is no complicated mechanism to get out of order. (Fig. 41).

A gauge of this sort is specially suitable for taking heavy falls in short periods, such as in thunderstorms, these falls being of great interest.

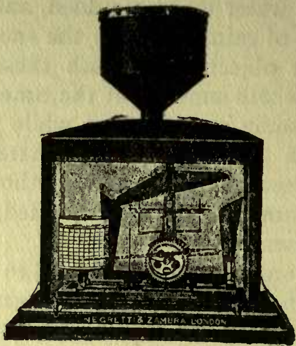


FIG. 42.
Self-recording Rain Gauge.

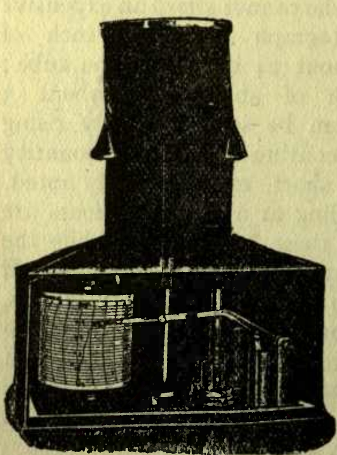


FIG. 42 (*a*).
Hyetograph.

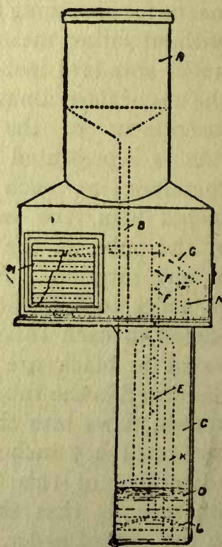


FIG. 42 (*b*).
Showing Sectional Construction of Hyetograph.

Dr. H. R. Mill, in *British Rainfall*, 1905, said: "Rainfall duration has not yet been much investigated, and it would be of real importance to obtain additional records on which to base an opinion as to geographical distribution of rainfall duration."

The only way to find out the *duration* of rainfall is with a *recording raingauge*, such as the *Hyetograph*, which has met with the complete approval of rainfall experts. (Figs. 42, 42a and 42b.)* With one of these it is possible to secure the maximum rate of rainfall during thunderstorms, and other heavy downfalls, in a manner entirely impracticable with an ordinary gauge, and we can also obtain the mean hourly fall for the month or year. With that known as the Hyetograph as long as rain continues to fall the float D rises, up to a maximum capacity of 4¼ inches, which is (as we have said) over the greatest fall likely to occur in England during 24 hours, except on very rare occasions. The clockwork is similar to that described on p. 54.

If we have a period of *more than fourteen* consecutive days, every one of which is a "rain day," that is, a day on which 0.01 in., or more, rain is measured we are said to have experienced a "rain-spell."

On the contrary, a similar duration of time without measureable rainfall is termed an "absolute drought," whilst twenty-nine days or more consecutively with less than 0.01 inch *per diem* is called a "partial drought."

Rainfall results should be sent once a year to the Superintendent of the British Rainfall Organization, of 62, Camden Square, London, N.W.1, who is always glad to supply forms on which observations may be entered.

*Fig. 42 shows Messrs. Negretti & Zambra's Tilting Bucket Gauge, and Figs. 42a and 42b, their Hyetograph.

CHAPTER IX.

SUNSHINE RECORDERS.

SUNSHINE Recorders are of two patterns—the burning glass and the photographic.

In the first the record is of actual bright sunshine sufficiently strong to burn a trace on a prepared card. In the second we get a record of sunlight upon sensitised paper.

The most generally used instrument for this purpose is that of the former pattern, Campbell Stokes Sunshine Recorder, which is employed by nearly all British meteorologists in order to insure that all returns of sunshine should be strictly comparable the one with the other.

The original instrument was invented by the late Mr. J. F. Campbell about the year 1857. The principle is that of focussing the sun's rays through a perfect sphere of glass upon a piece of cardboard previously prepared with a scale of hours and tenths. The sphere is of crown glass 4 inches in diameter, mounted in the centre of an accurately turned concentric frame.

This zodiacal frame was devised by the late Professor Sir G. G. Stokes, F.R.S., in 1879. This frame, or bowl, is divided into three separate grooves, into which we place a specially prepared piece of cardboard according to the season, the upper groove being used in winter, the lower in summer, and the middle one in spring and autumn.

These cards are printed with the hour scale and must be inserted and removed after sunset every day. The traces burnt upon them must be carefully calculated, all the portions being added together in hours and tenths until we get the whole amount of bright sunshine for the day. The picture of the instrument in Fig. 43 is a universal type of this apparatus, which can be adjusted to any latitude. In Fig. 44 the same kind of recorder is shown made for use at one particular station only; the frame being constructed for a given latitude, the ball being supported on a pillar. In latitudes between 0° and 43° it is not possible to support the sphere on a pillar, but it must be kept in position by clamps as in the universal type of instrument.

It will be found that the totalling of records is very difficult to gauge accurately by eye observation alone, and to overcome this difficulty the late Mr. R. H. Curtis, F.R.Met.Soc., devised a Template or Gauge. It consists of a glass measure on which are etched the hour and tenth lines. We place this over the card when we can at once measure off the burnt spaces without any difficulty. This is especially useful on a day when passing clouds have made the trace a series of dots and dashes, almost like a Morse Code message!

The Sunshine Recorder must, of course, be fixed in such a position that it catches the sunshine from sunrise to sunset without any obstacle intervening. This condition is in some cases very difficult to carry out. Some years since the author had experience of the many difficulties in finding an ideal exposure for a sunshine recorder.

At the time there was rather a keen competition between the South Coast resorts as to which had the greatest annual sunshine record, and among those which ran one another very close for first place were Brighton, Worthing and Hastings. It happened at that time that the occasion arose at one of these places to move the sunshine recorder, and the author was asked to advise as to a new position. After fixing the instrument in what seemed a perfect position it was found on a summer day, when the sun had shone from rising to setting, the record at a neighbouring resort always exceeded the one in the new position by about

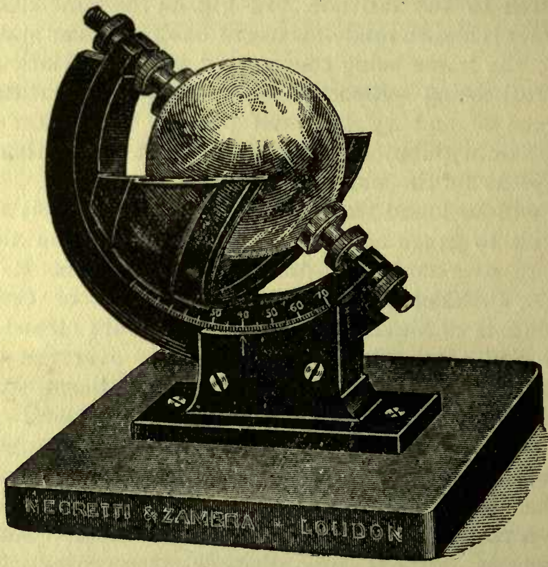


FIG. 43.
Campbell-Stokes Sunshine Recorder (universal type.)

half an hour, and it was discovered that this was caused by some large trees, quite a long distance away, coming between the recorder and the sun for that amount of time after its rising. The trees were cut down and the discrepancy eliminated.

In setting up a Sunshine Recorder it must be remembered that it should be placed quite level from east to west and the axis of the frame should be inclined to the horizon by an angle equal to the latitude of the place of observation. Then the image of the sun when due south should fall on the meridian line of the frame to which the noon hour line on the card must be adjusted.

The record of sunshine thus shows in hours of local time as is shown by a sun-dial.

FIG. 44.
Campbell-Stokes Sunshine Recorder made on pillar for use at one particular station only.

The accompanying diagrams (Figs. 45 and 46)* show the section of frame and the position of trace on the cards according to the time of year respectively.

With regard to the proper cards to be used the straight or equinoctial cards must be used from March 1 to April 12, and from September 1 to October 12. The long curved or summer cards must be used from

* Figs. 45 and 46 are reproduced from "Hints to Meteorological Observers," by permission of The Royal Meteorological Society.

April 13 to August 31, and the short curved or winter cards from October 13 to the end of February.

The recorder must be fixed facing *due astronomical south*, and it must be remembered that if we use a compass the magnetic variation in the British Isles is now 14°W., and this of course must be allowed for.

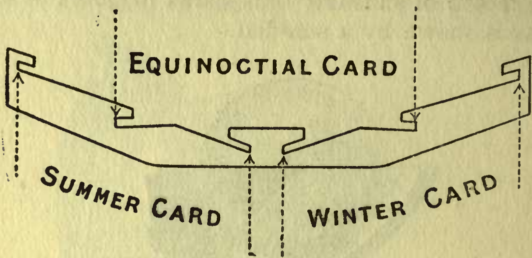


FIG. 45.
Section of Sun-recorder Frame for Cards.

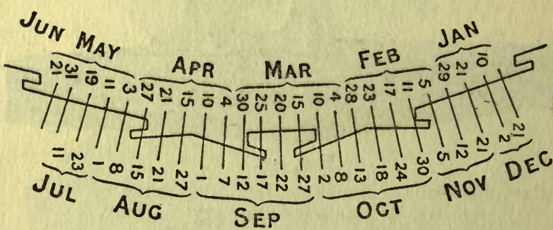


FIG. 46.
Showing position on Cards according to time of year.

It is quite possible that from an amateur's viewpoint the Jordan Photographic Recorder may be a more suitable instrument. In any case it costs about half the amount asked for the Campbell-Stokes instrument. In Fig. 47 is shown the single-cylinder pattern of Jordan Recorder, and in Fig. 48 the Improved Twin-Cylinder Recorder, which is the latest improvement of the Jordan Photographic apparatus.

This instrument was originally introduced and patented by Mr. J. B. Jordan in 1885. The record in this instrument is obtained by the rays of the sun being photographed as it were upon a specially sensitized chart. We see from this that the Jordan records the actinic light of the sun, whilst the Campbell-Stokes acts by its burning power. As we have already stated, the official meteorologist decided upon the Campbell-Stokes pattern as it is easier to secure from that pattern a distinct record, making returns closely comparable, but for the ordinary amateur the Jordan is, as we have said, the most easily managed instrument, and as it has been found that over lengthy periods the amount registered by the Jordan is practically the same as that from the Campbell Stokes,* the author can see no real objection to the use of the photographic instrument.

The trace on the sensitized chart is not permanent, and must be fixed by placing it for three or four minutes in cold water. This must be done before the record of the trace is tabulated.

In the twin-cylinder type of Jordan Recorder the sunshine trace will always be found in a straight line at right angles to the hour lines printed on the chart; the measurement is therefore much easier than in the single-cylinder instrument.

Also the apertures admitting the sun's rays are placed in such a way as to receive early and late sunshine, and there being only one opening in each chamber the diffused light admitted is only half that which enters the single cylinder form.

The morning chart being in the right hand cylinder and the afternoon one in the left allows for changing the chart twice a day; for example, the morning record may be removed and a new chart put in at any time after twelve o'clock, and the afternoon record of the

* *Vide* Symons's Meteorological Magazine, Vol. XLII. p. 148.

previous day can be changed in the morning without interfering with the morning record, which may be progressing at the time of observation. At the end of the day the two records can be joined together, making a complete whole for the day.

Messrs. Negretti & Zambra have specialised in the Jordan Recorder, having been associated with its inventor from its inception.

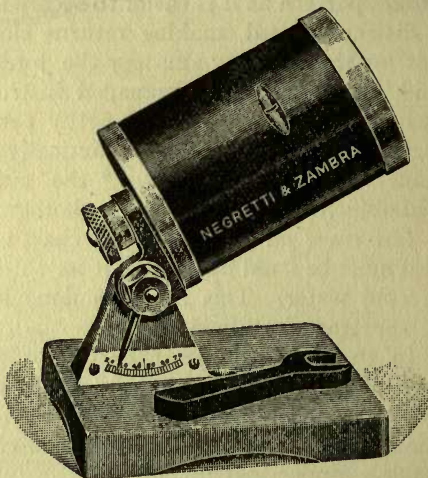


FIG. 47.
Jordan Photographic Sunshine-Recorder
(single cylinder pattern.)

In connection with rival records of sunshine at seaside and other resorts, some humorous aspects of the case came under the author's notice some little time since. In order to get the better of their neighbours one well-known watering place, which shall remain nameless, used to take the records in two parts of the town, and whichever was the best send that to be published in the London papers!

The lot of the local sunshine man, generally known as "Sunny Jim," is not a happy one. In all weathers he has to climb to almost inaccessible heights to get the records for the evening telegram for the newspapers, and, curious as it may seem, the trouble is worst in the summer time, and for this reason. The recorder has to be visited at 6 p.m. (now 7 p.m.) for the telegram just mentioned, and then if the sun continues shining after that hour the observer has to return again to

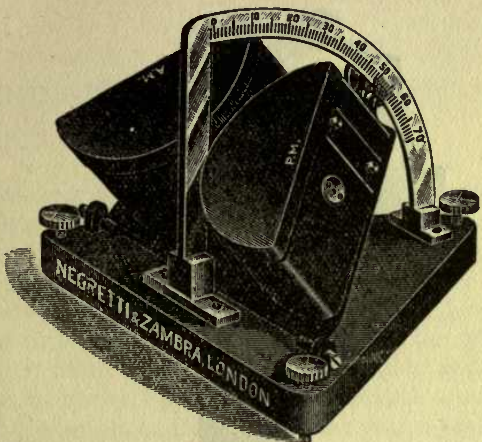


Fig. 48.
Improved Twin-cylinder Jordan Recorder.

get the rest of the record for the night post-card to the Meteorological Office, Sundays as well as week-days, and this leads us to point out to any amateur who thinks he will take up weather observations as a hobby, that he must be prepared when once the record is started, not only of sunshine recorders, but of every other instrument he may use, to remember that the three great points for the successful meteorologist are accuracy, continuity and uniformity.

Before concluding this chapter we must mention the Whipple-Casella Sunshine Recorder.* In Fig. 49 we see the "Universal" type of this instrument. It

* Illustration kindly lent by Messrs. C. F. Casella, London.

is of the "burning-glass" order, and by some observers is preferred to the Campbell-Stokes instrument. The readings of either are accepted by the Meteorological Office. The great advantage of the Whipple-Casella

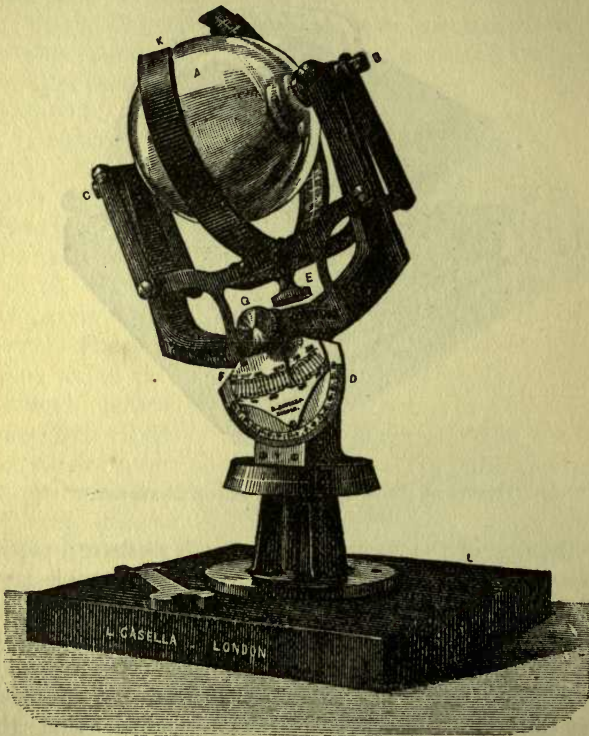


FIG. 49.
Whipple-Casella Universal Sunshine-Recorder.

over other forms of recorders is that only *one straight card* is required, instead of *three* strips of different sizes, so is easier to use.

CHAPTER X.

WIND: ITS CAUSE, DIRECTION AND FORCE.*

To take the above items in the order written necessitates grappling with the most difficult problem first, as the causes of some of the winds that blow over the surface of the globe are still rather obscure.

However, we will commence by dividing the earth's surface into the usual portions, giving the winds in their particular zones, and where possible adding the popular name by which these air currents are known. Starting, then, from the North Polar region we find the zone of south-westerly variables, in which are of course situated the British Isles. They extend roughly to latitude 35° N. Then from 35° to 30° N. we have the tropical dry belt, or the "horse latitudes," as they are commonly called. After this we come to the zone of the north-east trade wind, a belt of winds which varies with the season, and in the Atlantic and Pacific Oceans, as does also the boundary of the equatorial belt of calms and rains, known to sailors as the "doldrums." Passing the southern boundary of the "doldrums" we reach the zone of the south-east "trades," also a variable quantity, arriving at the southern "horse latitudes" at 30° S., and at 35° S., plunging into the "roaring forties," the north-westerly

* The charts in this chapter are reproduced from The Royal Meteorological Society's publications by permission of the Council.

variable region, and then coming to the Antarctic Circle. This "variable" zone is also known as the region of the "brave west winds," and is of course equivalent to the zone of S. W'ly variables in the northern hemisphere.

