INSTRUCTIONS TO OBSERVERS

IN THE

METEOROLOGICAL SERVICE

OF CANADA

DEPARTMENT OF MARINE
METEOROLOGICAL SERVICE OF CANADA

Instructions to Observers

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PREFACE

This Book of Instructions has been prepared primarily for the observers in the Meteorological Service of Canada at the request of the late Director, Sir Frederic Stupart. It contains an introduction giving the general principles underlying weather process in order that the observer may better understand the importance of the various observations that he has to make. The instructions for taking the various observations have been given very fully and expressed as far as possible in language devoid of technical terms so that even without previous training one should be able, by following the instructions very carefully, to take the observations correctly. Chapters are devoted to instrumental and non-instrumental observations, keeping of the records, the general organization of the service and self-recording instruments.

The drawings have all been prepared by Mr. Harold Bibby, a member of the staff. The photographs of clouds have been furnished by Dean A. L. Clark of Queen's University, Kingston, Mrs. Hutchinson who kindly gave to the office the fine collection of cloud photographs made by the late Mr. Hutchinson, Director of the Observatory at St. John, N.B., and the photographer at Camp Borden. Dr. W. J. Humphreys, Professor of Meteorological Physics of the United States Weather Bureau, Washington, D.C., in addition to furnishing some of the photographs very kindly selected and arranged the list. To these the Service desires to place on record its appreciation and thanks.

J. PATTERSON,

Director.

METEOROLOGICAL OFFICE, TORONTO,

August 1, 1929.

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INTRODUCTION

The main features of the weather are known to us through our feelings; thus they tell us if it is hot or cold, damp and oppressive or dry, clear and invigorating. Through our senses we know when rain, hail, snow or sleet falls and we have often witnessed the weather in all its fury when violent thunderstorms and gales are raging. Now it is the purpose of the meteorological or weather service to investigate all these manifestations in order to be able to predict them, but should we attempt to make a study of these phenomena from our recollection of our personal comforts and discomforts it would be found to be impossible on account of the information being absolutely unreliable. The trouble is that time dulls our memories and we forget; man is on this account a very poor historian of past weather. Consequently if an accurate history of the weather is to be obtained it must be by means that will not depend on our personal feelings; in other words we must have instruments. It is the purpose of this book to describe these instruments, to tell us how to use them and to keep the record of their doings, but before doing so a brief account of the different elements which constitute the weather and the principles involved in forecasting will be given.

Composition of the Air

The medium in which the weather processes operate is the air we breathe; it is composed of about four parts of nitrogen and one part of oxygen with small quantities of rare gases and some water vapour, and our instruments are required to register its doings.

Temperature

Temperature, as we all know, is associated with heat and cold, but as cold simply means that a body contains less heat than when it is hot we may consider that when we are dealing with temperature we are, in reality, dealing with heat. Now we know that heat is one of the great factors in our weather and it is important to understand the ways and means by which it can be transferred from one place to another. Actually there are three ways in which this transfer can take place.

First it can be transferred by one particle getting hot and heating its neighbour which in turn heats its neighbour and so on; as for example when one end of a poker is put into a fire; in a short time the end in the hand begins to get warm by the particles heating their neighbours but the particles themselves do not change their position in the poker; in this case the heat is said to be transferred by conduction.

In the second case the heat is transferred by the particles themselves; a room heated by a hot air furnace is an excellent example; here the air is heated by the furnace and rises through the pipes to the rooms which are thereby heated. In this case the rooms are heated by the transference of the hot air from around the furnace to the room, and the principle is known as convection.

The third method is quite different from the other two and can best be explained by an example; thus if you stand before a good fire you soon feel yourself getting hot but the heat is not brought to you by any particles of matter; in fact there does not appear to be any medium by which the heat is brought to you and we simply say that the transfer takes place by radiation. Light is transferred in the same way and in both cases we say that the heat and light are transmitted as radiant energy. The sun which gives light to the world also gives heat and is in fact the only source from which sufficient heat can be obtained to warm the earth. The heat is transmitted as radiant energy which on striking the earth is absorbed and the earth is thus warmed. Radiation thus plays the predominant role in the transfer of heat to the world.

By means of convection the winds transport warm or cold air from one region to another, and this is a very important factor in the distribution of heat throughout the globe. The radiant energy striking on the earth's surface warms it and the warm winds blowing over the surface also warm it but in order that the heat may penetrate into the earth or body it must be conducted from one layer to the next so that conduction enables the heat to penetrate into the earth. All three methods of heat transfer are thus employed in nature on a large scale.

While the earth is absorbing radiation from the sun during the day it is also giving out radiation to space and as soon as the sun goes down and no more radiation is coming to the earth the outward radiation begins to cool the earth. Cooling in this way is most intense during clear nights, especially in winter when the nights are much longer than the days; but on cloudy nights the outgoing radiation from the earth is absorbed by the clouds and the clouds radiate back to the earth so that the actual amount of radiation leaving the earth is very small and there is in consequence very little cooling. Thus there is radiation going on all the time—inward to the earth and outward from the earth. During the day the amount received by the earth is greater than that given off so that the earth is warmed, but during the night the outward radiation is greater than that received and the earth is in consequence cooled. This transfer of heat both ways by radiation enables a balance to be maintained so that the earth does not become overheated or supercooled.

Water Vapour

As explained in the previous section the earth receives its heat from the sun as radiant energy and this energy falls on land and water. On the land the surface is heated and this heat by conduction penetrates for some depth below the surface but when the radiant energy falls on the water surface it can both warm the water and evaporate some of it. This water that is evaporated passes into the air as vapour and the winds distribute it over the globe. This vapour is one of the essential constituents of the atmosphere as it supplies all our rain and without it the earth would be a vast desert. Evaporation is going on all the time from all the water surfaces of the globe and the heat required to evaporate the water is obtained from the water itself which is thereby cooled, from the warm air passing over and from the sun; even the ice and snow surfaces contribute a little vapour to the atmosphere so that we have at all times water in the form of vapour being taken up by the air from a very large part of the surface of the globe.

If then water is passing into the air in the form of vapour most of the time is there any limit to the amount that can pass into the atmosphere, or is it unlimited? In order to find this out it is necessary to resort to experiment and experiments have shown that the amount is very definitely limited and that the main limitation is put on it by temperature. If the temperature is low the air can hold very little vapour but if it is hot it can hold very much more. Observations show that 1,000 cubic feet of air at freezing point, 32°F. can hold about 5 ounces of water vapour, while at 80°F. it can hold about 25 ounces. On the other hand at 0°F. it can hold only an ounce. Experiments have thus shown that the amount of water vapour that the air can hold increases very rapidly with temperature and in the economy of nature this is of great significance.

When the air has all the moisture it can hold for any temperature it is said to be saturated for that temperature but should the air be heated by some means without the addition of any more water vapour it will no longer hold all the moisture it could and so will cease to be saturated. Thus in the example just quoted if the air were saturated at 32°F. and then warmed to 80°F. without the addition of any more water vapour it would only contain 5 ounces of water vapour per 1,000 cubic feet instead of 25 ounces which it could hold. In this case we would say that the air was very dry at 80°F. but very damp at 32°F. There are thus two factors that determine the state of the air as regards its dryness or dampness and they are the temperature and the amount of water vapour. As these two factors are very variable we have all degrees of saturation from exceedingly dry to complete saturation and it is necessary to have some simple means of expressing the degree of saturation. For this purpose it has been found convenient to define the water vapour in the air as the humidity and to express the actual amount of water vapour in the air as the fraction of what it could contain if the air was saturated for that temperature. This fraction thus gives the relative amount of water vapour (humidity) in the air compared to what it could contain if the air were saturated and is called the relative humidity. In the example already quoted if the air held 5 ounces per 1,000 cubic feet at 32°F., the fraction of the amount it could hold at 32°F. would be 5/5 or 1 while if it contained only this amount at 80°F. the fraction would be 5/25 or 1/5. In the former case the relative humidity would be one and in the latter a fifth but meteorologists abhor fractions and in order to get rid of them the values are multiplied by 100. Thus in the first case the relative humidity would be 100 and in the latter only 20. In this way fractions and decimals are avoided.

When the air contains very little moisture or the relative humidity is very low and the air in consequence very dry we all know how wood dries out; this is especially true in our houses in the winter and is perhaps best exhibited by oak furniture or floors; the floors dry out and the cracks or joints open up but in the summer when the relative humidity is high the oak floors swell up and often expand so much that they are raised up by the expansion. Now how is it that the wood swells up in this way? There has been no water put on it and yet the wood behaves as if there had been; it can only be that the wood takes up the moisture from the air on account of the increase of relative humidity and swells up in doing so. Experiments have shown that most dry woods have the property of being able to take up moisture when the relative humidity increases and to give it up or dry out when the relative humidity decreases; in fact experiments have repeatedly shown that there is a definite amount of moisture in the wood for a definite relative humidity so that there is a balance between the relative humidity and the amount of moisture in the wood. Bodies that possess this property of giving out or taking up moisture with changing humidity are said to be hygroscopic and it is found that most dry vegetable substances have this property. Moreover it has just recently been discovered that this property possessed by vegetable matter plays a very important role in nature and it is a great factor in forest fire hazards. The seriousness of a forest fire depends largely on the quickness with which the material will burn after the fire has been applied to it. We know that if the wood is wet that it is very difficult to get it to burn and that it has to be dried out first. On the other hand if the wood is dry it takes fire much more easily and the drier it is the more easily and readily it burns. The dead wood, humus, etc., on the forest floor are hygroscopic and take up and give out moisture as the relative humidity increases and decreases; if then the relative humidity becomes very low the material will get very dry and experiments have shown that when the relative humidity falls below a certain point this material becomes so dry that it will take fire without further drying. That is it begins to burn just as soon as the fire touches it. All the serious forest fires have invariably been associated with exceedingly low humidity conditions. These humidity conditions with high winds cause the fire to spread with extreme rapidity and produce an uncontrollable fire. Relative humidity has thus a new role in meteorological observations, and it is of the greatest importance that observations for the relative humidity should be taken with great care.

So far we have been considering the means by which water vapour passes into the atmosphere and its importance in weather conditions. Now the next problem that requires consideration is the mechanism by which vapour is reconverted into water; this involves changing it from a gas to a liquid. This is generally considered to be a very simple and easy problem; it was explained in a previous section that the amount of vapour that the air can hold depends on its temperature and the colder the air the less the vapour that it can hold, so that it would appear that by simply cooling the air the vapour will reappear in the form of water drops. When this was tried in the laboratory by putting air from the room into a closed vessel containing some water and then by suddenly cooling it a thick fog was produced. But if after allowing the fog to settle and the air to become clear the experiment was repeated it was found that the fog was not so dense and that after several repetitions it was not possible to obtain any fog unless the air was cooled very many degrees below the saturation point. If now some of the air from the room was mixed with that in the vessel and the experiment repeated fog was again produced but as before after several repetitions fog could not be obtained. The experiment has been repeated many times and in many places and the result has always been the same. The air being in a closed vessel over water was always saturated with water vapour so that there must have been something in the air which the fog on settling down removed and when it was all removed it was no longer possible to produce fog. We know of course, that the air contains many dust and smoke particles and experiments have shown that by completely removing them with a filter before letting the room air enter the closed vessel no fog could be obtained by suddenly cooling the air. We naturally conclude therefore that the vapour must condense on the dust and smoke particles and when these are absent fog cannot form. It has also been discovered that there are small electrified particles in the air called ions, and that by cooling the air until it has four fold saturation (that is when it holds four times as much vapour as it can ordinarily hold at that temperature) that the vapour condenses on the ions. All these particles, dust, smoke, ions, etc., on which the vapour condenses are now called condensation nuclei. Experiments have thus abundantly demonstrated that in order to convert the vapour into the liquid state it is necessary to have dust (condensation muclei) in the air and some cooling process. The laboratory experiments on producing fogs also showed that at first the fog produced consisted of very many very small particles and that on each repetition of the experiment the fog particles became larger and larger until when they were few, the drops became large enough to fall as fine rain.

If now the air has been cooled by some process the water vapour will condense on the dust particles and naturally the more numerous the dust particles the smaller will be the diameter of the droplets formed, while if the dust particles are few the droplets will be much larger.

The experiments on the production of fog or clouds have indicated that various degrees of cooling are necessary in order to cause the vapour to condense on the condensation nuclei and as we know the fog appears with very little cooling below the saturation point, it must be only the most efficient fog producing nuclei that take part in the process. An examination of the nuclei has fairly well demonstrated that it is the hygroscopic particles in the air (particles that absorb moisture with increasing humidity and swell up, or salt particles) that take up moisture; and as soon as the air reaches its saturation point the water vapour can condense on these nuclei and produce fog. Once fog is formed it is easier for the moisture to condense on the fog particles because they are larger, than on the dust particles that are still in the air, so that the latter probably take no further part in the operation.

Some people, in ignorance of the forces and process necessary to produce rain, are frequently putting forward all sorts of fantastic schemes for assisting nature in producing rain. Many of the most widely advertised schemes involve getting more dust or electrified particles in the air in the region of the cloud, fondly imagining that by getting more nuclei on which vapour could condense that rain would be produced even if there was no supply of water vapour. The utter absurdity of all such schemes is abundantly evident from the explanation given of the function of nuclei in producing condensation. In fact there would be more hope of success if most of the condensation nuclei could be taken out of the air, and then larger drops could be formed on the remainder. Fog or cloud particles are very small and contain very little moisture, in fact if all the fog particles could be collected from a dense cloud 800 feet thick there would only be a layer of water a hundredth of an inch deep, about enough to make a heavy dew.

Having discussed the mechanism by which water is converted into vapour and this vapour reconverted into water, we shall now consider the processes that bring about this reconversion and the forms (dew, hoar frost, mist, fog, cloud, rain, hail, sleet and snow) in which the vapour reappears.

Dew and Hoar Frost.—Dew, as we know, is usually deposited on grass, leaves, etc., on calm, clear nights, and is caused by these objects radiating their heat to the sky and thus becoming colder than the saturation point of the surrounding air, which on coming in contact with them is cooled below the saturation point and the excess moisture is deposited as dew. The same action is seen when a glass containing ice cold water has moisture condensing on its sides. Dew does not usually form when there is much wind, as there is then so much mixing of the air that it does not remain in contact with colder objects long enough for moisture to condense on them, nor does it form on cloudy nights because, as explained on page 2, there is very little cooling by radiation.

Mist and Fog.—The only difference between mist and fog is one of degree, the mist being thin and fairly transparent and the fog thick and hard to see through. In both cases the air has to be cooled, generally locally, until it becomes more than saturated with moisture, the excess vapour attaches itself to the hygroscopic nuclei present in the air and appears as fog or mist. If the cooling is very little more than sufficient to produce saturation, mist will likely be formed, as there will be few and very fine fog particles produced, but if the air is cooled below its saturation point many more and larger particles will be formed, the Scotch mist being the most pronounced example in which the cooling is sufficient to produce fog particles that can fall as a slight drizzle. In this case mist or fog is produced by local cooling of the air and generally when there is very little wind.

Cloud.—We all know that the temperature decreases with height above the surface, and observations have shown that this decrease amounts to about 3 degrees per thousand feet. Consequently if the air is forced to rise by any means it gets colder as it ascends, and when it reaches the level where the temperature is below the saturation point, or dew point, as it is generally called, the vapour condenses on the nuclei present, forming small water droplets, which in the aggregate we know as cloud. Now, one would expect, as water is much heavier than air, that the water droplets would fall as rain to the earth, but instead they appear to float. If, however, we could observe them closely in still air we would find that they do fall slowly, but only about eight feet a minute, an amount so small that we could not detect it. These very tiny particles cannot fall faster on account of the resistance of the air. To us this resistance appears negligible, but, while it is small, it is by no means zero, as we know when a person falls safely to the ground in a parachute. Here the resistance of the air is so great on account of the area of the parachute that the person in it falls very slowly, and the greater the area of the parachute the slower he falls. We thus see that the greater the area of the body to its weight the slower it will fall. The same holds true as regards water drops. If a drop is divided the weight of the smaller drop is reduced more than its area and consequently the smaller drops will not fall as fast as the larger ones. A large water drop contains about eight million small cloud particles, so that their area compared to their weight is very great and consequently they fall very slowly. On the other hand, the largest water or rain drops are about a quarter of an inch in diameter and can fall about 1,500 feet a minute. As water drops are of all sizes from tiny fog particles to large drops, they will fall with velocities ranging between 8 feet and 1,500 feet a minute. If now there should be an upward wind with a velocity equal to that with which the drop falls, the drop will remain suspended in the air, while if the velocity of the air is greater than that at which the drop would fall the drop would be carried upward. It is well known that there are both upward and downward currents in the air, or vertical winds, with their gusts and lulls, just the same as in surface winds with which we are familiar.

Should there be no upward currents at the cloud level the cloud particles would fall at least 8 feet a minute, but this fall would bring them into warmer air, where they would evaporate. If there should be upward currents exceeding 8 feet a minute and at the same time spreading outward from the centre, the cloud particles are carried upward and outward, and the more moisture the air contains and the more vigorous the action the higher the cloud will extend.

Rain.—We have discussed the process by which clouds are formed and why they float in the air, and we must now consider how the tiny cloud particles grow into drops large enough to fall as rain. It has just been said there are upward currents with gusts and lulls and that they are more vigorous at times than at others. If this rising air has a velocity greater than 8 feet a minute it will carry cloud particles up with it, and as the temperature falls with increasing height more vapour will condense on these particles. The air also will be passing the particles at about 8 feet a minute, because we must remember that if the drops could fall at 8 feet a minute the upward velocity of the drop will be 8 feet a minute less than the upward velocity of the air, so the air will be flowing up past the little droplets, which will now be the condensation nuclei on account of their larger size, and the drops will grow. Many of them will unite through collision in the general turmoil that is going on and so become heavier. Then when a lull in the upward current occurs some of the larger drops will fall and being cold will condense more moisture on them, and then when the next gust occurs they will be carried up again and all the time the air is either passing by them or they are falling through it so that they are steadily growing until they become heavy enough to fall through the uprising air when they descend as rain. Thus the more vigorous the action, the larger the drops and the heavier the rain, and this process will continue as long as the cloud is fed with moist air, but just as soon as the supply stops the rain ceases.

Thunderstorms and Hailstorms.—The most vigorous action in the production of rain generally occurs with an abundant supply of moisture and produces the thunderstorm or in extreme cases the hailstorm. In this case the drops cannot get down through the uprising winds and the larger ones are broken up, so that the only drops that fall are those which are carried outward from the storm centre to a region where they can fall through the upward currents. It is the breaking up of the drops that produces the separation of electricity, one kind remaining on the drop and the other being carried outward with the air. In this way the electric charge is built up until it is so great that a discharge takes place which we know as lightning. At other times the vertical currents may be so strong that the rain drops are carried up to great heights and into a region where the temperature is below the freezing point, but in this region the drops remain liquid at first and become cooled much below the freezing point or supercooled (as it is called). Experiments show that water drops can be supercooled to 4° below zero before they become solid, but at this temperature they instantly turn into a solid which is generally whitish in appearance. This temperature of 4° below zero occurs in summer at about 20,000 feet above the ground surface, so that in hailstorms the drops are at times carried up to this height. When a lull comes in the vertical currents, just as they do in the surface winds, the drops which have now become hailstones fall; but if in falling they collide with smaller drops on the way up, the small drop is immediately converted into ice; when the hailstone reaches the region where the temperature is just above the freezing point it collides with many small drops and comes in contact with the moisture in the air, but as it is away below the freezing point these small drops and the vapour freeze on the stone as clear hard ice. If the vertical lull is again succeeded by a vertical squall the hailstone is again carried up and the same process is repeated. Now the hailstone may be carried up and dropped in succeeding squalls and lulls until it has grown large enough to fall through the uprushing air, when it finally reaches the ground. Thus the size of the hailstone is a measure of the strength of the vertical currents in the storm.

Snow.—Snow of course occurs when the temperature is below freezing and the vapour condenses, not into the liquid drops, but crystallizes into the solid form of snowflakes.

Sleet.—In America sleet is usually defined as small pellets of ice which are in reality frozen rain drops and are produced by the rain drops falling through a region where the temperature is below freezing.

Pressure

We have now to consider one property of the air which cannot be detected, except under special circumstances, by our physical senses and that is the amount of air over the place of observation. As air can be cooled until it becomes a liquid just like water it must have weight, and it has been found to be very important in meteorological work to know the weight of the air over the locality but as the air extends many miles upward it would appear to be a very difficult matter to find this out for it would really be necessary to weigh a column of air, say an inch square and reaching up to the top of the atmosphere. This obviously cannot be done directly but it can be obtained in another way. If we take a U tube (fig. 1a) and pour water into it the water will stand at the same level in both limbs but if oil is now poured on top of the water in one of the limbs (fig. 1b) then the oil and water are no longer at the same height in the limbs, but as there is no motion the weight of the liquids on the two sides of the tube must be the same so that if we take a horizontal line cd across the two limbs at the level of the water and oil then the column of oil 'h' must be balanced by the column of water 'k' in the other limb. In other words the weight of the water in the column 'k' is equal to the weight of the oil in the column 'h' since the cross section is the same so that we can find the weight of the oil by weighing the column of water 'k' that balances it. We can do the same thing with our column of air; it can be balanced against a column of liquid in a

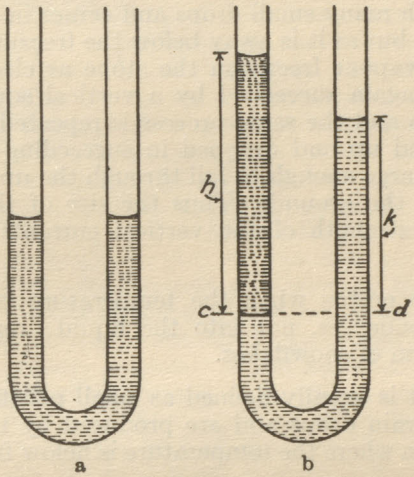


Fig. 1

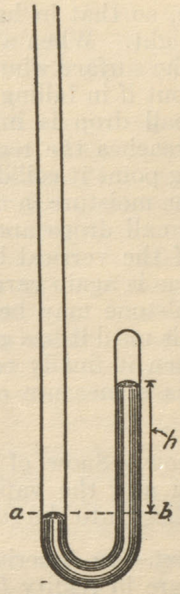


Fig. 2

U tube as shown in fig. 2. In this case, however, mercury is used for the liquid as it is the heaviest known. In this U tube it is necessary to have all the air out of one limb; this is usually done by closing the end and filling the tube full of mercury before placing it upright. Theoretically the tube containing the air should extend right up to the top of the atmosphere but as the tube is open to the air it is easy to see that this is not necessary. The mercury above the line ab must balance the column of air and consequently if the column 'h' of mercury is weighed it will give the weight of the air in an equal cross section, over the place of observation or the weight of the air above us. This weight for a unit area is called the pressure and it is measured by the instrument called the barometer. When it was discovered that the weight of the air per unit cross section above the place of observation could be obtained by balancing it against a column of mercury in a U tube closed at one end instead of expressing it as the weight of the mercury column it was given as the height of the column and hence the air pressure is measured in terms of length instead of weight. Within the British Empire and the United States the height of the mercury column is measured in inches and in most of the other countries in millimetres. Britain, however, has led the way in adopting an absolute scale for measuring pressure and according to this scale the pressure of the air on a square centimetre is called a bar; the bar is divided into a thousand parts, each of which is called a millibar, so that a thousand millibars make one bar or one atmosphere.

It has been explained by means of fig. 2 that the weight of the air column above the place of observation is balanced by the mercury column but if one were to go up into the air some distance directly above the place and repeat the experiment it would be found that the height of the mercury column would be less than before because there is less air above the new observation post than above the old one; the difference in height would be due to the weight of the air in the column between the two observation posts, and would be equal to the weight of the column of air of unit cross-section between the two places. The pressure of the air thus decreases upward and increases downward. If the difference in height between the two places is known it is possible to calculate the weight of the air in the column but as warm air is lighter than cold it is necessary to know the temperature of this air column also, as a column of warm air would weigh considerably less than if it were cold. By this means then, if the pressure is known at one station and the temperature of the air column, it is possible to calculate the pressure at the other station. On the other hand if the pressures at the two stations and the temperature of the air column are known, it is possible to calculate the difference in level between the two places. Again, if the height and the pressure are known the temperature could be calculated.

The land surface of the globe with its mountains and valleys, hills and plains, is very uneven so that if it were desired to compare the pressures at different places on this surface it could not be done directly as it is not likely that any of the places would be on the same level. The only way the pressures could be compared would be to refer them all to the same level first so that the height of the air column would be the same in all cases.

The only surface that has the same level the world over is that of the sea and consequently when it is desired to compare the pressures at different places the pressure is corrected to what it would be at the mean level of the sea if it were directly underneath the place of observation. This correction is obtained by adding to the pressure at the station the weight per unit cross-section of the column of air from the sea-level to the Station at the mean temperature of the air column (as already explained the presssure and the weight are expressed in terms of length). For this reduction each observing station is furnished with a set of reduction tables that enables the observer to reduce the pressure to that of mean sea-level.

It is necessary then on account of these variations to know the height of the barometer column accurately. We know that heat expands most substances and cold contracts them; this is true of mercury for it is on the expansion and contraction of mercury in the thermometer that the temperature is measured. If then the temperature of the column of mercury is changed, the height of the column will also be changed, so that there will be a different height for every temperature. To overcome this the height of the mercury column at 32 degrees, the freezing point of water, is taken as standard and tables are provided giving the correction that has to be applied to obtain the height of the barometer at 32 degrees. It may be stated here that the brass scale on the barometer also expands and contracts and provision has to be made for this in the correction; the brass scale is made so that it is standard at 62°F. and as a result the correction to the barometer does not change sign until the temperature has fallen to 29°F. that is above 29°F. the correction is subtracted and below 29°F. it is added. From the tables it is possible to correct the reading so as to give the true height of the barometer at 32°F.

As already stated, the pressure is the weight of the column of air or of the balanced barometer column per unit cross-section and it is found that if the same quantity or mass of mercury were weighed at the equator and at the poles the weight would be greater at the latter than at the former on account of the shape of the earth; it is thus necessary to apply a correction for what is called gravity. The weight of the mercury at latitude 45° is taken as the standard and all readings are adjusted so as to read correct at this latitude.

The observed pressure or barometer reading has thus to be corrected for temperature of the mercury column so as to read correctly at 32°F. or freezing point, for gravity and for sea level, but the gravity correction is usually embodied in the sea-level correction.

About the middle of the last century when observatories had become sufficiently numerous and the telegraph became available for transmitting messages it was found that when pressure was reduced to sea-level it not only varied upward but it also varied horizontally; with this difference however, that it always decreased upward but horizontally it sometimes increased outward from the place of observation and sometimes decreased, or it decreased in some directions

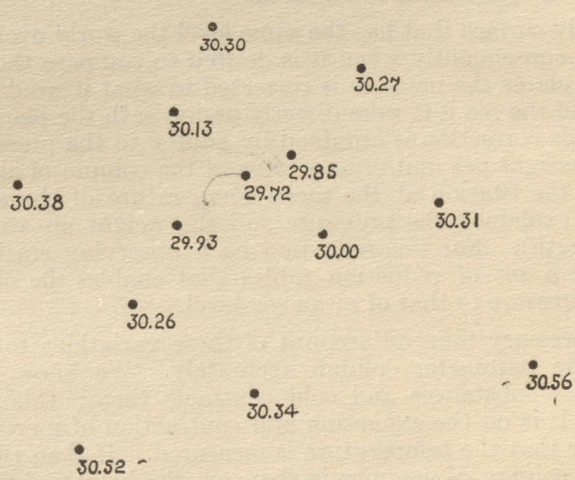


Fig. 3

and increased in others as illustrated in Fig. 3 where the mean sea-level pressures are plotted. It thus looked as if pressure variations were very haphazard and apparently without order or sequence until the meteorologists tried drawing lines through those places where the pressure was the same; in other words they drew equal pressure lines, which are now called isobars. Of course very few, if any, of the places had the same pressure but if the pressure indicated by the equal pressure line was between two stations where one had higher pressure and the other lower it was assumed that the line (isobar) would go between the two places, the distance being divided proportionally. When this was done Fig. 3 assumed the appearance given in Fig. 4 thus showing that the pressure distribution is not

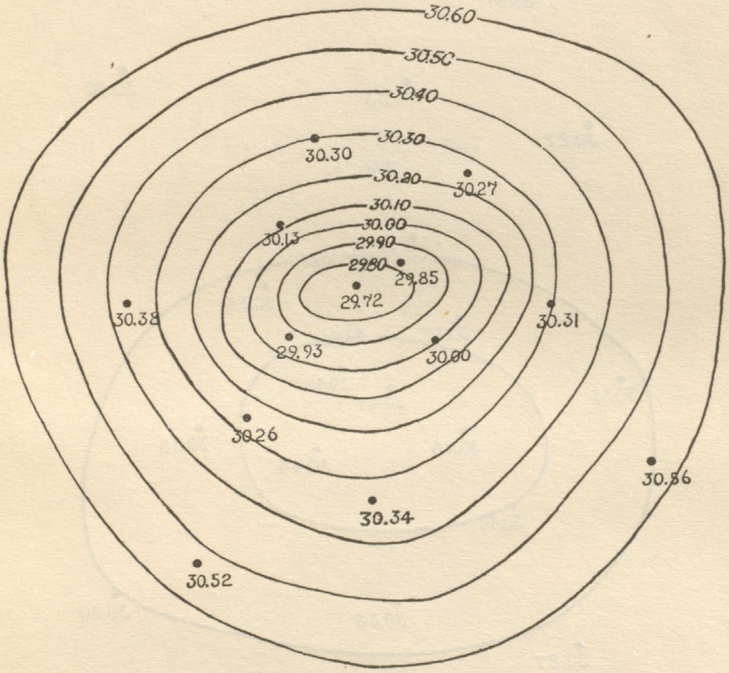


Fig. 4.

haphazard. Again these same places might have pressures as given in fig. 5 and as before by drawing the lines of equal pressure or isobars, fig. 5 is converted into fig. 6. An examination of these charts or figures shows that in the first case the pressure is lowest in the centre and increases outward, whereas in the second case the pressure is highest in the centre and decreases outward. When charts were prepared in this way it was found that these types of pressure were of common occurrence and one was called an area of low pressure and the other an area of high pressure, but even these names were felt to be longer than necessary and they are now just briefly designated as "lows" and "highs".