The south-westerly variables are sometimes called the "anti-trades," though they are so uncertain as to scarcely merit the name. However, they are the winds to which the mildness of the climate of Great Britain and Western Europe is due. We are too apt to attribute our equable climate to the Gulf Stream current, without taking into consideration in what way a stream of warm water out in the Atlantic can affect the atmosphere several hundreds of miles away. It is entirely owing to the prevalence of the south-westerly winds drawing in the relatively warm air from the Gulf Stream region that is responsible for the generally mild winters in the British Islands, and if the prevailing winds were easterly the Gulf Stream would have practically no effect on our climate. This can be demonstrated by the fact that the Gulf Stream flows at a short distance from the East Coast of North America, but its influence upon the climate of the "States" is almost negligible, as the prevailing winds are from the land. An old sea captain the author once knew gave it as his (unscientific) opinion that from his experience the wind seldom blew long from the south-eastward in the English Channel. He was right. If the prevailing wind was south-east instead of south-west the British Isles would experience a semi-continental climate; that is, their summers would be much hotter and their winters much colder than at present. But why are the prevailing winds north of 35° N. latitude south-westerly? the reader may ask. The explanation given is this. We must look upon the equatorial regions of the globe, between the tropics of Cancer and Capricorn, as the great "engine-room," or shall we say "power-house," for the heating of the world, and for the generation of all the wind currents of both hemispheres. The great heat of the sun in the zone named (the central zone in our list previously given) heats the air there so that it constantly rises, and then flows away towards the poles, descending to the earth's surface in about latitude 35° N. or S. as stated, and forming the south-westerly variables in the northern hemisphere and the "brave west winds" of the southern. The reason the winds of the northern temperate zone are more variable than those of the southern is that the greater amount of land in the former region interferes with the regular circulation of air currents under what is known as the "planetary influence," and these larger "whirls" become masked by local "eddies" due to differences in temperature between sea and land.

The north-east and south-east trade winds are caused by necessity for the constant influx of cool air to keep up the supply at the equatorial power-station, as the very "genesis" of wind is cool air rushing in to fill spaces made by the superheating of other layers of air, which as they are warmed rise, and make room for other masses of air, called "wind," to take their place.

It is curious to note that notwithstanding the violent process of air-heating that is always going on in the equatorial region, and vigorous convectional currents, that storms of the hurricane description are rare and almost unknown except on the borders of the zone. Here we find the tropical hurricanes which generally have a westward motion. They form the typhoons of the China Seas and West Indian hurricanes, happening chiefly in August and September. These storms are very rare in the South Pacific and practically unknown in the South Atlantic.

Coming now to the variable region of the North Atlantic, we find generally prevailing anti-cyclonic conditions in summer and cyclonic in winter. The general trend of storm-bearing cyclones is from west to east, and on this assumption an enthusiastic American meteorologist used to send cable messages from New York to the *Times* (of London) that a storm had started to cross the Atlantic at such and such a time, and might be expected in Great Britain on a certain day. But unfortunately for the success of it, these cyclonic depressions (as they are called) have a tendency to get "lost by the way," so that although some of them arrived "in due course," the greater portion never turned up, the scheme coming to an abrupt end. Some storms on rare occasions which have started life as full-sized West Indian hurricanes have succeeded in crossing the Atlantic and making things lively for everyone both on sea and land!

In endeavouring to explain the *cause* of the winds of the world we have to a large extent covered our second subject—*direction.*

Coming to "Buys Ballot's Law," we must explain its uses in avoiding storms at sea. It must be remembered that this is the law upon which the whole of modern meteorological science is built.

It will be remembered that this law, briefly stated, is this:—In the northern hemisphere, except close to the equator, "stand with your back to the wind, and barometer will be lower on your left hand than on your right." For the southern hemisphere the opposite holds good (except in equatorial regions) and the lower pressure would be on the right, when the wind is to your back.

This law not only applies to the ephemeral "depressions" and "anti-cyclones" of the temperate zones, but also to those larger and more permanent wind systems mentioned at the commencement of this chapter.

The practical application of this law shows us that north of the equator the wind will blow from *about* the northward when pressure is higher to west of our position than to the eastward. When the barometric reading is higher to the north than the south, winds

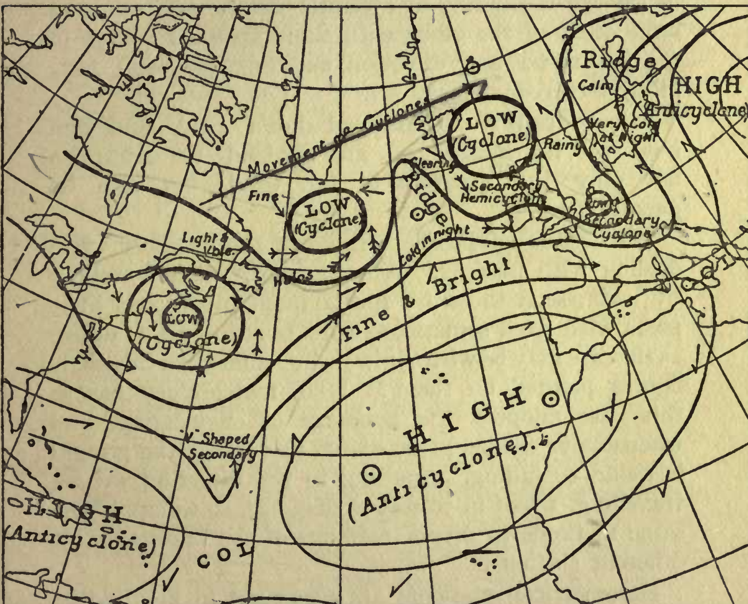


FIG. 50.

Synoptic Chart, or Weather Map, showing areas of high and low barometer pressure. (Anti-cyclones and depressions.)

from some easterly point may be anticipated; from some southerly quarter will the winds blow when the pressure is higher to the east than west, and westerly winds will accompany pressure higher to the south than the north. We have to say "about the northward," etc., as the wind seldom blows directly along the "isobars," * as the lines of equal barometric pressure are called. The wind often makes an angle of as much as 40 degrees to these lines.

It will be noticed then that the *direction* of the wind is largely determined by the positions of these isobars, hence the usefulness of synoptic charts, i.e., maps of large areas of the globe with simultaneous readings of the barometer and direction and force of wind, etc., plotted thereon. (Fig. 50).

But to return to Buys Ballot's Law, and find how by its means we are enabled to determine not only the *direction* of the wind, but also its *possible force.*

The means adopted are those of the engineer when dealing with inclines. Who has not, when travelling by train, seen those (to the layman) mysterious little posts with fixed semaphore arms pointing up or down, as the case may be with "1 in 70," or some such cabalistic figures painted on them? Well, meteorology has in this case adopted the language of engineering, and whereas our figures given above mean that the ground is rising or falling, according to the direction we are travelling, 1 foot in 70 feet of distance, so we apply the same methods to divers readings of the barometer at different stations.

Barometrical gradients are measured in hundredths of an inch to 15 nautical miles.† The strength of the wind will be proportionate to the "steepness" of the gradient. Thus, if the difference of the readings of two barometers situated 15 nautical miles from one another amounts on one day to .07 the wind would not be so strong as on the day they differed by .14, and

* Greek, ιδος, equal; βαρος, weight.

† =17 statute miles.

so on. The table of gradients in proportion to the strength of the wind is as follows :—

Gradient	0.5	3	7	15
Velocity of wind in miles per hour	7	25	50	80
Wind	Light breeze	Fresh breeze	Gale	Hurricane

The gradients are determined thus. If the barometer at station (*a*) reads 29.14 inches, and at station (*b*) 29.28 inches, (*b*) being 30 nautical miles away from (*a*), then the difference of readings is 14 hundredths of an inch in 30 nautical miles, or 7 hundredths in 15 nautical miles ; hence the gradient is 7.

The reason for the persistence of the "nor'-easters" in the English Channel mentioned in our first chapter is the fact that frequently the positions taken up by anti-cyclones are such as to cause fairly steep gradients for north-easterly winds, and although the barometer at any individual station may be high and even rising, yet the strong north-easterly winds will continue to blow until the gradients are "levelled up," so to speak.

We must now describe the approach and departure of a typical cyclonic storm in the zone of the "south-westerly variables," i.e., the north temperate zone. Although it is here specially descriptive of these cyclonic disturbances, yet it would to a certain extent apply to the appearances before any storm, but only in the northern temperate region would they behave entirely in the manner described. (Fig. 51).

On the approach of a depression the barometer may still seem inclined to rise, and indications from barometer readings alone are often misleading. Very frequently the first indications of coming trouble are the cirrus clouds described in the first chapter and a sudden rise in temperature. Especially is the latter the case in the winter. Then as the clouds thicken and temperature rises, the barometer usually suddenly shows a depression in the top of the column of mercury, or if an aneroid the indicator gives a sudden " jerk " backward. Thereafter the " glass " will fall steadily, and if the depression

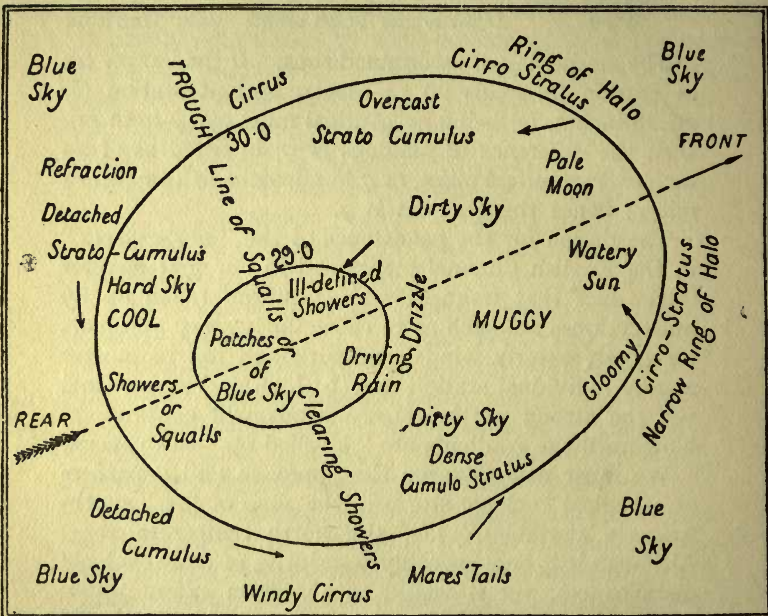


FIG. 51.

Path of a Typical depression, with accompanying weather conditions. (North temperate zone.)

be a " deep " one, will go down as much as an inch or even more. The more quickly the barometer falls the greater will be the strength of the wind. As the nimbus and fracto-nimbus clouds thicken up, so the wind comes up in sharp gusts from the southward, veering soon after to the south-westward, and blowing with the force of a whole gale, accompanied by heavy rain for a considerable time. When the centre of the cyclone is reached the wind for a while falls dead calm, the barometer remaining steady at the lowest point

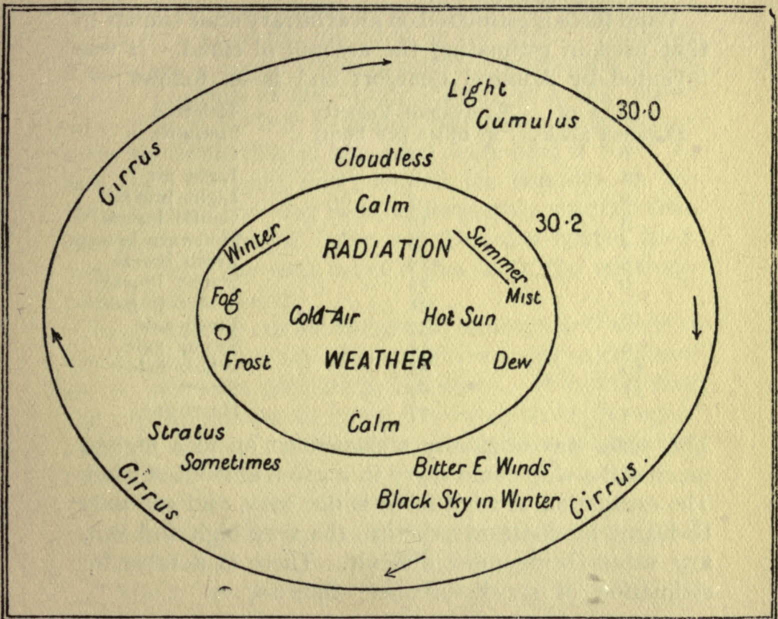


FIG. 52.

Showing the weather accompanying an Anti-cyclone. (North temperate zone.)

reached. But mark what Admiral Fitzroy said:—

First rise after low
Foretells stronger blow!

And so it is. For as the "glass" commences to rise, the wind springs up from the north-west and blows harder than ever, with heavy showers of rain and hail and a much colder atmosphere. Gradually the clouds disperse and presently the sun shines through picturesque masses of heaped white cumulus, and so ends our typical wind-storm. The weather during an anti-cyclone is shown in Fig. 52.

Wind force is estimated on an arbitrary scale similar to that used in estimating the amount of cloud. It was invented by Admiral Beaufort and is as follows :—

Force of Beaufort Scale.	Equivalent Velocity in miles per hour.	Relative Strength.
0	2	Calm
1	4	Light air
2	7	Light breeze
3	10	Gentle breeze
4	14	Moderate breeze
5	19	Fresh breeze
6	25	Strong breeze
7	31	Moderate gale
8	37	Fresh gale
9	44	Strong gale
10	53	Whole gale
11	64	Storm
12	77	Hurricane

This scale was originally reckoned on an idea of how much sail a ship could carry in a given amount of wind. The estimation of wind force is not easy, and can only be learnt by constant practice, the very high and very low values being most difficult. There is a table for estimation of sea-disturbance, thus :—

0. Dead calm
1. Very smooth
2. Smooth
3. Slight
4. Moderate
5. Rather rough
6. Rough
7. High
8. Very high
9. Tremendous

Forces "12" on the wind scale, and "9" on the sea scale seldom occur, and should not be used except under very abnormal circumstances.

As we have said, estimation of wind force is a difficult matter for the novice, but assistance can be obtained from noticing the movement of leaves, drift of smoke, flags, etc. These are also useful to determine the direction from which the wind is blowing, a thing which seems to confuse the individual uninitiated in weather matters more than it should do in these enlightened times; for it is only necessary to fix the points of the compass in our minds, and then notice the drift of smoke from a neighbouring chimney, and we at once have the direction of the wind. We must remember, however, that although a wind-vane points *to* the direction of the wind, smoke, or a flag, blows *away* from it.* It is a curious thing, but most people seem to think that if the wind feels cold it must be *east*, and if warm, *west*; but in the summer, in the British Isles, the east wind is frequently warmer than the west, because it blows off the super-heated land-areas, whilst the west wind comes from the relatively cool Atlantic Ocean.

In any case, if our ambition is to be amateur "weather clerks," we should not allow ourselves to get so confused as the captain's steward in the story. It is said that the captain wished to know the direction of the wind, and his steward, suddenly entering the chart-room, the captain asked him :—

"How's the wind, Wise?"

"Some says it's east, and some says it's west, sir."

"And which do you say it is, Wise?"

"Which you please, sir!"

* If clouds are present, apart from their actual movement, wind direction is shown by their "trend" or "lie," the clouds lying *away* from the direction of the wind.

CHAPTER XI.

ANEMOMETERS.

It is necessary to make a separate chapter for Anemometers and actual wind force as, while in the majority of cases observers will be satisfied with the estimation of wind force, some will wish to go in for instrumental observations.

Anemometry is a very difficult subject, and should not be essayed by the amateur unless he possesses three things: firstly, a suitable situation in which to place the anemometer, so that in every wind that blows nothing can in any way obstruct the play of the wind on the anemometer cups. Secondly, expense must be no object, and this for reason three, which the author gives from his own experience, that, if one cannot afford an electrical recording instrument, anemometry is best left alone.

The most usual form of wind-gauge is the Robinson Anemometer, shown in Fig. 53. This is the ordinary form, and, as we have said, it must be erected in a clear situation on a high pole, and kept well oiled. With this pattern of wind-gauge we can only get the mean force of the wind for a period of twelve or twenty-four hours, as there is no means of finding the velocity of the greatest gusts in a gale, as it would be impossible to stand on a ladder watching the indicator in a storm. Even supposing we could do so, the author had the fact brought home to him some years since that such observations were of little use. He fixed a Robinson Anemometer on the top of a sky-light on the roof of a large house in such a way that, whilst the cups were free to catch every wind that blew, the observer could stand on a ladder sheltered from the wind inside the

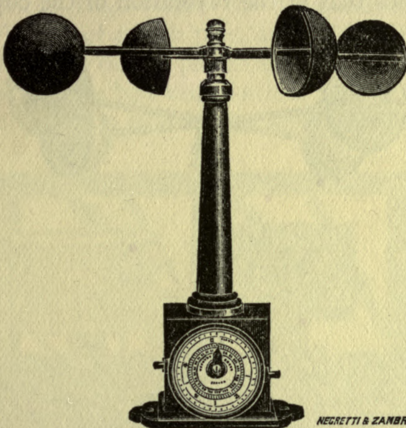


FIG. 53.
Robinson's Anemometer.

sky-light, and watch the indicator, but these observations were very unsatisfactory, as the eddies along the roof and round the sky-light caused the cup arms to bend, and during a gale the apparatus got out of order and made such a noise that it disturbed the whole household, and the instrument had to be unshipped and placed in a more suitable position.

That the author's experience was not unique is shown by a series of experiments made by the Meteorological Office many years ago, when similar conclusions were officially arrived at.

In Fig. 54, we see the Transmitter of Lowne's Patent Electrical Recording Anemometer, and in Fig. 54*a*, the Recorder.