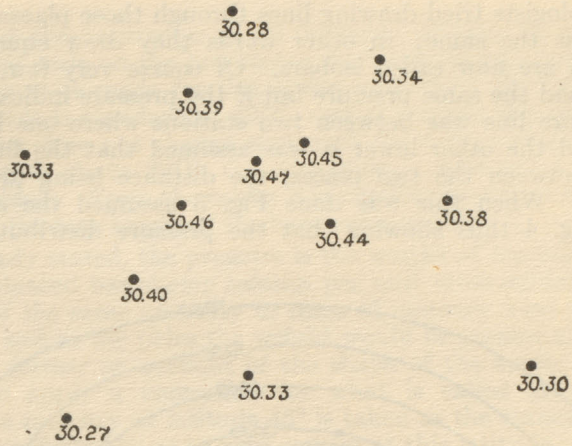


FIG. 5.

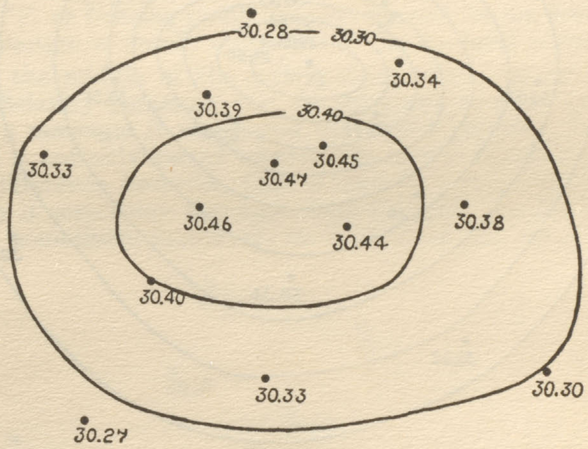


FIG. 6.

WIND

As the systems were more carefully studied and the weather characteristics plotted on the map at the same time it was found that the systems had very definite winds associated with them. Thus fig. 7 was obtained by adding the wind to fig. 4. An examination of fig. 7 shows that the winds are all cutting across the isobars and that they have a sort of spiral motion toward the centre. These winds are distributed anti-clockwise about the system, that is their apparent direction of rotation is opposite to that of the hands of a watch. On adding the winds to fig. 6 to obtain fig. 8 it was found that in the case of the high the motion was reversed as would be expected and the winds were blowing outward clockwise, but again they were across the

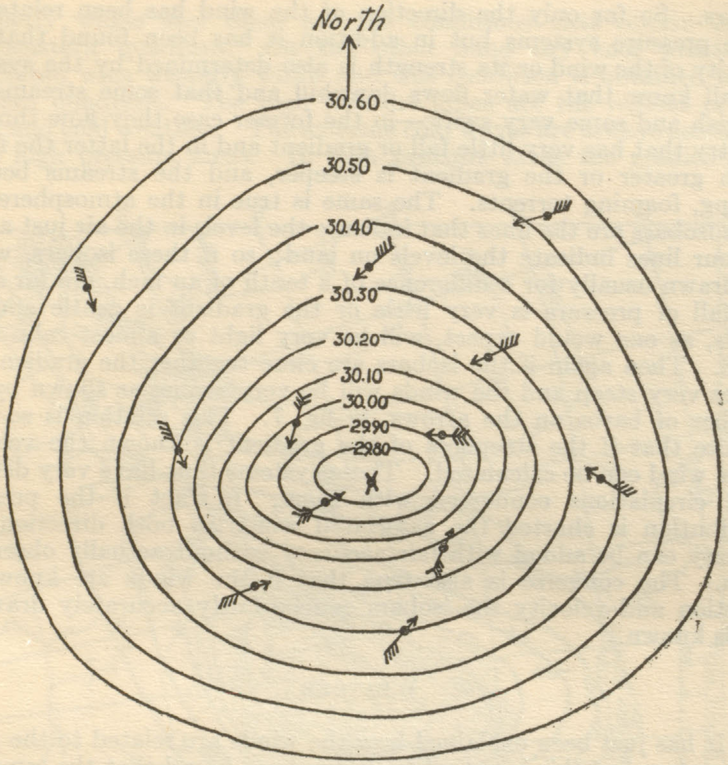


FIG. 7.

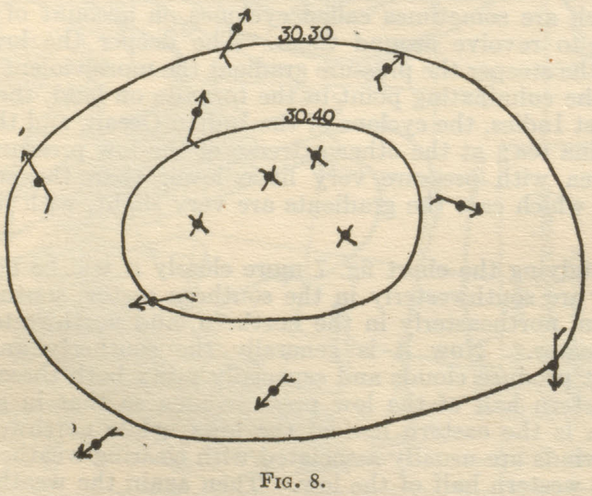


FIG. 8.

isobars. So far only the direction of the wind has been related to these pressure systems but in addition it has been found that the velocity of the wind or its strength is also determined by the system. We all know that water flows downhill and that some streams are sluggish and some very swift;—in the former case they flow through country that has very little fall or gradient and in the latter the fall is much greater or the gradient is steeper, and the streams become roaring, foaming torrents. The same is true in the atmosphere and these isobars are the lines that indicate the levels in the air just as the contour lines indicate the levels on land; so if these isobars, which are drawn usually for a difference of a tenth of an inch, are far apart the fall of pressure is very little or the gradient is gentle and the winds, as one would expect, will be very light or almost calm as in fig. 8. Then again if the isobars are close together the gradient becomes very steep and the winds will be very strong as shown by the number of barbs on the arrows, in fig. 7. This relation is so very definite that if the steepness of the gradient is known the velocity of the wind can be calculated. These systems thus have very definite wind circulations connected with them. In fact if the pressure distribution is charted the associated winds in both direction and velocity can be added with fair accuracy without actually observing them. The converse is also true that if the winds are known in direction and velocity the isobars can be fairly accurately drawn if one is known.

Weather

It has just been explained how the winds are related to the pressure system but this is not all for it has been found that the temperature, clouds, rain and weather are also closely connected with the pressure distribution. All storms are associated with low pressure areas which are sometimes called cyclones on account of the winds appearing to revolve around them. The deeper the low pressure area, *i.e.*, the steeper the pressure gradient the more violent the storm, reaching the culminating point in the tornado on land, the hurricane of the West Indies, the cyclone of the Indian Ocean, and the typhoon of the China sea; at the other extreme of the low pressure area is a central area with pressure very little lower than the surrounding regions in which case the gradients are very slight, with little if any wind.

On studying the chart fig. 7 more closely it will be noticed that the winds are southwesterly in the southern sector, southeasterly in the eastern, northeasterly in the northern, and northwesterly in the western sector. Now it is generally the southerly and easterly winds that produce clouds and especially rain; both these winds are on the eastern half of the low pressure area so that in general the rainy area is the eastern half of the lows, while northwesterly and westerly winds are usually associated with clearing weather and they are in the western half of the low. Then again the weather is often sultry, muggy, moist and hot in summer or warm in winter with southerly winds and these are the conditions that obtain in the southeastern quadrant. On the other hand dry cool weather is associated with westerly winds and this condition is obtained in the western quadrant. The high pressure areas are the regions of fine, clear and cold weather. The extreme cold waves are always associated with high pressure areas. In high pressure areas the gradients are

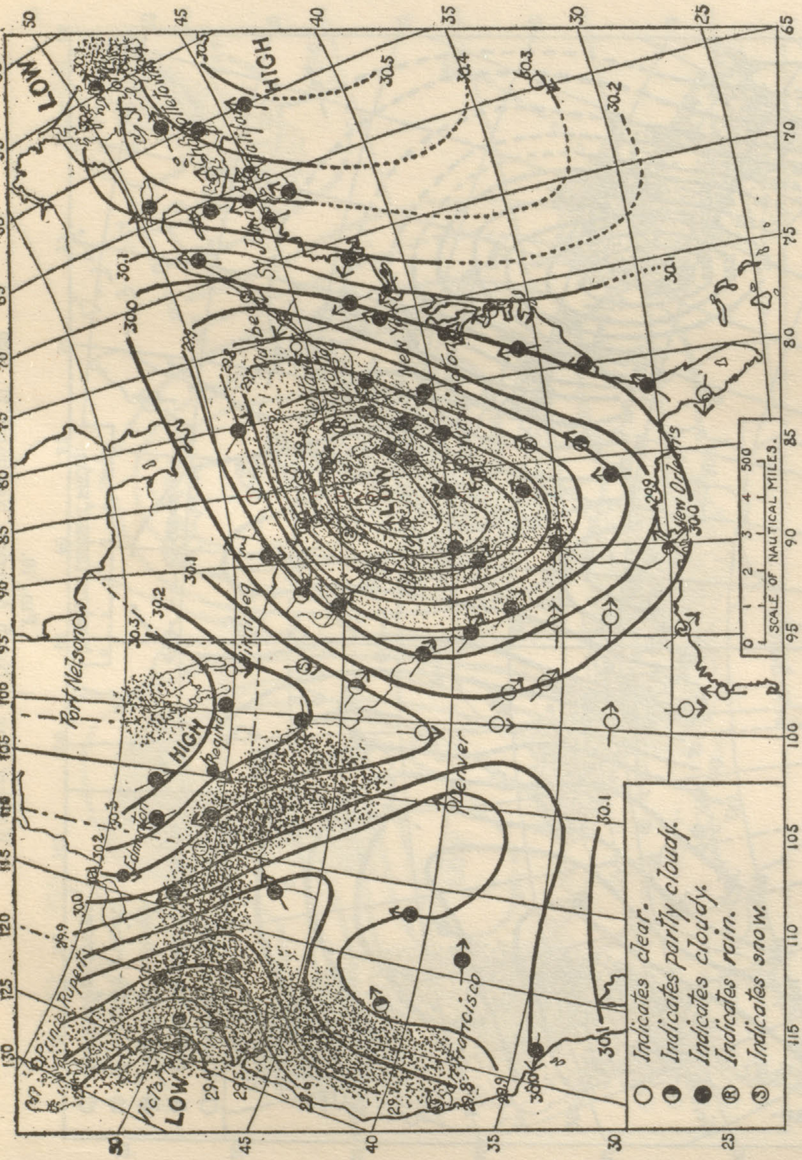


Fig. 9.
Weather Map of North America, November 26, 1926

always very slight and the region is one of calms. Thus if the pressure distribution is known the weather is also known for the region.

Weather Maps.—So far we have been examining the two pronounced types of pressure distribution and the weather associated with them but before we can make any use of them it is necessary to see what happens to the systems from day to day. For this purpose

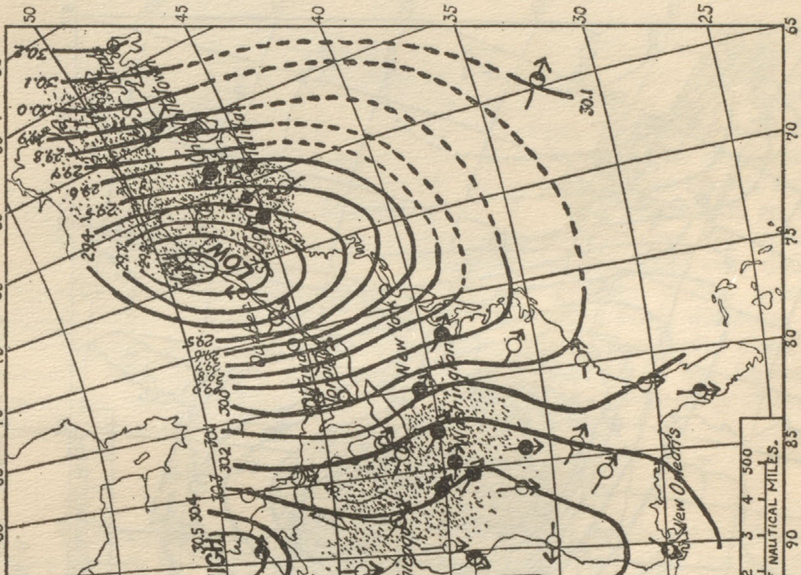


Fig. 10.
Weather Map of North America, November 27, 1926

actual weather maps for North America for November 26, and 27, 1926, are reproduced in figs. 9 and 10. They show that on the 26th a very pronounced low was centred near Chicago with high pressure over the Canadian West and off the Atlantic coast. By the following morning the low had moved to the mouth of the St. Lawrence and the high pressure had moved southeasterly. The dotted areas indicate

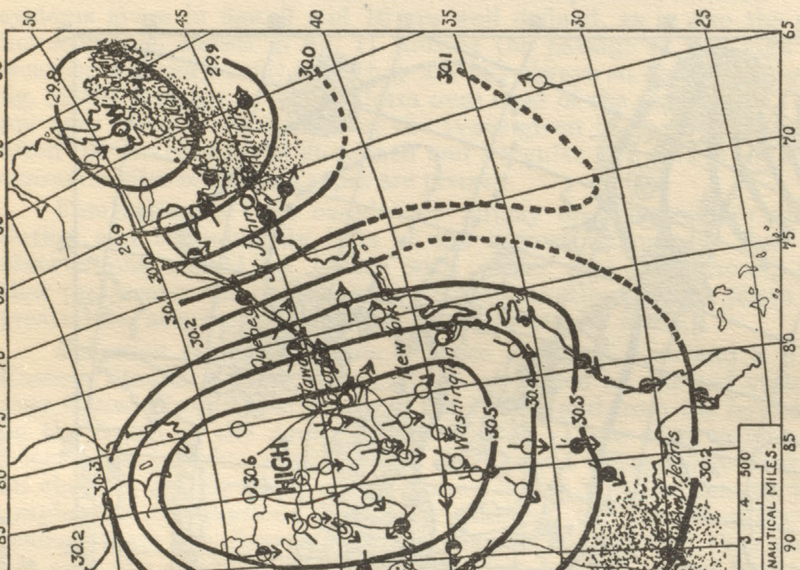


FIG. 11.
Weather Map of North America, March 5, 1926

the regions where rain or snow had fallen during the previous twenty-four hours. It thus seems that these areas move or in other words these systems are great tourists, regular globe-trotters, and they exhibit all the types, varieties and vagaries of the tourist; sometimes they linger long until we long for them to pass, and again they rush by with the speed of an express train. Now the forecaster's problem

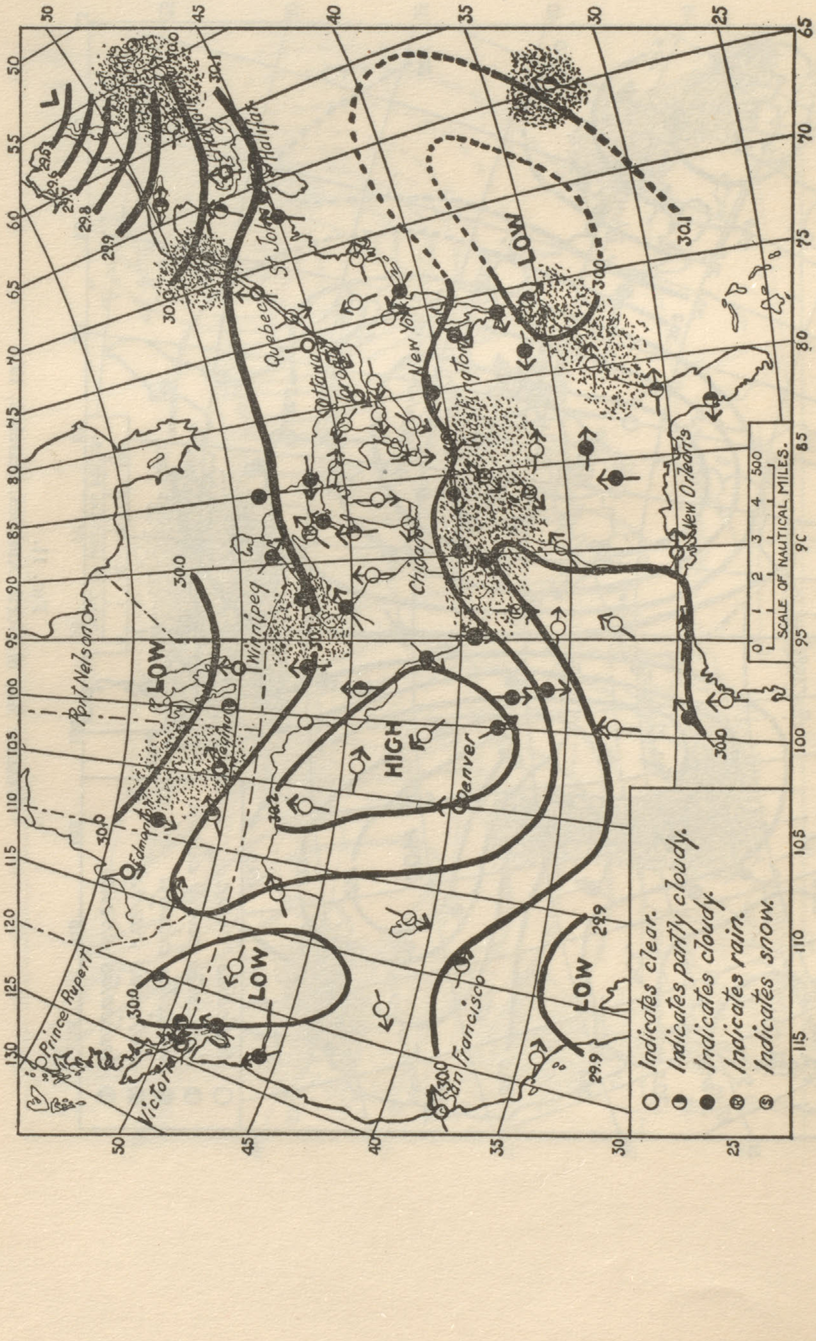


Fig. 12.
Weather Map of North America, August 17, 1923

is to foresee what is going to happen to these systems, how are they going to behave and what they are going to do. If he can forecast these he can make an accurate prediction of what the weather is going to be but at times they do not behave as expected. It may be that the indications are for them to travel with a certain velocity and in a certain direction but instead they move at a different rate and in a different direction and the forecast is in consequence incorrect. The systems given in figs. 9 and 10 are well defined, as is also the pronounced high shown in fig. 11 (during the passage of this high the weather was very cold), but they are not always so definite, thus, in fig. 12 the pressure is very uniform over most of the continent. There are very many variations from the types given in these figures, and often the distribution is ill-defined and irregular but always the main characteristics of the two types are present.

Forecasting is thus based very largely on the pressure distribution and consequently it is of the utmost importance that the observations should be taken with great care. It shows, too, that the greater the region over which observations can be taken the greater the accuracy with which forecasts can be made.

Collection of Weather Data.—Twice a day, 8 a.m. and 8 p.m., Eastern Standard Time, observations are taken at selected stations over Canada from the Atlantic to the Pacific and from the boundary on the South to the Arctic on the North. These observations are telegraphed by wire or wireless to the Central Office, where they are all charted, and in addition the United States Weather Bureau telegraphs the observations from their stations, the Canadian Service sending them the observations from Canada. The chart thus shows not only the weather map for Canada but for the United States as well. The preparation of a weather map or the issuing of a forecast is thus not the work of a single individual or a Central Office, but it is the work of a vast organization and each observer in that organization is an essential part of the system; especially is this true of the observers who are at the outposts of civilization, for it is from them that the first indications of weather changes that often seriously affect the whole continent are received. This opportunity is taken to express to them our appreciation of the faithful service that they are rendering.

Units

Meteorological measurements in most of the English-speaking countries are made in an arbitrary system of units comprising: the inch of mercury, the degree Fahrenheit, a mile per hour, and an inch of rainfall, and for all practical purposes these units are just as convenient or more so than an equally arbitrary system, comprising the millimetre of mercury, the centigrade degree, a metre per second or a kilometre per hour, and a millimetre of rainfall, in use in all but the English-speaking countries.

In recent years, the exploration of the upper air and the international exchange of meteorological information have accentuated the demand for an international system of units that will obviate the necessity of changing the units from one arbitrary system to another. Fortunately in Canada and the United States, the same units are in use, but with the development of world maps and the international exchange of meteorological information, both systems have to be used.

The only truly scientific system of units is that based on the centimetre (length), gramme (mass), second (time), and is called the C.G.S. system. It is the system used for electrical and magnetic units and most suited theoretically for meteorological work; it is now used in all upper air investigations and is in partial use in Britain.

It has already been explained that the pressure of the air is the weight of the air per unit section over the place of observation and instead of measuring it in pounds per sq. inch, it is measured as a length; if, however, we express this height of the mercury column in our absolute system of units (C.G.S.) we find that the standard barometer which is taken as 30 inches is 1,105,900 dynes per square centimetre where the dyne is the unit of pressure in the C.G.S. system. This number, fortunately, is so near one million that meteorologists have decided to define the standard atmosphere or barometer as one million dynes per sq. centimetre and call it "one bar." The bar for practical purposes is divided into a thousand parts, each part being called a millibar. There are thus a thousand millibars in a bar or a standard atmosphere. One millibar equals 0·029 inch of mercury. This unit is in world-wide use for observations in the upper air and is in use in the British Isles for the surface observations. The barometers that are now being used in Canada have this scale in addition to the standard inch scale.

The unit for temperature in English-speaking countries is the degree Fahrenheit in which the freezing point of water is 32 degrees and the boiling point 212 degrees. In countries using the metric system the degree centigrade is used in which the freezing point is 0 degrees and the boiling point 100 degrees. In Canada in the winter temperature is generally below the freezing point, so that if the centigrade degree were in use most of the temperatures recorded would be below zero and thus have to be indicated by negative or minus signs. In the Fahrenheit scale the temperature only goes below zero occasionally in some parts of Canada and generally in others for part of the year, so that the negative signs have to be used freely but not to the same extent as in the centigrade scale. When the meteorologist desires to use these quantities in mathematical equations, he cannot do so because the units are again arbitrary and in order to introduce them he has to change them into an absolute system. In this system the freezing point of water is 273 degrees and the boiling point of water 373 degrees. This is an unfamiliar unit to the vast majority of people, but it has the great advantage that it has no negative numbers and is the proper system to use for scientific purposes; it is known as the absolute or tercentesimal scale.

The velocity of the wind is usually expressed in English units in miles per hour, or in feet per minute or feet per second as alternative methods, while in the metric system the velocity is usually expressed as metres per second or kilometres per hour. A metre per second is 2·24 miles per hour. In the absolute system the velocity is expressed as metres per second.

Rainfall is measured in English units in inches and in the metric and absolute in millimetres.

We have, thus, the three systems of units:—

—	English	Metric.	Absolute.
Pressure	Inches of mercury	Millimetre of mercury	Millibar
Temperature	Fahrenheit	Centigrade	Tercentesimal
Wind	Miles per hour	Metres per second	Metres per second
Rainfall	Inches	Millimetres	Millimetres

CHAPTER I

MERCURIAL BAROMETER

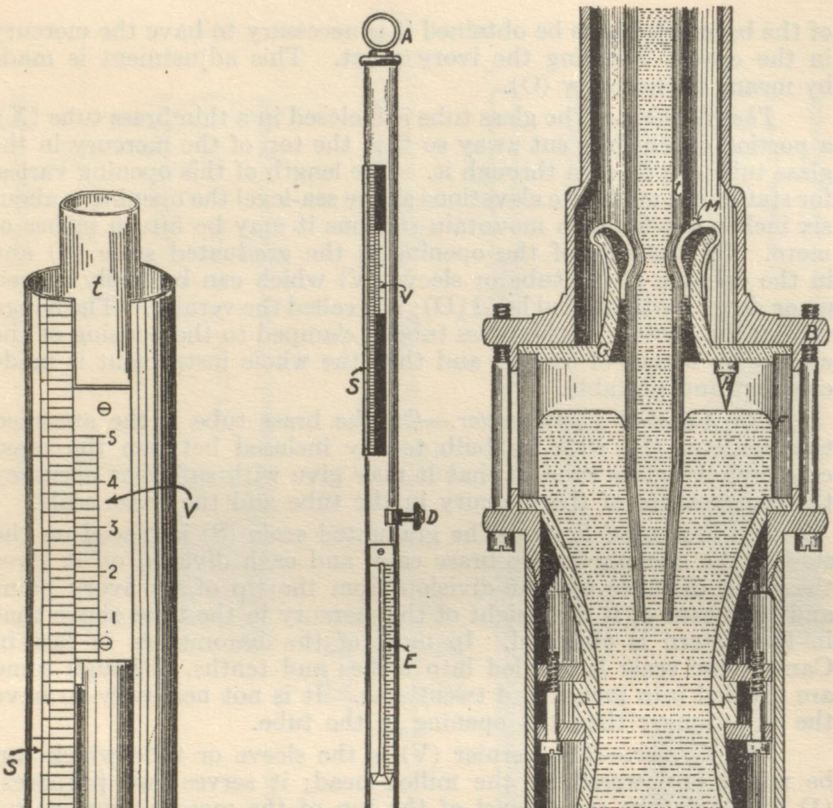
As already explained the pressure of the air is measured by the height of the mercury column in a barometer, the essential features of which are (1) a glass tube filled with mercury and dipping into a cistern of mercury, (2) an accurate means of measuring the distance between the top of the mercury in the cistern and in the tube, and (3) a suitable housing to protect the glass tube and make the barometer portable. The two designs that fulfil these conditions and are in most common use are known as the Kew and the Fortin.

The principal parts of the Fortin barometer are: the glass tube, the cistern, ivory point, housing, graduated scale, and vernier. (See fig. 13.)

The Glass Tube.—The glass tube (t), fig. 13, is about 33 inches long, a quarter of an inch inside diameter, closed at one end and the other drawn down until the opening is less than an eighth of an inch in diameter. This tube has to be filled by a special process with pure mercury so as to ensure that the tube is free from all air and moisture.

The Cistern.—One form of cistern is shown in section in fig. 13, R and consists of a glass cylinder (F) held between two boxwood supports; the upper (G) is a disk with a hub on it through which the glass tube enters the cistern, and by means of a fine kid leather collar the tube is attached to the boxwood in such a way that the mercury cannot get through it but it allows the air to pass through and thus equalize the pressure between the outside air and that in the cistern. At the bottom of the glass cylinder are two hollow boxwood pieces joined as shown, and to the bottom is attached a kid leather bag (N). This bag has a very important function to perform as by raising or lowering it with the screw (O) the height of the mercury in the cistern can be adjusted. If the bag is raised sufficiently it will force the mercury up until it fills the cistern and the tube but in this case there is a heavy strain on the bag and the cistern on account of the height of the mercury in the glass tube and if the bag is raised too far it may burst or the mercury may be forced out through the joints. On that account the mercury should only be raised until it is about an inch from the top of the tube and the screw should not be tightened too much.

The Ivory Point.—On the boxwood disk is attached a small conical piece (H) generally called the ivory point, the technical name of which is the "fiducial point." This forms a fixed and definite point to which the level of the mercury can be adjusted and is the zero point of the scale; consequently if a correct reading



P Q R

FIG. 13.

of the barometer is to be obtained it is necessary to have the mercury in the cistern touching the ivory point. This adjustment is made by means of the screw (O).

The Housing.—The glass tube is inclosed in a thin brass tube (X), a portion of which is cut away so that the top of the mercury in the glass tube can be seen through it. The length of this opening varies; for stations at moderate elevations above sea-level the opening is about six inches but for high mountain stations it may be fifteen inches or more. On the side of the opening is the graduated scale (S) and in the opening is the tube or sleeve (V) which can be easily moved up or down by the milled head (D); it is called the vernier. The flange (B) on the bottom of the brass tube is clamped to the housing of the cistern by means of screws, and thus the whole instrument is made compact and portable.