The principle is that of the Robinson Anemometer in that the records of the instruments have been calculated on the assumption that the velocity of the wind is three times that of the revolution of the cups. This

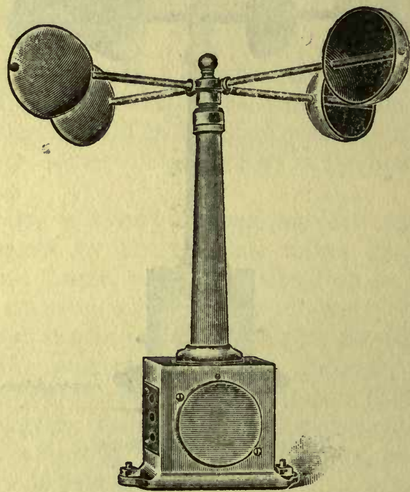


FIG. 54
Lowne's Patent Electrical Recording Anemometer.

value, however, is really too high, and varies with the distance of centre of the cups from the centre of the axle. If this be 24 inches, and diameter of cups 9 inches (as in the Kew pattern), the factor should be about 2.2. Should the distance from centre of cups to centre of axle be 18 inches, and the diameter of cups 6 inches, then the factor is 2.8. It is therefore necessary to give the following particulars of the Anemometer :—(*a*) Length of arm-axis to centre of cup; (*b*) Diameter of cups; (*c*) How the registration is effected (mechanically, electrically, or otherwise); (*d*) Name of maker; (*e*) Height of transmitter above general surface of the ground.

The great advantage of the Electrical Recording Anemometer is that whilst the transmitter may be placed at the top of a high pole, away from all obstructions, the recorder can be placed in our hall, or study, so that, no matter how bad the weather, we can follow the varying velocity of a gale, whilst safely seated indoors.

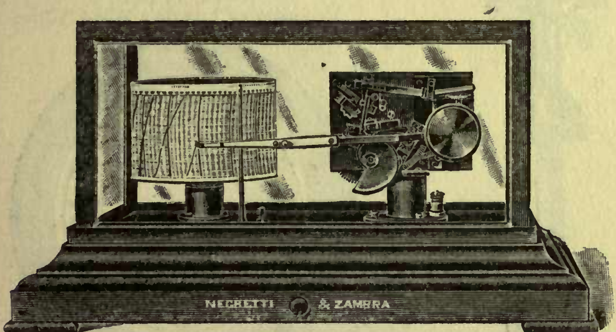


FIG 54 (*a*).
The Recorder.

In Fig. 55, we see the Transmitter, or vane, and in Fig. 55*a*. the dial, or indicator, of Lowne's Electrical Wind Vane.

As in the case of the Electrical Anemometer, the transmitter can be placed at the top of a pole, or on the roof of a house, and the dial, or recorder, in a room where we can observe the direction of the wind at our leisure in all weathers.

In a more recent invention Messrs. Negretti & Zambra have produced an instrument which is a combined Anemo - Biagraph and Wind - Direction Recorder, which gives a true record of the pressure, velocity, and direction of the wind, thus combining in one instrument the functions of the two apparatus we have just described with that of the Dines Pressure-tube Anemometer. Fig. 56. shows the head and Fig. 56*a*. the recording instrument respectively.

The head of this instrument resembles a wind-vane, except that what would otherwise be the point of the

Fig. 55.
Lowne's Electric Wind Vane.
Fig 55 (*a*).
Recorder of Lowne's Wind Vane.

Fig. 55.

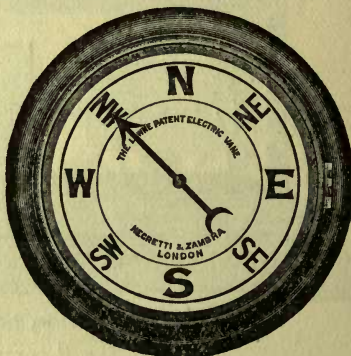


Fig. 55 (*a*).

arrow is an open tube, which is kept facing the wind. The wind blowing down the tube produces an increase of pressure within it. A piece of tube is placed vertically and has in it some small holes. The wind blowing over these holes causes a small decrease of pressure inside this tube. These variations of wind pressure are communicated by lengths of tube to any distance where the recording part of the instrument may be placed, where the pressure of the wind in pounds per square feet may be read off, as in the other instrument we observed wind-velocity in miles per hour, or, as is

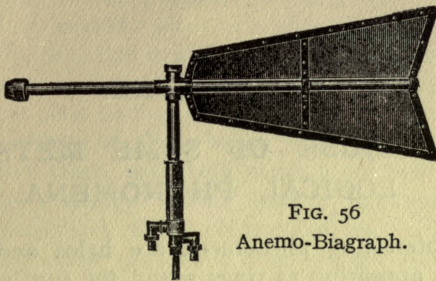


FIG. 56
Anemo-Biagraph.

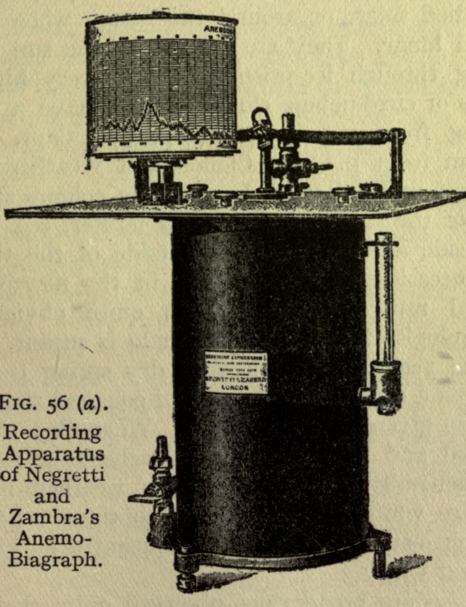


FIG. 56 (*a*).
Recording Apparatus of Negretti and Zambra's Anemo-Biagraph.

now adopted officially, metres per second. Also every gust and lull is accurately recorded on the chart and consequently the wind structures can be investigated.

CHAPTER XII.

THE CAUSE OF SOME METEOROLOGICAL PHENOMENA.

SOME interesting phenomena are halos and coronæ, whether appearing as rings round the sun, when they are called solar, or around the moon, when they are termed lunar. They are caused by the sun or moon shining through ice-prisms in some very high cirro-stratus or cirro-nebula clouds. Halos have a diameter varying from 22° to 42° (Fig. 57. Capt. Barker's diagram from p. 31, "Clouds and Weather Signs"). It is not unusual for halos to have colours similar to those of the rainbow, but much fainter, red being on the inside and blue on the outside of the ring. On these occasions we see reports in the newspapers of unusual rainbows, when it is quite obvious to a meteorologist that a coloured halo is meant.

Some years since in a very dry spring the author observed a complicated system of coloured rings similar to those given in the diagram. When these halos are coloured and accompanied by parhelia or mock-suns they generally precede very dry weather, but when they are white, appearing in a continuous pallium of grey cirro-stratus, they are frequently harbingers of rain and wind.

Coronæ are broad rings observed quite close to the sun or moon, and have orange colour on the outer and blue on the inner side of the rings; they are generally caused by the loose edges of drifting cumulus clouds.

In considering the objects which have just been discussed as weather prophets, we must take into account the kind of weather which has obtained for some time previously, and this brings us to an important subject in meteorology: *weather tendencies*. That is to say, if we have been having a long period of rainy weather, the appearance of these halos, and the clouds which accompany them, may well mean a further downfall. If, on the contrary, a long spell of dry weather has been experienced, these phenomena may appear and pass away again without a drop of rain reaching the ground.

The reason for this is that in rainy weather the atmosphere is more or less saturated in its lower as well as in its upper strata, so that the raindrops, which have their origin in the upper clouds, increase as they fall through the moisture-laden air, whilst in dry weather it frequently happens that the cloud is floating high above warm, unsaturated air, and consequently the raindrops get dried up and vanish before they can reach the ground.

Off the estuary of the Thames the author has frequently noted this phenomenon in dry, summer weather. One can see the rain clouds approaching the Isle of Thanet with every evidence of a considerable downpour, but gradually the "cows'-tails" seem to draw up into the clouds, the clouds themselves slowly breaking up and dispersing without causing any precipitation whatever.*

It is also a remarkable fact that a shower of rain may fall from a cloudless sky, and this is due to the raindrops forming in air the temperature of which has fallen below the dew-point, but which is practically

* In dry seasons the author has noticed similar phenomena n London and in the Western Counties.

dust-free, there being very few solid motes to act as nuclei. It must be understood that clouds are caused by water vapour adhering to dust particles, and if there were no dust in the atmosphere there would be no clouds and no rain as we know it, but a continual state of saturation similar to a vapour bath.

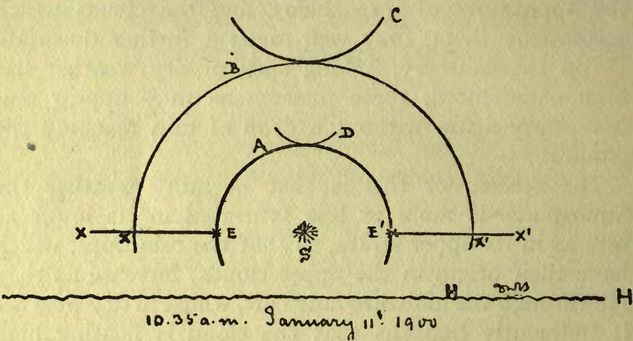


FIG. 57. Ashenden, Sussex.

EXPLANATION.

S.—Sun shining through Cirrus haze.
H.—Horizon.
A.—Inner and bright halo, showing colours, red inside.
B.—Faint large halo, white.
C.—Brilliant portion of halo, showing colours, distinctly, red outside.
D.—Small halo, showing faint colours.
E, E^1.—Mock Suns.
E X, E^1 X^1.—Rays from mock suns, white, brighter from East one than from W. one.
It lasted like this for about half-an-hour.

When the water vapour in the clouds condenses at a temperature below the freezing-point we get snow instead of rain, the water forming into small clear spicules of ice which always cross at an angle of 60°, so that, as will be seen on reference to Fig. 58, snow-crystals invariably have six rays exactly arranged around a centre. It will be noticed that the snowflakes have a great variety of form.

The apparent whiteness of snow is caused by the reflection and refraction of light over and over again indefinitely among the small crystals. Their real colour would be a greenish hue like a piece of ice. A good deal of air is contained in these snowflakes, and it is this which makes the snow a non-conductor of heat and is therefore nature's blanket to keep the earth warm and protect vegetation from frost. The

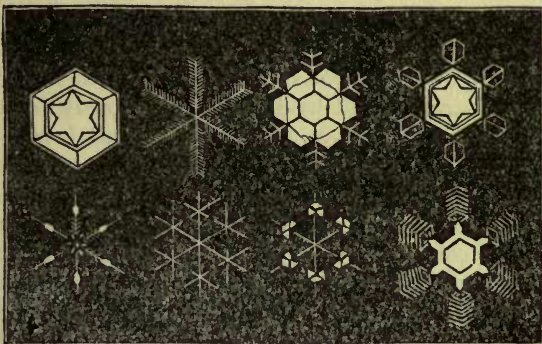


FIG. 58.
Snow Crystals.

author has tested this warming attribute of snow practically by laying a minimum thermometer on the surface of the snow and burying another about six inches beneath it. Whilst the first named thermometer has frequently fallen as low as 15° F., the one buried beneath the snow has never registered lower than 33° F., being one degree above the freezing point. This experiment speaks for itself and requires no further comment.

Sometimes in the winter months instead of snow we experience showers of tiny snowballs of the size of small peas. This is soft hail, or *graupel*, and it would seem to be formed by large and small ice-particles in a cold cloud overtaking and adhering to one another. Real hail, such as we mentioned in Chapter II., is quite a different matter, and generally falls in warm summer weather during thundershowers, or thunderstorms, being to a certain extent of an electrical origin. They sometimes weigh several ounces and have been known to attain a weight of three pounds. Such hail is naturally very destructive, breaking windows and other glass, destroying crops, and even killing birds, animals and human beings.

According to Ferrel, hailstones of this sort are due to ascending or convection currents. When these currents are very strong a soft hailstone, as previously described, starts its journey from a cloud at a great height from the ground. Before having traversed very much of the distance towards the earth's surface it is caught in a powerful ascending current of air back again into a high, cold region. The hailstone then begins to descend again, and this process may be carried on several times, on each occasion the original nucleus gaining a fresh coat of snow and ice alternately, until the initial small hailstone becomes sufficiently heavy to fall to the ground.

It will be seen that this theory shows us why these true hailstones always occur in summer thunderstorms, for it is only under those conditions that the necessary convection currents are found.

Hail being so intimately connected with thunderstorms, it will be apposite to take lightning as our next subject for discussion.

Should the reader ever have seen a lecturer demonstrating experiments of electrical potential on the platform, then, if he recalls the sudden flash, crash, and splutter, when positive and negative poles of the electrical apparatus were brought in contact, he will be able to figure to himself that what he saw take place was a miniature exposition of what happens in nature hundreds of times in the course of what we call a "thunderstorm."

For what happens on a hot summer's afternoon is simply this:—The ground becomes superheated by continued insolation (i.e., the heat of the sun's rays) until strong convection currents are started; as the hot air ascends it mixes with the colder atmosphere of the upper regions and heavy squall cumulus clouds or "thunder-heads" are formed. Presently the electric potential of one cloud becomes higher than that of another, or of the earth beneath, whereupon a violent discharge takes place. If between the two clouds it will be harmless, but, on the contrary, if it is between a cloud and the earth, destruction of life and property may ensue.

On the flash of lightning taking place nearly all the electrical energy is instantaneously converted into heat, hence the air is rendered incandescent along the whole path of the lightning flash.

The intensely heated air expands quickly and contracts again as suddenly, creating a succession of air waves, which we hear in the shape of a crash as of broken glass followed by a long rumble when the thunder is near, and as a growling noise when far away. It must be remembered that whilst lightning at night can be seen for over one hundred miles, thunder can only be heard for about twenty miles.

There is a curious misconception about the uses of lightning conductors, quite a number of people supposing that the conductor is put up on a building to catch flashes of lightning! As a matter of fact its real use is to prevent an electrical discharge ever taking place over a building so protected, by keeping up a continual equalisation of electrical potential between the earth and the clouds in the vicinity of the building fitted with conductors.* If, however, the foot of a lightning conductor is not kept in wet earth, and examined from time to time to see that it has not become defective, it is worse than useless. Also to be of real use lightning rods should be made of copper throughout, as iron is far too apt to rust or corrode, and every chimney or finial on a large building should be protected, one conductor being insufficient for any but a small house, or a church, where the tower or steeple stands so much higher than the rest of the edifice as to render it practically immune. An interesting occupation during thunderstorms is for the observer to seat himself or herself well back in a room so that the lightning may not be prejudicial to the eyesight, also keeping the window *shut*, as lightning has been known to enter an open window and strike a person in the room. If, however, we take up a position well away from the fireplace, or doorway, and keep the door open, we can feel fairly safe, and placing before us a watch having a second's hand, and a note-book which should have been previously ruled thus :—

L.	T.	TI.	RC.	RO.	W.	RA.
h.m.s.	h.m.s.	secs.	h.m.	h.m.		in.
..	6.51 .op.m.	..	..	..	S.E. Fresh	..
6.55.31	6.55.39	8	6.56	7.5	S.E. Light	0.26
6.56.40	6.56.45	5				
6.58. 2	6.58. 3	1	7.13	7.30	S. Light	0.59
7. 0. 6	7. 0. 6	S				
7. 1. 2.	7. 1. 10	8	..	..	S.W. Strong	..

Total R. 0.85

We then enter our observations.

* This statement does not imply that lightning conductors have never been struck.

In this " L." means lightning, " T." thunder, " TI." time interval between T. and L., i.e., the number of seconds between the lightning being seen and the thunder heard. If they are simultaneous, write " S." in column for " TI." " RC." is for the time the rain commenced, and " RO." for the time the rain was over. " W." for the wind. A " remarks " column may be added if desired. In the above we have imagined a summer thunderstorm commencing at 6.51.0 p.m. Being daylight the distant thunder is heard before the lightning is seen. The rain during a thunderstorm is generally intermittent, and therefore it is necessary to note each interval when it commences and leaves off, as shown in the above example.

If the observer possesses a storm raingauge, as described in Chapter VIII., he can make use of the last column, as shown, to get the amounts of each interval of rainfall, otherwise that part had best be omitted, as it is never safe to go out of doors to our ordinary raingauge during a thunderstorm.

As soon as the lightning is seen the time of the flash must be noted, and then the number of seconds counted between the flash and the resultant peal of thunder. By means of this the observer is enabled to compute the distance at which the flash has occurred by a simple sum in arithmetic. For example :—We have, in the table given above, supposed that our observer notes a flash of lightning at 6h. 55m. 31s., and hears the thunder at 6h. 55m. 39s., therefore it is plain that the sound has taken *eight seconds* to reach the observer from the point of discharge, and knowing, as we do, that sound travels at about two-tenths of a mile per second, that the lightning flash therefore took place just over one and a half miles away. This is termed the " Time Interval " (T.I. in the table), and apart from other uses has the virtue of being a good nerve sedative to those folks who always imagine that a thunderstorm is much nearer to them than it really is!

The moment of final cessation of rainfall should also be noted, and such phenomena as hail, sudden wind-squalls, etc., should not be overlooked.

Another point which may be noted is the *colour* of the lightning, though this is a somewhat unsatisfactory observation to make, owing to the large difference of opinion which exists between different observers.

Further, we must notice the form which the various lightning flashes appear to take, for although we now know, chiefly through the application of photography to the study of such phenomena, that the "*zig-zag*" flash is not really so, but is more in the nature of a sinuous stream of electric current, yet still to the eye it *appears* to move in a *zig-zag* fashion owing to the *retina* being unable to observe all the movements sufficiently quickly to perceive the true form of the flash. Therefore lightning is for purposes of optical observation still divided into three classes, viz: *forked*, or *zig-zag*; *sheet* or *diffused*; and *globular* or *ball* lightning, the last named being very rare (Plate V.).