The Attached Thermometer.—On the brass tube is the attached thermometer (E) with its bulb totally inclosed between the brass case and the glass tube so that it may give with sufficient accuracy the temperature of the mercury in the tube and the brass scale.

The Graduated Scale.—The graduated scale (S) is placed on the side of the opening in the brass case, and each division on it gives the exact distance of that division from the tip of the ivory point and by means of it the height of the mercury in the tube above that in the cistern is obtained. In most of the barometers in use in Canada the scale is divided into inches and tenths, although some are divided into inches and twentieths. It is not necessary to have the scale longer than the opening in the tube.

The Vernier.—The vernier (V) is the sleeve or tube which can be raised or lowered by the milled head; it serves two purposes: (1) to obtain the exact level of the top of the mercury surface by setting the lower edge at an exact level with the top of the mercury surface by means of the milled head (D), and (2) by means of the scale on the vernier to obtain a more exact and finer reading of the height of the mercurial column than is possible with the graduated scale on the side.

Kew Barometer

The other type of barometer, known as the Kew differs from the Fortin in that there is no adjustment of the mercury to a fixed point. As the quantity of mercury in the barometer is constant it follows that when the mercury rises in the tube it must fall slightly in the cistern. In the Fortin this change is taken care of by the device which permits the setting of the surface of the mercury in the cistern at the level of the ivory point; but when there is no ivory point provision must be made by other means to correct for the change in the level of the mercury in the cistern. In the Kew barometer the internal diameters of the tube and the cistern are accurately determined and a scale constructed that takes care of the change of the level in the cistern.

Fig. 14 gives a general view of the Kew pattern barometer; it differs from the Fortin chiefly in the cistern and the tube. The

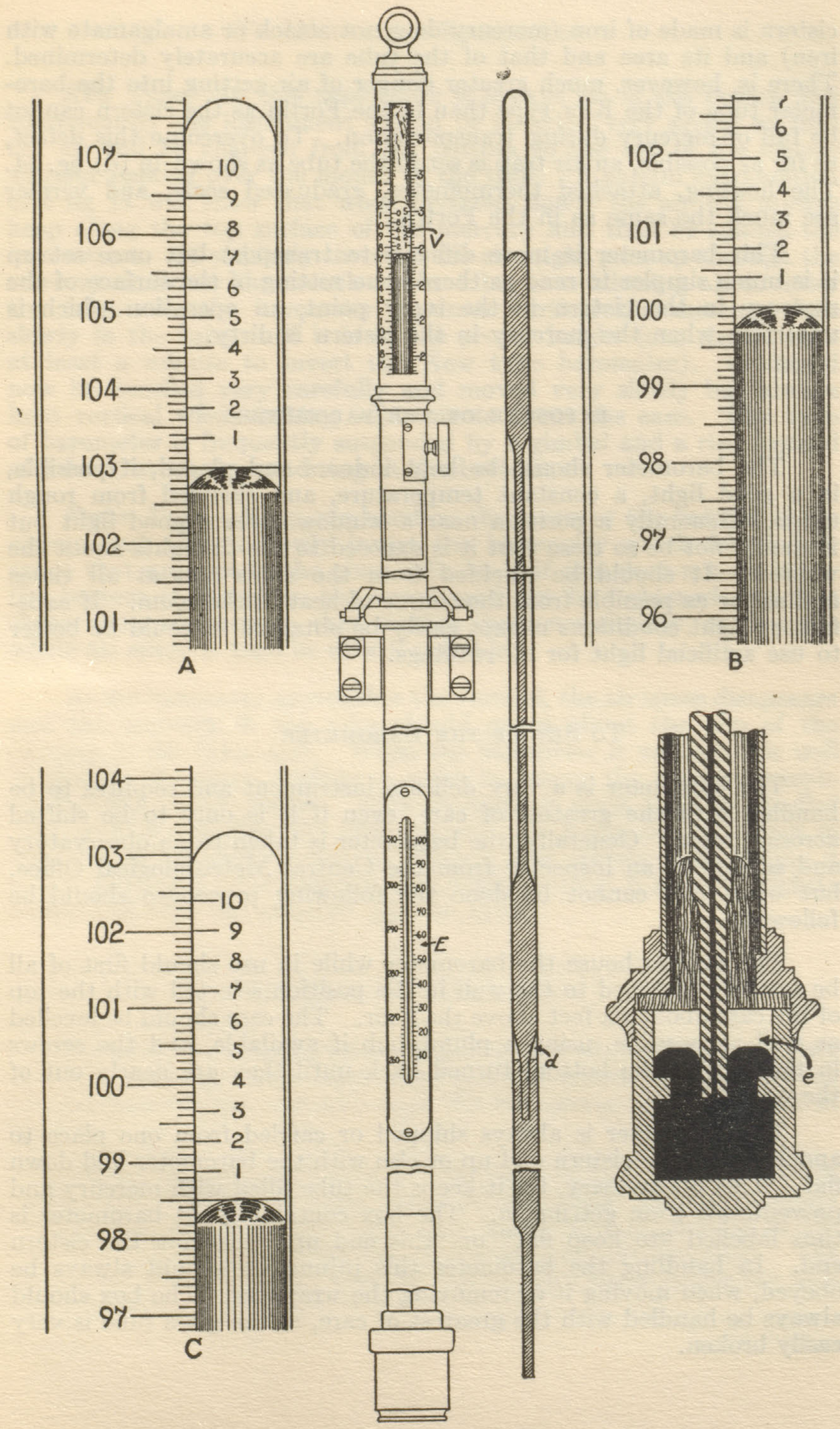


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FIG. 14.

cistern is made of iron (mercury does not attack or amalgamate with iron) and its area and that of the tube are accurately determined. There is, however, much greater danger of air getting into the barometer tube of the Kew type than in the Fortin as the cistern cannot be full of mercury during transportation. To overcome this defect, as far as possible, an air trap is set in the tube as shown in (d) fig. 14. The housing, attached thermometer, graduated scale, and vernier are much the same as in the Fortin.

This barometer is more difficult to transport but once set up it is much simpler to read as there is no setting of the surface of the mercury in the cistern to the ivory point, an operation which is uncertain when the mercury in the cistern is dirty.

EXPOSURE OF THE BAROMETER

The barometer should be kept indoors and placed, if possible, in a good light, a constant temperature, and shielded from rough usage. Generally a position near a window gives a good light but it should not be so close that it is exposed to the draughts about the window. It should be shielded from the sun's rays at all times and as far as possible from the source of heat in the room. If satisfactory light conditions cannot easily be obtained it would be better to use artificial light for all readings.

To Set up the Barometer

The barometer is a very delicate instrument and requires to be handled with the greatest of care, even if it is only to be shifted across a room. Generally, the barometer is taken to an observatory and set up by an inspector from the Central Meteorological Office, but when this cannot be done the following procedure should be followed:—

The case to house the barometer while in use should first of all be securely fastened to the wall in the position selected with the top of the case about six feet above the floor. The case should be levelled as well as possible, using a plumb-bob if available, and the screws in the ring at the bottom turned back until they are nearly out of the ring.

The barometer is always shipped or carried from one place to another with the cistern end up or else with the barometer laid down flat. This is necessary, for it keeps the tube filled with mercury and prevents air from getting in. The box containing the barometer is thus labelled "to keep flat" or "this end up," meaning the cistern end. In handling the barometer this injunction should always be obeyed, when moving it or removing the wrappers. The box should always be handled with the greatest of care, as the glass tube is very easily broken.

To Invert the Barometer

Kew Type.—In this type there is always air in the cistern and consequently the instrument should be inverted very slowly so that the air will be changed from the bottom to the top of the cistern without passing over the mouth of the tube. A careful examination of *e* fig 14 will show that when inverted slowly the air will always keep along the top surface of the mercury and thus be against the iron cistern. If suddenly inverted the air might pass up through the mercury and over the mouth of the tube, thus allowing air to enter the tube. As the barometer becomes vertical the mercury falls slowly in the tube until it is at the proper height (one should take at least a minute to invert the Kew type barometer). It should now be handled very carefully and moved very slowly but always kept vertical when making adjustments about the case. This type of barometer is frequently suspended by a gimbal and a ring instead of a hook at the top and ring at the bottom.

Fortin Type.—Keep one hand on the screw at the bottom of the cistern and as you slowly invert the barometer watch for the air space that appears in the glass cylinder. If this does not go below the bottom of the glass, the screw need not be tightened, but if it shows signs of doing so, then tighten the screw slightly, so that the whole air space is kept in view if possible.

As the barometer approaches the vertical, the air space disappears and the mercury in the tube should stand about the top of the opening in the brass case. When the barometer is vertical it is well to slacken the screw slightly in order to relieve the excessive strain on the bag of the cistern. (The barometer must now be handled very carefully so that the mercury will not pump up and down in the tube and possibly break it. This is best prevented by taking it up or putting it down slowly and when moving it have it slightly inclined so that the mercury fills the tube.)

To Hang the Barometer

Unscrew the knurled screws *a* fig. 15, out of the ring until they are flush with the inner side; then put the cistern or small rod on the bottom into the ring and hang the barometer on the bracket at the top.

If now the barometer touches the sides of the ring, remove the barometer and set it in some corner or safe place, keeping it nearly vertical, and level the barometer case by putting in packing at the top or bottom until the barometer hangs freely in the ring. The operation may have to be repeated two or three times before the final adjustment is obtained.

When the barometer is hanging freely in the ring, bring the screws in until they just do not touch the cistern, and adjust each a little nearer until they finally touch the cistern; then tighten them sufficiently to keep the barometer in position without turning when taking the readings.

If no case is supplied or available, having selected a position on the wall for the instrument, put in a screw or nail at a convenient height and hang the barometer on it. The barometer should be held rigid for ease and certainty in reading, and this may be accomplished by driving in the nail or screw until the cistern is just not touching the wall; then take two screws or 2½-inch nails and put them in one on each side of the cistern. When the instrument is finally set up tie a string criss-cross around the nail heads and in

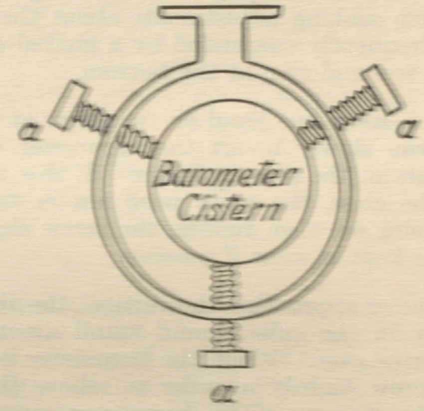


Fig. 15.

front of the cistern so that the barometer will be held rigid. Put a piece of pure white paper behind the cistern and the vernier in order to get a good surface to reflect the light.

In all these operations one should on no account drive a nail or screw with the barometer hanging on it, or beside it.

When the Fortin-type barometer is finally set up, lower the mercury in the cistern by means of the screw at the bottom until it is just below the ivory point.

Should it ever become necessary to change the position of the barometer in the house, or to move it to another building (provided it is only a short distance away) the instrument may be carried in a position slightly inclined from the upright, so that the mercury fills the tube. In this way the dangerous pumping of the mercury against the top of the glass tube is avoided.

Whenever a barometer is shifted, the date should be recorded in the record book and any change in the height of the barometer should be noted. This latter is most important, as the barometer readings change with height above sea-level and if there is a change in this height it should be determined accurately and the Central Meteorological office notified at once.

TO SET AND READ THE BAROMETER

There are four distinct operations in taking a barometer observation; they are in order:—

(1) Read the attached thermometer.

(2) *(a)* The Kew type. Tap the barometer sharply with the finger.

(b) The Fortin type. Set the ivory point or fiducial point.

(3) Set the vernier.

(4) Read the vernier.

(1) *To Read the Attached Thermometer.*—The thermometer, (E) figs. 13 and 14, attached to the barometer is read to the nearest whole degree, that is if the top of the mercury in the thermometer is nearer the upper degree mark than the lower, the reading should be that of the upper degree mark. The thermometer should be read first and before the instrument is handled because the heat from the body or other source may affect the thermometer without affecting the barometer itself.

(2) *(a) Kew type.* It is essential to tap the barometer fairly sharply with the finger before taking the reading so that it will be certain to take up its true position. The mercury adheres to the glass quite firmly at the top of the column and the pressure may change slightly before the column takes up its true position. Tapping breaks this adhesion and allows the column to take up its true height.

(b) Fortin type. To set the ivory point or fiducial point in the Fortin barometer, it is necessary to adjust the level of the mercury in the cistern until it is just touching the ivory point, (h) fig. 13; to do this lower the mercury below the ivory point by the milled head screw (O) fig. 13, then slowly raise it. The image of the point can be seen in the mercury, which is slowly raised until the two points touch. The correct setting is shown in (A) fig. 16. There are two ways in which the setting may be in error: *(a)* the ivory point may not touch the mercury and *(b)* it may extend down into the mercury. As regards *(a)* the appearance is as shown in (B) fig. 16. This incorrect setting may occur owing to the observer holding his eye too high or too low for the level of the mercury, or in a poor light. The observer should always shift his eye so as to get in the best possible position, and if using artificial light it should be shifted about also until the best illumination is obtained for seeing the ivory point; a piece of white paper at the back of the cistern helps very much in giving a good light. In the second case we have the condition shown

in (C) fig. 16; here on examining the surface carefully the observer will notice that the mercury is indented at the place where the ivory point touches it, this indentation or depression is noticeable if the point is depressed by the smallest amount below the surface. The mercury should be adjusted until it is not possible to see any depression nor to see any space between the ivory point and its image in the mercury. The final adjustment should always be made by raising the mercury. On lowering the mercury it tends to adhere to the ivory point and produce the condition shown in (D) fig. 16 before separating. On this account the final setting should always be by raising the mercury.

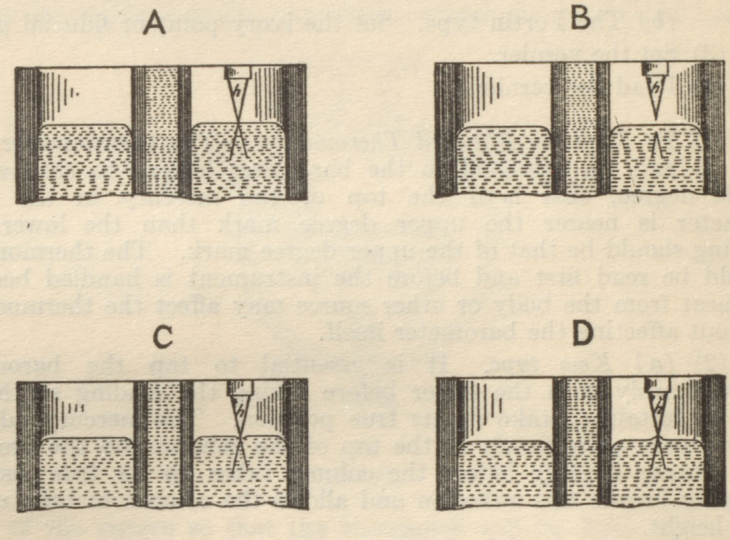


FIG. 16.

(3) *To Set the Vernier.*—The operation is the same for both types of barometer. There should be a white background for the setting of the vernier, in order to see it properly. The operation consists in lowering the vernier, (V) figs. 13 and 14, until the light is just shut off at the top of the rounded mercury column, but not at the sides as shown at (A) fig. 17. As in the setting of the ivory point, the vernier may not be lowered far enough or too far, and the former usually happens if the eye is not held on an exact level with the top of the mercury column. Thus an eye held in the position (B) fig. 17 could see no light over the top when the vernier was in the position shown, because the eye is above the level of the top of the mercury, or again an eye too low would see the light all shut off in the position (C) fig. 17. If now in the former case the eye is lowered a little, or in the latter raised, the observer would again see light over the top of the mercury column; this then gives the clue to avoiding this error in the setting of the vernier. After you think you have set the vernier

correctly, alternately raise and lower the eye a little to see that there is no light coming over the top of the mercury column; when the vernier is correctly set, it will appear as shown in (A), and the eye can see no light over the top of the column.

If now the vernier is lowered below the level of the top of the mercury column, it will shut out all light from the sides; thus in the correct setting the parts marked d fig. 17 should show light through them, but none from the top. When the vernier is pulled down too far this light disappears, so that in this case the vernier should be raised until the light appears over the top as well, and then

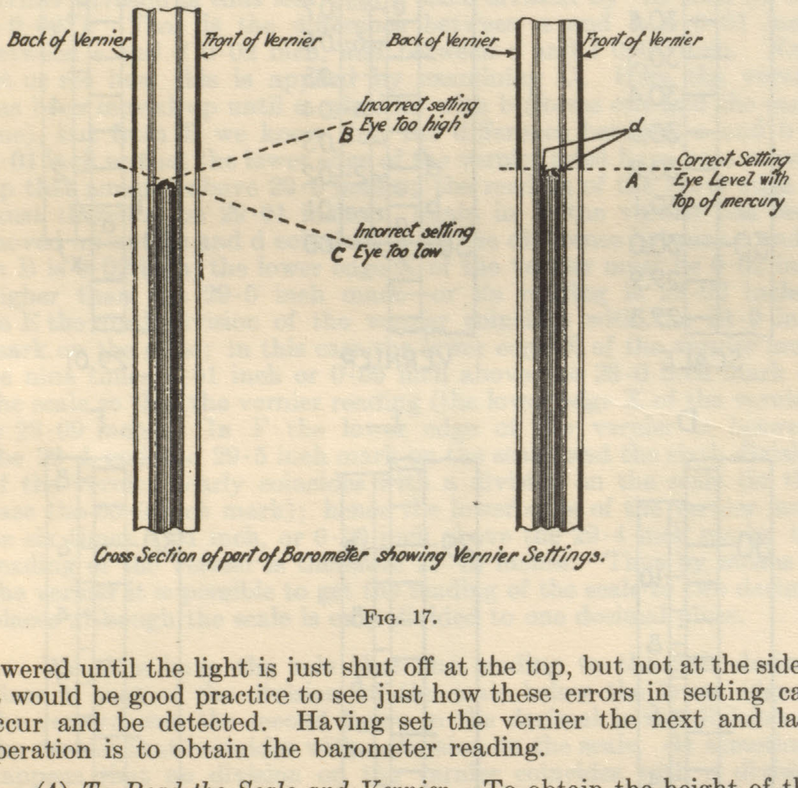
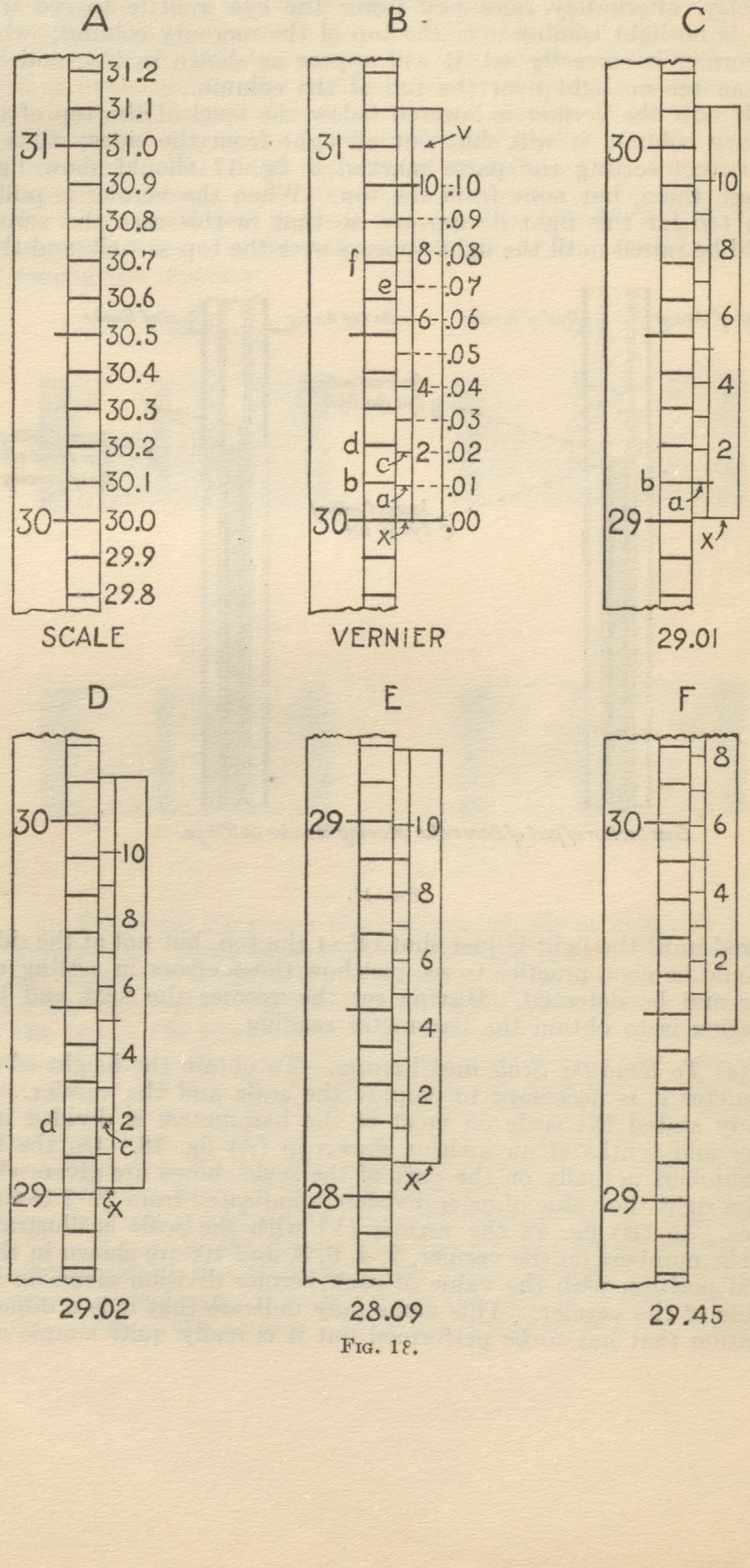


FIG. 17.

lowered until the light is just shut off at the top, but not at the sides. It would be good practice to see just how these errors in setting can occur and be detected. Having set the vernier the next and last operation is to obtain the barometer reading.

(4) *To Read the Scale and Vernier.*—To obtain the height of the barometer it is necessary to employ the scale and the vernier. As already stated the scale on most of the barometers is divided into inches and tenths of an inch as shown in (A) fig. 18. On the left the numbers actually on the part of the scale shown are given while on the right the value of each division is indicated from 29·8 to 31·2 inches. In (B) fig. 18 the vernier (V) with the scale is illustrated and the numbers on the vernier, 2, 4, 6, 8, and 10, are shown in their actual position with the value of each vernier division given on the outside of the vernier. This name may indicate that it is a difficult operation that has to be performed but it is really quite simple and



A
31.2
31.1
31
31.0
30.9
30.8
30.7
30.6
30.5
30.4
30.3
30.2
30.1
30
30.0
29.9
29.8
SCALE
B
31
V
10 .10
.09
8 .08
f
e
.07
6 .06
.05
4 .04
.03
d
c
2 .02
b
a
.01
30
x
.00
VERNIER
C
30
10
8
6
4
2
b
a
29
x
29.01
D
30
10
8
6
4
d
2
c
29
x
29.02
E
29
10
8
6
4
2
x
28
28.09
F
8
30
6
4
2
29
29.45

Fig. 18.

will be easily understood by carefully studying the various examples given in the figure.

In order to properly understand the vernier let us first of all see how the value of a vernier division is obtained. On examining B we see that the lower edge X of the vernier is exactly in line with the 30·0 inch mark on the scale and that the ten division mark on the vernier coincides (is exactly in line) with the 30·9 inch mark on the scale. Ten divisions on the vernier are thus equal to 0·9 inch; one division therefore is a tenth of 0·9 inch, or 0·09 inch; a vernier division is thus less than a scale division by ·01 inch (0·10″ −0·09″). That is the difference between a and b is 0·01 inch; between c and d 0·02 inch, and between e and f 0·07 inch. Next let us see how this is applied by examining C. Here the vernier has been moved up until a coincides with b (forms one and the same line), but from B we know that the difference between a and b is 0·01 inch so that the lower edge of the vernier must have been moved up that amount above 29·0 inches; the reading of the lower edge X must therefore be 29·01 inches. Again in D the vernier has been moved up until c and d coincide, or, as the difference between c and d in B is 0·02 inch, the lower edge X of the vernier must be 0·02 inch higher than the 29·0 inch mark—or its reading is 29·02 inches. In E the ninth division of the vernier coincides with the 28·9 inch mark on the scale; in this case the lower edge X of the vernier must be nine times 0·01 inch or 0·09 inch above the 28·0 inch mark on the scale so that the vernier reading (the lower edge X of the vernier) is 28·09 inches. In F the lower edge of the vernier is between the 29·4 and the 29·5 inch mark on the scale, and the sixth division of the vernier nearly coincides with a division on the scale (in this case the 30·0 inch mark); hence the lower edge of the vernier must be six times 0·01 inch, or 0·06 inch above the 29·4 inch mark; the reading of the vernier is therefore 29·46 inches. Thus by means of the vernier it is possible to get the reading of the scale to two decimal places although the scale is only divided to one decimal place.

We thus have the rule that the reading to the first decimal place is that of the division on the scale below the lower edge of the vernier, and the second figure in the decimal is the division on the vernier that coincides with a division on the scale. It sometimes happens that no division on the vernier coincides with a division on the scale as in F, but a close examination shows that the fifth and sixth marks on the vernier are between two consecutive marks on the scale, and in this case we take the division on the vernier that most nearly coincides with a division on the scale, or if as in the present case they are equally distant the reading can be taken as 29·455. In fact it is possible to estimate the third decimal place with fair accuracy from the position of the two marks with reference to the scale divisions.

So far we have been studying only vernier scales but we shall now take up some examples of actual barometer settings. In A, fig. 19, the lower edge X of the vernier stands on an exact level with the top of the mercury column and it is the correct reading of this edge that we wish to obtain. First we notice that the edge is between the 29·3 and 29·4 graduation on the scale and as only the partial reading is obtained from this scale we must take the lower; hence the first part of the reading is 29″·3 and to get the

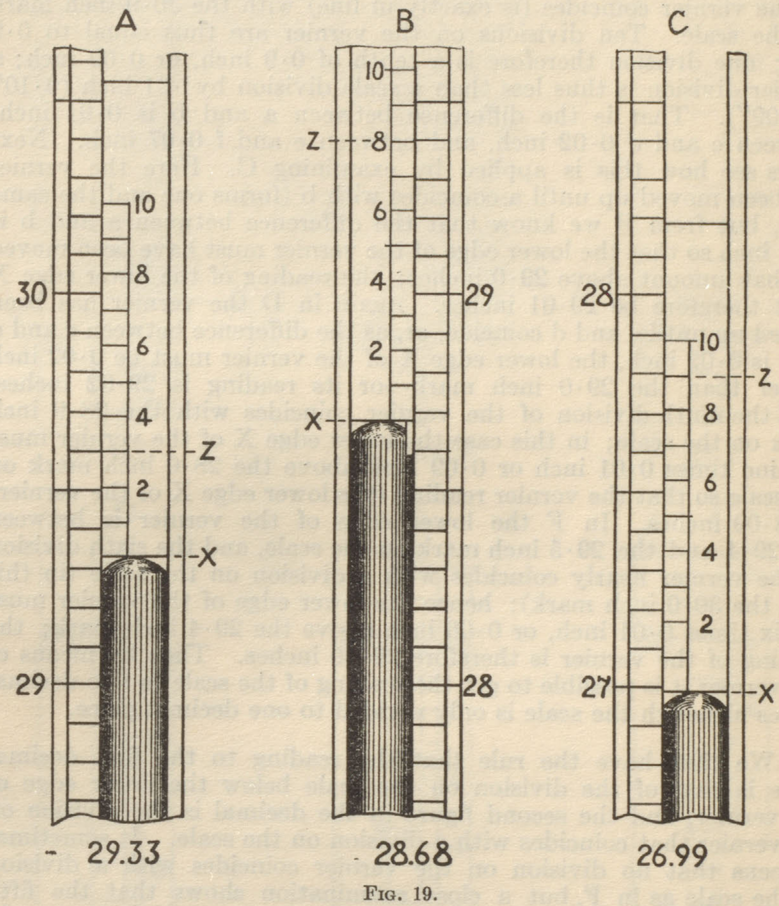


FIG. 19.

second decimal figure we use the vernier as just explained. An examination shows that the third line Z on the vernier coincides with a line on the scale; consequently the second decimal figure is 3 and the reading of the barometer is 29″·33.

In the second example, B, the scale reading is 28″·6 and the line on the vernier that coincides with a line on the scale is the eighth, Z, so that 8 is the second figure in the decimal and the barometer reading is 28″·68.

In the third example, C, the scale reading is 26″·9 but now in this case we do not have any line exactly coinciding with a graduation on the scale; we see however that the vernier division Z is nearer to being in a straight line with the upper scale division than with the lower one. This division is 9 so that the barometer reading is 26″·99.