Forked lightning is that seen close at hand when the thunder produced by it is audible. Sheet (sometimes called "summer" lightning) is the reflection of forked lightning from a distant storm. This can only be seen during the hours of darkness.

Ball lightning is, as said above, of comparatively rare occurrence, and on those few occasions when it has been observed has been mistaken for a "thunderbolt" by the uninitiated. It must be understood here once and for all that "thunderbolts" *do not exist*, but if a flash of lightning strikes a sandy soil, it fuses or vitrifies the silicious particles into a *fulminary tube* or *fulgurite* (Lat. *fulgur, flashing lightning*). The German term is very expressive—Blitzrohren, "*light-*

ning tubes."* In March, 1888, in a paper read before the Royal Meteorological Society, the late Mr. G. J. Symons, F.R.S., effectually disposed of the thunderbolt myth.

Objection may be made by some readers that "thunderbolts" have been found in soils that were not sandy and have even been discovered embedded in trunks of trees. These bodies found in clay soils or in trees are not of electrical origin at all, and have no connection with the lightning flash or thunderstorm. They are in fact meteoric stones which have come from the realms of outer space, and meeting our atmosphere at a speed of many miles per second,† become heated during their passage through it, and sometimes arrive white hot at the ground. If any aerolite should happen to fall during the hours of darkness, we see what is termed a *meteor* or *shooting star* of large proportions careering through the air, and whether day-time or night-time, sometimes a loud report followed by a rumbling sound as of thunder is heard.

Before leaving this subject we must just mention that the late Mr. G. J. Symons, F.R.S., invented an instrument called a *Brontometer*, which is now in the possession of the Royal Meteorological Society, for recording simultaneously all the characteristics of a thunderstorm, but as only one of these apparatus was constructed it may be presumed that its use was too complicated for the ordinary observer.

As a storm or shower passes away a very frequent phenomenon is the rainbow. These are best seen when the sun is at a rather low altitude, indeed, they cannot be formed if the sun has an altitude of over 42°.

* "Meteorology, Practical and Applied," by Sir John W. Moore, M.D. (Rebman).

† The Leonid Meteors travel at a speed of 44 miles per second.

As we have previously pointed out rainbows must not be confused with halos, the former being always seen opposite the sun, whilst the latter surround it in a more or less perfect circle. To obtain a perfect bow, not only must the sun be near the horizon but rain must be falling heavily in the opposite direction to the position of the solar orb, but although a dark cloud tends to show up the colours, it is by no means an essential background to a rainbow, as the author has frequently noted very fine specimens against a bright blue sky. The cause of the rainbow is stated by saying that the rays of the sun are refracted by the rain drops, thus showing the colours of the Solar Spectrum, each colour having a different amount of refrangibility.*

On occasions when all the conditions are most favourable the primary bow is followed by a secondary arc *outside* the original one ; in this case the colours of the Solar Spectrum will be seen *reversed*. On very rare occasions also a third bow has been observed, but this is a very unusual occurrence, indeed. The rainbow is as much a part of the *nimbus*, or rather of the rain falling from it, as the halo is of the *cirro-stratus*, and hence the wide difference between their origin, although they are somewhat similar in appearance.

Enthusiasm is always a good thing, and especially in weather observing, which has frequently to be performed under adverse circumstances, but it is at the same time advisable not to overdo it, as will be shown by the following little story.

In the days of the old-fashioned sailing-ship (or wind-jammer, as it was called) weather changes were of even more importance than now-a-days, and a certain captain, before turning in, had carefully instructed the

* The primary bow subtends an angle of 41° the secondary an angle of 52° to the observer's eye.

officer of the watch, a somewhat " raw " third mate, in his duties.

" Call me if there is any change," he told him.

" Aye, aye, sir," rejoined the " third," cheerfully, and the captain retired to his bunk.

In the middle of the night he was awakened by a terrific knocking at his cabin door.

" What's the matter ? " he asked, irritably.

" Please, sir," piped his subordinate fearfully, " you told me to call you if there was any change, and there's a halo round the moon ! "

CHAPTER XIII.

CHARTS : SYNOPTIC AND OTHERWISE.

In Chapter V. we gave the simplest form of Weather Register. Another method is to draw the barometer and thermometer observations on prepared forms (ordinary squared paper will do), placing the days of the month along the top of the chart and the barometer scale in inches and tenths on one side, and the thermometer scale in degrees, Fahrenheit or Centigrade, on the other. Only the barometer is shown in the diagram, but the thermometer scale can be added on the right hand side (Fig. 59).* Then we plot the barometer and thermometer movements on the chart in the following manner :—At the point where the barometer stands at 9 a.m. place a dot ; then wherever it may be at 9 p.m. put another dot ; join these by a line, and you have graphically shown the movement of the barometer during the twelve hours. And so on day after day. The author's own method is to make the dot for 9 a.m. come on the dividing line for the days, and that for 9 p.m. midway between.

As regards thermometer readings, we may place dots for maximum and minimum temperatures each day and join them, thus making a "zig-zag" line, or take the mean of maximum and minimum, or the 9 a.m. and 9 p.m. readings, or the mean of these, as one pleases,

* Figs. 58 and 59 are from *Cassell's Book of Scientific Pastimes.*

for such methods of showing these observations graphically cannot have that precision that the actual

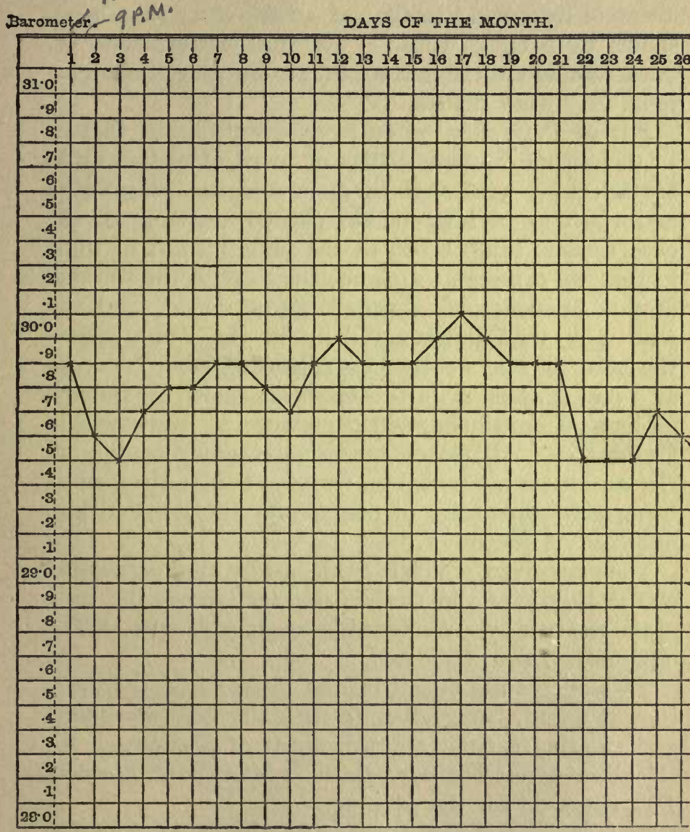


FIG. 59.

Barometer Chart, with Barometer Records.

writing of figures in columns must show. Wind direction and force can also be shown by arrows flying with the wind; pointing from the top of the chart meaning north, and from the bottom, south, etc.; the number of barbs on the arrow shaft from one to six showing forces of light wind to that of a gale, etc.; *calm* being shown by a circle, thus :— ⊙. It is better, however, in the opinion of the author, to put down wind observations in "plain figures."

But we must now get on to Synoptic Charts, that is, as their name implies, charts or maps of certain areas of the globe with various meteorological phenomena and readings of instruments plotted thereon, all the observations being taken at the same instant of time, so that we can see at a glance the state of the weather at that moment over a very large portion of land and sea. The map published daily in the *Times* shows the state of the weather over North-Western Europe at 6 p.m., G.M.T. On this chart are shown the isobars, or lines of equal barometric pressure as mentioned in Chapter X. All places having the same reading of the barometer are joined up with these lines, the reading being given in inches of mercury at the one end and millibars at the other.

The map given, which is published by kind permission of the Editor of the *Daily Telegraph*, shows the state of the weather over Western Europe at 7.30 p.m., S.T.,* on June 17, 1919 (Fig. 60).

These maps are issued by the Meteorological Office; that at 8 a.m. being given in the daily weather report, and showing a similar arrangement of phenomena for the morning as the *Times*, *Daily Telegraph* and *Morning Post* maps do for the evening.

The shade temperature is given in figures and the direction and force of the wind is shown by arrows, a calm being designated by a circle with a dot in the centre, thus ⊙.

* Summer time.

To prepare these maps barometer and thermometer readings, the state of weather, sky and direction of wind, are taken at a large number of stations over Western Europe at 7 a.m., G.M.T., and are then sent

FIG. 60.
Daily Telegraph Weather Map, June 17th, 1919.

to the Meteorological Office, where they are plotted on charts, which are finally reproduced as maps and issued in the "Daily Weather Report" to subscribers. At 6 p.m., G.M.T., the same process is gone through for the newspaper maps.

These up-to-date weather maps are the final results of an idea put forward by Admiral Fitzroy in the year 1854, when he pointed out that the weather had a general habit in the British Isles of travelling from west to east, and that the kind of weather that is in one place on one day will be in another place the next, and so on. Indeed the modern Science of Meteorology is built on the foundation of the opinion put forward by Fitzroy over sixty years ago.

Even the word "forecast" is of his invention, and it has been adopted, as nothing better has ever been found to surplant it.

Fitzroy also first instituted the system of telegraphing information from various weather stations to a central office, to be collated and used for weather forecasting, which is the method now in use.

Now-a-days, in addition to the ordinary weather report and forecast, there is a special forecast for airmen showing whether the conditions over the Atlantic and in other areas will be suitable for flying, and giving the probable strength of the wind in miles per hour and metres per second, not only at the earth's surface, but also at various altitudes.

As far back as 1861 forecasts of weather were made; and even earlier than that there was a system of storm warnings on the coasts for sailors and fishermen.

These warnings were first given by means of drums, and later on by cones, hoisted on the signal flag-staff at coastguard stations, or entrances to harbours.

The cones are still used to this day. When a gale is anticipated from the south-east, south, south-west, or west, the South Cone (with point *downwards*) is hoisted on receipt of a telegram by the Coastguard Officer, or Harbour Master, instructing him to do so. Should the storm be expected from the north-west, north, north-east, or east, then the North Cone (with point *upward*) is run up on the signal flagstaff.

Very few people seem to know that the general public can have the services of the Meteorological Office for private purposes. On inquiry, and on paying a small fee, farmers can have a daily telegram sent to them during the harvest season with a forecast of the weather for the ensuing twenty-four hours. These telegrams may be had by any one who cares to pay for them, and in some places it has become the custom for clergymen and others to subscribe for these forecasts and exhibit them for the benefit of the rural inhabitants.

The Meteorological Office will also assist the public with regard to the state of the weather on past occasions, information of this sort having frequently been made use of in the Law Courts. It so happens that sometimes disputes arise as to whether it has rained, snowed, etc., at some special time or particular occasion.

It is interesting to note that 95% of the forecasts made by the British Meteorological Office are correct in every detail, the remaining 5% being mostly correct in several particulars, if not in all.

The modern weather map should do much in increasing the interest of the general public in Meteorology. When the author sees the elaborate maps given in the weather reports of some of the daily papers he wonders how many of the newspaper readers really gain any advantage from the amount of space taken up.

To make an intelligent use of such weather maps the reader should turn to Chapter X., and carefully study the Synoptic Charts printed therein. In this way he or she will become accustomed to the various configurations and movements of the divergent depressions and anticyclones and will soon master the types of weather which accompany them.

An interesting study of these charts was suggested by Prof. J. F. Nowack, writing from Denmark Hill, London, to *Symons's Meteorological Magazine* for June, 1908, p. 95, in which he pointed out that for eighteen years he had used the official charts in a special manner which he proceeded to describe in the following way. "The isobars given on the last chart are drawn on tracing paper. This tracing is then superposed upon the isobaric chart of the day before. The outline of the land having been previously drawn on the tracing paper, it is easy to secure the correct super-position. The places where the isobars of the two charts cross each other are thus readily marked upon the tracing paper, the differences, positive or negative, at these points, being also carefully noted. By drawing lines through those points which have the same difference, a new series of isobars is obtained, as well as new centres of high and low pressure. In fact, a new chart is the result, to which I give the name 'Differential Chart,' and by comparing it with the last official charts it is not very difficult to trace the coming changes in position of the centres of high or low pressure.

It has been long known from experiments with balloons that such centres of high and low barometric pressure are to be regarded as self-subsisting or separate 'bodies,' which may lie one over the other, as well as side by side. This, perhaps, accounts for the striking difference that is sometimes found to exist in respect to the positions of barometric maxima and minima, as indicated by the official and 'differential' charts, respectively. In fact, the one may show a high centre where the other has a low, and so on. But the important point to notice is, that in such cases, great atmospheric disturbances usually follow in the course of the next few days. It is merely a question of increased meteorological skill to find out the actual districts likely to be affected, and where, therefore storm warnings should be issued.

It must be pointed out, however, that the method does not lay claim to mathematical accuracy. It cannot, under the circumstances, give more than approximate results, but, nevertheless, these may be capable of being put to great practical use, especially by all who are in any way connected with seafaring. The storms of the past week,* for example, were well indicated by this method. The matter is, therefore, I think, one that is worthy deeper inquiry, so that practical application may be made of it . . . For my own studies I find it very convenient to colour high centres blue and low red, and to arrange (say) 40 charts of each kind together on a board. The latest chart is every day inserted in place of the oldest, so that the series is always up to date."

†The Weather Bureau of the United States reached its present development in three stages, the first being entered in 1870, the second in 1872, and the third on 1st October, 1890, when the Department, which had previously been a part of the military arrangements of the country, was transferred to the Weather Bureau of the Department of Agriculture. From that time the Chief of the Weather Bureau has had charge of forecasting the weather, issue of storm warnings, the display of weather signals for the benefit of navigation, etc.; the maintenance and operation of sea-coast telegraph lines, and the collection and transmission of marine intelligence.

The original idea of the organisation seems to have been to supply a signal service for the benefit of naviga-

* May, 1908.

†[By the courtesy of the Chief of the U.S. Weather Bureau I am able to give the following interesting details of the work of the Department.—D.W.H.]

tion on the sea coast, showing that the chief object was to help seamen in their constant struggle with the meteorological elements.

The Signal Service of the War Department was finally taken over by the Department of Agriculture on 1st July, 1891, and the Weather Bureau started on its career as we now know it.

Observations of local weather conditions are taken daily at 8 a.m. and 8 p.m. (75th meridian time) at about 200 regular observing stations scattered throughout the United States and the West Indies; upon reports from these and other parts of the Northern Hemisphere are based the daily forecasts and weather maps. The forecasts embrace the weather conditions to be expected during the following 36 to 48 hours. The telegraphic data upon which the forecasts and maps are based are temperature, barometer pressure (reduced to sea level), precipitation (rain and snow fall), direction of wind and velocity, state of weather, clouds, and maximum or minimum temperature since last observation. From these the forecaster is able to trace the paths of storm areas from day to day, and predict the probable weather conditions, the forecasts being successful in ninety cases out of a hundred. Within two hours of the morning observations having been taken forecasts are telegraphed to about 1,600 distributing points, whence they are further disseminated by telegraph, telephone, wireless telegraphy and mail. These forecasts reach about 90,000 addresses daily by mail. Telephone subscribers, to the number of more than 5½ millions, can have them within an hour of the time of issue. The weather map is mailed immediately after the morning forecast is telegraphed. On this map current weather conditions are graphically represented with values of temperature, precipitation, etc., from all observing stations, and an explanation of the main features of the map. A small weather map is also printed in some of the newspapers.

There is as well an Ocean Meteorological Service which collects, through the co-operation of shipmasters and others, weather observation at sea. It provides for this purpose blank forms for reporting observations, collects and charts them, reduces them to mean values, and prepares the results for publication on the Pilot Charts for the several oceanic areas issued by the Hydrographic Office of the United States Navy.

Radio-telegraphy has recently made possible transmission by ships at sea to shore stations and so to a central Meteorological Station. There has also been organised a system of meteorological observations for vessels navigating the coastal waters of the Middle and South Atlantic States, the Gulf of Mexico, and the Caribbean Sea; the idea being to gain information of sub-tropical storms which traverse these waters. Observations are already made on more than 50 vessels and by wireless telegraphy to shore stations, and to the central office of the Weather Bureau, where they are utilised on the synoptic charts for making forecasts and storm warnings. A service of this sort is also maintained on the Pacific Coast. The forecasts and warnings are then distributed daily to merchant shipping through the co-operation of the radio service of the United States Navy.

A further service to shipping performed by the Weather Bureau is in the reporting of ships as they pass exposed or dangerous points on the Atlantic Gulf and Pacific Coast, the reports being sent to the owners and to great shipping centres.

As well as the foregoing, which may be termed the Marine Department of the U.S. Weather Bureau, it has its activities extended to many meteorological problems on land, especially that of assisting agriculture and fruit growing.