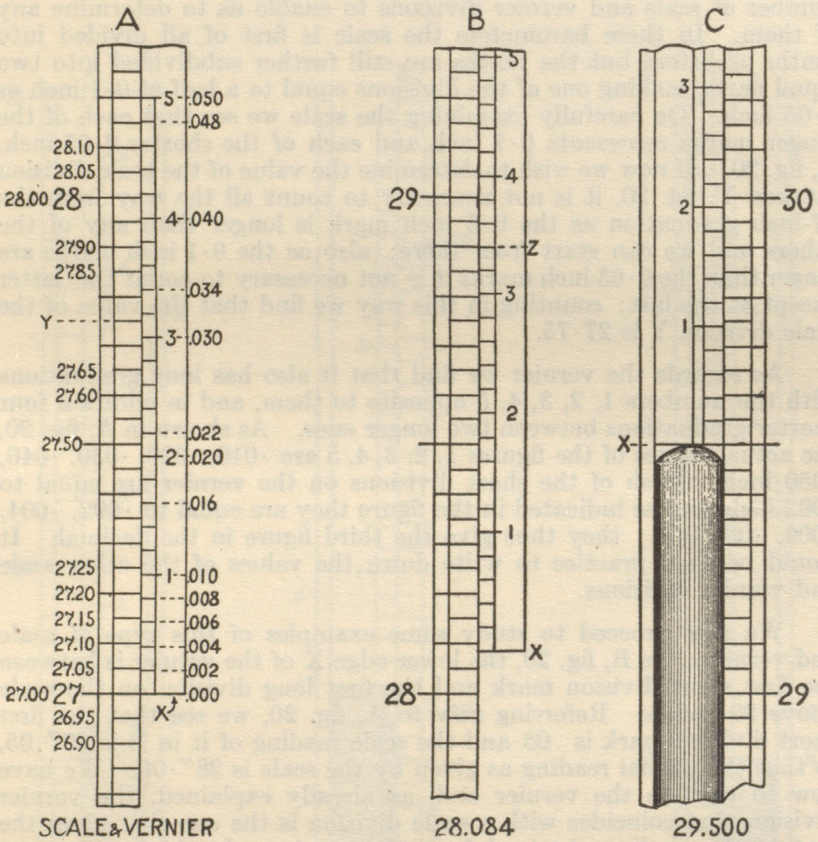


FIG. 20.

Observers often find a difficulty in obtaining the correct reading when the bottom of the vernier lies between the inch mark and the first division mark. This difficulty can easily be avoided if reference is made to A, fig. 18, and the correct value of the scale obtained from the numbers given on the side. The error that is frequently made is the omission of the "0" in the first decimal place and putting the second decimal figure for the first decimal. This could not happen if the full scale value as given in A, fig. 18, is written down before the vernier is used.

In some barometers the scale and vernier are graduated so as to read to the third decimal place instead of the second; in such cases the reading is both more accurate and more difficult; however a careful study of the following examples and a little practice will soon enable one to become quite proficient in reading this scale. In A, fig. 20, the actual numbers 27, 28 on the scale and 1, 2, 3, 4, 5 on the vernier are given and in addition the actual values of a sufficient number of scale and vernier divisions to enable us to determine any of them. In these barometers the scale is first of all divided into tenths as before but the tenths are still further subdivided into two equal parts, making one of the divisions equal to a half of 0·1 inch or 0·05 inch. On carefully examining the scale we see that each of the longer marks represents 0·1 inch and each of the shorter 0·05 inch, A, fig. 20. If now we wish to determine the value of the scale division marked Y, fig. 20, it is not necessary to count all the way from the 27-inch graduation as the 0·5 inch mark is longer than any of the others and we can start from there; also as the 0·1 inch marks are longer than the 0·05 inch marks it is not necessary to count the latter except at the last; counting in this way we find that the value of the scale division Y is 27·75.

As regards the vernier we find that it also has long graduations with the numbers 1, 2, 3, 4, 5 opposite to them, and in addition four shorter graduations between two longer ones. As shown in A, fig. 20, the actual values of the figures 1, 2, 3, 4, 5 are ·010, ·020, ·030, ·040, ·050 inch. Each of the short divisions on the vernier are equal to ·002 inch, and as indicated in the figure they are equal to ·002, ·004, ·006, ·008 inch; they thus give the third figure in the decimal. It would be good practice to write down the values of the other scale and vernier divisions.

We now proceed to study some examples of this type of scale and vernier. In B, fig. 20, the lower edge X of the vernier is between the first short division mark and the first long division on the scale above 28 inches. Referring now to A, fig. 20, we see that the first short division mark is .05 and the scale reading of it in B is 28″.05, so that the partial reading as given by the scale is 28″·05. We have now to turn to the vernier and, as already explained, the vernier division that coincides with a scale division is the one that gives the part of the reading obtained from the vernier. In this case we see that the line marked Z coincides. A reference to A, fig. 20, shows that as Z is between 3 and 4 the partial reading of the vernier must be ·030 and as each of the short divisions is equal to ·002 inch and the second one above 3 coincides its value must be ·004; this is also seen from a reference to A, fig. 20. We can now sum up our results thus:—

Partial reading obtained from the scale..........................	28″·05
First partial reading obtained from the vernier....................	·030
Second partial reading obtained from the vernier..................	·004
Vernier reading....................................	28·084

In the example of a baromter given in C, fig. 20, the scale is on the opposite side to what it was in the first two cases, but otherwise it is the same. Here we see that the lower edge X of the vernier is right in line with the 29·50 inch mark on the scale, consequently the barometer reading is 29″·50, but as these barometers read to three decimal places it is necessary to give the third figure which, of course, is '0' and the reading is 29″·500.

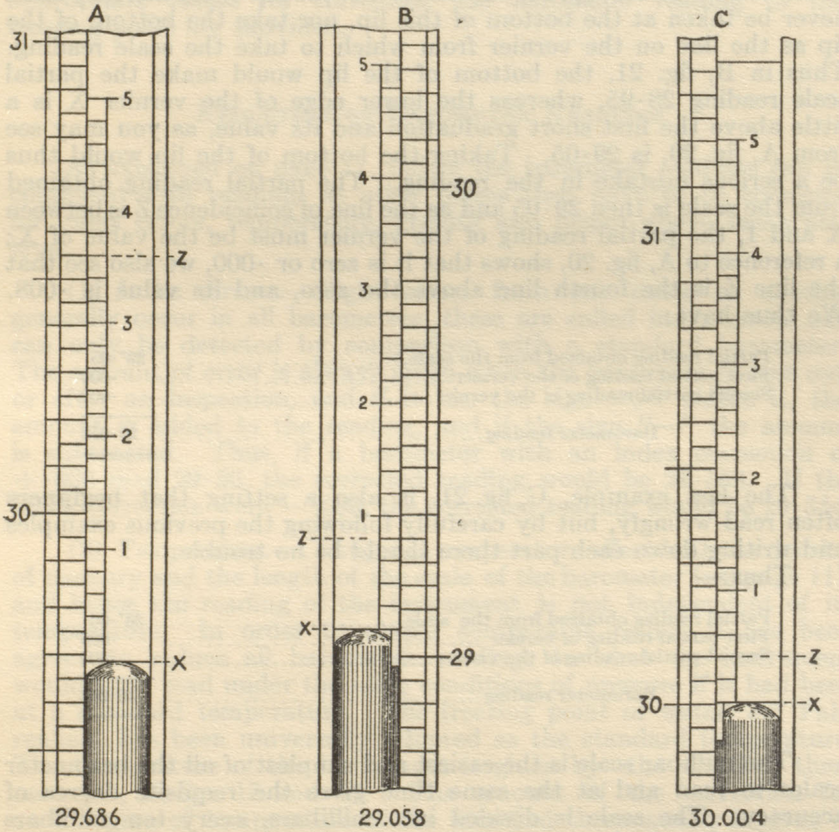


Fig. 21.

In A, fig. 21, we see that the lower edge X of the vernier is between the 29·60 and 29·70 inch graduations on the scale and above the short graduation, so that the first part of the reading as obtained from the scale is 29″·65. Next we see that the line on the vernier which coincides with a line on the scale is marked Z; it is above the 3 graduation and A, fig. 20, shows that the first partial reading of the vernier is ·030, it is also seen that Z is the third line above 3, and referring again to A fig. 20 its value is ·006; summing up, we have:

Partial reading obtained from the scale..........................	29″·65
First partial reading of the vernier..........................	·030
Second partial reading of the vernier..........................	·006
Barometer reading..........................	29·686

Some barometers have a small projection or lip on the vernier, as shown in B and C, fig. 21, but the level of the top of the mercury must never be taken at the bottom of this lip, nor take the bottom of the lip as the line on the vernier from which to take the scale reading. Thus in B, fig. 21, the bottom of the lip would make the partial scale reading 28·95, whereas the lower edge of the vernier X is a little above the first short graduation and its value, as you may see from A, fig. 20, is 29·05. Taking the bottom of the lip would thus be a serious mistake in the reading. The partial reading obtained from the scale is then 29·05 and as the line of coincidence Z is between X and 1, the partial reading of the vernier must be the value of X; a reference to A, fig. 20, shows that it is zero or ·000, we also see that the line Z is the fourth line above the zero, and its value is ·008. We thus have:

Partial reading obtained from the scale..........................	29″·05
First partial reading of the vernier..........................	·000
Second partial reading of the vernier..........................	·008
Barometer reading..........................	29·058

The last example, C, fig. 21, is also a setting that beginners often read wrongly, but by carefully following the previous examples and writing down each part there should be no trouble.

Thus:—

Partial reading obtained from the scale..........................	30″·00
First partial reading of vernier..........................	·000
Second partial reading of the vernier..........................	·004
Barometer reading..........................	30·004

The millibar scale is the easiest and simplest of all the barometer scales to read and at the same time gives the requisite degree of accuracy. The scale is divided into millibars, every ten millibars being numbered, either as millibars– 890, 900, —— 940, —— etc. but generally as centibars (10 millibars)– 89, 90, 91, —— 102, — etc. by multiplying by 10 the latter become 890, 900, 910, —— 1020, —— etc. millibars (mb). The values in millibars of the successive divisions beginning with 89 are thus 890, 891, 892, —— 898, 899, 900, etc. The scale thus gives the number of millibars and to get the reading to the first decimal point, which is all that is required, it is only necessary to find the line on the vernier which coincides with a scale division, and as this line is numbered, it gives the reading to the first decimal point.

Three settings of the barometer with a millibar scale are given in fig. 14; in A fig. 14, the top of the mercury column is above 1029 and the line 7 of the vernier coincides with a division on the scale, consequently the correct reading is 1029·7. In B, the reading is 1000·1 and in C, 985·0. If the decimal is zero it should always be entered, otherwise it would not be known whether or not the barometer was read to the first decimal place.

A different scale, called the absolute or tercentesimal, is used on the attached thermometer instead of the Fahrenheit, and the appropriate tables for correcting the barometer reading to the freezing point are provided.

Reduction of Barometer Readings

As explained on page 11, before the barometer readings can be compared with readings at other places they have to be corrected for index errors, temperature, gravity and height above mean sea-level.

(1) *Index Errors.*—Slight errors from one cause or another generally occur in all barometers, these are called index errors and can only be detected by comparison with a standard barometer. The amount of error is always given when the barometer is sent out, or after an inspection, and if it has the sign "+" before it, the amount is added to the reading, and if the sign "−" the amount is subtracted. Thus, if a barometer with an index correction of +·008 read 29·56, the corrected reading would be 29·568. If the index correction were −·006, the corrected reading would be 29·554.

(2) *Temperature.*—Changes of temperature affect both the density of mercury and the length of the scale of the barometer (see page 11), and hence the reading of the instrument is not independent of its temperature. In order to obtain comparable results it has been agreed to reduce all barometric readings to what the instrument would have read under the same conditions of pressure if it had been at a standard temperature. The freezing point of water, 32° Fahrenheit, has been universally adopted as the standard temperature. The temperature of the instrument is given by the attached thermometer, E, figs. 13 and 14. The amount of the correction for each degree of temperature of the attached thermometer is given in special tables. At temperatures below 29° the amounts shown in the table are to be added, at temperatures above 29° they are to be subtracted.

As an example, if the attached thermometer read 72° and the barometer 29·560, the tables give the temperature correction as ·116 (to be subtracted); hence the corrected reading would be (29·560 −·116) or 29·444. If the temperature of the attached thermometer were 14°, the correction from the table would be ·039 (to be added) and the reading corrected to 32° would be (29·560 +·039) or 29·599.

The force of gravity varies slightly with the latitude of the place of observation (see page 12), and hence the barometric readings require to be reduced to a standard latitude. Forty-five is the latitude adopted. The amount of the correction is always given or combined with other corrections.

(3) *Reduction to Mean Sea-level.*—A further reduction must be applied to barometric readings intended for use in weather maps, as all such readings must be reduced to a standard altitude, and for the latter the mean sea-level is universally adopted (see page 11). To effect the reduction an amount must be added to the observed reading which is equal to the length of the column of mercury required to balance a column of air extending from mean sea-level to the height of the cistern of the barometer. The magnitude of this correction will depend on the pressure, temperature and humidity prevailing at the time and on the height of the station above mean sea-level.

For convenience of the observer the Central Meteorological Office supplies manuscript tables for making the above reductions to mean sea-level, generally combined with the correction for gravity. These tables refer only to the heights above mean sea-level of the barometer cistern, for which the table has been made out, and if the position of the barometer is changed so as to make it higher (above mean sea-level) or lower than before, either new tables have to be supplied or else a correction has to be applied before making the sea-level reduction; these, however, are always given by the Central Meteorological Office.

It must be carefully noted that the temperature to be used in these tables is the mean of the current and preceding reading of the *dry-bulb thermometer in the thermometer-shed and not that of the attached thermometer.*

Tables for the reduction of the barometer to mean sea-level are made out in either of two ways and an example of each is given in tables I and II. In the method used in table I the mean sea-level reading is given for the barometer reading at the top of the column and the air temperature given on the left under the heading Temperature. To reduce to mean sea-level by this method first of all obtain the column that gives the barometer lower than the reading but nearest to it; in this column in line with the air temperature or dry bulb reading obtain the sea-level reading and add to it the difference between the pressure at the top of the column and the actual barometer reading. Thus in table I, if the barometer reading corrected to 32° is 29″·27 and the mean temperature obtained from the dry bulb thermometer in the shed is 45°, then from the column headed 29·20 and in line with the temperature 44° (that being the nearest given) we find the mean sea-level reading is 29·68; the difference between 29·27 and 29·20 is ·07 and this has to be added to 29″·68, making the true mean sea level reading 29″·75. Again for a barometer reading of 29″·71 and mean dry bulb temperature of 24°, we can easily find that the mean sea-level reading is 30″·22.

TABLE I

REDUCTION OF BAROMETER TO MEAN SEA-LEVEL

(T is the mean of present reading and twelve hours previous of Dry-bulb in Thermometer Shed)

T	Barometer in inches corrected and reduced to 32°				
	28·80	29·20	29·60	30·00	30·40
4°	29·31	29·72	30·13	30·54	39·94
14°	29·30	29·71	30·12	30·52	30·93
24°	29·29	29·70	30·11	30·51	30·92
34°	29·28	29·69	30·09	30·50	30·91
44°	29·27	29·68	30·08	30·49	30·90
54°	29·26	29·67	30·07	30·48	30·89
64°	29·25	29·66	30·06	30·47	30·88

In the second method as given by table II the amount of the correction to be added to the barometer is given under the column for barometer reduced to 32°, and on the line giving the mean air temperature. In this case select the column with the pressure nearest the barometer reading and the temperature nearest the mean air temperature (and if necessary take the proportional parts) and add this correction to the barometer reading to get the reading at mean sea level. Thus in table II for a barometer of 29″·15 (corrected to 32°) and a mean dry bulb temperature of 54°, the reading is nearest 29″·00 and 56° and we find from this column and line that the amount to be added is ·63″ so that the mean sea level reading is (29″·15+ ·63″) or 29″·78.

As a second example if the barometer reading is 29″·64 and the mean dry bulb temperature is −6° (six below zero), then the reading is nearest 29″·80 and −8°, so that the amount to be added is ·75″ and the mean sea level reading is (29″·64+·75″) or 30″·39.

TABLE II

REDUCTION OF BAROMETER TO MEAN SEA-LEVEL

(T is the mean of present reading and twelve hours previous of Dry-bulb in Thermometer Shed)

T	Barometer in inches corrected and reduced to 32°				
	28·60	29·00	29·40	29·80	30·20
-8°	0·72	0·73	0·74	0·75	0·76
0°	0·71	0·72	0·73	0·74	0·75
8°	0·69	0·70	0·71	0·72	0·73
16°	0·68	0·69	0·70	0·71	0·72
24°	0·67	0·68	0·69	0·70	0·70
32°	0·66	0·66	0·67	0·68	0·69
40°	0·64	0·65	0·66	0·67	0·68
48°	0·63	0·64	0·65	0·66	0·67
56°	0·62	0·63	0·64	0·65	0·66

In order to enable you to apply corrections properly several examples are given which if carefully studied will help you to apply all the corrections accurately:—

STATION X

Height above mean sea-level, 436 feet........................Latitude 54°
Index correction, + ·014
Gravity correction included in reduction to mean sea-level table.

Barometer as read	28″·93	29″·67	30″·09
Attached thermometer	72°	21°	34°
Dry-bulb thermometer reading twelve hours previous	57	13	46
Dry-bulb thermometer present reading	60	3	33
Mean dry-bulb temperature	58	8	39
Barometer as read	28″·93	29″·67	30″·09
Index correction	+ ·014	·014	·014
Barometer corrected for index	28·944	29·684	30·104
Temperature correction as given by attached thermometer	−·113	+·020	−·015
Barometer corrected to 32°	28·831	29·704	30·089
Partial mean sea-level reading from table I	29·26	30·13	30·50
Add difference between figures at head of column in table and actual barometer reading at 32°	·031	·104	·089
Mean sea-level reading	29·291	30·234	30·589

The three examples shown above are to illustrate the method of reduction to mean sea-level by the use of table I, and the three examples which follow are reduced to sea-level by the second method, table II:—

STATION Y

Elevation, 592 feet above mean sea-level........................Latitude 44

Index error, +·018″. Gravity correction included in M.S.L. Reduction.

Dry-bulb reading twelve hours previous	24°	64°	32°
Present dry-bulb temperature	8	49	25
Mean dry-bulb temperature	16	56	28
Attached thermometer	18	87	31
Barometer as read	28″·69	30″·05	29″·54
Index correction	+·018	+·018	+·018
Barometer corrected for index error	28·708	30·068	29·558
Correction to 32° from attached thermometer	+·027	−·157	−·007
Barometer corrected to 32°	28·735	29·911	29·551
Correction to mean sea-level from table II	·68	·65	·68
Mean sea-level barometer reading	29·415	30·561	30·231

It is to be noted that in the last example above (at the right of the page) advantage is taken of using proportional parts to get the "Correction to mean sea-level from table II"; the mean dry bulb temperature T is actually 28°, now on the line for 24° in the table, under column headed 29·40, the correction given is ·69 and in the same column on the line for 32° the correction is ·67 but notice that 28° is exactly half way between 24° and 32°; it is therefore more accurate to take for the correction ·68 which is half way between ·67 and ·69.

Sufficient accuracy will be attained if the reading is given to the nearest ·01 inch but to secure this degree of accuracy the three places of decimals should be retained until the final step is reached.

CHAPTER II

THERMOMETER SITE

The temperature of the air depends to a very considerable extent on the place where the instruments are exposed, and if the temperature of one place is to be compared with other places they should all have, as far as possible, the same exposure. An ideal location would be a plot of level ground about 30 feet by 20 feet covered with short grass; the distance of the instruments from any object (building or trees) being twice the height of the object.

The plot should generally be on level ground, as a station on a steep slope or in a hollow is usually subjected to unusual meteorological conditions.

For a rural station the most unrestricted exposure should be aimed at, as the observations are intended to be comparable with other rural stations, and are of general meteorological interest. For urban stations local meteorological conditions are of importance, and an open space near the middle of the town is desirable.

Exposures on roofs are not appropriate for meteorological comparisons.

The above considerations are general. Each case in which they cannot be complied with requires special consideration.

The location is generally made by an inspector, but if the observer has to make the selection he should send a sketch of the location, noting the height of the different objects surrounding the plot and their distances.

Thermometer Screen

In getting the temperature of the air it is not sufficient to simply place the thermometers outside and expect to get a true air temperature, as rain, snow and the direct rays of the sun would all seriously affect them; it is thus necessary to house them properly. At the same time this house must permit of free circulation of the air if the true air temperature is to be obtained. The house that fulfils all these conditions is known as a Stevenson screen or shed fig. 22. It has double louvred sides and a double roof, the under one being louvred in the latest pattern. The screen stands on four posts, above short grass, and the bottom of the screen should be 3 feet 9 inches above the ground. While there may be several methods of erecting the shed, the most convenient and one of the best is shown in fig. 22. Here four posts are driven or planted in the ground well below the frost line and to preserve them they should be coated with either tar or creosote. On top of the posts 2-inch by 4-inch

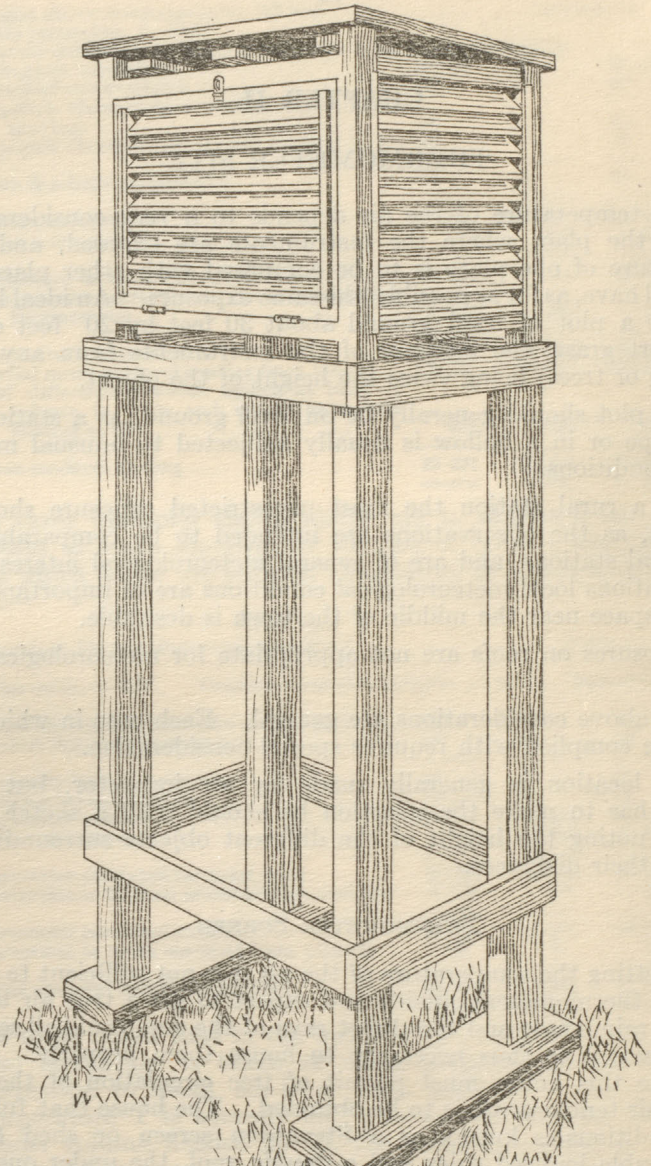


FIG. 22.

pieces are nailed and to them are securely attached the 2-inch by 4-inch posts that support the shed. These should be firmly secured so that the instruments in the shed will not be shaken by gales. There should be no slab or board under the shed and the grass should be kept short. The screen should be set with the door facing North, so that the sun will not shine on the instruments when the readings are being taken.

The screen and posts should be painted white, preferably every spring, in order to keep them in good condition.

A

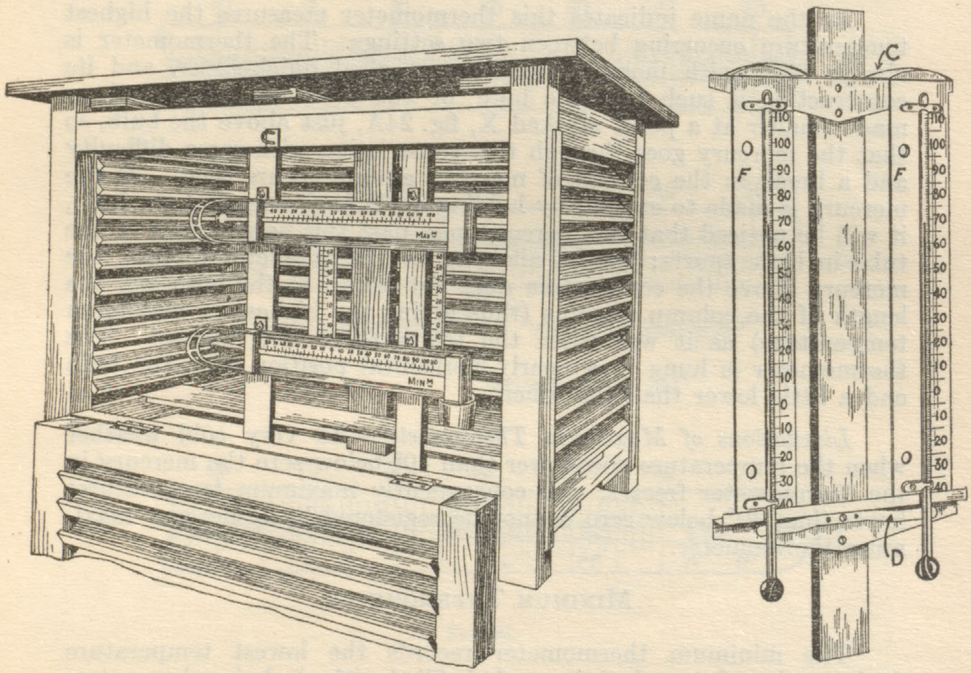


Fig. 23.

Arrangement of Thermometers in Screen

This is shown in A, fig. 23. Hooks for the suspension of the maximum and minimum thermometers are generally inserted before the shed is sent out; the maximum is generally placed above the minimum, and if the hooks are not in place they should be so inserted that when the thermometers are suspended they are nearly horizontal, the bulb end being a little lower (about ¼-inch) than the other. In the older types of shed the dry-bulb and wet-bulb thermometers are placed at the back of the shed on supports provided, the wet-bulb usually being on the right side and the dry-bulb on the left. In the latest design the dry-bulb and wet-bulb are placed in front and to the side, so that they can be read first and easily accessible. A very simple and convenient device for holding the dry-bulb and wet-bulb thermometer has been designed by Mr. F. White, of this office. It is shown in B, fig. 23. The spring C holds the thermometer firmly against the lower support and spring D holds it against the front so that it cannot shake. To remove the thermometer simply raise it up until it is clear of the front edge of the support.

The Maximum Thermometer.

As the name indicates this thermometer measures the highest temperature occurring between two settings. The thermometer is always filled with mercury, sometimes called quick-silver, and its construction is such that the bore of the stem is constricted or made smaller at a point marked X, fig. 24A, just above the bulb, so that the mercury goes through this constriction with some difficulty and a break in the column of mercury always occurs there. If the mercury is made to expand by holding one's fingers around the bulb, it will be noticed that the mercury goes past this narrow part of the tube in little spurts; but on allowing the thermometer to cool, the mercury above the constriction does not return to the bulb and the length of the column remains (thus giving the highest or maximum temperature) as it was when the temperature was highest. The thermometer is hung in a nearly horizontal position with the bulb end a little lower than the other.

Limitations of Maximum Thermometer.—In very cold weather when the temperature goes lower than 40° below zero the mercury in the thermometer freezes, and consequently maximum temperatures lower than 40° below zero cannot be registered by a mercury maximum thermometer.

Minimum Thermometer

The minimum thermometer records the lowest temperature during a given interval of time. It is filled with alcohol and an examination of the top of the column shows that it is curved as in fig. 24, B, C, D. This curved part is called the meniscus and is in reality a film or thin skin at the surface of the liquid (a property of all liquids) and it is quite strong. In the liquid there is a small dumb-bell shaped rod, Y fig. 24, B, C, D, called an index, which is the distinguishing feature of the minimum thermometer. The index can slide freely along the tube when in the liquid and consequently the thermometer must be placed nearly horizontal when in use. Fig. 24B shows the index at the top of the column against the meniscus; when the temperature falls, the meniscus draws the index back with it; but when the temperature rises the liquid can flow freely by the index, so that the index is left at the lowest point reached since it was last set, fig. 24C.

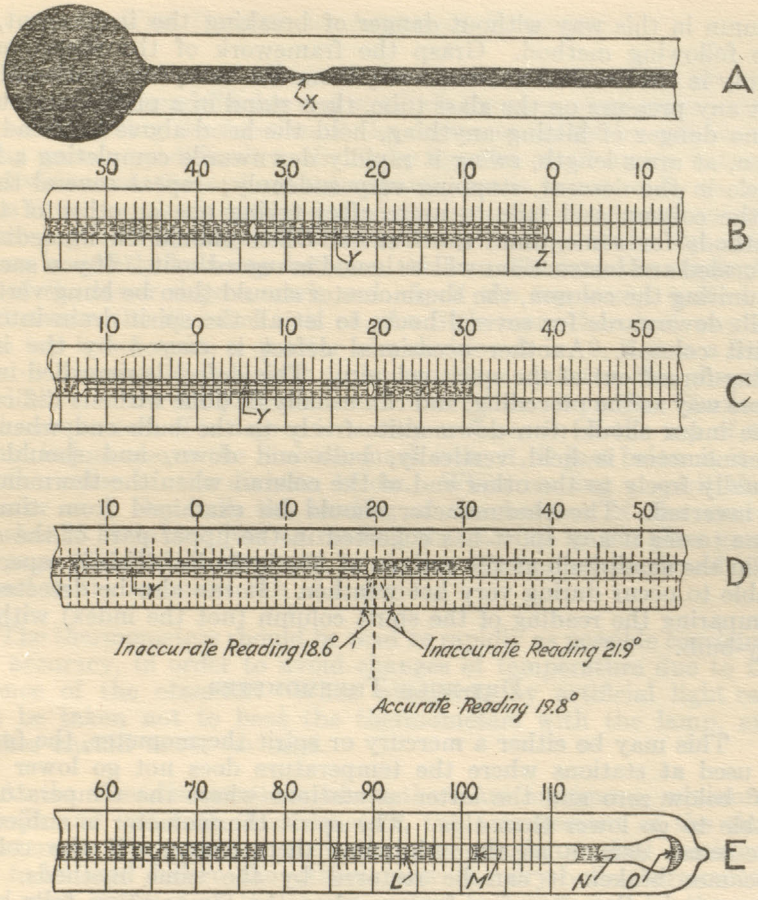


FIG. 24.

DEFECTS

The Minimum or Spirit Thermometer is the most liable of all the instruments to get out of order by the spirit column breaking into several detached pieces as shown at L, M and N, fig. 24 E. The thermometer is especially liable to have the spirit column broken in this way during shipment. It is quite evident that it is useless while in this condition. The defect can sometimes be remedied by grasping the framework of the thermometer with one hand and tapping the bulb end of the instrument against the palm of the other hand (never against a hard substance); the taps should be gentle at first and repeated several times; if there is still no sign of any of the detached portion uniting, gradually increase the strength of the taps until the column unites, or if it does not appear possible to unite the column in this way without danger of breaking the instrument, try the following method. Grasp the framework of the thermometer firmly in the hand at the end away from the bulb, taking care not to put any pressure on the glass tube, then stand in a place where there is no danger of hitting anything, hold the hand above the head and then, at arms length, swing it rapidly downwards completing a half-circle in the descent, stopping very suddenly; repeat several times; if the column still fails to unite after trying one or other of these methods for some time, the Central Office should be immediately informed and instructions will be issued in regard to it. If you succeed in uniting the column, the thermometer should then be hung vertical, bulb downwards for several hours to let all the spirit drain into the spirit column. Another occasional defect is caused by the index being forced out of the spirit column. This defect is remedied in the same way as the preceding, and can usually be done without difficulty. The index should run down quite freely to the bulb end when the thermometer is held vertically, bulb end down, and should run equally freely to the other end of the column when the thermometer is inverted. The thermometer should be examined from time to time to see if any spirit has collected in the upper part of the stem or in the small bulb at the end, as at O, fig 24 E. This is especially liable to occur during very hot weather. It can also be detected by comparing the reading of the spirit column (not the index) with the dry-bulb.

Dry-bulb Thermometer

This may be either a mercury or spirit thermometer, the former is used at stations where the temperature does not go lower than 40° below zero and the latter at stations where the temperature is liable to go lower than this. The spirit thermometer is subject to the same defects as the minimum thermometer; if the column becomes broken it can be restored by the same methods. The mercury in thermometers freezes when the temperature falls below −40°, and it sometimes happens that very minute bubbles of air get into the mercury column and defy all attempts to unite it. In such cases the circumstance should be reported to the Central Office without delay.

The management of the wet-bulb thermometer is discussed under "Hygrometers."

Reading and Setting the Thermometers

As the mercury or spirit column is not in the same place as the thermometer scale, great care must be exercised to see that the line joining the top of the column and the eye is at right angles to the stem, otherwise serious errors may occur as illustrated in fig. 24 D. The correct position is obtained by the observer placing his eye on the same level as the end of the mercury column if the thermometer be vertical, or squarely in front if it be horizontal.

The Degree of Accuracy Required

To obtain accurate values of the humidity and vapour pressure it is necessary to read the dry and wet-bulb thermometers as accurately as possible, giving the fraction of the degree to tenths by estimation. It may seem very difficult to divide by eye the small space between two divisions on the scale into ten parts, but it is not really so, and with a little practice it can be done quite accurately and very quickly. One very good and simple method is the following: if the top of the column is exactly half-way between the two divisions the reading is that of the lower degree mark and ·5; if the top is not quite half way between the divisions it is ·4, if a little more than half way ·6. If the top is not quite a quarter of a division it is ·2, if it is a little more ·3 but should it appear to be exactly a quarter, the observer would have to use his judgment and take either ·2 or ·3. Similarly for three-quarters of a degree it is either ·7 or ·8; if the top of the column is just above the division mark it is ·1, if just below it is ·9 and the value of the division below. When reading a spirit thermometer as a Dry-bulb the reading of the bottom of the curved part should be taken, just as reading the rainfall in the glass gauge (see page 60). Maximum and minimum thermometers should also be read to the nearest tenth of a degree.

The thermometers should be read as rapidly as possible consistent with accuracy, in order to avoid changes of temperature due to the presence of the observer. When observing by artificial light care must be taken not to heat the thermometers with the lamp, and matches should never be used.

At the Canadian stations where there are maximum, minimum, dry-bulb and wet-bulb thermometers, the arrangement of the thermometers in the screen is such that the maximum and minimum have to be read before the others; now the dry-bulb thermometer is the most liable of all the thermometers to be affected by the presence of the observer, and if it is possible it should be read first; generally, however, in the older type of shed, it is not; that means that the maximum and the minimum have to be read first and then removed; so the order of observing is to first read the maximum, then the minimum and having noted them in the pocket register, remove the maximum and minimum and read the dry-bulb as quickly as possible, and then the wet-bulb, entering the readings as before in your pocket register.

In a new type of shed that is being designed the thermometers will be so placed that it will be possible to read them all without removing any of them.

In the case of the wet and dry-bulb, and maximum thermometers the position of the end of the mercury or spirit column (as the case may be) should be observed, while in the minimum the end of the index farthest from the bulb should be read.

Check the entries in the pocket register;

(a) by comparing them again with the instrumental readings, special attention being directed to making sure that no errors of 5° or 10° have been made;

(b) by ascertaining that the reading of the maximum thermometer is as high as or higher than the dry-bulb reading taken at or since the previous setting, and similarly, that the reading of the minimum thermometer is as low as or lower than the dry-bulb reading taken at or since the previous setting. The maximum reading should be at least as high as, and the minimum at least as low as those readings.

The next operation is to put water in the reservoir of the wet-bulb thermometer and then set the maximum and minimum thermometers. The minimum is very easily set by simply holding it vertical with the bulb end up and letting the index run down to the end of the spirit column when it will stop of its own accord; never try to hasten the process by tapping as you may break the spirit column by so doing; then when the thermometer is put back in position the end of the index should be at the top of the spirit column, and its reading should be about the same as the dry-bulb reading. Next to set the maximum, hold it vertical with the bulb end down and gently jolt it against the palm of the hand until it reads nearly the same as the dry-bulb, then put it back in position taking care that the column of mercury does not run down the stem; when set in position its reading should be nearly the same as the dry-bulb thermometer; any slight differences between the two is due to index errors in the thermometer.

The Wet and Dry-Bulb Hygrometer

The dryness or dampness of the atmosphere is usually determined from readings of dry and wet-bulb thermometers placed in a Stevenson screen. The combination of the two instruments is known as a "psychrometer".

A wet-bulb thermometer is made by coating the bulb of an ordinary thermometer with muslin kept moist with water. Its action depends on the fact that evaporation takes place from every free water surface as long as the air in contact with it is not saturated with water vapour. The heat required to bring about this evaporation is, in the case of a wet bulb taken in part from the thermometer itself, and hence a wet bulb generally reads lower than a dry bulb placed in the same screen. In a saturated atmosphere both instruments should read the same. In unsaturated air the amount of lowering depends on the rate of evaporation, and this in turn on the temperature and dryness of the air.

Mounting of the Wet-Bulb

The wet-bulb thermometer should be covered with a single thickness of thin, clean muslin or cambric, which is kept moist by attaching to it a few threads of darning cotton (No. 8) or of white

"Artsylk" dipping into a small reservoir of water placed near it. The muslin and thread must be kept entirely free from grease, otherwise they will not keep moist. To remove grease they may be washed in water containing ammonia. Care must be taken that the muslin is stretched smoothly on the bulb, creases must be avoided as far as possible. The muslin may be tied on to the bulb with a cotton thread or it may be secured in position by looping three strands of the cotton used for supplying moisture to the bulb in a clove hitch or in the manner shown in fig. 25. In the case of thermometers having a

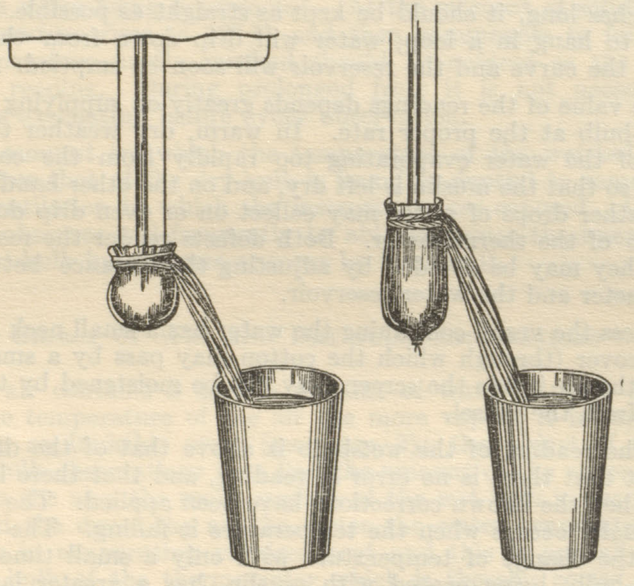


Fig. 25.

cylindrical bulb a small "finger" of muslin should be sewn exactly to fit the bulb. After fixing the muslin it should be carefully trimmed with a pair of scissors; all superfluous material and all loose ends should be cut off.

The muslin must be clean and must, therefore, be changed before it gets dirty. In country districts it will generally suffice to change it once a month, but in towns this should be done oftener. At coast stations the muslin and wick, as well as the water, should be changed immediately after a storm with an on-shore wind, as salt carried by the spray invalidates the readings of the wet bulb. The change should be made immediately after or sometime before observing. At least fifteen minutes should elapse after the change has been made before reading; if the clean water supplied is not at the same temperature as the air a much longer time is required. The water used for moistening the wet bulb must be soft; distilled water or rain-water is to be preferred. If hard water is used the bulb and muslin become encrusted with a deposit and the readings become inaccurate. Sea-water must never be used.

The dates in which the muslin, wick and water are changed should be noted in the pocket register and entered in the monthly returns.

The vessel containing the water supply should be placed below and a little to one side of the bulb of the thermometer.

The part of the cotton thread exposed to the air, that is the length between the wet-bulb and the water should be from two to three inches long, it should be kept as straight as possible. If it be allowed to hang in a loop, water will drip down from the lowest point of the curve and the reservoir will soon be emptied.

The value of the readings depends greatly on supplying water to the wet-bulb at the proper rate. In warm, dry weather there is a danger of the water evaporating too rapidly from the conducting threads, so that the muslin is left dry, and on the other hand in damp cold weather drops of water may collect on or even drip down from the bulb of the thermometer. Both defects render the reading too high; they may be avoided by adjusting the distance between the thermometer and the water reservoir.

Unless the vessel containing the water has a small neck it should have a cover (through which the cotton may pass by a small hole), so that the air inside the screen may not be moistened by the evaporation from the vessel.

If the reading of the wet-bulb is above that of the dry, make sure first that there is no error in reading, and that there is still an excess when the known corrections have been applied. The phenomenon usually occurs when the temperature is falling. The dry bulb follows the change of temperature with only a small time-lag, but the wet-bulb, being coated with muslin, has a greater lag, if the temperature is falling sufficiently quickly, this may produce the result mentioned.

Management of the Wet-Bulb during Frost.

The management of the wet-bulb during frost or at times when the wet-bulb reading is below 32° is troublesome, as the freezing of the water on the conducting threads cuts off the supply of moisture to the muslin. In order to secure satisfactory results the bulb must be coated with a THIN layer of ice from which evaporation takes place just as it does from water. It is therefore necessary to wet the muslin slightly with ice-cold water by means of a camel-hair brush or feather, ten or fifteen minutes before reading. After the moistening of the muslin the temperature remains steady at the freezing point, 32°, until all the water has been converted into ice, and it then commences to fall gradually to the true wet-bulb reading. No reading should be recorded until the temperature of the wet-bulb has fallen below that of the dry-bulb and become steady.

The water used must be at the freezing point (it is best taken from under ice), otherwise a very much longer period is required for it to cool. As little water as is consistent with thorough moistening of the muslin should be used. If excess is put on not only is the time of waiting much increased, but a thick layer of ice forms on the thermometer which interferes with the accuracy of this and subsequent readings.

After water has been applied, the temperature of the wet-bulb may fall considerably below the freezing-point without the formation of ice, the water being supercooled. At the moment of solidification the temperature rises to 32° F. and then commences to fall again. The temperature finally reached should be entered as the correct wet-bulb reading. During prolonged frost it is not necessary to renew the ice-coating before every observation.

The amount by which the temperature of the wet-bulb is reduced below that of the dry-bulb is found to depend to some extent on the ventilation to which the instruments are exposed. On calm days the observer will frequently be able to reduce the temperature of the wet-bulb by a degree or more by fanning it.

Object of Wet and Dry-bulb Observations

The air contains a certain amount of water vapour, and the higher the temperature of the air the more vapour it is capable of holding in an invisible state (see page 3); the object of the wet and dry-bulb observations is to find the amount of the water vapour present in the air; the moist surface of the wet-bulb is evaporating water and the dryer the air the faster the water evaporates; now the water in evaporating requires heat and this is partially taken from the bulb of the thermometer which is thereby cooled, and so reads lower than the dry bulb. From a long series of observations and experiments Tables have been constructed from which the amount of water vapour in the air can be obtained from the readings of these two thermometers. The amount of water vapour in the air may be expressed in several ways:—

(1) The actual weight of water vapour present in a definite volume of air.

(2) The pressure that this vapour exerts, expressed in the same way as the pressure of the air.

(3) The dryness or dampness of the air.

No. 2 is called the vapour pressure, tension or force of vapour. "Vapour pressure" is the expression to be preferred. No. 3 is generally known as the relative humidity or simply the humidity. It expresses the condition of the atmosphere as it affects our sensations of dryness, dampness, etc., and it is measured by expressing the percentage of the moisture in the air to that which it would contain if it were saturated; thus saturated air would have a relative humidity of 100 per cent or 100, while air that contained no moisture would have a relative humidity of 0. If the air were half saturated it would have a relative humidity of 50. (See page 3.)

The methods of finding the vapour pressure and relative humidity are given in the book of tables and it is not necessary to give them here.

Terrestrial Radiation Thermometer. (Grass Minimum)

As injury to the tissues of growing plants is not caused until the temperature has fallen appreciably below the freezing point of water (32° F.) a "ground frost" is regarded as having occurred when the thermometer on the grass has fallen to 30° F. or below. If the thermometer is read to tenths of a degree the limit is 30·4° F. A minimum thermometer exposed freely over a grass surface is used to enable the number of "ground frosts" at night to be determined. The wooden mounting of the ordinary minimum thermometer is dispensed with and generally an outer glass jacket surrounds the stem to prevent distillation of the spirit and the removal of the blacking from the graduation on the stem by dew. The stem of the grass-minimum thermometer should be graduated from −30° F. to 100° F. The thermometer should be supported on two Y-shaped pieces of wood at a height of one or two inches above the ground, which should be covered with short grass; care should be taken that the bulb does not touch the supports.

The proximity of walls, trees, benches, etc., should be avoided, and it should be noted that the use of any protecting cage for the thermometer would invalidate the readings.

When the ground is covered with snow, the thermometer should be supported immediately above the surface of the snow, as near to it as possible without actually touching it.

If snow has fallen during the night in sufficient quantity to cover the thermometer, the snow should be carefully removed and the thermometer read at the morning hour of observation. The reading should be entered in the registers and marked "?" A note should be made in the remarks column "grass minimum buried in snow."

Hours of Reading and Setting, the Grass Minimum

The instrument should be set at the hour of the evening observation; the reading should be taken in the morning.

Bubbles in Stem

During great cold and also when exposed to strong sunshine grass minimum thermometers are very liable to the development of bubbles in the bulb or stem, or to the condensation of drops of spirit in the upper part of the stem. Great care must be taken to avoid errors due to either of these causes. In summer the instrument should be placed in the shade during the daytime in a vertical position, bulb downwards, while not in use. It is convenient to fix in the floor near a back corner of the Stevenson screen a small pill-box so that the bulb of the thermometer can rest in the box in the daytime, the stem being supported in the corner of the screen. Directions for making the spirit column join up again, should it become broken, have already been given. (See page 49.)

Thermometer Errors

Thermometers are not perfect instruments nor are they made absolutely true, the reason for this is principally due to the great difficulty in getting the fine bore of the thermometer tube exactly the same diameter throughout its length, and to the glass changing its size with age. These errors have to be determined before the instrument is sent out and the card with the instrument tells you how much, if any, you have to correct the reading in order to get the true temperature.

CHAPTER III

THE RAIN GAUGE

The rain gauge is used to collect and measure the amount of rain that falls. It is made of brass with copper receiving vessels and the diameter of the gauge used at all Canadian stations is such that its mouth has an area of exactly 10 square inches. A diagram of the instrument is shown in fig. 26. The upper part of the gauge D fits tightly over the lower part at C, and is removed when taking out the vessels to measure the rainfall that has been collected. The inner copper receiving vessel B holds more than an inch of rainfall and is put inside a large copper vessel A, so that if the inner vessel is filled to overflowing the excess is collected in the vessel A. Generally there are two of the vessels B supplied to each station.

Site and Erection

The quantity of rain collected in the rain-gauge depends to some extent on the exposure of the gauge, and for purposes of comparing the rainfall of one place with another the conditions of exposure of the gauges must be as far as possible the same. The gauge should be exposed on level ground, not on a terrace or a slope, and never on a wall or a roof. It is most important that the gauge should not be exposed on a steep slope facing the prevailing wind. The distance of the gauge from surrounding objects should be twice the height of the objects; particular attention should be paid to this rule when the gauge is exposed in a flower or vegetable garden.

Provided the above conditions are satisfied, then a position sheltered from the wind is preferable to an exposed one. Especially at mountain, prairie or coast stations, care should be taken to see that the gauge is not unduly exposed to the wind. A belt of trees or a wall conforming to the conditions mentioned in the preceding paragraph forms an efficient shelter. Generally the gauge is placed in the same plot and about ten feet away from the thermometer screen; it is best to have the gauge to the south of the screen.

The gauge should be fixed on level ground by putting a post a little bigger than the base of the gauge into the ground and letitng it project about 3 inches above. The gauge should be screwed down on to this post so that its mouth is one foot above the level of the ground. This height is necessary to prevent water splashing into the gauge, but if it is higher the wind causes eddies about the mouth of the gauge and less rain is collected, roof exposures are inadmissible for a similar reason. The top of the gauge must be perfectly level and it is best to level it with a spirit level, for unless it is level it will not measure the amount of rainfall received on a horizontal surface of ten square inches. Grass should not be allowed to grow to a height

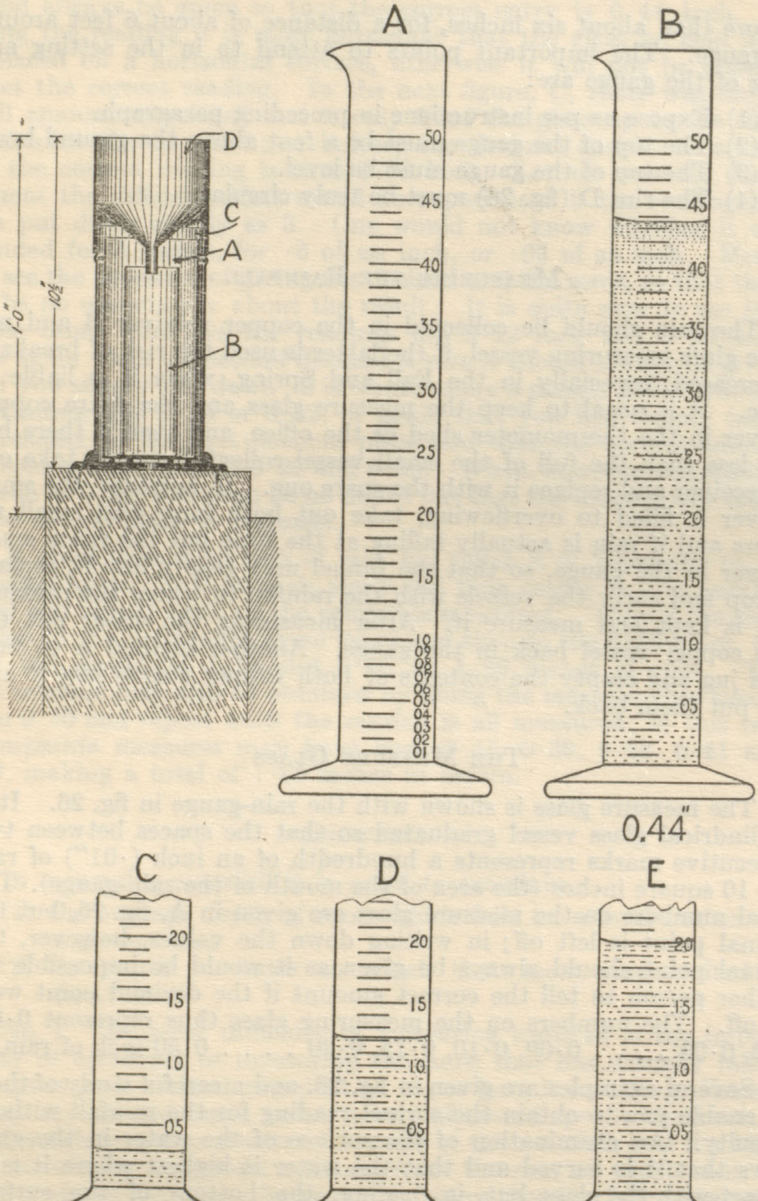


Fig. 26.

of more than about six inches, for a distance of about 6 feet around the gauge. The important points to attend to in the setting and fixing of the gauge are:

(1) Expose as per instructions in preceding paragraph.
(2) The top of the gauge must be a foot above the ground level.
(3) The top of the gauge must be level.
(4) The rim D (fig. 26) must be truly circular.

Measuring the Rainfall

The rain should be collected in the copper receiver B and not in the glass measuring vessel, if the latter is used the risk of breakage is increased, especially in the Fall and Spring, when it is liable to freeze. It is usual to keep the measure glass and the spare copper receiver in the thermometer shed or the office, and then if there has been less than the full of the small vessel collected simply take out the receiver and replace it with the spare one. If, however, the small receiver is filled to overflowing, take out both large and small receivers and if rain is actually falling at the time put the spare small receiver in the gauge, so that the funnel may empty into it, replace the top and carry the vessels with the rainfall to where the measure glass is kept and measure it. After measuring the water put the large copper vessel back in the gauge. Another method is to take out a jug and empty the contents of both copper vessels into it and then put them back.

The Measure Glass

The measure glass is shown with the rain-gauge in fig. 26. It is a cylindrical glass vessel graduated so that the spaces between two consecutive marks represents a hundredth of an inch (·01″) of rain over 10 square inches (the area of the mouth of the rain-gauge). The actual numbers on the measure glass are given in A, fig. 26, but the decimal point is left off; in writing down the values, however, the decimal point should always be given as it would be impossible for another person to tell the correct amount if the decimal point were left off. The numbers on the measuring glass thus represent 0·01, 0·02, 0·03 . . . . 0·09, 0·10, 0·15, 0·20 . . . . 0·50 inch of rain.

Several examples are given in fig. 26, and a careful study of them will enable you to obtain the correct reading for the rainfall without difficulty. An examination of the surface of the water in the glass shows that it is curved and that the water is highest where it is in contact with the glass, but, in reading, the bottom of the surface should always be taken. In B fig. 26 it is found after pouring the water from the collecting vessel into the measuring glass that the glass is filled above the graduation marked 40, the bottom of the water surface is between the third and fourth division but nearer the fourth than the third, so that the fourth mark should be taken and the reading is thus 44, but, as already explained, the decimal should always be given so that the correct entry is 0·44 inch. In taking the reading it is most important that the glass be held level or placed on a horizontal surface, otherwise it will not be possible to get the correct reading. In the next figure, C, there was only a small amount of rainfall and it only filled the glass up to the third division or the 03 mark; as before, the decimal should be added, and the correct reading is thus 0·03 inch. Let us consider for a moment the difficulty that would be experienced if the reading had been put down simply as 3. One would not know whether it was intended for 3 inches, for ·3 of an inch, or ·03 of an inch. Hence you see the necessity of giving the decimal and the zeros, so that there can be no uncertainty about the result. It is quite easy to see that in the other examples the readings are 0·12 inch and 0·20 inch. Here again when the second decimal is zero it should always be given, for if you simply put down ·2 it would make a person doubt whether the reading was 0·20 or 0·02, or again that you had simply taken the reading to the first decimal place and that the correct amount was somewhere between 0·20 and 0·30. When, however, the reading is given as 0·20, there can be no doubt but that the reading was taken to the second place of decimals.

If more than 0·50 inch of rain has fallen it is necessary to fill the glass up to the 0·50 inch mark and then empty it into another vessel and repeat until all the rainfall is measured. Thus if the glass is filled to the 0·50 mark three times and then to the 0·36 mark, the total fall would be 1·50 and 0·36, or 1·86 inches of rain. The total amount may also be obtained by filling the measure glass nearly up to 0·50 and repeat until the rainfall is all measured; in this case the separate measures may have been 0·45, 0·39, 0·48. 0·41 and 0·13, making a total of 1·86 inches as before.

Snowfall

In measuring snowfall it is usual to ascertain

(1) the average depth of snow which falls on a level surface in a given time;

(2) the depth of water to which that snow when melted is equivalent.

No. 1. The great difficulty in measuring snowfall is the impossibility of collecting or measuring the snow that has actually fallen on a given area without any drift on to, or from it occurring. Except in very exceptional cases, unless a very sheltered spot is obtained, it is impossible to get an accurate measure of the snowfall, and if a high wind is blowing one could estimate from the rate at which snow is falling and the duration, the amount of snow that has fallen as accurately as he could measure it.

The usual method is to measure the depth of the snow by means of a rule divided in inches. The measurement should be taken from the surface of the newly fallen snow to the surface of the ground, or if there had been snow before, to the surface of the snow already on the ground before the storm began. The depth should be measured in two or three places where the snow is fairly level and does not appear to have been much drifted, or to have had the snow drifted off, and the average taken.

No. 2. To get the equivalent of this snowfall in inches of water it is assumed that ten inches of snow is equal to one inch of water if melted. This means that the water equivalent to the snowfall is one-tenth of the depth of snow measured; thus if the snowfall were 3 inches, the water equivalent would be 0·30 inches, or if it were 19·5 inches the water equivalent would be 1·95 inches.

CHAPTER IV

WIND

Instructions for Taking Wind Observations when there are no Instruments

For the complete specification of the wind it is necessary to know:

(1) the direction from which it comes;
(2) its force or velocity.

Wind Direction

When recording wind direction the point from which it comes should be stated and should be given to 8 points of the compass, i.e., N., NE., E., SE., S., SW., W., NW. If there is no line available from which to determine the true North point, it may be done by the method described on page 107.

When identifying wind direction the observer must be on his guard against mistaking local eddies due to buildings, trees, etc., for the general drift of air over the station. He may use as his guide the indications of a wind-vane or those afforded by the direction of drift smoke from elevated chimneys, the set of flags, etc.

If a wind vane be used care must be taken

(1) that it is freely exposed on all sides and not affected by local eddies, etc.;
(2) that it moves freely—with most vanes it will frequently happen that the wind is too feeble to move them. Under such circumstances the direction of drift of smoke, etc., must be used for determining wind direction;
(3) that the cardinal points, if indicated on the vane are correctly set, and that the vane is well balanced, i.e. that it has no bias to set itself in a particular direction.

An excellent wind indicator is furnished by a streamer attached to a tall flagstaff in an open situation.

Whatever mode of observation is used, errors due to perspective are liable to be made unless the observer stands vertically below the indicator.