It is curious in how many different ways the information supplied by the Bureau is utilised "on the other side." Frequently shipments of perishable goods are accelerated when it is found possible to get them to their destination before the expected unfavourable temperature conditions arrive. When this cannot be done the goods are protected until the weather changes. To take an example, bananas must be kept at a temperature of 58° to 65° F., during shipment, as a fall of temperature to below 55° chills the fruit in such a manner as to cause a deterioration in quality, whilst if it rises above 65° it will ripen too soon. Precautions similar to these, based on the daily forecasts and weather maps, are used in regulating shipments of vegetables, fruits, and other perishable goods.

Most of the instruments used by the Bureau are similar, if not identical, with those used on this side of the Atlantic, but with one notable exception, shown in Plate VI (Fig. 1). Instead of taking observations of Relative Humidity, etc., from a dry and wet bulb instrument standing in frequently stagnant air, as in a Stevenson Screen, they employ a whirling machine, as seen in the picture, and before an observation is taken the muslin of the wet-bulb is thoroughly wetted, and then the two thermometers are rapidly rotated by means of the handle for a minute or two, and then a reading is quickly taken. The "sling" psychrometer is a variation of the same thing, but is rotated by swinging it at arm's length.

CHAPTER XIV.

METEOROLOGY IN RELATION TO AVIATION.

THE state of the weather constitutes such an important factor in the Science of Aviation, that we need hardly apologize for introducing the subject.

During the past twenty years the state of the upper air has been very thoroughly investigated by means of kites, balloons, pilot-balloons, and *Ballons-sondes*. The *Ballon-sonde* has given us the temperature of the atmosphere up to considerable altitudes, on one occasion going as high as 36 kilometres (22 miles), and on several occasions 20 km. has been reached. Kites and balloons have shown themselves suitable for finding direction and force of wind, temperature, and humidity, to a height of 3 km. (10,000ft.). The pilot-balloon is useful in clear weather to show the direction and velocity of the wind in the upper strata, when, owing to the absence of clouds, they cannot otherwise be discovered. These have been used beyond 10 kilometres (6 miles), and have frequently ascended to 4 km. (13,000ft.). They are now in daily use at a great many stations for the guidance of airmen.

From these observations we have gathered that distribution of atmospheric pressure is probably decided by that at a height of about 9 kilometres at the top of the *troposphere* (Fig. 61) just below the *stratosphere*.

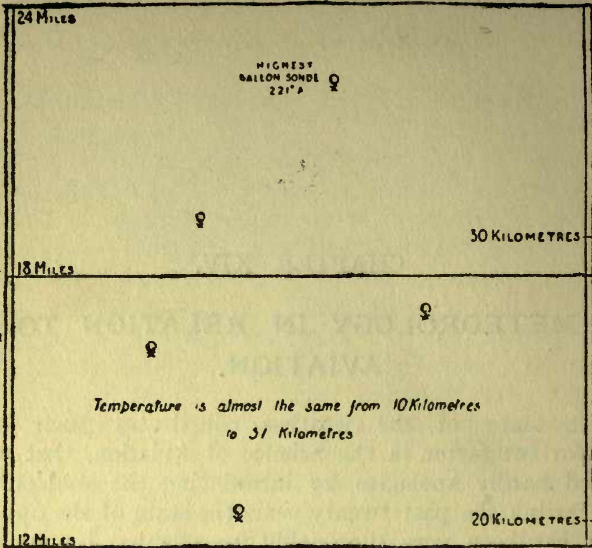
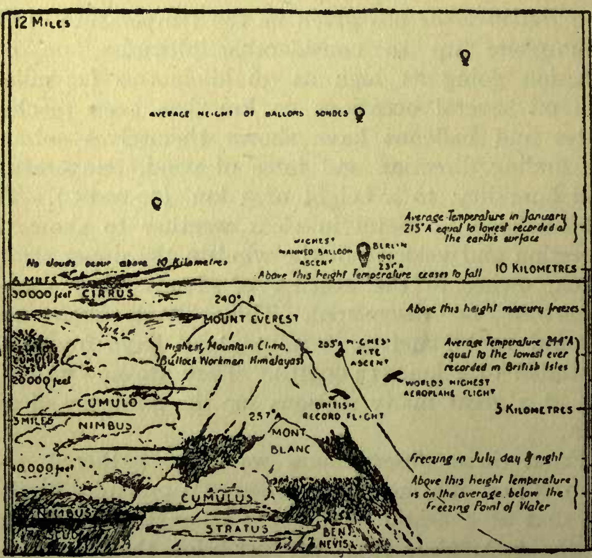


Fig. 61.—Stratosphere rom 12 to 24 miles above the earth's surface.



The Troposphere and Lower Region of Stratosphere. Reproduced from *The Weather Map*, by Sir Napier Shaw, F.R.S., by permission of H.M. Stationery Office.

The rest of the air below that level seems to have little effect in controlling our weather. It may therefore be inferred that local weather is "manufactured," so to speak, at that very high altitude, and is also affected by the intermingling of warm and cold currents between that region and the earth's surface.

It has been found that as we ascend temperature falls about 10°F. for each kilometre until a height of 10 km. is reached. There an *isothermal layer* which extends up to 37 km. exists and in this space temperature remains almost the same throughout. With an east wind at the surface, one may, in exceptional cases, find at a height of 10 kilometres a westerly current blowing.

The rate of fall of temperature is practically the same all over the world, except in Canada and Siberia, where the low surface temperature affects the results. Another meteorological condition which affects the airman, besides the actual temperature of the air, is barometric pressure. According to the height of the barometer, the density of the air varies, and the lift exerted on the wings of an aeroplane changes in the same proportion. The running of the engine is also influenced by differences in air density as is shown by the speed indicator.

The effect of the wind upon an aeroplane is not so great as might, on first consideration, appear. When the machine has once left the ground, except as regards drift, it does not matter which way, or with what velocity, the wind may be blowing. Regarding possible velocity of wind at certain heights, it is fairly safe to infer that at a height of a few thousand feet the wind will roughly double *in speed* and veer a few points in *direction.*

It will thus be realised how important is the study of the upper air to aerial navigation. From the moment an airman leaves the ground he passes through different strata of atmospheric conditions. Although he may start from *terra-firma* in a dead calm, before he is a mile up he may be in a 40-mile-an-hour gale.

Instruments for recording the climatological conditions of the upper air have hitherto been found so expensive that anything like a general interest in the science has been rendered almost impossible.

Mr. W. H. Dines, F.R.S., however, has designed the combination of instruments illustrated in Fig. 62,* and the question of ultimate cost having been carefully considered by the manufacturer, it is hoped that the subject may be more generally taken up.

The pens write on a disc of paper 11 inches in diameter instead of on a drum. The paper lies flat on a piece of thin wood, and turns about a pin passing through its centre. It is driven by contact near its circumference with a small milled wheel, which is driven in its turn by a clock. A roller mounted on a spring on the other side presses the paper against the milled wheel, and ensures sufficient friction. The pens describe arcs of circles on the paper disc, the chords of the arcs being roughly coincident with radii of the disc. It will thus be seen that the time scale being angular is not uniform, but depends on the position of the pen.

The barograph pen is actuated by an aneroid box made of thin metal, and sealed with some air at atmospheric pressure inside. The corrugated face of the box is very yielding, and hence the volume of the enclosed air is dependent chiefly on the external pressure and on its own temperature. The arrangement necessitates a large correction for temperature, but the result has proved satisfactory, since independent observations of the height of the kite have mostly

* The author is indebted to Mr. J. J. Hicks for the description and illustration of this instrument.

agreed with the heights given by the Meteorograph within 2½ per cent., instead of the 5 per cent. previously given by the exhausted boxes.

The hygrograph depends on the extension of a bundle of human hairs, protected from rain and spray, 6 ins. (15 cm.) long, multiplied eight-fold by a lever. Although the scale is short it is probable that this arrangement enables the relative humidity to be determined to about 5 or 10 per cent.

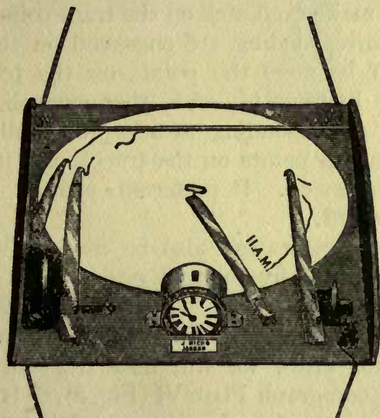


Fig. 62.
The "Dines" Kite Meteorograph.

This thermograph depends on the expansion of spirit enclosed in a thin brass tube ¼ in. diameter and 20 ins. long (6 mm. diameter, 50 cm. long); this communicates with a small aneroid box, also full of spirit and its expansion and contraction actuates the pen.

The scale is obtained by direct comparison with a mercurial thermometer, and is about 40° F. to one inch (1° C. to 1.2 mm.). The arrangement gives a powerful control over the pen, so that blurring due to the shaking of the Meteorograph seldom occurs.

The pens write on a disc of paper, and the traces are tabulated by placing the paper discs under a celluloid transparency on which the scales are engraved. The certainty of synchronous readings is ensured in the following manner :—On each trace, while the paper is on the Meteorograph, nicks are made simultaneously by hand by the pens. On placing the celluloid transparency on the paper, with a pin through the centres of both, by turning it round it should be possible to make each nick on the trace coincide exactly with the corresponding arc engraved on the celluloid. If this can be done the points on the traces of the barograph, hygrograph and thermograph, which lie under the corresponding arcs on the celluloid must be simultaneous points on the traces, and if not allowance can be made. If preferred, printed paper discs can be supplied.

These instruments can also be used as an ordinary thermograph and hygrograph either in a room or in the open.

The Meteorograph described above is suitable for use with kites, we will now treat of the Dines Balloon Meteorograph Plate VI (Fig. 2).* It is light and simple, weighing only 28 grammes. The trace is made by the scratching of a steel point on a piece of thin sheet metal about the size of a postage stamp and the record is read by means of a microscope. The metal is electroplated first with copper and then with silver, and this forms a soft, non-corrodible surface free from all scratches, on which the scratch of the actual record is plainly seen.

The trace is the extension-temperature diagram of an aneroid box, as will be readily seen from the figure. As the balloon rises the aneroid box A opens

* The descriptions and illustrations are given by permission of the Controller of His Majesty's Stationery Office.

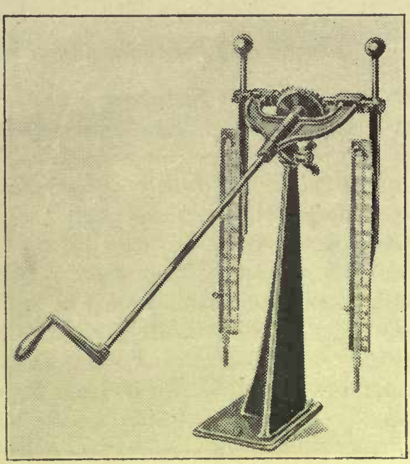


FIG. 1.—Whirled Psychrometer. Used by the U.S. Weather Bureau instead of dry and wet bulb thermometers. Before a reading is taken the machine is turned rapidly by the handle.

By permission of U.S. Weather Bureau.

Engraved by Strand Newspaper Co.

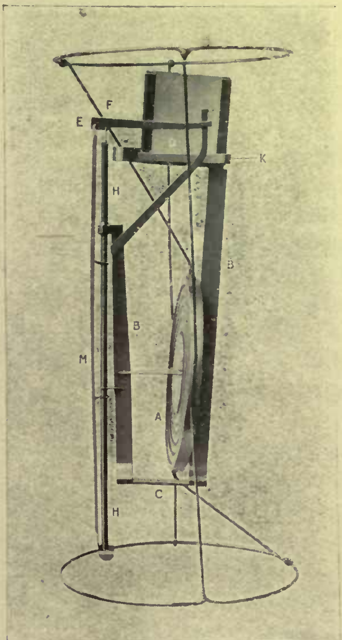


FIG. 2.—General view of a Balloon Meteorograph recording pressure and temperature only.

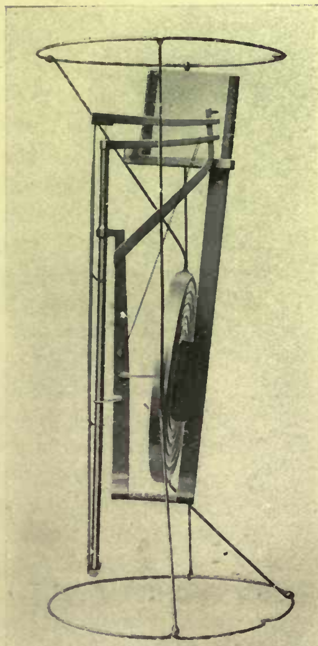


FIG. 3.—General view of a Balloon Meteorograph recording humidity also.

To face p. 138.]

under the decreased pressure, and the two sides of the frame B B which are connected by the spring C move away from each other. One side carries the metal plate and the other the writing point, and the result is a scratch on the plate which is practically an arc of a circle with centre near B. Any change of temperature provides a movement perpendicular to this arc, and is recorded by the expansion and contraction of a strip of very thin German silver, 125 mm. long, 9 broad and .2 thick. The contraction is multiplied some ten times by the lever E F D and the action is as follows :—H is a bar of invar, a nickel steel alloy which does not rust and has no appreciable co-efficient of expansion with heat. It ends at E in a short length of flat spring, which is soldered to the lever at F. The strip of German silver, M, is soldered at the one end to the lever at E and at the other to the invar bar. As the German silver contracts with the cold, the end of the lever D, which is turned down and ends in a point, moves outwards, giving a scale of about 1 mm. to 50° C, which can be easily read by a low power microscope to a sufficient degree of accuracy.

The frame is cut out of one piece of German silver about .8 mm. thick, the end C being turned down at right angles so that the frame may open and shut like a pair of spring scissors under the action of the aneroid box; the invar bar is rigidly attached to the frame at one end and by a sliding joint at the other, so as to allow for the expansion of the frame.

The writing point of the lever D is pressed on the plate by the natural spring of the frame and apparatus, but when the instrument is not in use it is held off by a spring K. When the instrument is to be used the spring is depressed by a small wedge inserted at the back, to which a piece of red string is tied. The finder of the instrument is asked to pull out the string and thus remove the wedge, so that the writing point may be lifted off the trace. The instrument is held by four pieces of stout wire soldered to the edge of the aneroid box as shown, and the small plate that carries the record slides in and out of the plate holder, into which it should fit tightly. In handling the instruments only the wire frame or the edges of the aneroid box should be touched.

The aneroid box is made of very thin metal and some air is left inside it; it is soldered up finally with the opposite faces in contact at the centre. In consequence the temperature correction is large, but this is of no importance, especially as it is impossible to make a box to cover so large a pressure scale that does not require some correction; the advantage is that the extension of the box depends primarily on the elasticity of the included air and but slightly on the metal, and hence there is very little hysteresis.

A second scratching point is employed, rigidly attached to the arm of the frame which does not carry the plate. This gives a fiducial mark on the plate. It is not used in calibration, but it shows whether the plate has moved in the plate-holder between the calibration and the ascent; should such movement occur the scratch made by the fixed pen would be duplicated.

The control exerted by the aneroid box is very powerful, so that the friction of the scratching points is quite negligible in comparison. The instrument is protected by a thin cylindrical case of aluminium, and is hung from the balloon so that the axis of the cylinder is vertical; this allows a stream of air to pass over the instrument as it rises or falls and provides sufficient ventilation. Moreover, the thermograph is of bright metal and is protected from the sun by the metal case which is also bright both inside and out;

thus it should not be susceptible to radiation, and owing to the thinness of the strip of German silver, which is the basis of the thermograph, it is very sensitive and has very little lag of temperature.

A hygrograph is easily added if desired; a third writing point is arranged to make a scratch about 4 mm. inside the temperature scratch, and the point is held in by a short length of hair against a light spring. Plate VI (Fig. 3.)

When we are ready to take an observation we place the instrument in its own numbered cyclindrical case with the writing end against the cross wires of the case, and wire it in by putting a piece of aluminium wire through the holes provided at the other end and then turning over the ends. The finder seldom meddles with the wire but will untie string.

Prepare a small wooden wedge and tie to it some six inches of fine red string with half a match tied to the other end. Insert the wedge by means of a small pair of pliers in its place so as to bring the pens down on the plate. Take great care not to shift the plate in the process.

Next prepare the "spider." Take three strips of split bamboo of about ⅛-inch section and 3 feet 6 inches long. Tie them together about 1 foot from the ends and place them so that each one is perpendicular to the cross formed by the other two. Fix them in this position by ties of fine cotton running from the extreme ends of each to the ends of the cross formed by the other two. Then tie a small red silk flag on each of the six ends. The result is that this "spider" when lying on the ground must have three red flags well above the ground and is, therefore, readily visible. Its weight should not exceed an ounce. Plate VII (Fig. 1.)

Tie the instrument to the "spider" by string from the cross wire of the case to the centre of the "spider." Tie securely, so that the case is jammed tightly against the three bamboo strips. Neglect of this precaution will make a blurred trace. Do not forget to attach the label offering the reward: that used in England reads as follows :—

M.O. 074.

O.H.M.S.

INTERNATIONAL INVESTIGATION OF THE UPPER AIR.

5 SHILLINGS REWARD.

DELICATE METEOROLOGICAL APPARATUS.

This instrument is the property of the Meteorological Office, London. The above reward will be paid for the instrument if it is not tampered with. The finder is requested to pull out the piece of red string (with the match-end attached), to put the instrument away in a safe place and to write to the Director, Meteorological Office, London, S.W.7., when instructions, and if desired, information, will be sent.

The balloon need not be returned.

Copy of label attached to the meteorograph before the ascent.