The wind force at stations where there are no anemometers is best expressed in what is known as the Beaufort scale. This scale was first adopted by Admiral Beaufort for use on sailing vessels which have since become obsolete. The scale has, however, been maintained and has from numerous observations been compared with anemometers and adapted for use on land. By this scale the wind force is estimated on a numerical scale ranging from "0" Calm to "12" a hurricane and in the following table is given the effect that a wind of a force represented by each of the numbers in the scale would have on local objects.

BEAUFORT SCALE FOR WIND

Beaufort number	General Description of wind	For Coast Use	For use on land, based on observations made at land stations	Equivalent velocity in miles per hour	Limits of velocity
0	Calm	Calm	Calm, smoke rises vertically	0	Less than 1
1	Light air	Fishing smack just has steerage way.	Direction of wind shown by smoke drift, but not by wind vanes.	2	1 to 3
2	Slight breeze	Wind fills the sails of smacks which then move at 1-2 miles per hour.	Wind felt on face, leaves rustle; ordinary wind vane moved by wind.	5	4 to 7
3	Gentle breeze	Smacks begin to careen and travel 3–4 miles per hour.	Leaves and small twigs in constant motion; wind extends light flag.	10	8 to 12
4	Moderate breeze	Good working breeze, smacks carry all canvas with good list.	Raises dust and loose paper; small branches are moved.	15	13–18
5	Fresh breeze	Smacks shorten sail	Small trees in leaf begin to sway; crested wavelets form on inland waters.	21	19–24
6	Strong breeze	Smacks have double reef in main sail. Care required when fishing.	Large branches in motion, whistling heard in telegraph wires; umbrellas used with difficulty.	27	25–31
7	Moderate gale (high wind).	Smacks remain in harbour, and those at sea lie to.	Whole trees in motion; inconvenience felt when walking aginst wind.	35	32–38
8	Fresh gale ("gale")	All smacks make for harbour if near.	Breaks twigs off trees; generally impedes progress	42	39–46
9	Strong gale	....	Slight structural damage occurs (chimney pots and slates removed).	50	47–54
10	Whole gale	....	Seldom experienced inland; trees uprooted; considerable structural damage occurs.	59	55–63
11	Storm	....	Very rarely experienced; accompanied by widespread damage.	68	64–75
12	Hurricane	....	....	Above 75	Above 75

It will be noticed that the criteria referred to in many cases depend rather on the effects which the observer perceives on objects round about him than on his own physical sensations. By adopting this method an estimate of wind force may be obtained which is to some extent independent of the observer's actual position. The latter may be comparatively sheltered, but it should be such as to command a good view of a number of objects, by the behaviour of which wind force can be estimated.

Difficulties of exposure frequently render a good estimate of wind force preferable to a measurement with an instrument. The latter can only record the speed of that portion of the air which passes it, and unless its exposure is satisfactory this may differ greatly from the general speed of the air passing over the surrounding country.

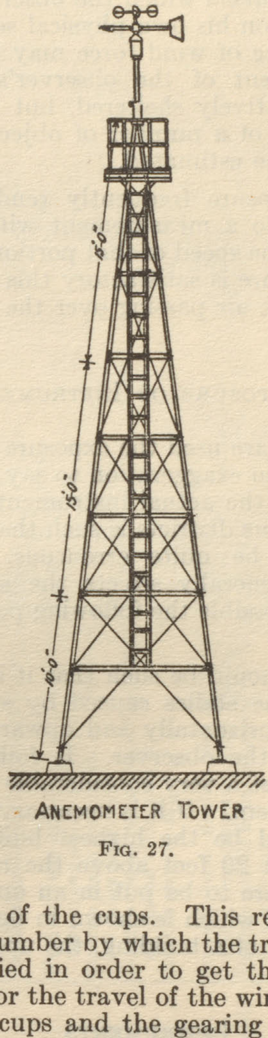
Exposure of Instruments

When instruments are used the exposure is so important in wind observations that it is no exaggeration to say that the exposure is of more importance than the actual instrument used in measuring the wind, and in mountainous districts is such that records obtained from the instruments may be quite erroneous. An official from the Meteorological Office generally selects the site for the instrument but when that is not possible the following points should be observed in making a selection.

The site selected should be such that it is not sheltered by trees or buildings because the eddies caused by such obstacles extend to great distances, both horizontally and upwards, at the same time it must be accessible to the observer. It follows therefore that the anemometer should be at a very considerable distance from buildings or trees or else above them. If it is necessary to put the anemometer on a building it should be the highest building in the immediate neighbourhood, at least 20 feet above the roof. It is the practice when the instruments are to be put in an open space to place them on towers, a drawing of which is shown in fig. 27. When they have to be placed on the top of a building, the upper 20 feet of the tower will generally suffice.

Instruments

At all the Canadian stations provided with instruments, the direction is given by a wind vane, familiar to all, and the velocity is obtained by means of an instrument called an anemometer. The anemometer consists of a number of hemispherical cups attached to the ends of the spokes of a wheel to turn in a horizontal plane. The difference of pressure of the wind on the convex and concave sides of the cups causes the wheel to rotate and by suitable gearing, the number of revolutions of the wheel can be counted. Experiments have shown that there is a relation between the travel of the wind



ANEMOMETER TOWER

FIG. 27.

and that of the centre of the cups. This relationship is called the "factor": it gives the number by which the travel of the centre of the cups has to be multiplied in order to get the velocity of the wind. Thus knowing this factor the travel of the wind can be obtained from the revolutions of the cups and the gearing used in this country is arranged so that it gives directly the number of miles of wind that passes the instrument. The miles can be counted in various ways; some instruments have a suitable gearing that permits the mileage between two readings to be obtained, but others are constructed so that by suitable wiring the count can be obtained on an instrument called the Anemograph placed in the office. It is the latter method that is employed at all Canadian stations. This anemograph is so arranged that not only the mileage of the wind is given but its direction to 8 points as well.

Most of the anemometers in use up to the present have four cups at right angles to each other, but, through the courtesy of the University of Toronto and Professor Parkin, extensive experiments carried out in the wind tunnel of the University proved that three cups were decidedly better than four; this was also verified by the United States Weather Bureau. This type is now used as the standard. Experiments were also carried out in the wind tunnel on different types of wind vanes and it was proven that a stream lined wind vane was much more sensitive than the old splayed type illustrated in fig. 28. As a result the stream lined vane shown in fig. 29 is now being introduced.

The Anemometer and Wind Vane

The old type of Anemometer in use at Canadian stations has four cups and makes five hundred revolutions of the cups per mile of wind. The wind vane is mounted separately and lower so as not to interfere with the flow of the air past the instrument. They are shown diagrammatically in fig. 28, wired to the Anemograph. As these instruments are being replaced it is not necessary to describe them further.

The instrument that is replacing the one described in the last paragraph has the anemometer and wind vane combined into one instrument which will henceforth be called the anemovane. The anemometer part of this instrument has three cups instead of four and is so designed that the cups make 640 revolutions for a mile of wind.

Fig. 29 gives a perspective view of the instrument and its mounting; and fig. 30 a vertical section, showing the mounting of the working parts. The bearings N, J, ES, and CS, fig. 30, are oiled by means of wick dipping into oil contained in the reservoirs M, L, G and Y. The oil cup M is partially filled with wick so that the oil will not spill out and the oil cup G is attached to the direction transmitter T and turns with it. All the reservoirs except L can be easily replenished, but the instrument has to be dismantled to renew the oil in L. The reservoir, however, is large and well protected, so that the oil should last a long time without renewing. The pin Q in the shaft U, fig. 30, engages in a slot cut in the anemometer head R, so that the head cannot turn on the shaft. The shaft is prevented from being lifted out by a locking device Z.

Fig. 31 shows the wiring, the interior mechanism and the gearing. The wheel containing the pin X makes one revolution per mile of wind and when the pin comes in contact with the spring S the circuit through the anemograph is closed and a registration is made on the chart. The spring S can be adjusted by the screw R until it just touches the contact pin. In this way there is very little danger of the anemometer stopping on contact and the period of contact can be made very brief. If the contact wears so that the circuit is not closed, it can very easily be adjusted by the screw R.

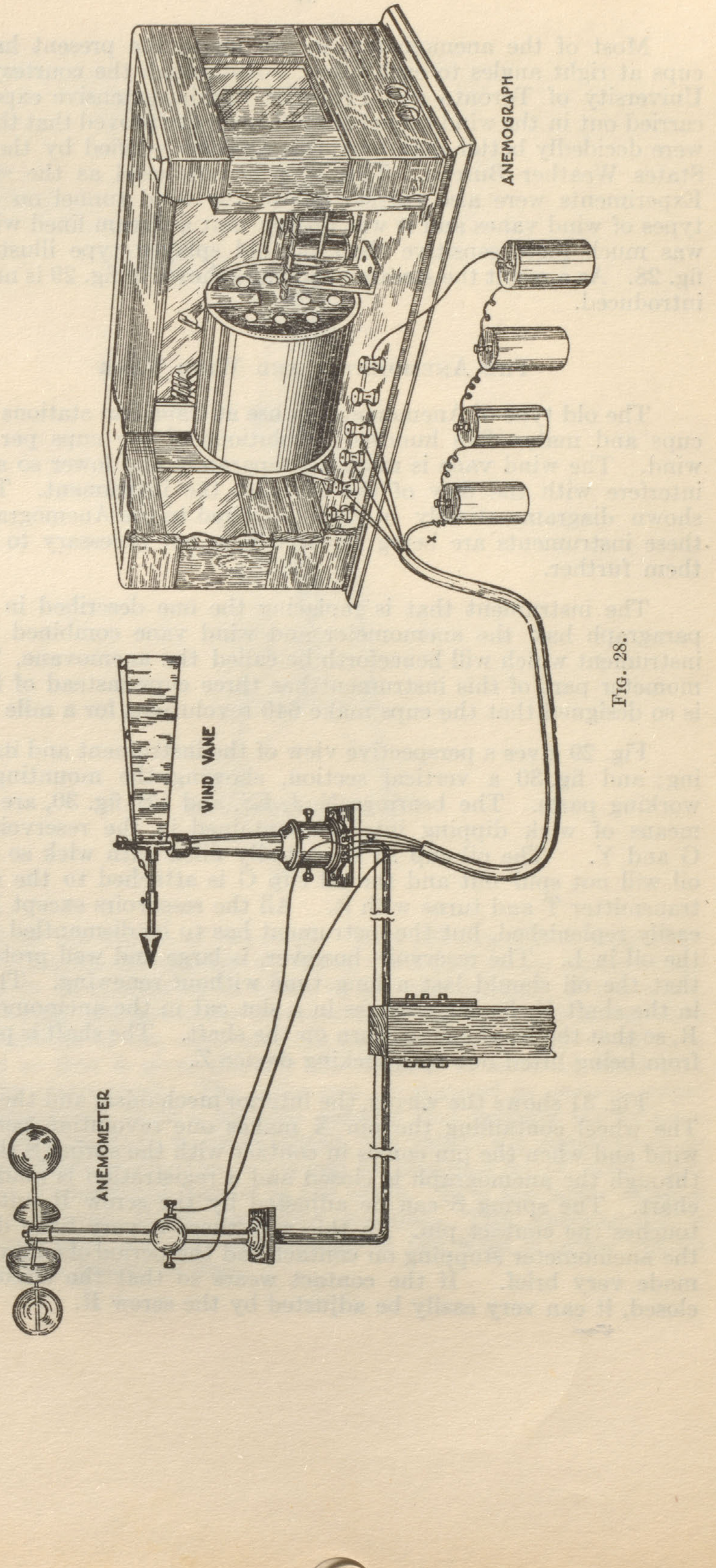


FIG. 28.

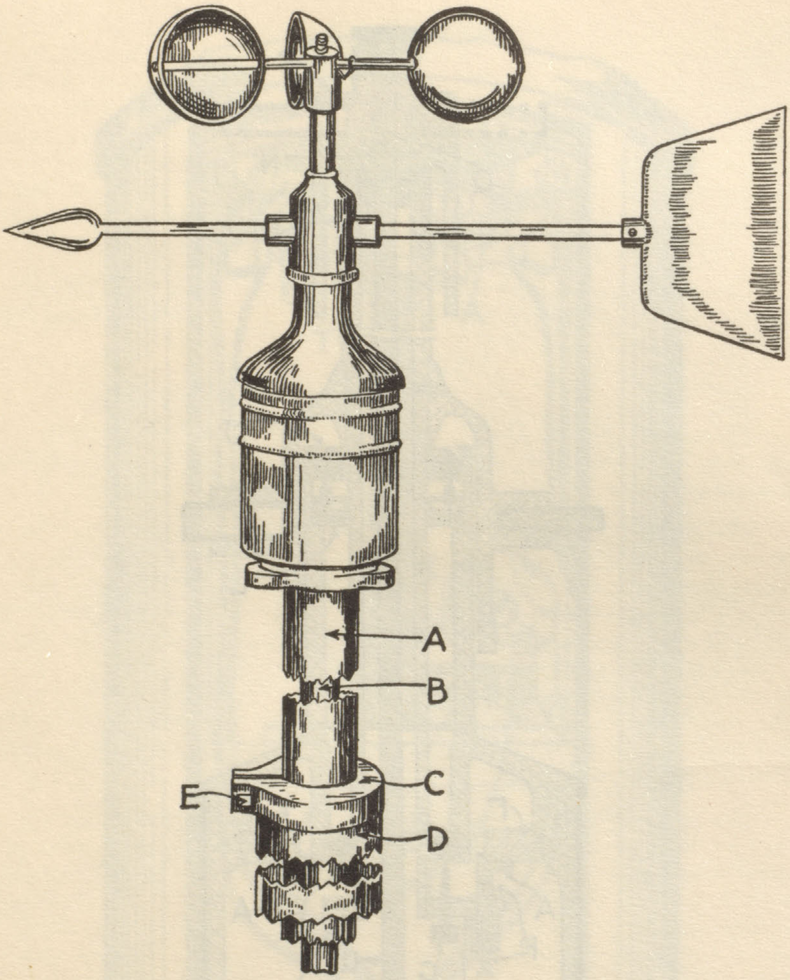


Fig. 29.

The vane is also mounted on ball-bearings and its shaft carries the direction transmitter T, figs. 30 and 31. This transmitter turns with the shaft and by means of the two plungers P makes contact with the brass ring A, figs. 30 and 31. This ring is cut into four quadrants each insulated from the other and mounted on the fibre block F, fig. 30. It is so arranged that when the centre of the two plungers is at the centre of a quadrant that the vane points to one of the cardinal points, N., E., S., or W. Each of these quadrants thus gives one of the cardinal directions and is connected to the mechanism that gives that direction on the anemograph. In observing the direction of the wind to eight points it follows that all winds between NNW. and NNE. will be North, between NNE. and

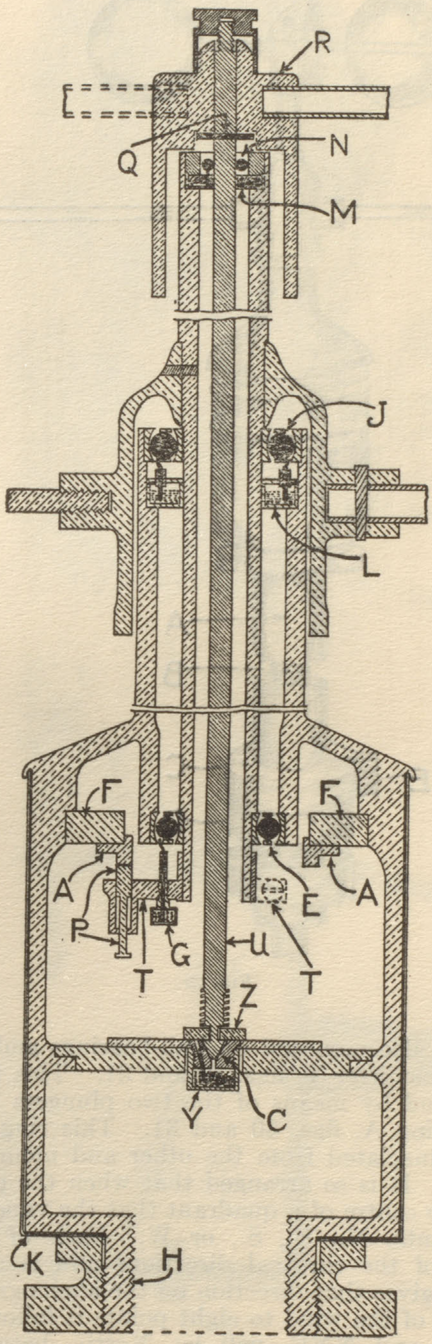


FIG. 30.

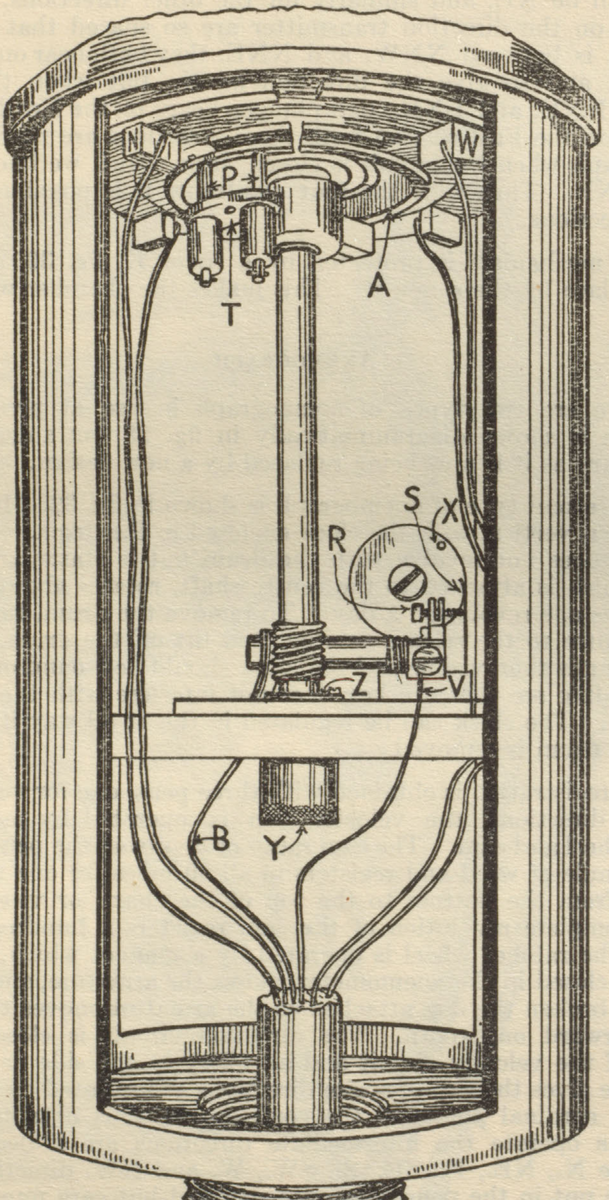


FIG. 31.

ENE. will be NE. and similarly for the other directions. The two plungers on the direction transmitter are so spaced that as long as the wind is between NNW. and NNE. they both bear on the North quadrant and so give the direction as N., but when the wind is between NNE. and ENE., one plunger bears on the North quadrant and one on the East so that both these directions are marked on the anemograph when the circuit is closed, from which we know that the wind is NE. Thus with the four quadrants it is possible to obtain eight directions.

The mechanism is protected by a cover K, fig. 30, and this is held in place by the screw H. This makes the chamber water-tight.

Anemograph

There are two types of anemograph in use at present. The first type is shown diagrammatically in fig. 28, but a description is unnecessary as it is now being replaced by a new design.

The second type of anemograph is shown in fig. 32. In this case the drum is vertical with the clock enclosed in the drum. The clock, however, does not revolve with the drum but is stationary and the drum, which is attached to the centre shaft, rotates about the clock and makes one revolution a day. To remove the drum, turn the nut in the centre to the release position and lift off the drum. The key for winding is then visible and the clock should be wound once a week after winding see that the key does not interfere with the setting of the drum. The clock can be regulated in the usual way if necessary when the drum is removed.

The registration is obtained with three pens, one for velocity and two for direction; the velocity pen is operated by means of a ratchet wheel and cam. The cam raises or depresses the pen one space for each mile of wind and registers in all 50 miles for one traverse of the pen from the bottom to the top of the chart, or vice versa, so that a complete revolution of the cam registers a hundred miles of wind. The ratchet wheel is operated by a magnet which, when the circuit is closed in the anemometer, closes the armature, and when the circuit is broken the dog attached to the armature moves the ratchet wheel forward one tooth. The direction circuit is closed on the closing of the velocity circuit and an offset to one side or the other of the line gives the two opposite directions as indicated on the chart. The four cardinal points of the compass are thus obtained, and if both pens operate the intermediate directions are indicated, thus giving the N., NE., E., SE., S., SW., W. and NW. directions. Ink should be put in the pens whenever required but care must be exercised so that an excess of ink is not put in and a heavy line obtained or the ink thrown out onto the charts. When the pen is new there may be difficulty in getting it to mark but by taking a fine pen or the small blade of a pocket knife and just drawing it gently through the pen the ink will be induced to flow; after that there is usually no

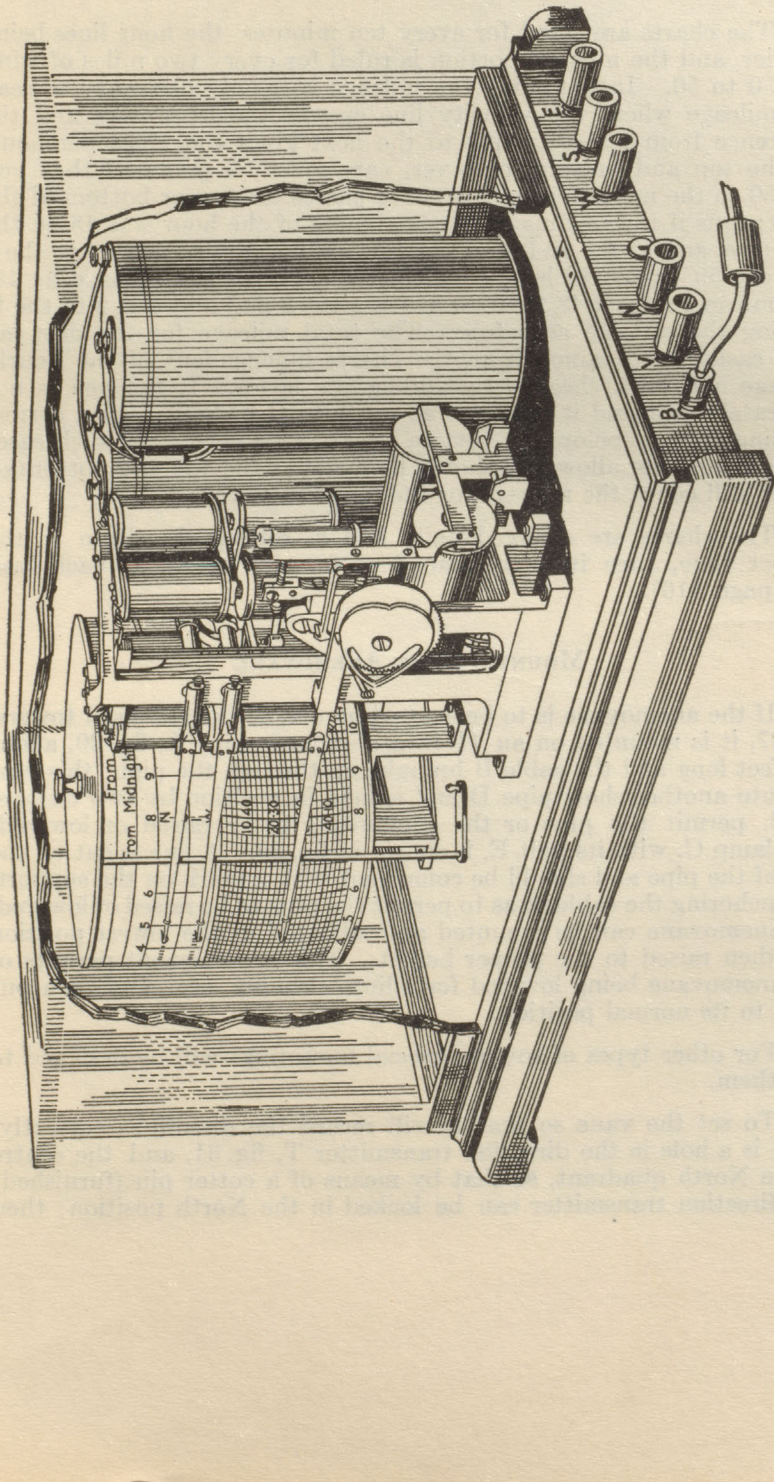


FIG. 32.

difficulty. Should the line become heavy and thick, the pen should be removed and carefully washed with gasoline and dried; this generally removes the trouble, but if not a new pen should be put on.

The anemograph is operated by two dry cells placed in the receptacle provided for them.

The charts are ruled for every ten minutes, the hour lines being heavier, and the mileage portion is ruled for every two miles of wind from 0 to 50. In obtaining the mileage it is only necessary to read the mileage where the velocity line crosses the hour lines and the difference from one hour line to the next gives the miles per hour. At the top and bottom, however, care must be exercised that you add 50 to the mileage after the curve passes the top or bottom of the chart; thus if the reading at the beginning of the hour was 48 on the up curve, and at the end 9 on the down curve: on adding 50 to the 9 you get 59 from which you subtract 48, giving the mileage as 11; or you can subtract 48 from 50 which gives 2 and add this 2 to the 9, making the mileage as before. The total mileage for the day can very easily be obtained from the charts independent of the hourly mileage and both checked by adding the latter. If the pen is not accurately adjusted it may not go quite to the top and go a corresponding amount below the bottom line, or vice versa. In such cases either the proper allowance should be made at the top and bottom or better still count the mileage for the hours involved.

The charts are changed daily and in setting the drum to the correct time, turn it back instead of forward to avoid back lash (see page 116).

Mounting the Anemovane

If the anemovane is to be erected on one of the standard towers, fig. 27, it is mounted on an $1\frac{1}{2}$ inch aluminum pipe A, fig. 29, about five feet long and the cable B brought up through the pipe; this pipe fits into another short pipe D and is held in position by two clamps, which permit the pipe or the anemovane to be raised or lowered; the clamp C. with its bolt E. is shown in fig. 29. A line is cut on the side of the pipe and should be coincident with a mark on the support. By anchoring the cable so as to permit the pipe to be raised or lowered, the anemovane can be mounted and adjusted in the lowest position and then raised to the proper height. This arrangement permits of the anemovane being lowered for oiling, cleaning, etc., and then put back to its normal position.

For other types of towers, special mountings will be designed to suit them.

To set the vane so that it will record the directions correctly, there is a hole in the direction transmitter T, fig. 31, and the centre of the North quadrant, so that by means of a cotter pin (furnished) the direction transmitter can be locked in the North position; then by loosening the screw that clamps the transmitter to the shaft, the vane can be turned until it points to the true North (not magnetic). The transmitter is then firmly clamped to the shaft and the cotter pin removed. Instructions for finding the true North are given on page 107.

The wires are then connected to the different binding posts as shown in fig 31, the marked wire being connected to B.

The next operation is to get the wires connected to their proper binding posts on the anemograph. If the wires are all marked this is quite simple, but if not, then in the old type of anemograph the battery wire or marked wire is connected to one of the poles of the battery, while the other pole of the battery is joined to the binding post B on the anemograph, shown diagrammatically in fig. 28. In the new type the marked wire is connected to the binding post marked B. Have some one up at the anemovane and first put the vane to the North, now by means of the push-button on the old anemograph or in the new type by closing the direction circuit, try each wire in turn by touching it to the North binding post until you get the one that operates the magnet. This then is the North wire and should be connected to the binding post marked N. Then take each of the other cardinal directions in turn and proceed as before until you get the right wire for each direction. The remaining wire should then be joined to the binding post marked V.

CHAPTER V

VISIBILITY

The importance for navigation and especially for aerial navigation, of the degree of transparency of the atmosphere has given rise to a demand for observations of this element of greater precision than made in the past under the rather vague headings fog and mist. The most direct manner of specifying the degree of transparency is to give the extreme distance at which objects are visible to an observer under normal conditions of illumination. This method presupposes an accurate knowledge on the part of the observer of the distance of all objects within his range of vision, and therefore is hardly practicable, and moreover it would result in reports of numerous distances varying from 10 yards to 50 miles, which would be difficult to summarize and compare. In practice, observations are therefore restricted to a number of selected objects at fixed distances, the distances increasing roughly in such a way that each distance is nearly double the next smaller distance. All the selected objects can be seen under normal conditions of illumination when the air is clear; and the determination of the nearest object of the series which is invisible on any given occasion constitutes the observation of visibility.

No observer should attempt observations of visibility whose eyesight is defective to the extent that, for example, he cannot identify a church spire six or seven miles distant when the spire is viewed against a sky background on a clear day in good daylight (with the aid of his ordinary outdoor spectacles or eyeglasses if he wears them, but without the aid of field-glasses or telescopes).

The International Scale of Visibility

In 1921 the International Meteorological Committee adopted a scale of visibility for use in telegraphic weather reports exchanged between meteorological services. The exigencies of the telegraphic code make it necessary to limit this scale to one of 10 steps and it is thus an arbitrary scale from 0–9 according to the following table:

Prominent objects are invisible at	Approximate equivalent in British units	Descriptive term for fogs	Scale number	Visibility described as
50 metres	55 yards	Dense fog	0	Dense fog
200 metres	220 yards	Thick fog	1	Very bad.
500 metres	550 yards	Fog	2	Bad.
1,000 metres	$\frac{5}{8}$ mile	Moderate fog	3	Very poor.
2,000 metres	$1\frac{1}{4}$ mile	Mist or haze	4	Poor.
4,000 metres	$2\frac{1}{2}$ miles		5	Indifferent.
7,000 metres	$4\frac{1}{2}$ miles		6	Fair.
12,000 metres	$7\frac{1}{2}$ miles		7	Good.
30,000 metres	19 miles		8	Very good.
Prominent objects visible beyond 30 km. or 19 miles.			9	Excellent.

The following notes will guide the observer in selecting suitable objects.

For the nearer distance, the objects should be relatively small, (a lamp post, a bush, a gate, a large stone, are suitable for 0 and 1). Those for greater distance should increase progressively in actual size in such a way that the apparent size of the part above the horizon remains about constant. The ideal object for the longer distances beyond 2 is one which stands above the horizon so that it is seen against the sky.

Thus a house or tall tree would be suitable objects for 3 and 4; a church spire or a clump of trees would serve for 5 and 6; while 7 requires an object giving the natural features of the landscape of considerable size. For 8 and 9 an island, mountain summit or crest of a hill may be used.

It is not always possible to find objects at the exact distances specified, at any rate throughout the whole scale. A variation of 10 per cent from the standard distances is therefore allowed. It is not necessary to have exactly the same standpoint for near as for distant objects.

A visibility of 3 is the standard criterion for fog; if the object is invisible at $\frac{5}{8}$ mile, the state of obscurity should be called "fog" but if it is visible the expression "fog" should not be used in the "remarks" or elsewhere. The visibility may also be very seriously affected by smoke from fires and especially if accompanied by haze. In such cases it must not be entered as fog or mist, but it should be noted in "Remarks" column for visibility and in the notes on the weather that the obscurity is caused by smoke, very thick haze, or smoke and haze. These notes, in regard to visibility when there is obscurity due to smoke, are of very great importance and observers are requested to pay special attention to them in their notes.

Objects suitable for the scale numbers 0–3 at least should be determined at all stations, in order that the important climatic condition "occasions of fog" may be determined.

The distances of the nearer objects should be determined by direct measurement; those of the intermediate objects should be measured from a survey map, while the farther objects can usually be obtained from a good Atlas.

Difficulties may arise in connection with the choice of objects where the visibility at the station varies in different directions owing to permanent local conditions, for example, where the station lies to one side of a smoky area. In such a case if there is a choice of objects at a given standard distance the one likely to be most clearly seen is to be adopted. Accuracy of distance is, however, not to be sacrificed for this purpose.

It is hoped that observers at stations of exceptional situation having a wide range of vision or a considerable number of suitable objects will take additional observations for their own use; for example interesting comparisons might be made between the visibilities of objects at the same distance in different directions. A special case of such comparison is the relative visibility in a landward and seaward direction.

At stations contributing telegraphic reports in connection with the Forecast Service special provision is made for observing and entering landward and seaward visibility separately.

It is a frequent occurrence at coast stations that there is a fog or mist on the sea and none on the land or vice versa. These conditions occur in very different meteorological stituations but it is obviously important that an observer should not rest content with recording the land visibility by noting one or more of the distant objects, when it is clear to him that there is fog on the sea. In such circumstances he should make use of the remarks column for indicating the visibility measured, or arrange for two regular and independent sets of observations, one to seaward and the other to landward.

It is not always possible to get a complete set of objects seawards and in such cases the observer must use the experience which he acquires from the observation of his objects to estimate to the best of his ability the visibility in the seaward direction.

Method of Observation

The visibility is to be determined by noting the most distant of the objects 0, 1, 2, 3, etc., which is visible; e.g., suppose 3 is visible and 4 is not visible, then the visibility number to be entered in the register is 4.

It is necessary to have a criterion of what is meant by an object being visible. It is often possible to see that there is "something" without being able to see what it is, unless one knows beforehand what it is; in such a case the object is not visible according to the Meteorological Office convention. An object is therefore to be regarded as "visible" if it can be distinguished by eye; if the object is a tree and it can be distinguished as a tree, it is to be noted as visible. In many cases a complete scale of objects is not available owing to lack of suitable objects. In such cases of "gaps" in the scale it is necessary to estimate which one of the missing objects would be visible if it existed. The method of estimation is as follows: Assuming there are objects for 4 and 6 and no objects for 5, the entry of 5 should be made if 4 stands out clearly while 6 is invisible. Again if the available scale ended at 6 and this object was visible with extreme clearness on a given occasion the observer would enter 7 if he judged that an object about 7½ miles away would be invisible or 9 if he judged that one more than 19 miles away would be visible.

For the purpose of routine, observations should be confined to one and the same series of standard objects. Where the returns provide separate columns for land and sea visibility two series of objects should be used, one for land and one for sea. Observations of duplicate objects in different directions or of objects not complying with the standards of distance may be entered in the remarks column if of special interest. In the case of missing objects, observations of objects not in the standard scale may be utilized.

It may occasionally happen that a more distant object of the series is visible while a nearer one is not. In this case the usual rule of entering the most distant standard object that is invisible should be followed, but a note should be made in the remarks column that the nearer object or objects of the scale were obscured. In such circumstances the entry of remarks on the visibility or invisibility of other nearer objects not in the scale would obviously be of interest.

The observer is recommended to draw up a table for himself showing (1) the list of objects chosen, (2) their actual distances and bearings, (3) the number by which each is to be known.

Observations Made at Night

In the case of observations made at night the numbers will be used to denote as nearly as possible the same degree of atmospheric obscurity as in daylight observations. This part of the subject presents difficulties and a good deal must be left to the observer, as the aids available for indicating atmospheric obscurity at night vary so much from one place to another. Stationary lights at known distances will in general provide the basis of estimation, but it is usually difficult to get a selection of fixed lights at the appropriate distances. Care must also be used to avoid the difficulty raised by the fact that a very bright light such as that of a powerful lighthouse may cause an appearance of brightness in its direction, or show light on the sky, in a state of atmospheric obscurity which would not permit the observer to see the actual source of the light in the same sense that he can see one of his daylight objects. The observer should therefore use his knowledge in such a way as to bring observations made with lights at night into line with the daylight scale to the best of his ability. Apart from the use of lights, a careful observer can derive a considerable amount of information as to night visibility from a general inspection. It is surprising how much can be seen even on a fairly dark night, e.g., a distant range of hills can often be made out against the skyline in circumstances which indicate that in daylight an object at that distance would be "visible."

Verbal Description

It has been found convenient to assign verbal descriptions to the various degrees of atmospheric transparency indicated by observations of the standard objects 0 to 9, but there is some risk of inconsistency and therefore of confusion in any such attempt to assign specialised meanings to words such as fog, or mist, which are in general use. The descriptions given in the fourth column of the Visibility table should therefore be used as purely technical expressions defined in terms of horizontal visibility. It has been customary in the statistical summaries published by meteorological offices to include particulars of the number of occasions of fog, but the lack of precision in the definition of fog has rendered such summaries of doubtful value for comparative purposes. It is hoped that the adoption of the more definite standards of the visibility scale will overcome this difficulty and ultimately give a homogeneous body of statistics.

In all statistics issued by the Meteorological Office it has been decided to count as occasions of fog only occasions when an observation of visibility has produced an entry of one of the number 0 to 3. If object 4 is visible the occasion is not counted as one of fog. In other words an occasion of fog is one on which the range of vision is less than 1,100 yards.

In order to prevent confusion observers are particularly requested not to use the Beaufort letter for fog in the weather groups or the international symbol in the "Remarks" column of their registers in connection with occasions when the visibility reaches or exceeds this limit.

For a "thick fog" the limit is taken at 220 yards.

CHAPTER VI

CLOUDS

Cloud observations, when carefully taken, very materially assist in forecasting and are of great practical importance in aerial navigation. *Observers therefore should give very careful attention to their study and observation. For this purpose it is convenient to consider and record them under four headings:*

(I) Amount.
(II) Kind or Form.
(III) Height.
(IV) Direction and Velocity of Motion.

(I) Cloud Amount.

The degree of cloudiness is to be given by the figures 0-10, in which 0 represents a sky quite free from cloud, and 10 an entirely overcast sky in which no patches of blue sky are visible. We are required to estimate the number of tenths of the area of the sky which would be covered by the cloud present supposing them moved up to each other so as to form a continuous sheet, with the proviso that as stated above, 0 is used only when there is no cloud, and 10 only when there is no clear sky. The numbers given are to refer solely to the amount of the sky covered and not to the density, height or other quality of the cloud. If desired the density of the cloud may be indicated by adding suffixes 0, 2, where 0 refers to light cloud and 2 to heavy cloud thus 4_0 indicates that rather less than half the sky is covered by light cloud and 7^2, that seven-tenths is covered by heavy, dark clouds, while no suffix would indicate that the cloud was moderately heavy.

Each observer will soon form his own methods of estimating the amount of cloud in the sky; but may find the following method useful. If there is very little cloud present the amount is to be entered as 1; if about a quarter of the sky is covered with cloud the amount entered is either 2 or 3, depending on whether there is less or more than a quarter of the sky covered; if there is a little less or more than a half, the amount is either 4 or 6; half the sky covered would, of course, be 5; somewhat less or more than three-quarters is 7 or 8; and almost all the sky covered is 9.

Another way is to mentally sub-divide the sky into quadrants by means of diameters at right angles to each other. An estimate (on the scale 0-10) is then formed for each quadrant separately, and the figure finally entered in the register is the mean of the four numbers so obtained. The direction of the dividing diameters should be selected to give convenient sub-divisions of the prevailing cloud canopy.

It was the general custom until recently to note only the total amount of cloud of all forms and to leave out of consideration questions of height or form of the cloud when making the observation. The information regarding the amount of cloud published in the Monthly Weather Record of the Meteorological Office is still prepared on that understanding.

Sometimes the amount of cloud of a specified form or type is required. This is found by imagining that every other visible form or type of cloud is replaced by blue sky, and by determining the amount of the specified form or type in the manner already described.

On occasions of fog or mist, if the vertical thickness of the fog is so great that it is impossible to tell whether there is cloud above it, the cloud amount should be entered as 10. This applies, for example, to all cases of fog in the day time in which the sun is quite invisible.

If cloud can be seen through the fog then the amount should be estimated as well as possible and entered in the ordinary way. The form can also be recognized under these conditions more or less correctly and should be noted.

If the sun or stars can be seen through the fog, and there is no evidence of cloud above the fog, the amount of cloud should be entered as 0 irrespective of the horizontal thickness of the fog.

(II) Cloud Forms

Luke Howard, at the beginning of the 19th century, distinguished four fundamental types of cloud, namely, Cirrus, the thread-cloud; Cumulus, the heap-cloud; Stratus, the flat-cloud or level sheet; and Nimbus, the rain-cloud.

There are many intermediate forms between these four primary types and a sub-committee of the International Meteorological Committee prepared and published a Cloud Atlas in which ten main types have been defined as follows:—

(1) Cirrus (Ci)—Plate I.—Detached clouds of delicate appearance, fibrous (threadlike) structure and feather-like form, generally white in colour. Cirrus clouds take the most varied shapes, such as isolated tufts of hair, *i.e.* thin filaments on a blue sky, branched filaments in feathery form, straight or curved filaments ending in tufts (called cirrus uncinus) and others. Occasionally cirrus clouds are arranged in bands, which traverse part of the sky as arcs of great circles, and as an effect of perspective appear to converge at a point on the horizon, and at the opposite point also, if they are sufficiently extended. Cirro-stratus and cirro-cumulus also are sometimes similarly arranged in long bands.

(2) Cirro-Stratus (Ci-St)—Plate II.—A thin sheet of whitish cloud; sometimes covering the sky completely and merely giving it a milky appearance; it is then called cirro-nebula or cirrus haze; at other times presenting more or less distinctly a fibrous structure like a tangled web. This sheet often produces halos around the sun or moon.

(3) Cirro-Cumulus (Ci-Cu)—Plate 3, fig. 1 (Mackerel Sky).—Small rounded masses or white flakes without shadows, or showing very slight shadow, arranged in groups and often in lines. French—Moutons. German—Schafen-wolken.

(4) Alto-Cumulus (A-Cu).—Plate III, fig. 2, Plate IV, fig. 1.—Larger rounded masses, white or greyish, partially shaded, arranged in groups or lines, and often so crowded together in the middle region that the cloudlets join. The separate masses are generally larger and more compact (resembling strato-cumulus) in the middle region of the group, but the denseness of the layer varies and sometimes is so attenuated that the individual masses assume the appearance of sheets or thin plates of considerable extent with hardly any shading. At the margin of the group they form smaller cloudlets resembling those of cirro-cumulus. The cloudlets often group themselves in parallel lines, arranged in one or more directions.

(5) Alto-Stratus (A-St)—Plate IV, fig. 2, Plate V, fig. 1.—A dense sheet of a grey or bluish colour, sometimes forming a compact mass of dull grey colour and fibrous structure. At other times the sheet is thin like the denser forms of cirro-stratus, and through it the sun or moon may be seen dimly gleaming as through ground glass. This form exhibits all stages of transition between alto-stratus and cirro-stratus, but according to the measurements its normal altitude is about one-half of that of cirro-stratus.

(6) Strato-Cumulus (St-Cu)—Plate V, fig. 2.—Large lumpy masses or rolls of dull grey cloud frequently covering the whole sky especially in winter. Generally strato-cumulus presents the appearance of a grey layer broken up into irregular masses and having on the margin smaller masses grouped in flocks like alto-cumulus. Sometimes this cloud-form has the characteristic appearance of great rolls of cloud arranged in parallel lines close together. (Roll-cumulus in English, Wulst-cumulus in German.) The rolls themselves are dense and dark, but in the intervening spaces the cloud is much lighter and blue sky may sometimes be seen through them. Strato-cumulus may be distinguished from Nimbus by its lumpy or rolling appearance, and by the fact that it does not generally tend to bring rain.

(7) Nimbus (Nb)—Plate VI, fig. 1.—A dense layer of dark, shapeless cloud with ragged edges from which steady rain or snow usually falls. If there are openings in the cloud an upper layer of cirro-stratus or alto-stratus may almost invariably be seen through them. If a layer of nimbus separates in strong wind into ragged cloud, or if small detached clouds are seen drifting underneath a large nimbus (the "Scud" of sailors), either may be specified as fracto-nimbus (Fr. Nb.)

(8) Cumulus (Cu)—(Woolpack or Cauliflower Cloud) Plate VI, fig. 2.—Thick clouds of which the upper surface is dome-shaped and exhibits protuberances, while the base is generally horizontal. These clouds appear to be formed by ascensional movement of air in the daytime which is almost always observable. When the cloud and the sun are on opposite sides of the observer, the surfaces facing the

observer are more brilliant than the margins of the protuberances. When, on the contrary, it is on the same side of the observer as the sun it appears dark with bright edges. When the light falls sideways as is usually the case, cumulus clouds show deep shadows.

True cumulus has well-defined upper and lower margins; but we may sometimes see ragged clouds—like cumulus torn by strong wind—of which the detached portions are continually changing; to this form of cloud the name Fracto-Cumulus may be given.

(9) Cumulo-Nimbus (Cu-Nb)—Plate VII, fig. 1.—The Thunder Cloud; Shower Cloud.—Great masses of cloud rising in the form of mountains or towers or anvils, generally having a veil or screen of fibrous texture (false cirrus—well shown in the photograph) at the top and at its base a cloud-mass similar to nimbus. From the base local showers of rain or of snow, occasionally of hail or soft hail, usually fall. Sometimes the upper margins assume the compact form of cumulus amd form massive heaps round which the delicate false cirrus floats. At other times the margins themselves are fringed with filaments similar to cirrus clouds. This last form is particularly common with spring showers. The front of a thunderstorm of wide extent is frequently in the form of a large low arch above a region of uniformly lighter sky.

(10) Stratus (St)—Plate VII, fig. 2.—A uniform layer of cloud like fog but not lying on the ground. The cloud layer of stratus is always very low. If it is divided into ragged masses in a wind or by mountain tops, it may be called Fracto-Stratus. The complete absence of details of structure differentiates stratus from other aggregated forms of cloud.

The following remarks are added in the "International Atlas" as instructions to Observers:—

(*a*) In the daytime in summer all the lower clouds assume, as a rule, special forms more or less resembling cumulus. In such cases the observer may enter in his notes "Stratus or Nimbus-cumuliformis."

(*b*) Sometimes a cloud will show a mammillated surface and the appearance may be noted under the name "Mammato-cumulus."

(c) The form taken by certain clouds, particularly on days of sirocco, mistral, föhn, chinook, etc., which show a lens-shape with clean outlines and sometimes colour, will be indicated by the name "Lenticular," for example: cumulus lenticularis, stratus lenticularis (Cu-lent., St-lent.).

(*d*) Notice should always be taken when the clouds seem motionless or if they move with very great velocity.

The following supplementary definitions of special forms, through not yet incorporated in the International Classification, may be usefully added:—

(11) Lenticular Cloud Banks.—Banks of cloud of an almond or airship-shape, with sharp general outlines, but showing on close examination, fretted edges, formed of an ordered structure of cloudlets

FIG. 1—Cirrus (Ci) (height 26,000—30,000 ft.)

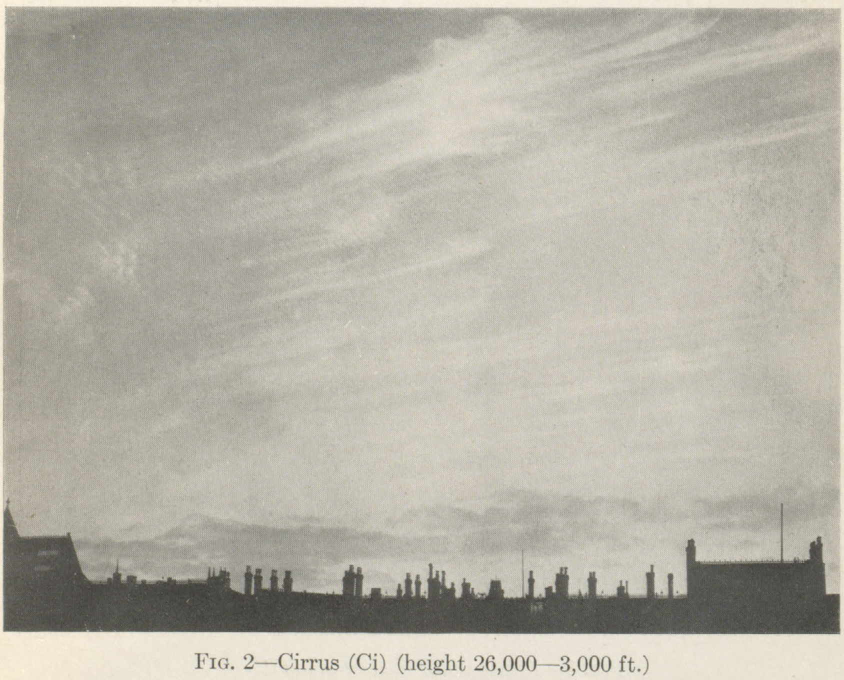


FIG. 2—Cirrus (Ci) (height 26,000—3,000 ft.)

Fig. 1—Cirrus (Ci) to Cirro-Stratus (Ci-St.) Height above 26,000 ft.

Fig. 2—Stratus (St) (Below 3,300 ft).

FIG. 1—Cirro-Cumulus (Ci-Cu) mackerel sky Height about 26,000 ft.

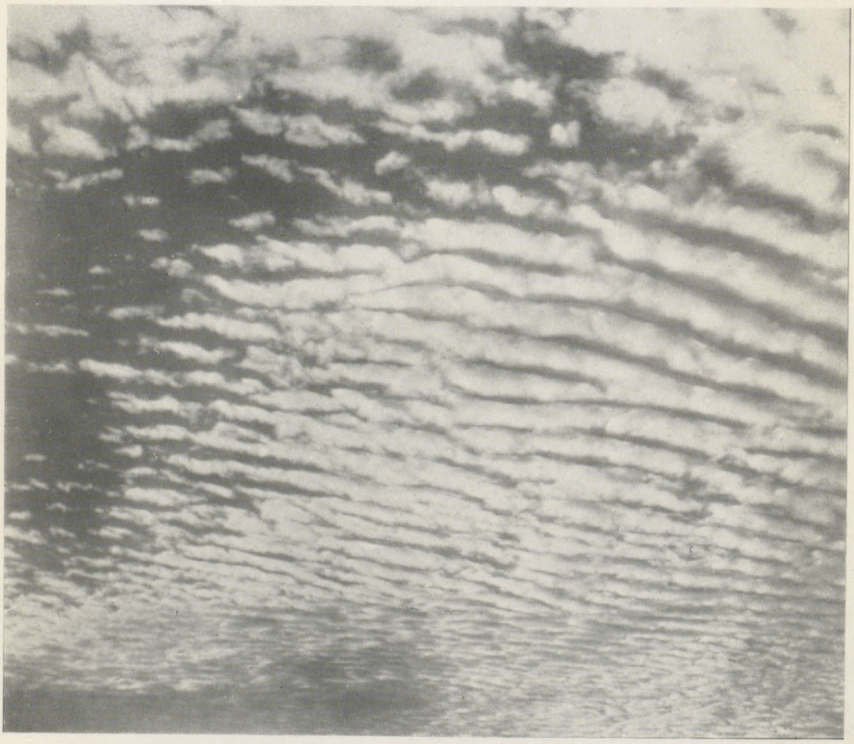


FIG. 2—Alto-Cumulus (A-Cu) Height 10,000—23,000 ft.

FIG. 1—Alto-Cumulus (A. Cu) Height 10,000—23,000 ft. with patches of Cumulus (Cu) Average height 4,600 ft.

FIG. 2—Cirro-Stratus (Ci-St) Height above 26,000 ft.

FIG. 1—Alto-Stratus (A-St) Height 10,000—23,000 ft.

FIG. 2—Alto-Stratus (A-St) Height 10,000—23,000 ft.

Plate VI.

Fig. 1—Strato-Cumulus (St-Cu) (below 8,000 ft.)

Fig. 2—Cumulus (Cu) (Base average height 4,600 ft.)

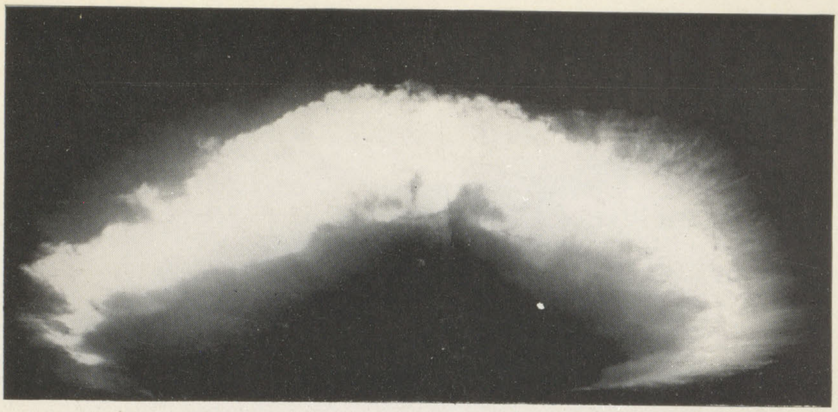


FIG. 1—Cumulo-nimbus (Cu-Ni) Average height of base 4,600 ft.

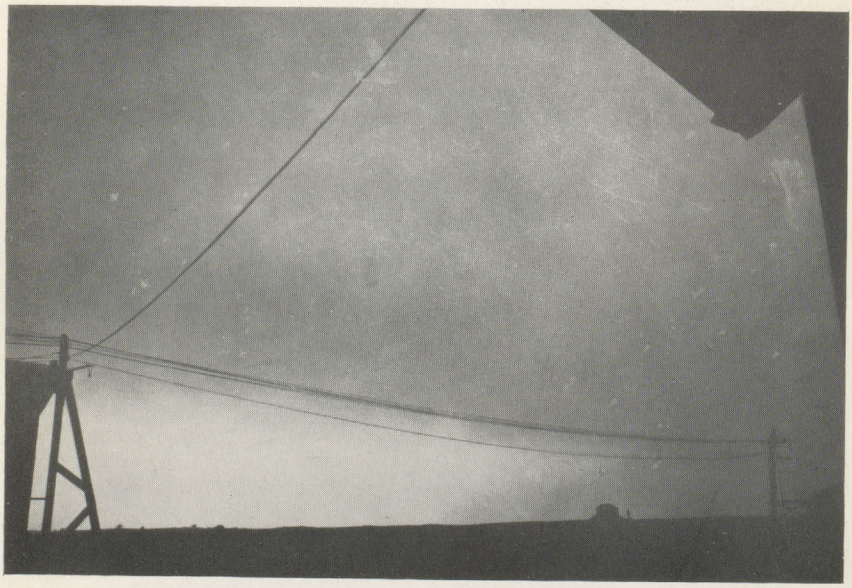


FIG. 2—Nimbus (Ni) (Base may be as low as 200 ft. average height about 1,500 ft.)

similar to alto-cumulus or cirro-cumulus, which is also seen in the bank itself when the illumination is favourable. Sometimes the body of the cloud-bank is dense, and the almond shape is complete, fore and aft, but sometimes the bank thins away from the forward edge to clear sky within, so that the bank presents the appearance of a horse-shoe seen in perspective from below at a great distance. The bank appears nearly or quite stationary, while the cloudlets move rapidly into it at one side and away from it at the other.

We may add a description and illustration of a form of cloud to which Clement Ley gave a separate name:—

(12) Alto-Cumulus-Castellatus.—"Little miniature cumulus rising in many heads from a more or less compact layer of alto-cumulus." "Not a very common cloud in these latitudes but sometimes seen in summer, and when coming from a westerly or southwesterly point is almost always a sign of the approach of shallow depressions which bring thunderstorms."

Hints on the Classification of Clouds

The problem presented to those who classify clouds is of a dual character. There are first the forms of individual clouds, stratus, nimbus, cumulus and cirrus, while the other forms are really aggregates, or groups of clouds or cloudlets, arranged sometimes in a continuous mass, sometimes in rows or waves, not infrequently in double or even triple sets of waves. There are all sorts of gradations, from the dappled mackerel sky of cirro-cumulus to the alto-cumulus, with a dense central portion and separate clouds on the margins, the irregular masses of strato-cumulus, and finally the continuous strata which are to be found at various levels—low, intermediate and high. We can hardly exclude the continuous stratus itself from consideration as a group or aggregate, because when it thins it breaks up into detached clouds.

Lenticular, lentil-shaped or almond-shaped clouds have attracted some attention in recent times. They have a peculiar outline. In many cases they are very suggestive of an airship, and are perhaps the clouds in "Hamlet" which are very like a whale. In others the inner part of the cloud becomes very thin, or disappears, so that the shape looks like a large horse-shoe as seen from beneath at a very great distance. Photographs and eye-observations show that the bank of clouds which keeps its position with little apparent change is really composed of a mass of cloudlets, forming and drifting into the cloud-bank with the wind at one side and drifting away from it and dissolving at the other. Thus the stationary appearance of the cloud-bank is illusory as regards the wind. The wind blows through the cloud-bank, which is formed by the massing of the drifting cloudlets. The cloudlets belong apparently to the type of alto-cumulus or cirro-cumulus.

Very often the intermediate clouds of the cirro-cumulus, alto-cumulus and strato-cumulus types may be seen massed together in long oval or torpedo-shaped sheets. These are termed Lenticular clouds, from the resemblance of their form to that of the cross-section of a lens. These lenticular masses are found sometimes detached but at other times cover the sky in dense sheets at several different levels, and are generally seen when the wind is blowing from some point in the southwest quadrant. The following conditions are found to accompany their appearance: (1) The sky, when visible, is usually of a very intense blue colour; (2) the barometer is exceedingly unsteady, rising and falling jerkily at very short intervals of time; (3) the wind is usually strong or high and of a very gusty character, and in addition there is a periodic rise and fall in its average velocity. At times the lower clouds, such as cumulus and stratus are seen to assume a somewhat similar form in quiet weather, but in such cases the conditions above mentioned will be absent.