This label is soaked in melted paraffin wax to protect it against wet. Secure the apparatus to the balloon by strong thread, so arranged that the axis of the case of the instrument must be vertical during the ascent. In England the distance between the case of the instrument and the centre of the balloon at starting used to be made equal to 13 metres, but is now increased to 40 metres. The angle which this distance subtends is measured on a micrometer scale at the focus of the theodolite telescope, and by this means a fairly accurate calculation of the distance of the balloon, and therefore of the rate of ascent and of the velocity of the wind, can be made.

It is necessary when a balloon is sent up in strong sunshine—and since there are no clouds above 8 or 9 k. this means when it is sent up between sunrise and sunset—that the instrument should not hang too near the balloon, as if it does the readings of the thermometers will be vitiated by the wake of heated air which has been in contact with the balloon which gets heated by the sun's rays; indeed it has been found that this might make a difference of as much as 50° A. in the temperature recorded. To obviate this difficulty the following apparatus has been devised.

A piece of thread, some 40 metres or so long, is coiled round a long thin strip of wood, and cannot uncoil or slip off over the end without imparting a spin to the strip. A rapid spin is prevented by the air resistance of a cross piece, and so soon as the instrument is hanging freely the thread begins to uncoil at the bottom and the instrument drops gradually down to its full distance below.

It is not desirable to give the balloon any extra weight to carry, and hence it is arranged that when the thread has completely uncoiled the wood shall fall away.

The plan is shown in the figure, Plate VII (Fig. 2.), the stamp showing the scale. The long vertical strip, some 75 cm. long, the bottom of which is not shown, and the cross piece have notches cut across them so that they may lie loosely over one another at right angles in the same plane. There is a short piece with a longitudinal groove cut in the upper part in which the thread lies until it is below the cross piece, it is then coiled round and round and holds the short pieces in position. When the uncoiling is complete there is nothing left to hold the three pieces together, and they fall to the ground free from the thread and from each other.

It is essential that the thread should leave the arrangement symmetrically at the top; hence the longitudinal groove is cut. The coil should not be unduly tight, the wood should be smooth, and care should be taken that there is no place where the thread can hitch itself, but no special skill is required in making it, and the coil need not be a single one. Only the upper part is shown in the figure.

The plan has been in use about two years, and so far as the author knows has never failed. The pieces may usually be seen to drop away a minute or two after the start, the time being dependent on the length of the cross piece. About 20 cm. is a suitable length, and the notch must be in the middle so that the centre of gravity of the whole arrangement may be in the vertical strip.

It would be too complicated to go further into this matter, and for calibrating the instruments and reading the records the reader is referred to The Computer's Handbook (M.O. 223, Section II.), from which extracts have been made by kind permission of the Meteorological Office and H.M. Stationery Office.

As time passes the modern aircraft becomes more and more immune from the effects of the elements, but at the same time the airman will never be quite able to do without the assistance of the meteorologist, and a course of meteorology will soon become as essential for Air Pilots as it has already been made by the Board of Trade for Ships' Officers.*

* Due acknowledgment must be made for some of the facts and figures in this chapter to *The Weather Map*, by Sir Napier Shaw, F.R.S., and to *The English Mechanic and World of Science*. The diagrams are reproduced from *The Weather Map* and *The Computer's Handbook*, by permission of The Controller of H.M. Stationery Office.—D.W.H.

CHAPTER XV.

HOW TO MAKE SOME OF THE INSTRUMENTS.*

ALTHOUGH from an orthodox scientist's view-point instruments of any sort made by an amateur are practically useless, yet there will no doubt be some of our readers who would like to try to manufacture some of the apparatus of which we have been treating in this volume.

The easiest meteorological instrument we can essay to make is the raingauge, for all we require is some sheet zinc and a knowledge of soldering.

In Fig. 37 *ante* is shown a sectional illustration of a Snowdon Raingauge. Let us now see if we can make it.

Having secured an oilman's funnel about five inches in diameter, we must also obtain a sheet of zinc about 16 in. × 16 in., and from this construct a tube 4⅞ ins. in diameter. Solder in a bottom and fix three iron legs. We must now braize a brass rim to the top of our funnel and then fit it into another tube 6 inches long and made to fit tightly over the other tube. If we braize the brass rim to the top of the funnel as just stated we shall be making what is known as a "Glaisher" raingauge.† (Fig. 40 *ante*). To

* The illustrations of how to make thermometer and barometer tubes are reproduced by permission from *Cassell's Book of Scientific Pastimes* and *Shenstone's Methods of Glass Blowing* (Longmans).

† Diameter of funnel 8 in.; the 5 in. being known as the "Howard" gauge.

transform it to a true Snowdon* pattern we must fix the funnel inside the upper tube at 4 inches from the top and braize the brass rim at the top of the upper tube at an angle of 45°, so as to leave an exact space 5 inches or 12.7 centimetres in diameter. To catch the rain we can obtain a large bottle from a chemist, or a tin can, 3 or 4 inches in diameter, to fit inside our raingauge.†

It is always as well to first paint and then enamel white all zinc gauges, as this preserves them from the effect of weather.

We have now made our raingauge, but if we have not been very careful we shall by no means have such a reliable instrument as we could purchase from a good maker for something less than a pound. Therefore the question is apt to arise both in this case and the making of other instruments: "Is the game worth the candle?" For it must be borne in mind that after we have finished the raingauge proper we shall still have to buy a measure glass, as it would be quite impossible for an amateur to make one of these glasses with a sufficient degree of accuracy, besides which quite good glasses can be bought for about four shillings.

For some time the author had in use, as a check on his copper "Snowdon" gauge, a "Howard" pattern gauge, which he had put together himself in the following manner. He had by him the funnel of an old raingauge, the bottom portion and container having been destroyed. He obtained a box from the grocer, and turning it so that one of its narrow ends was upmost, cut a hole in the top for the funnel tube

* As has been pointed out in Chapter VIII. the "Snowdon" rain-gauge has a funnel 4 in. deep.

† The author has a tin can made from two old tins which originally contained canned goods.

to pass through, making the lid into the door at the side, by means of which the bottle could be removed and the measurement taken.

To make a thermometer is a far more complicated piece of work requiring, as it does some slight knowledge of chemistry and glass blowing.

The first thing to do is to get some thermometer tubing from a scientific instrument maker and also a small quantity of dry, clean mercury.

Before starting operations we should have a large, clean box-lid inverted on our working table, as its cardboard sides will prevent the elusive quicksilver from running away and being lost, if we should happen to spill any.

Next we must blow a bulb (Fig. 63) at the end of our tube. To do this we play on the end of the tube with the blowpipe flame until it is sealed up, and when it has become quite soft we must blow through the open end until the bulb is formed. This blowing process should be done in short puffs, as in this way the process can be stopped at the right moment; in fact, small thermometer tubes should not be blown with the mouth, as there is a certain amount of moisture in the breath, which is afterwards very difficult to remove. A better plan would be to employ a small indiarubber bulb or bottle, like those used in spray-producers Of course, if this is used it must be securely attached to the open end of the tube. During the whole process the glass must be steadily rotated.

We mentioned just now that if the tube is of large bore it would be advisable to make a constriction. (Fig. 64). This is how it is done. Soften the tube at the part to be constricted, and then pull the ends slightly apart, playing on the narrow portion meantime with the blowpipe. This thickens the glass at the constriction, and with practice we can judge fairly well when to discontinue the process, thus forming a strong constriction.

Now, having allowed the whole thing to cool down, we must warm the bulb, placing the open end of the tube in a receptacle filled with the prepared mercury. (Fig. 65). Invert the tube and shake the mercury into the bulb. No amount of shaking, however, will entirely fill the bulb with the elusive substance, so we now have a very delicate operation to perform, as the little mercury we have already persuaded into the bulb must be boiled, and while mercury vapour fills the bulb and tube we must carefully, though quickly, put the unsealed end into the cold mercury. Should we be successful, as the bulb and tube cool they will both be quite filled with mercury. If a bubble or two of air should appear, gently shake the tube, and it will escape at the open end. Now place the bulb of our "embryo" thermometer in boiling water and watch carefully how high the mercury rises. Make a constriction at the point noted, and allow it to cool.

Then we must heat the bulb very carefully above the flame of a spirit-lamp till the mercury column rises about half an inch above the constriction. Finally we have to seal off the top, or opposite end, of the tube to the bulb. This is done by using the blowpipe to direct a small flame against the narrow part or apex of the tube, whilst the mercury-thread is still continuous, thus cutting off a small portion of mercury.

Now comes the graduation of our thermometer. The two first points to fix experimentally are the freezing and boiling points. To find the first of these we place our thermometer in a glass jam-jar, so that it is immersed in small pieces of ice. This ice must be thoroughly crushed, so as to completely surround the bulb. This is *most* important. We then place an indiarubber band in such a way that it can easily be slipped up and down the stem. Move this so that it corresponds with the top of the mercury column. Then make a slight scratch on the glass with a small file. This is the freezing-point of water : 32° Fahrenheit, 0° Centigrade, 273° Absolute.

Before proceeding further we must decide which style of graduation we are going to adopt. Although we in England cling tenaciously to that of Fahrenheit, the Centigrade scale is by far the most simple, the two chief points—freezing and boiling—being exactly 100 degrees apart—hence the name. It also has the advantage that its degree divisions are exactly the same, and are directly convertible, in whole numbers, into the new scale now in use by official meteorologists, and also by chemists—the Absolute, in which 0° Centigrade is represented by the figures 273° Absolute, and so on.

But, whatever scale we decide to use, as the bore of a piece of thermometer tubing is never mathematically the same at any part, it is absolutely imperative to fix other points between the freezing and boiling-points, and this is done by comparing our thermometer with a standard instrument. The two thermometers should be tested together by being immersed in water at 15° C. and 30° C., a scratch being made at these points when the experimental and standard instruments synchronise.* Having ascertained the boiling-point by immersing the thermometer in a glass vessel over a spirit-lamp, the vessel being closed in such a way that only dry steam from the boiling water reaches the bulb (Fig. 66) and then marking off the point to which the mercury rises, we must then divide our stem into the necessary degrees.

* If the Fahrenheit scale is used, the most suitable temperatures will be 62° and 92° F.

This fixing of the boiling-point is for purely experimental and laboratory use. If we only require our thermometer, as in this case, for meteorological purposes, we can cut off and seal our tube at the point where the standard thermometer marks about 50° C. or 120° F.

FIG. 63.
Thermometer
Bulb.

FIG. 64.—Constriction.

FIG. 65.
Filling the Thermometer.

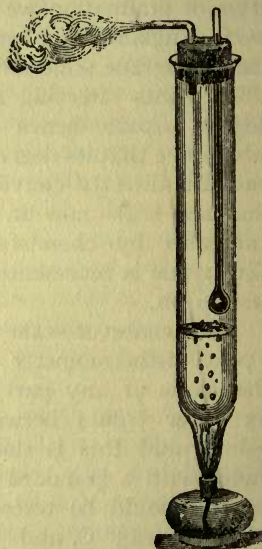


FIG. 66.
Fixing the Boiling Point.

We will now treat of how to etch the scale on the glass stem and other processes to complete the making of the finished instrument. Presuming, now that we have fixed the freezing, boiling or other testing points on our thermometer, and have decided to adopt the Centigrade scale for the sake of simplicity, we have now to divide the stem between these two points into a hundred equal parts or degrees. To do this we must first divide the length of the tube into ten equal parts, and then divide each of those parts into ten further divisions, making 100 degrees. In Fig. 67 we see how to divide the line A B into nine equal parts, and by moving that line, which in practice represents the thermometer stem to be divided, out to C, we could get ten parts.

But first we will graduate our thermometer into nine parts, and so obtain a scale of 90° C. Therefore, suppose line A B is our thermometer. Adjust a hinged rule so that points A and B coincide with inside edges of the limbs, one of them, A, being at the ninth division (*i.e.*, ninth inch) of C. E. Then, if lines parallel to E D be drawn from each division of the scale to meet A B, A B will be divided into nine equal parts, B being the zero line.

To obtain the greatest accuracy in reading the thermometer it will be necessary to etch the scale on the stem itself. This is best done by first coating the glass with a thin layer of beeswax. The scale and figures are then carefully scratched in the wax, so that the surface of the glass is exposed only where the markings are to appear. Having finished this operation the parts to be etched are very carefully saturated by means of a brush with hydrofluoric acid. Do not allow any of this to get on your hands, or blood poisoning may supervene.

If less accuracy is aimed at it will be sufficient to mark the testing points at 0°, 15° and 30° C. with a file, as before mentioned, and then fix to a wooden frame, when the scale divisions and figures can be easily marked on the wood itself or on to a piece of paper pasted beside the stem of the thermometer. If the scale and figures are first marked in with a hard blacklead pencil on the wooden scale, and afterwards inked in, the ink will not run. We have thus made our thermometer from first to last.

Having now made the thermometer we must mount it on a wooden frame in the following manner: Mark its position, perfectly upright, on the board, bore holes so as to come each side of the stem at about an inch from the top and also just above the bulb. Then take a piece of thin wire and push through the holes from front to back, carefully twisting the ends with a pair of pliers until the thermometer stem is held firmly against the woodwork; do not pull too hard, or you will break the glass. Great care should be taken in this operation.

In this connection it is better when sealing the top of the thermometer to draw a pointed piece towards the back, as, when mounting, this can be inserted in a hole in the wood, so preventing the stem turning round or the tube from slipping down on the scale.

To make a dry and wet bulb we have only to construct two thermometers in the manner just described and fix a water receptacle, muslin, and darning cotton to the bulb of one of the thermometers (see chapter VI.), and we have a complete Mason's Hygrometer.

Having succeeded in the manufacture of thermometers and hygrometers, the making of a dial barometer (Fig. 68) will prove fairly simple to the amateur mechanic.

Obtain a piece of glass tube about 44 inches in length and ¼ in. bore. Thoroughly clean it by pushing a piece of cotton-wool through it by means of a length of wire. This should be done carefully or we shall break our tube to start with. Then see that it is thoroughly dry. Seal up one end of the tube according to instructions given for making thermometers, and then, at about 8 in. from the open end bend the tube round until it is parallel to itself (Fig. 69).

For bending a glass tube we do not employ the blowpipe. The flame of an ordinary fish-tail gas

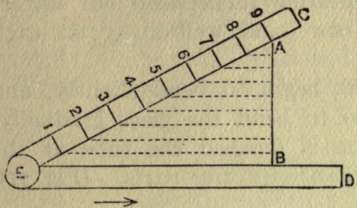


FIG. 67.—Dividing the scale.

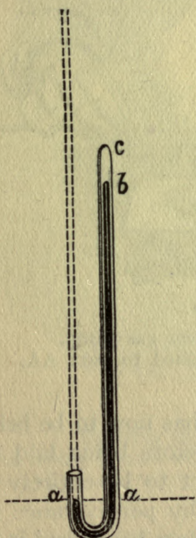


FIG. 69.
Tube bent parallel to itself.

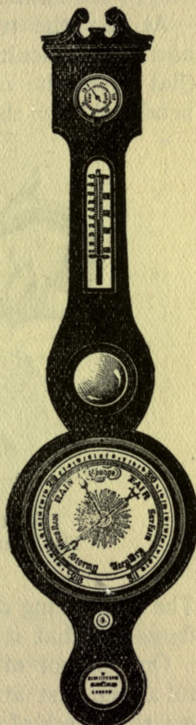


FIG. 68.
Dial Barometer.

burner is the most suitable for the purpose (Fig. 70). The portion of the tube to be bent is gradually brought into the gas flame which should be regulated to about one and a half to two inches in width. First the glass gets smoked, then it becomes red-hot; but all this while we must keep rotating it between our fingers and thumbs, keeping one hand well away on each side of the flame.

At last the tube will begin to bend slightly, and now the difficulty is so to bend the glass gradually, that after the operation is finished the tube at the bend will be no thinner than in its other parts. (Fig. 71).

FIG. 70.
Heating the tube over gas-flame.
The heat should be applied to part AA.

The bend being completed, it has now to be held in the flame, so that it is smoked before being laid down.

One cannot of course expect to be entirely successful at the first attempt; but by perseverance we shall get the knack of making a perfect bend, and it is worth while trying for this perfection, for our work will never look nice if our tubes are uneven and unsightly.

We have now completed the barometer tube; the next thing is to fill it with dry mercury. Heat the mercury in a porcelain receptacle to about 120° C. Place the tube in a horizontal position, the shorter limb being uppermost. Now we must make a small funnel having a horizontal stem just a little longer than the short limb of our tube (Fig. 72a.) The hot mercury is now poured down this as shown in Fig. 72b. until the tube is full up to the bend. During this process the tube must be firmly fixed in position, for should

FIG. 71

Bending the tube whilst still warm.
If in trying to heat side A, side B is not heated enough, the tube may break on the convex side B.

it turn over suddenly the mercury would be wasted, and it is quite possible that our tube would break off where we have bent it. Supposing, however, that we have so far been successful we now place the tube in an upright position, keeping our thumb over the open end, when the mercury in the longer limb will sink and an empty space is left at its upper end c, b, Fig. 69

ante. This space is called the Torricellian vacuum, after the Italian chemist who discovered it.

Our barometer tube finished, we must now fix it to a banjo-shaped base-board (see Fig. 73). In this sectional diagram we see our siphon tube A, B, fixed on the left. Floating on the top of the mercury in the short limb of the tube is suspended a glass float W, by a silk cord which we must pass two or three times round a small brass pulley, P. At the end of the cord is fixed a small weight to act as a counterpoise, E. The two weights must be of equal size to balance one another. This axis of the pulley must be carried through the base-board of the baro-

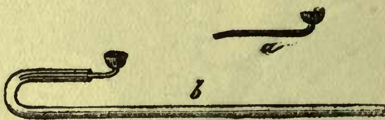


FIG. 72.
Filling the Barometer Tube.

meter to the front of the instrument, so as to show its readings by means of an indicator attached to it, working over a graduated dial. When the mercury in the upper tube A rises, the silk cord and weight W descend, causing the index-hand to move to the right, and as the mercury falls the index will be carried to the left. Having bored a hole through the centre of our base-board at the point P, and having braized an extended axis on our brass pulley, we must fix the pulley so that the extended axis passes through to the front of our base-board. Before fixing the indicator we must make a cardboard dial like a round clock-face, and fix it temporarily with a couple of drawing-pins to the face of the base-board; then fix the indicator (which can be made from a pair of old clock-hands or cut out of a piece of zinc) by means of a bayonet socket. Then our barometer must be tested beside a reliable mercury barometer, always remembering

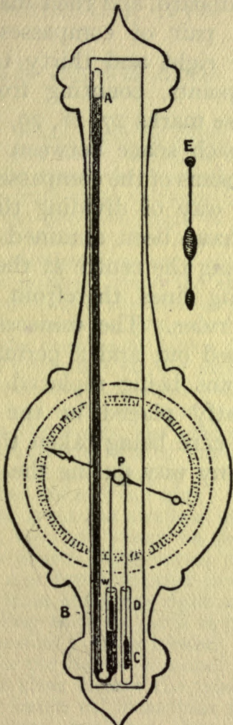


FIG. 73.
Sectional Diagram of Dial Barometer.

that we must allow an inch space on our dial to a tenth of an inch on the mercurial column.

Supposing at the time of making our test the standard barometer shows a reading of 30.00 inches.

Mark the point at which our indicator stands with a lead pencil on the cardboard dial, then when the standard barometer has moved a tenth of an inch in either direction mark off an inch space on the circumference of the cardboard, and then mark similar spaces, measured with a pair of compasses, until we have ten spaces to the right and thirty to the left; then mark the chief points, counting from left to right, at each ten of these marks 27, 28, 29, 30 and 31. Then we must divide each space between these marks into ten divisions, by means of the compasses, for hundredths. A more accurate way of dividing the scale after the first two points have been obtained would be to use a protractor, placing the centre at the axis of the indicator and drawing lines therefrom at the requisite intervals with a ruler. The unnecessary pencil lines can then be rubbed out and a permanent scale inked in, the drawing-pins being replaced with small tacks or gimp-pins neatly placed in the extreme margin of the dial, great care being taken that the cardboard is not moved in any way during the process.

CHAPTER XVI.

WEATHER SAWS AND RULES.

THE hollow winds begin to blow,
The clouds look black, the glass is low,
The soot falls down, the spaniels sleep,
And spiders from their cobwebs creep.
Last night the Sun went pale to bed,
The moon in halos hid her head,
The boding shepherd heaves a sigh,
For, see! a rainbow spans the sky;
The walls are damp, the ditches smell,
Closed is the pink-eyed pimpernel;
Hark how the chairs and tables crack!
Old Betty's joints are on the rack;
Her corns with shooting-pains torment her
And to her bed untimely sent her;
Loud quack the ducks, the peacocks cry,
The distant hills are looking nigh;
How restless are the snorting swine!
The busy flies disturb the kine;
Low o'er the grass the swallow wings;
The cricket, too, how sharp he sings!
Puss on the hearth, with velvet paws,
Sits wiping o'er her whiskered jaws;
The smoke from chimneys right ascends,
Then spreading back to earth it bends;
The wind unsteady veers around,
Or setting in the South is found.
Through the clear stream the fishes rise,
And nimbly catch th' incautious flies;
The glow-worms, num'rous, clear, and bright,
Illumed the dewy dell last night;
At dusk the squalid toad was seen
Hopping and crawling o'er the green;
The whirling dust the wind obeys,
And in the rapid eddy plays;
The frog has changed his yellow vest,
And in a russet coat is dressed;
The sky is green, the air is still,

The merry blackbird's voice is shrill,
The dog, so altered is his taste,
Quits mutton bones on grass to feast;
And see yon rooks, how odd their flight!
They imitate the gliding kite,
And seem precipitate to fall,
As if they felt the piercing ball.
The tender colts on back do lie,
Nor heed the traveller passing by.
In fiery red the sun doth rise,
Then wades through clouds to mount the skies.
T'will surely rain—I see with sorrow
Our jaunt must be put off to-morrow.

The above lines, which are supposed to have been written by Dr. E. Darwin and have also been attributed to Dr. Jenner, practically sum up all old weather sayings in one "poem," if we may so describe it.

Taking them as a whole most of these weather signs may be relied on, but the author takes exception to the quacking of ducks and crying of peacocks being in any way a forerunner of rain. During the long droughts of 1887, 1893, 1911, and 1919; peacocks were heard to cry continuously every evening for a long period without a drop of rain falling. With regard to puss washing her face, this seems to be a variation of the old idea of rain being imminent when the cat takes her paw over her left ear during the process. Some years since a sailor told the author that a cat was an excellent barometer. "Watch your pussy, sir," he said, "and if she runs up and down you will surely have a gale of wind soon after; and if she sits with her back to the fire rain is sure to follow."

On testing these feline prognostications the author found them to be quite correct.

From time immemorial there has been a popular idea that the time at which the moon changes affects the weather. This idea put in a nutshell is as follows:—

"The nearer to twelve in the afternoon, the drier the moon."

"The nearer to twelve in the forenoon, the wetter the moon."

This notion has had several different applications, but the most concrete is that which is still given in many almanacks, the original of which appeared in the *European Magazine* (Vol. LX., p. 24), and was at one time ascribed to the astronomer—Dr. Herschel, although it has since been proved that he had nothing to do with it.

Here is the table for what it is worth and readers may like to test it for themselves :—

If Moon changes between	In Summer.	In Winter.
12 and 2 a.m.	Fair.	Frost, unless wind S.W.
2 ,, 4 a.m.	Cold and showers.	Snow and stormy.
4 ,, 6 a.m.	Rain.	Rain.
6 ,, 8 a.m.	Wind and rain.	Stormy.
8 ,, 10 a.m.	Changeable.	Cold rain, if wind W.
10 ,, 12 a.m.	Frequent showers.	Cold and high wind.
12 ,, 2 p.m.	Very rainy.	Snow and rain
2 ,, 4 p.m.	Changeable.	Fair and mild.
4 ,, 6 p.m.	Fair.	Fair.
6 ,, 8 p.m.	Fair, if wind N.W.	Fair and frosty, if wind N. or N.E.
8 ,, 10 p.m.	Rainy, if wind S. or S.W.	Rain or snow, if S. or S.W.
10 ,, 12 p.m.	Fair.	Fair and frosty.

Although there does not seem much justification for the many sayings attributing weather changes to lunar influences, yet the author is not inclined to entirely disbelieve that the moon has something to do with the weather. Of course, if the influence was an obvious one such as that we have just been commenting upon there would be no mystery of the weather at all. The effect of the moon, if any, is an obscure one, and will only be discovered by a careful scrutiny over a long period of weather observations in many parts of the world, but such a controversial subject must not be gone into further here.

As far back as the time of Shakespeare the weather was a subject of interest, as we find him saying in Richard II. (iii. 2).

> "Men judge by the complexion of the sky
> The state and inclination of the day."

Going back to the time of the Ancient Greeks we still find that weather prediction was a matter of interest, for Theophrastus in his "Weather Signs" is found saying: "If the early autumn is mild the sheep generally suffer from famine"; and "If at the beginning of winter there is dark weather and heat, and these pass away under the influence of winds without rain, it indicates that hail will follow towards spring."

It is a curious thing, but with regard to the last of Theophrastus' sayings it is true to-day in England that such weather as he describes in November is frequently followed by a cold winter.

Another of the Greek philosopher's axioms is—"If the spring and summer are dry, the early autumn and the late autumn as well are close and free from wind."

There is a popular belief to the effect that the weather always "pays its debts," and this seems to have arisen from a saying of Lord Bacon which runs as follows:—"A serene autumn denotes a windy winter; a windy winter, a rainy spring; a rainy spring, a serene summer; a serene summer, a windy autumn, so that the air on a balance is seldom debtor to itself."

The same philosopher tells us that "A hot and dry summer and autumn, especially if the heat and drought extend far into September, portend an open beginning of winter, and cold to succeed towards the latter part of the winter and beginning of spring."

Professor Boerne in his Latin MS., 1677-1799, also opines "A wet summer almost always precedes a cold, stormy winter, because evaporation absorbs the heat of the earth. As a wet summer is favourable to the growth of the blackthorn, whenever this shrub is laden with fruit a cold winter may be predicted."

Many and varied are the sayings appertaining to the weather; many of them really useful as being

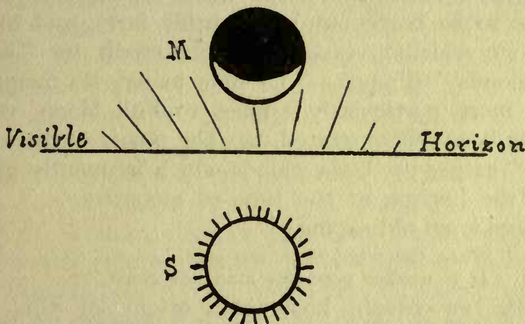


Fig. 74.

Showing why the moon appears "on her back" at certain seasons. M=Moon. S.=Sun below horizon.

the result of long continued observations by those whose outdoor occupation has made it necessary for them to study meteorological conditions, though some of them are little less than absurd; such for instance as the idea of the moon lying on her back being a portent of rain. The ridiculousness of such a notion is apparent if we consider what is the cause of the moon seeming to be on her back.

When the moon is apparently vertical over the sun after sunset, or before sunrise, as she is bound to be at certain periods of the year, in the first case between the phases known as "New Moon" and "First Quarter," and in the second between "Last Quarter" and "New Moon" again, she will infallibly appear to be "on her back as receiving the *whole of her light from the sun*, if she appears directly above him, she must be illuminated on the *under* side as seen from the Earth (Fig. 74). How can this, then, have anything to do with the weather? Extraordinary influences supposed to be due to the moon might be multiplied indefinitely, but there is one idea which seems to be borne out by scientific facts, and that is the one which gives our satellite credit for "eating the clouds" (French—"La lune mange les nuages"). This more particularly applies to Full Moon, which, as has been demonstrated, has the power of dispersing (i.e., "eating up") the clouds which frequently gather near the horizon at the time of moonrise.

There is an old saying—

> "When the wind is in the east,
> It is neither good for man nor beast."

Very few people know the origin of this true "saw"; it comes from the following, of which it is probably a corruption—

> "The wind from north-east
> Neither good for man nor beast,"

which is a quotation from Teonge's Diary, 1675.

It is quite certain that the axiom propounded by Bacon that "wet weather with an east wind continues longer than with a west, and generally lasts a whole day" is true. This is caused by the fact that heavy rains of long duration are generally due to secondary disturbances over the English Channel, which cause easterly winds over Great Britain. This idea is also voiced in the couplet:—

> "When the rain is from the east,
> It is for four-and-twenty hours at least."

Another good saying is—

"If hoar-frost come on mornings twain,
The third day surely will have rain."

An important opinion of Prof. Dalton, and which is absolutely correct is that "In winter, during a frost, if it begin to snow, the temperature of the air generally rises to 32° (or near it), and continues there whilst the snow falls; after which, if the weather clear up, expect severe cold."

Some good weather rules founded on facts are: "If rain commences before daylight, it will hold up before 8 a.m.; if it begins about noon, it will continue through the afternoon; if it commences after 9 p.m., it will rain the next day; if it clears off in the night, it will rain the next day; if the wind is from the north-west or south-west, the storm will be short; if from the north-east, it will be a hard one; if from the north-west a cold one, and from the south-west a warm one. If it ceases after 12 a.m., it will rain next day; if it ceases before 12 a.m., it will be clear next day. If it begins about 5 p.m., it will rain through the night. If raining between 8 and 9 a.m., it will go on till noon, and if not then ceasing will go on till evening."

Further Belville says: "A high temperature, with a high dew-point, and the wind south or south-west, is likely to produce a thunderstorm. If the mercury falls much previous to the storm, the latter is likely to be succeeded by a change of weather. Sometimes heavy thunderstorms take place overhead without any fall of the mercury: in this case a reduction of temperature does not usually follow." This is very true, but in the south and south-east of England the wind is more likely from the author's experience to be east or south-east before a thunderstorm, the wind shifting to the south-west or west as soon as the storm is over. Indeed this change of wind may be taken as a sure and certain sign that all fear of electrical disturbances is over when once the change of direction has taken place. Also even after a "heat" thunderstorm a fall of temperature will generally occur.

Concerning thunderstorms there is a saying that the thunderstorms of the season will all come from the same quarter as the first one.

This "saw" requires some modification. It is true that thunderstorms have a tendency to always come from the same direction, but this is not a peculiarity of season, but of locality.

The author frequently noticed, when residing in a certain district in South London, that thunderstorms only approached from the south-west. If they were situated in any other direction they might be safely relied upon to go away after a distant rumble or two.

Each district has this peculiarity, and where he now is, storms only approach from the south-east.

Bacon says about these phenomena: "Thunderstorms almost always occur when the weather is hot for the season. They are generally caused by a cold wind coming over a place where the air is much heated. They do not cool the air; it is the wind that brings them which makes the weather cooler. If a thunderstorm comes up from the east, the weather will not be cooler after it. This will not happen till another storm comes up from the west. Thunderstorms are the more violent the greater the difference of temperature between the two currents of wind which produce them.

The air useth to be extreme hot before thunders."

The general inference to be deduced from this is that even in Bacon's day it was understood that heat thunderstorms, being what he called coming from the east, did not cool the air like cyclonic storms coming from the west.

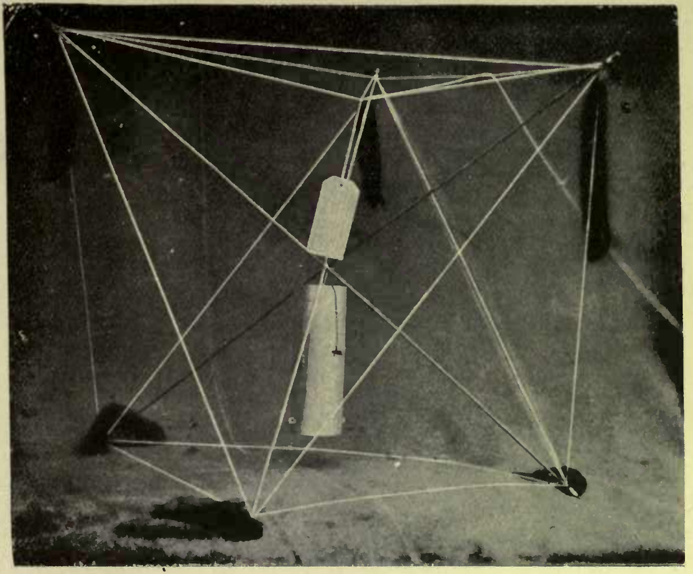


FIG. 1.—Bamboo frame or "Spider" inside which the Meteorograph is suspended during an ascent, The cotton shown here is unduly coarse, so that it may be seen in the photograph.

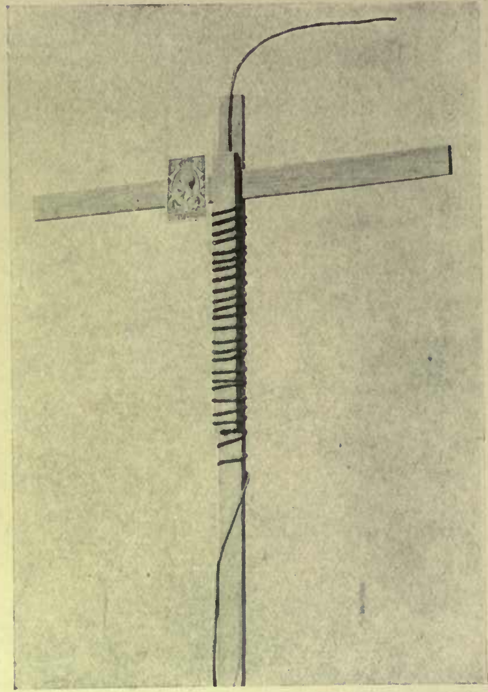


FIG. 2.—Apparatus for keeping Meteorograph away from balloon during ascents.

From *Computer's Handbook*, by permission of Meteorological Office, by H.M. Stationery Office.

To face p. 166.]

Barometer Warnings.	Indicating.
If mercury falls during a high wind from S.W., S.S.W., W., or S.	Increasing storm.
If the fall be rapid	Violent, but short.
If the fall be slow	Less violent, but longer continuance.
If the mercury falls suddenly whilst the wind is due W.	A violent storm from N.W. or N.
If the mercury, having been at its usual height (29.95) is steady or rising, while the thermometer falls and the air becomes drier.	N.W., N. or N.E. winds, or less wind, or less rain, or less snow.
If the mercury falls while the thermometer rises and the air becomes damp.	Wind and rain from S.E., S., or S.W.
When the mercury falls suddenly with a W. wind.	A violent storm from N.W., N. or N.E.
If the mercury falls when the thermometer is low.	Snow.
When the mercury rises, after having been sometime below its average height.	Less wind, or change to N., or less wet.
With the first rise of the mercury after it has been very low (say 29 in.).	Strong wind or heavy squalls from N.W., N., or N.E.
When a gradual, continuous rise of the mercury occurs with a falling thermometer.	Improved weather.
If the mercury suddenly rising, the thermometer rises also.	Winds from S. or S.W.
Soon after the first rise of the mercury from a very low point.	Heavy gales from N.
With a rapid rise of the mercury.	Unsettled weather.
With a slow rise of the mercury.	Settled weather.
With a continued steadiness of the mercury with dry air.	Very fine weather.
With a rapid and considerable fall of the mercury.	Stormy weather, with rain or snow.
With an alternate rising and falling of the mercury.	Threatening, unsettled weather.
When the mercury falls considerably, if the thermometer be low (for the season), the wind will be N.; if high, from S.	Much wind, rain, hail, or snow, with or without lightning.
When the mercury is low, the storm being beyond the horizon.	Lightning only.

Those who have the idea that Bacon wrote "Shakespeare" are invited to compare the cold, calculated sentences just quoted with the following:

> "We often see, against some storm,
> A silence in the heavens, the rack stand still,
> The bold wind speechless, and the orb below
> As hush as death: anon the dreadful thunder
> Doth rend the region."*

That empirical observations made long before meteorology had any pretensions to be an exact science were not so very far from the truth is shown by the fact that John Pointer, M.A., in 1723, in his "Rational Account of the Weather," observed that various flashes of lightning followed the same track, and he judged the reason to be that the first flash rarefies the air and makes a path for the succeeding ones.

Up-to-date photographic methods completely confirm this opinion.

We will conclude this chapter with some more scientific notions with regard to prognostics.

The first is from the barometer, being taken from "Weather Warnings." By "The Clerk Himself," 1877. (See Table on p. 167).

The foregoing table is well worthy of careful study by the would-be-weather-prophet, as according to a long experience the author has found them to be absolutely correct and entirely reliable. If they are taken in conjunction with observations of the clouds and with the following remarks of Mr. C. L. Prince on the thermometer, hygrometer and telescope, and the indications of the rain-band spectroscope, one should be able to make a very fair forecast of the weather for the ensuing twenty-four hours.

With regard to the thermometer, if the temperature increases between 9 p.m. and midnight, when the

* Hamlet.

sky is cloudless, expect rain; and if during a long and severe frost the temperature increases between midnight and sunrise, expect a thaw.

The greater the difference between the lowest temperature of the air at four feet from the ground, and that of terrestrial radiation under a cloudless sky, the less will be the probability of the existing state of weather continuing— and *vice versa.*

Coming to the hygrometer, the greater difference between the readings of the wet and dry-bulb thermometers, the greater will be the probability of fine weather, and *vice versa.*

The telescope, though not exactly a meteorological instrument, will detect air tremors and haze. If the images of stars or the moon appear ill-defined and surrounded by much atmospheric tremor, expect both wind and rain.

The greater the tremor, the sooner the change, except when the wind is easterly.

A peculiar haze sometimes occurs which obscures the smaller stars, but is, nevertheless, extremely favourable for astronomical definition. This haze may be considered to be an indication of approaching fine weather for a few days.

The principal rain band in the spectroscope is on the red side of the D; the more intense this is, the greater the fall of rain which is to take place.

The percentage of band on the red side of C line foretells either slight rain or vapour in form of clouds above or mist below.

The reddish tint of the blue end of the spectrum is generally noticeable before drizzling rain with not much wind.

[The spectroscope is to be turned towards the direction from which the wind is blowing or likely to turn to].

The notes on spectroscope are taken from some by Mr. F. W. Cory in the *Times*, of February 7th, 1883).* From the author's own experience the following "signs" are most reliable. In summer if bats are seen to fly *high* at sunset the following day is sure to be fine. If they fail to put in an appearance, rain will ensue within twelve hours. *Low* flight of any bird shows unsettled weather. Cirrus clouds, thickening at evening, may portend wind only, and not rain as well, if they are detached from stratus, but, if joined thereto, rain will occur as well.

The best of the "Saws" is:—

"Rain before seven,
Fine before eleven."

as it has the advantage that in nine cases out of ten it proves true. The converse is also equally correct, and in unsettled weather it will be found that if the early morning be very fine, showers will arrive before noon. This is, however, more applicable to inland stations than to those situated near the sea, for reasons which have already been explained in the chapter on the clouds.

Another true saying is:—

"Thunder in spring
Cold will bring."

How true this is may be found by allowing the thoughts to travel back over a few years, and it will instantly occur to anyone who takes any intelligent interest in the weather, that a spring with many thunderstorms in March and April is frequently (one might say always) followed by a cold May and June, with more thunderstorms, and a good deal of rain.

"An English summer, two hot days and a thunderstorm," is also in many cases a true description of

* Most of the foregoing quotations are from *Weather Lore: A Collection of Proverbs, Sayings and Rules concerning the Weather.* By Richard Inwards, F.R.A.S., etc. (Elliot Stock.)

our evanescent climatological conditions, and for this reason, that in an unsettled year, when the ground is saturated with moisture, the two fine hot days produce rapid evaporation and convection currents, cumulus clouds form up, and a thunderstorm takes place, cooling the air, and generally leaving a moist unsettled state of affairs behind it.

We are apt to think that the summers each year become more belated, and the winters follow the example of the summers by getting later and later. Judging by old sayings, however, this is not so, as we are told by two ancient saws that :—

"As the days begin to shorten
The heat begins to scorch them."

And—

"As the day lengthens,
So the cold strengthens."

Both of these sayings, it will be admitted, are as applicable to the present day summers and winters as they were when invented by our forefathers hundreds of years ago.

"January 14th, St. Hilary,
The coldest day in the year."

This is a Yorkshire saying, but the truth of it is borne out for more southern latitudes by the fact that the average temperature of sixty-five years at Greenwich on that date is 38.2°, or within 0.3° of being the lowest of the year, which occurs only a few days earlier. This is also true of the popular idea of the "Dog Days" being the *hottest* part of the year, as although the days are simply named thus on account of the *cosmical** rising of the "Dog Star," yet the Greenwich averages go to show that the highest mean temperature occurs about the middle of the period, i.e., 63.4° on July 16th.

* Cosmical Rising.—Sirius, the "Dog Star" rises during this period at the same time as the sun.

A French proverb says "St. Mamertius, St. Pancras and St. Gervais (i.e., the 11th, 12th and 13th of May) do not pass without a frost." It is true that the middle of the "Merry Month" seldom passes without a cold spell both in France and England, indeed in Western Europe generally, and it is said that the French have applied the term "La semaine gelée" to the third week in May, but the cold period frequently spreads itself over a period of ten days, culminating in a severe frost or two about the 20th or 21st of May.

The late Dr. A. Buchan constructed a table of cold and warm periods which may be summarized thus:—

Cold Periods.		Warm Periods.	
February	7–10	July	12–15
April	11–14	August	12–15
May	9–14	December	3– 9
June	29–July 4		
August	6–11		
November	6–12		

It may have been noticed by readers that an easterly or north-easterly wind, even in places far removed from the smoke of large towns, always has an accompaniment of a peculiar brownish haze. This is caused by the surface easterly current, which is only temporary, becoming mixed at a high altitude with the permanent south-westerly air current of the north temperate zone (see Chapter X).

Even in Biblical times the east wind was referred to, and the weather was a subject of comment in the inspired pages, as:—

"God prepared a vehement east wind."—Jonah iv. 8.

"Dost thou know the balancings of the clouds, the wondrous works of Him Which is perfect in knowledge?"—Job xxxvii. 16.

"When it is evening, ye say, It will be fair weather: for the sky is red. And in the morning, It will be foul weather to-day: for the sky is red and lowring.—Matthew, xvi. 2, 3.

"He causeth the vapours to ascend from the ends of the earth; He maketh lightnings for the rain; He bringeth the wind out of His treasuries."—Psalm cxxxv. 7.

CHAPTER XVII.

CONCLUDING REMARKS.

IN these utilitarian times when everyone asks the eternal question "*Cui bono?*" it will be advisable to explain the uses to which the various observations we have described can be put.

Putting aside the actual business of weather forecasting as being too obvious a reason for weather observation to need further comment, we come to the usefulness of taking continuous rainfall observations at a large number of stations. There are at present over 5,000 voluntary observers reporting to The British Rainfall Organization, whose results are published annually in *British Rainfall,* notwithstanding which many more observers are still required in many parts of Great Britain and Ireland.*

From a study of rainfall statistics engineers are able to calculate the watershed of a given district, which enables them not only to arrange for the water supply of large towns, but also to find the amount of strength of bridges, etc., necessary to enable them to withstand the greatest probable floods likely to occur in that locality.

For instance, an annual rainfall of 131 inches, which would be quite normal for Seathwaite, in Cumberland,

* A postcard to the Superintendent of The British Rainfall Organization will bring a reply as to where rainfall stations are most needed.

the wettest place in England, would be highly improbable if not quite impossible, in London where 24 inches is about the average.

Rainfall is influenced not only by geographical position, but by height of mountains, or even hills and sometimes by forests.

In this connection Dr. H. R. Mill, the late Director of The British Rainfall Organization, in a paper read before The Royal Meteorological Society in October, 1907, stated "The increasing strenuousness of the struggle for the possession of large water supplies is producing in England, and especially in Wales, a great amount of local jealousy and strife . . . but I think that the map study of rainfall can do something to suggest the lines on which such disputes should be settled."

An increasing interest is given to this subject from the fact that we in England are slowly beginning to realise that a vast amount of water power in this country is allowed to run to waste. It is about time that something was done in this matter, as in the United Kingdom *less than one per cent.* of water power is utilised out of the whole amount of power used, while in other countries as much as 40 per cent. is made use of.* Then again we may be asked what is the use of taking the temperature below the ground level? The answer to this is very easy. When the temperature at 4ft. below the ground rises above 55° F. doctors have discovered that infantile cholera becomes prevalent. The temperature of the earth seldom rises above between 55° and 60°, these points being attained at one foot below the

* The author is aware that the water resources of the United Kingdom are comparatively meagre when compared with those of other countries, but even allowing for this, the amount of water-power actually utilized in this country is ridiculously small, and there is abundant scope for development in this direction.

surface in July, but at a depth of 4ft. are not reached until August.

These earth temperatures are also of value to the farmer and gardener, as according to the warmth of the ground, and, incidentally, the roots of the plants and trees, so is the growth helped on or retarded.

It is hardly necessary to point out the great utility of synoptic charts and weather maps to shipping and aviation, as without these and wireless telegraphy we should be reduced to the state of affairs obtaining one hundred years ago.

By means of these charts one is able to see not only the kind of weather conditions in one's immediate vicinity, but also over the whole area covered by the map, so that we can foretell the weather with considerable accuracy for the ensuing 24 or even 48 hours, and in anticyclonic weather 3-day forecasts are possible.

When we come to thermometers we find an instrument that has many other uses besides weather observation; we have already seen how it may be used to plumb the depths of the ocean and discover the temperature below the surface of the earth. To come to more domestic uses of the thermometer, we have the "hygienic," or indoor thermometer, generally graduated from 50° to 70° F., it being considered that a temperature of 60°, or at any rate one between 55° and 65°, is the most suitable for a room, though it is difficult to see how in cold weather in winter, especially with the open window now so universally recommended by doctors, a temperature of even 55° is to be maintained, when it is perhaps from twenty to thirty degrees lower outside!

Another thermometer is the clinical thermometer (Fig. 75), used for finding the temperature of our bodies, the normal temperature of which is 98.4°. They are generally graduated from 95° to 110° F. or from 35°

to 45° C. If our temperature is over 100° F. it is said to be *abnormal,* and it is generally time to call in a

Fig. 75.
Clinical Thermometer.

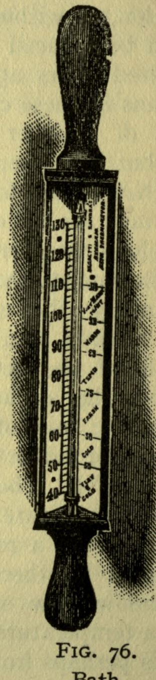


Fig. 76.
Bath Thermometer.

doctor. These instruments must now be accurate to 0.2° F.

The thermometer also has two other domestic uses.

the one being for finding the temperature of our baths (Fig. 76), and the other of our ovens for cooking purposes. The former are graduated up to 140°, and sometimes to 180°, but as boiling point is 212° F. we must not plunge them into boiling water or we shall burst the bulb. The oven thermometer is generally graduated up to 500° or over, an ordinary cooking temperature being 420° to 480° F.

Then we have the maximum thermometer that will tell us by means of ringing an alarm when our house is on fire, as when it is set at a certain temperature, when that point is reached it rings a bell by means of an electric contact.

In the garden we have thermometers for finding the warmth of our hotbeds, mushroom beds, and greenhouses; the last named being marked with the temperatures suitable for various plants and flowers.

It will be seen from this that the thermometer deserves a better acquaintance than it has from most people; but the author hopes that none of his readers will feel inclined to treat the instrument with such contempt as an old lady he once knew. Being obliged to go away for a short time, he asked her to attend to his garden, fowls, and thermometers, when she replied:

"Oh, I can manage them chickens all right, sir, but I don't understand them chronometers!"

This little story needs no apology and points a moral; that is, if we take weather observations we should always be careful to train an assistant so that if we are ill or go away, the readings may still be carefully taken; for, as we have pointed out elsewhere, *continuity* is a *sine quâ non* in weather observation.

* * * * * *

The great philosopher, John Ruskin, said of Meteorology that: "It is the science of the pure air and the bright heaven, its thoughts are amidst the loveliness of creation, it leads the mind as well as the eye to the morning mist, the noonday glory and the twilight cloud, to the purple peace of the mountain heaven, to the cloudy repose of the green valley ; now expatiating on the silence of stormless æther, now on the rushing of the wings of the wind. It is indeed a knowledge which must be felt to be in its very essence full of the soul of the beautiful."

We will conclude with a quotation from Virgil's *Georgics*,* in which the poet comments upon many phases of our science, showing that philosophers, both ancient and modern, had a greater respect and reverence for the weather than the ordinary individual of the present day. This, it is to be presumed, is on account of the fact that, whilst the town dweller is to a certain extent immune from the effects of meteorological conditions, those who have made it a habit to go forth into the open to observe and admire nature have better grasped the grandeur of a thing that to indoor workers seems a merely ordinary, and sometimes troublesome commonplace. The lines run :—

For ere the rising winds begin to roar,
The working seas advance to wash the shore,
Soft whispers run along the leafy woods,
And mountains whistle to the murmuring floods.
Even then the doubtful billows scarce abstain
From the tossed vessel on the troubled main ;
When crying cormorants forsake the sea,
And, stretching to the covert, wing their way ;
When sportful coots run skimming o'er the strand ;
When watchful herons leave their watery stand,
And, mounting upward with erected flight,
Gain on the skies, and soar above the sight :
And oft, before tempestuous winds arise,
And seeming stars fall headlong from the skies,
And, shooting through the darkness, glide the night
With sweeping glories and long trails of light ;
And chaff with eddy winds is whirled around,
And dancing leaves are lifted from the ground ;

* Dryden's Translation.

And floating feathers on the waters play:
But when the wingèd thunder takes his way
From the cold north, and east and west engage,
And at their frontiers meet with equal rage;
The clouds are crushed; a glut of gathered rain
The hollow ditches fills, and floats the plain;
And sailors furl their drooping sheets amain.
Wet weather seldom hurts the most unwise;
So plain the signs, such prophets are the skies.
The wary crane foresees it first, and sails
Above the storm, and leaves the lowly vales;
The cow looks up, and from afar can find
The change of heaven, and snuffs it in the wind;
The swallow skims the river's watery face;
The frogs renew the croaks of their loquacious race;
The careful ant her secret cell forsakes,
And drags her eggs along the narrow tracks;
At either bourn the rainbow drinks the flood;
Huge flocks of rising rooks forsake their food,
And, crying, seek the shelter of the wood.
Besides the several sorts of watery fowls
That swim the seas or haunt the standing pools,
The swans that sail along the silvery flood,
And dive with stretching necks to search their food,
Then lave their backs with sprinkling dews in vain,
And stem the stream to meet the promised rain,
The crow with clam'rous cries the shower demands,
And single stalks along the desert sands.
The nightly virgin,* while her wheel she plies,
Foresees the storm impending in the skies,
When sparkling lamp† their splutt'ring light advance
And in the sockets oily bubbles dance.
Then after showers 'tis easy to descry
Returning suns and a serener sky.
The stars shine smarter; and the moon adorns,
As with unborrowed beams, her sharpened horns:
The filmy gossamer now flits no more,
Nor halcyons‡ bask on the short, sunny shore;
Their litter is not tossed by sows unclean;
But a blue, droughty mist descends upon the plain;
And owls that mark the setting sun declare
A starlight evening and a morning fair.
Tow'ring aloft, avenging Nisus§ flies,
While dared below the guilty Scylla lies.
Wherever flighted Scylla flies away,
Swift Nisus follows and pursues his prey;
Where injured Nisus takes his airy course,
Thence trembling Scylla || flies and shuns his force.
This punishment pursues the unhappy maid,

And thus the purple hair is dearly paid,
Then thrice the ravens rend the liquid air,
And croaking notes proclaim the settled fair,
Then round their airy places they fly
To greet the sun; and seized with secret joy,
When storms are overblown with food repair
To their forsaken nests and callow care.
Not that I think their breasts with heavenly souls
Inspired, as man who destiny controls;
But with the changeful temper of the skies,
As rains condense and sunshine rarefies,
So turn the species in their altered minds:
Composed by calms and discomposed by winds.
From hence proceeds the birds' harmonious voice;
From hence the cows exult, and frisking lambs rejoice.

FINIS.

* The Moon. † Glow-worms. ‡ Kingfishers.

§ Hawk. || Lark.

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