A word must be added about cirrus. It is generally understood to be not only a cloud of thread-like structure, as its name implies, but at the same time a very high cloud, its normal height being about 9 kilometres, or nearly 30,000 feet. No doubt the best and most durable examples are to be found at those great heights, but thread-like clouds, indistinguishable in appearance from wisps of true cirrus, may be found at much lower levels just as the so-called false-cirrus is formed at various heights. Capt. C. K. M. Douglas, from close observation in an aeroplane, expresses the opinion that false cirrus, or in other words, thread-like structure, is always attributable to clouds formed of ice-crystals, and if that be the properly distinctive characteristic of the thread-like structure, it only hampers our conception of the atmospheric processes if we assume all clouds which show that structure to be at a very high level. The form is really suggestive of the formation of cloud by some special physical process, such as the reduction of the pressure of a mass of air which contains an exceptional quantity of water-vapour in streaks or wreaths. It is better, therefore, to regard cirrus as being a special form of cloud which may be developed in suitable circumstances at any level where ice crystals can form, and where a reduction of pressure, in consequence of external changes, may occur; this may be any region beyond the four-kilometre level in our latitude.

(III) Height of Cloud

Measurement with Balloons.—At stations where the observation of the wind in the free atmosphere by means of pilot balloons is undertaken, a simple method of determining cloud height is readily available. As the balloon rises at a known rate, all that is necessary is to note the time that elapses between the release of the balloon and its disappearance in the lower surface of a cloud. Care must, however, be taken to distinguish between cases when the balloon is seen to enter a cloud and cases in which the balloon is obscured by a cloud at some lower level drifting across the field of view.

Measurement by Comparison with Hills and Mountains.—In hilly and mountainous districts the heights of the bases of clouds which are lower than the tops of the visible hills can be determined with some accuracy by inspection, when the clouds are banked-up against the hills, provided the heights of the different features of the hill-side are known. These heights can be obtained from a Survey Map of the district.

Estimating Cloud Heights.—At stations in level country where pilot balloon observations are not made, and direct measurements are not possible, we have to fall back on estimates. In view of the great practical importance of a knowledge of the height of the low clouds, in aerial navigation, estimates of the height of the lowest clouds are now included in the meteorological reports sent from telegraphic reporting stations in order that this information may be made prompt'y available to pilots of machines. Some guidance in forming such estimates can be obtained from the following table giving the approximate average heights of the different forms of clouds.

Estimations of cloud height, if given, must however be derived from observation and not from a direct application of the Table; that is, it should not be assumed for example that the bases of all cumulus clouds are at a height of 4,600 feet. Observers who have the necessary experience or information to enable them to form satisfactory estimates of cloud height in thousands of feet should note the information in the monthly returns.

Form	Average height—feet
Low clouds (below 8,000 ft.)—	
Stratus	below 3,300
Cumulus	(base) 4,600
	(top) 6,000
Cumulo-nimbus (base of)	4,600 (the top of cu.-nb. frequently extends to heights of 10,000 to 26,000 ft.)
Nimbus (base of)	about 1,500 ft. (the upper part of nimbus may extend into the region of high cloud).
Strato-cumulus	below 8,000.
Medium clouds (between 8,000 and 26,000 ft.)—	
Alto-stratus	10,000 to 23,000.
Alto-cumulus	10,000 to 23,000.
High clouds (above 26,000 ft.)—	
Cirro-stratus, Cirro-cumulus, Cirrus	30,000

(IV) Direction and Velocity

The direction of motion of clouds is always stated as the direction from which the cloud is coming as in the case of giving the direction of the wind. It is best observed by sighting the cloud against a fixed point. At night-time and when the cloud canopy is broken, stars near the zenith form very suitable fixed points. At other times the top of a flagstaff, gable of a house, etc., may be used. If the cloud motion is slow the observer will find it advantageous to rest his head against some fixed support while taking the observation; otherwise the apparent cloud motion which he observes may be due to motion on his own part. To avoid errors due to perspective he should stand as near as may be vertically below the fixed point and confine his attention to clouds near the zenith. A little experience will enable the observer to give a qualitative statement of the apparent velocity of clouds by means of such designations as slow, moderate, fast, etc.

CHAPTER VII.

WEATHER

Under the heading "Weather" are classified the various appearances and phenomena that describe the chief characteristics of the weather for the day or at the time of observations. These phenomena generally indicate modifications in the water-vapour in the atmosphere.

The first system of notation to indicate the weather phenomena was devised by Admiral Beaufort, and is called the "Beaufort System." In this system the phenomenon is generally denoted by the first letter of the word for it. In 1873 the International Congress of Meteorologists at Vienna worked out a system of symbols which was independent of any language. A combination of both these systems has been in use in the Canadian Service.

Of late years there has been a desire to indicate not only the phenomenon but also its intensity and duration. This is accomplished in the Beaufort system by the use of capitals to denote unusual intensity and by the subscript "$_o$" with the small letters for slight intensity, while continuity is expressed by repeating the letter.

In the International system intensity is indicated by adding the exponent "^{2}" or the subscript "$_o$", giving three degrees of intensity; no provision is made for expressing continuity in this system, but it could easily be done by repeating the symbol as in the Beaufort system.

The demand for weather information in connection with Aviation and Airships, however, has led to more explicit definition of the different types of weather, and for code purposes these types are most easily expressed in numbers. Instead, then, of using the Beaufort or International systems, it is now proposed to use numbers to express the different types of weather as given in the table below. The different types are grouped generally in tens and it is thus a simple matter to find the group giving the number descriptive of the weather.

It is assumed that the description of the weather at the time of observation refers to the weather at the time of observation and for the hour immediately preceding. Weather for the interval between two observations can be given in the same numbers and in the column for that purpose in the records and forms, with any additional explanation that may be necessary.

Ground and optical phenomena will be described as briefly as possible in the column for "remarks" or "general state of the weather."

Explanations, where necessary, of the phenomena, follow the table. The first twenty numbers give general descriptions of the weather, and can usually be used in describing the weather between the times of observation.

00–19 Abbreviated description of sky and special phenomena
00 Cloudless. (0–1)
01 Partly cloudy. (2–4)
02 Cloudy. (5–8)
03 Overcast. (9–10)
04 Fog over sea (coast station); fog on lower ground (inland station)
05 Haze (but visibility greater than 2,000 m. $1\frac{1}{4}$ miles).
06 Dust devils seen.
07 Distant lightning.
08 Mist (visibility between 1,000 and 2,000 m., 1,100 yards and $1\frac{1}{4}$ miles.)
09 . . . .
10 Precipitation within sight.
11 Thunder, without precipitation at the station.
12 . . . .
13 Ugly, threatening sky.
14 Squally weather.
15 Heavy squalls } in last 3 hours.
16 Waterspouts seen } in last 3 hours.
17 . . . .
18 Signs of tropical storm forming.
19 Signs that tropical storm has formed.

20–29 Precipitation in last hour but not at time of observation.

20	Precipitation (rain, drizzle, hail, snow or sleet		In last hour but not at time.
21	Drizzle	other than showers	
22	Rain		
23	Snow		
24	Sleet		
25	Rain shower (s)		
26	Snow shower (s)		
27	Hail or rain and hail shower (s)		
28	Slight thunderstorm.		
29	Heavy thunderstorm.		

30–39 Dust storms and storms of drifting snow (visibility less than 1,000 m., 1,100 yards).
30 Dust or snow storm.
31 " " has decreased.
32 " " no appreciable change.
33 " " has increased.
34 Line of dust storms.
35 Storm of drifting snow.
36 Slight storm of drifting snow } generally low.
37 Heavy storm of drifting snow } generally low.
38 Slight storm of drifting snow } generally high.
39 Heavy storm of drifting snow } generally high.

40–49 Fog or thick dust haze (visibility less than 1,000 m., 1,100 yards).

40	Fog.	
41	Moderate fog in last hour.	
42	Thick fog in last hour.	
43	Fog, sky discernible	has become thinner during last hour.
44	" sky not discernible	
45	" sky discernible	no appreciable change during last hour.
46	" sky not discernible	
47	" sky discernible	has become thick during last hour.
48	" sky not discernible	
49	Fog in patches.	

50–99 Precipitation at time of Observation.

50–59 Drizzle (precipitation consisting of numerous minute drops).

50	Drizzle.	
51	Intermittent	slight drizzle.
52	Continuous	
53	Intermittent	moderate drizzle.
54	Continuous	
55	Intermittent	thick drizzle.
56	Continuous	
57	Drizzle and fog.	
58	Slight or moderate	drizzle and rain.
59	Thick	

60–69 Rain.

60	Rain.	
61	Intermittent	slight rain.
62	Continuous	
63	Intermittent	moderate rain.
64	Continuous	
65	Intermittent	heavy rain.
66	Continuous	
67	Rain and fog.	
68	Slight or moderate	rain and snow.
69	Heavy	

70–79 Snow.

70	Snow or sleet.	
71	Intermittent	slight snow in flakes.
72	Continuous	
73	Intermittent	moderate snow in flakes.
74	Continuous	
75	Intermittent	heavy snow in flakes.
76	Continuous	
77	Snow and fog.	
78	Granular snow or sleet (clear ice particles with or without rain).	
78a	Snow pellets or soft hail.	
78b	Rain freezing as it falls. (Ice storm).	
79	Ice crystals.	

80–89 Shower (s)

80	Shower (s)		
81	Shower (s) of	slight or moderate	rain.
82	" "	heavy	rain.
83	" "	slight or moderate	snow.
84	" "	heavy	snow.
85	" "	slight or moderate	rain and snow.
86	" "	heavy	rain and snow.
87	" "	granular snow or sleet.	
88	" "	slight or moderate	hail or rain and hail.
89	" "	heavy	hail or rain and hail.

90–99 Thunderstorm.

90	Thunderstorm.	
91	Rain at time	Thunderstorm during last hour, but not at time of observation.
92	Snow or sleet at time	Thunderstorm during last hour, but not at time of observation.
93	Thunderstorm, slight, without hail or soft hail, but with rain (or snow)	At time of observation
94	Thunderstorm, slight, with soft hail	At time of observation
95	" moderate, without hail but with rain (or snow)	At time of observation
96	" moderate, with soft hail	At time of observation
97	" heavy, without hail, but with rain or snow)	At time of observation
98	" combined with dust storm	At time of observation
99	" heavy, with hail	At time of observation

Ground Phenomena

Dew
Hoar Frost
Rime
Silver Thaw
Glaze
Snow on the ground

Brief descriptions to be given in the Observer's notes or daily register.

Optical Phenomena

Solar Corona
Solar Halo
Lunar Corona
Lunar Halo
Rainbow
Double rainbow
Aurora
Zodiacal Light
Mirage

Brief descriptions to be given in the Observer's notes or daily register.

Notes

Whenever the description "intermittent" is used the fog or precipitation has not continued without break during the last hour, or between the periods of observation. The distinction between intermittent precipitation or showers is that the showers are from isolated clouds and are, therefore, of short duration. Between the showers there is a definite clearance unless stratiform clouds are filling the gaps between the shower clouds. In intermittent precipitation, the precipitation may cease for an interval, but the same general level of cloud is maintained.

Snow Showers are also generally described in this country as snow flurries.

Fog.—When the sky is discernible through fog, the cloud is reported as if no fog were present, but when the sky is not discernible the cloud amount is reckoned as "10", and the height of the base of low cloud as "0".

Ground Fog.—A fog which does not exceed the height of a man. It should be given by the number "04".

Figures 20 to 29 are never to be used when there is precipitation actually falling at the time of observation.

Thunder, Lightning and Thunderstorms.—Distant lightning, which is also known as sheet lightning, should always be given by the figure "07", while when thunder is heard without precipitation at the Station, the figure "11" should be used. When there is precipitation with thunder and lightning, one of the figures which best describes the thunderstorm should be given. They are found in numbers 20 to 29, and 90 to 99. The times at which thunderstorms occur should be given in the "remarks" or appropriate column. It is desirable to note the time of commencement of a thunderstorm as given by the first thunder and the time of the more prominent flashes to the nearest minute. The directions from which thunder clouds approach should always be noted.

It is very important also to note in the remarks if a line squall accompanies the thunderstorm.

Line Squall.—A line squall is a sudden squall of wind, usually blowing at right angles to the preceding wind and lasting from about 5 to 15 minutes. It marks a discontinuity (or sudden change) in the atmosphere, and its passage over a station is always accompanied by a sudden drop of temperature and a sudden rise of pressure. At stations equipped with a barograph or a thermograph the line squall may be distinguished from a gust of wind by this change of temperature and pressure; at other stations the distinction must be made by the observer by considering the direction of the wind in the squall and the drop in temperature. The squall is usually felt simultaneously with more or less intensity all among the line, which may be some hundred of miles in length, and the most severe thunderstorms usually occur just after the passage of this line over a station. The line squall, may, however, occur with sufficient intensity to be noticed without being followed by a thunderstorm. It occasionally occurs in fair weather, and is then recognizable by a long line of cumulus cloud, and it is from this line of cloud that the phenomenon originally obtained its name.

Hail and Soft Hail.—There is a distinction between true hail and soft hail. The former occurs almost exclusively with summer thunderstorms, and the stones are hard, as they consist of ice and compact snow, generally in concentric layers.

Soft hail, on the other hand, consists of little pellets of snow like tiny snowballs, and falls chiefly in early Spring and late Autumn It is also defined as pellets of closely agglomerated ice crystals and is a form of snow. If these pellets are large they may break on impact with a hard substance and therein differ from true hail. When soft hail falls during thunderstorms the appropriate number describing it will be given in 90 to 99, but otherwise, it is to be given as 78a.

Granular Snow, Sleet.—Granular snow is small white ice grains of irregular shape, while sleet is small grains of clear ice, and is simply small raindrops which freeze before reaching the ground.

Either of these two forms of precipitation may occur with or without rain; generally, however, if there is rain it freezes as it falls.

Rain Freezing as it falls.—When rain falls with the temperature below freezing point, a layer of smooth ice is formed upon all objects exposed to it. This is often called an ice storm, and at times causes heavy damage to trees, transmission lines, etc. The coating of ice that is formed is called "Glaze" on this continent.

These diferent forms of precipitation should be given by the number 78, but Observers are requested to distinguish between them by means of the letters as indicated. It is important to make careful notes of these occurrences and especially of ice storms, on account of the damage that they do; the time of beginning and ending of the storms should also be noted.

Ground Phenomena

Dew is moisture condensed from the atmosphere on exposed surfaces. It is caused by the loss of heat from blades of grass, shrubs, roofs, etc., by nocturnal radiation and consequent cooling below the temperature at which the water-vapour present in the atmosphere is sufficient to saturate it.

Hoar Frost resembles dew in the manner of its formation. When the temperature falls sufficiently low the water-vapour may be deposited in the solid state or the dew originally deposited in the liquid state may become frozen. The deposit thus formed is hoar frost. It presents a white crystalline appearance, but the particles have been shown to be amorphous in structure in most cases.

Rime is the rough frost-like deposit of delicate structure, which may be deposited at all hours during foggy weather at moderate to

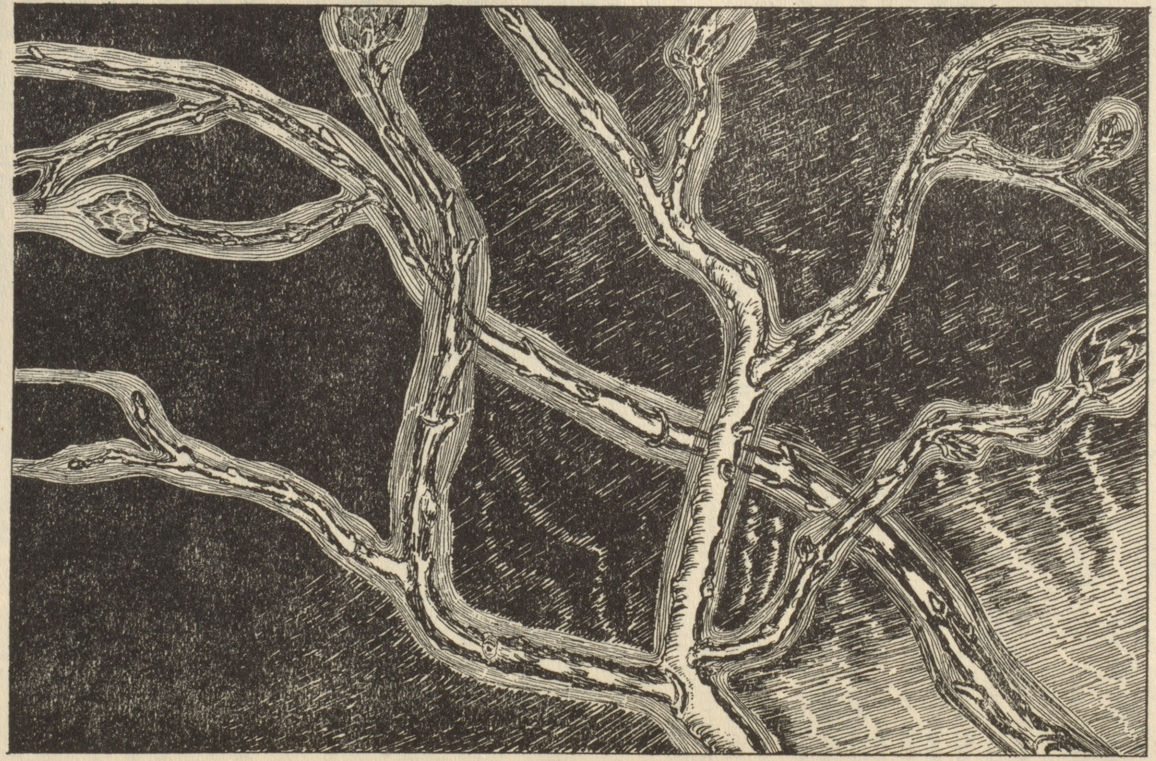


FIG. 33.—Glazed frost on twigs and branches during sleet storm at Toronto, on March 21st, 1927, sketch by Mr. Harold Bibby.

severe cold temperatures, on the branches and leaves of trees, on all corners, joints and edges of upright objects. It forms not at all, or in insignificant amounts, on horizontal surfaces. Since it is built of the fog particles driven by the wind it grows most rapidly on the windward side of objects, i.e., it grows against the wind. Rime does not form uniformly on all objects at the same height; the smallest twigs may be so loaded with it that they seem to be incrusted, while at the same time the branches and stem of the plant remain free from it.

Silver Thaw.—After a spell of severe frost the sudden setting in of a warm, damp wind may lead to the formation of ice on exposed objects, which being still at a low temperature cause the moisture in the air to freeze and make the surfaces appear as if they were covered with hoar frost. This deposit of frozen moisture may become very thick and last for a day or more if the cold spell is very severe and prolonged. This phenomenon is known as "Silver Thaw."

Glaze.—Fig. 33.—When rail falls with the temperature below the freezing point a layer of smooth ice, which may attain considerable thickness, is formed on all objects exposed to it. This layer of ice is known as "Glaze". The accumulation of ice is frequently sufficient to do extensive damage to transmission lines, such as telegraph, telephone and power lines. It is therefore very important that the thickness of the coating should be estimated as carefully as possible, and a full description of the damage done, noted.

It is important to distinguish between rime, silver thaw and glaze. This is most easily done by noting carefully the mode of formation in each case; thus, Rime is only deposited during foggy weather in moderately severe cold temperatures, and on the windward side of objects. Silver thaw is simply the frozen moisture that deposits on all exposed objects which are very cold in comparison with the warm, damp air that is surrounding them. It thus forms on all sides, while rime only forms on the windward side. Glaze is a coating of smooth ice caused by an ice storm or rain freezing as it falls.

Snow on the Ground.—The depth of snow that has accumulated on the ground determined once a week or as instructed, by plunging an inch rule vertically into the snow in a place where it is lying evenly, should be entered in the column provided or in "remarks," care being taken that the measurement is clearly stated. The mean of measurements made in several different places should be given.

CHAPTER VIII

OPTICAL ATMOSPHERIC PHENOMENA

There are a large number of optical phenomena which not only arrest the attention of the observer on account of their beauty, but also are more or less closely connected with the weather; they are of importance for both reasons, and observers are recommended to note them carefully.

For exact measurements of optical phenomena suitable instruments are required. For rough estimates a graduated rod held at arm's length may serve. The position of such phenomena as a "mock sun" may be determined by noting its relation to fixed objects in the landscape. The diameter of a corona may be estimated by taking the diameter of the sun or moon (approximately 30′ of arc) as unit.

The following instructions for observing optical atmospheric phenomena are based on the instructions which were drawn up by the late Prof. J. M. Pernter and incorporated in the handbook issued by the Austrian Meteorological Department. They received the approval of the International Conference of Directors of Meteorological Institutions which met at Innsbruck in 1905.

Halo. Solar Halo; Lunar Halo.

Many different kinds of halo have been observed. The most common is the halo of 22°—a large ring (a, fig. 34) round the sun or moon, having a radius of very nearly 22° (of a great circle). When of no great intensity the ring appears white, but when it is more strongly developed we may easily recognize the fact that the edge nearest the sun is red—a very pure red— and that orange, yellow and, under very favourable circumstances, green, follow on, as we go outwards. The latter colour is always rather faint and whitish, and the blue is almost always so faint that it is not recognized as blue. Violet is never recognizable. The ring thus appears white on its outer edge.

A ring of about twice the radius, halo of 46°, b fig. 34, occurs more rarely. Its luminosity is much less than that of the halo of 22°; the arrangement of the colours, if visible, is the same.

Occasionally a colourless white ring, which passes through the sun parallel to the horizon, may be recognized. This is called the horizontal circle or mock sun ring. The latter name has been given to it because the mock suns lie on or near it. It is represented in fig. 34 by the circle C; generally the part within the halo of 22° is not visible.

A fourth ring is exceedingly rare; it is white, and has a radius of about 90°; it is known as the halo of 90°. It is obvious that this halo can never be seen in its entirety in our latitudes, for this would require the sun to be in the zenith.

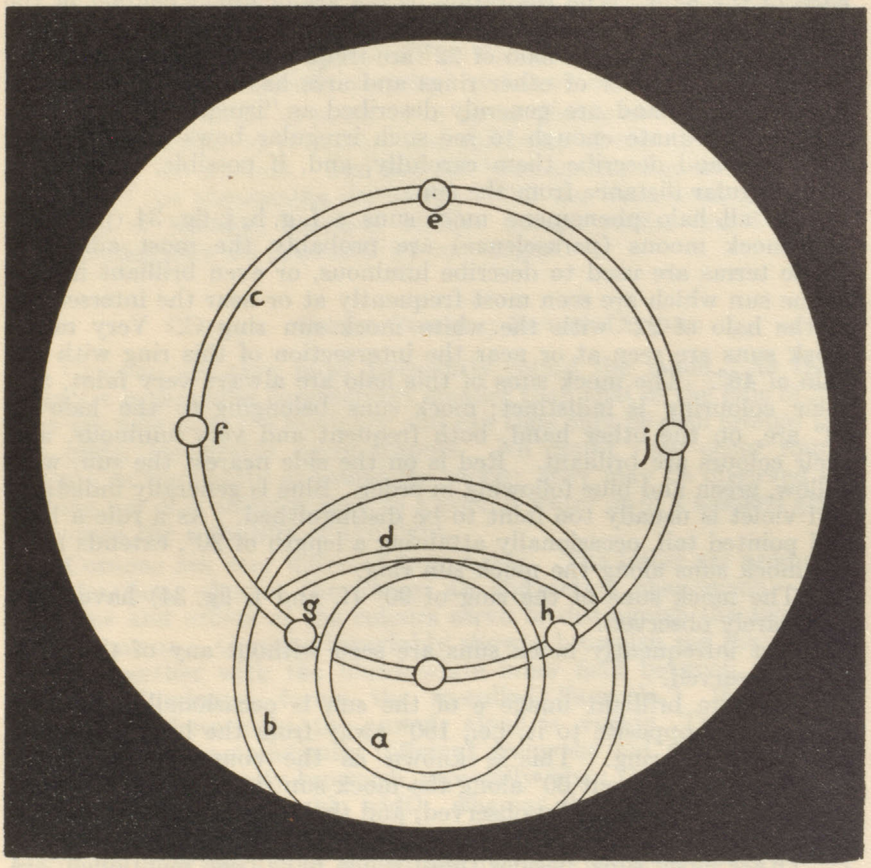


FIG. 34.—Halo Phenomena, 10 a.m. to 11:30 a.m., April 20th, 1922, at Fort Good Hope, N.W.T. seen and sketched by Mr. Harold Bibby.

It should be mentioned that the rings are frequently incomplete in the cases of the three first-mentioned halos also; at times only small portions of them can be seen.

There are a number of other halo phenomena which, from their method of formation, can only be seen as arcs. Among these are the so-called arcs of contact, of which one, the upper tangent arc d of halo 22°, is shown. Arcs of lower contact may occur in connection with both these rings, but they are very rare.

Contact arcs appear occasionally at the sides of the halos of 22° and 46°, but they are as rare as the arcs of lower contact. The arcs of upper contact are very luminous at the points of contact, which have occasionally been described as "mock suns." The colour effects are often brilliant, red being turned towards the sun, i.e. on the convex edge of the halo. The coloration of the arc of upper contact of the halo of 46° is frequently exceedingly brilliant. The ends of the arc of upper contact of the halo of 22° are frequently bent downwards.

A large number of other rings and arcs have been observed on rare occasions, and are generaly described as "irregular"; observers who are fortunate enough to see such irregular bows are requested to sketch and describe them carefully, and, if possible, to measure their angular distance from the sun.

Of all halo phenomena mock suns e, f, g, h, j, fig. 34 (parhelia) and mock moons (paraselenae) are probably the most admired. These terms are used to describe luminous, or even brilliant images of the sun which are seen most frequently at or near the intersection of the halo of 22° with the white mock sun ring C. Very rarely mock suns are seen at or near the intersection of this ring with the halo of 46°. The mock suns of this halo are always very faint, and their colouring is indistinct; mock suns belonging to the halo of 22° are, on the other hand, both frequent and very luminous, and their colours are brilliant. Red is on the side nearest the sun, with yellow, green and blue following in order. Blue is generally indistinct and violet is usually too faint to be distinguished. As a rule a long and pointed tail, occasionally attaining a length of 20°, extends from the mock suns along the mock sun ring.

The mock suns of the ring of 90° (f, and j, fig. 34) have been very rarely observed.

Not infrequently mock suns are seen without any of the rings being observed.

A white brilliant image e of the sun is occasionally observed immediately opposite to it, i.e., 180° away from the luminary along the mock sun ring. This is known as the counter sun. Mock counter suns, at about 60° along the mock sun ring from the counter sun, have been repeatedly observed, and their distances from the sun have been measured.

Other mock suns, besides those which have been mentioned, are occasionally seen. Observers are requested to sketch and describe what they see carefully, should they happen to see one of these. If possible, they should determine its position by measurement.

Other very beautiful halo phenomena are afforded by " sun pillars," which are most easily observed at sunrise or sunset. These frequently extend about 20° above the sun and generally end in a point. At sunset they may be entirely red, but as a rule they are of a blinding white and show a marked glittering. If the sun is high in the heavens, white bands may appear vertically above and below it, but these are not very brilliant and often they are very short. Occasionally these white columns appear simultaneously with a portion of the white mock sun ring, and so form another very remarkable phenomenon, viz. the "cross".

Frequently parts only of the rings and arcs are visible, having apparently no connection with one another, thus lending a very peculiar appearance to the sky; not infrequently these arcs intersect obliquely, which increases the strangeness of the appearance.

Many other halo phenomena are known to occur, but the space which can be devoted to the subject in a book of instructions to observers is limited, and they cannot all be described here. All halo phenomena should be carefully sketched and described.

Halos only occur in presence of cirrus clouds or of light ice fog; they are produced by refraction and reflection of the rays of the sun or moon by ice crystals. The sun has been assumed as the source of light in all the phenomena described. This has been done solely for the sake of brevity; precisely similar though rather less brilliant appearances may be produced by moonlight.

Corona. Solar Corona; Lunar Corona

Coronae are seen most frequently round the moon. As their diameter is generally considerably smaller than that of the halo of 22° they are very near the luminary and can thus only be seen around the sun under favourable circumstances. No doubt they occur round the sun as frequently as round the moon; they may be observed by making use of a reflector such as a pool of water or of a smoked glass to reduce the intensity of the light.

Coronae are very different from halos. The latter are produced by refraction, whereas the former are diffraction phenomena. The positions and orders of the colours serve to distinguish the two sets of phenomena. Coronae invariably show a brownish red inner ring, which, together with the bluish-white inner field between the ring and the luminary, forms the so-called "aureole." Frequently, indeed very frequently, the aureole alone is visible, The brownish red ring is characteristically different from the red ring of a halo; the former is distinctly brownish, especially when the aureole alone is visible, and of considerable width, whereas the latter is beautifully red and much narrower. If other colours are distinguishable, they follow the brownish red of the aureole in the order from violet to red, whereas the red in a halo is followed by orange, yellow and green. The order of the colours is thus reversed.

The size of the diameter of the ring has been erroneously suggested as a criterion for distinguishing between halos and coronae, but a corona may be quite as big as a halo. The diameter of a corona is inversely proportional to the diameter of the particles in the atmosphere by the agency of which it is formed. Bishop's ring has furnished a well-known example of such a corona. The criteria which an observer should apply to distinguish the two sets of phenomena are not the diameters of the rings, but the sequence of colour and the presence of the brown-red of the aureole.

As coronae are diffraction phenomena they occasionally show the sequence of colour two or three or even four times over. This can never be the case with a halo. Observers are requested to note carefully the colours which they can identify and also the order in which they follow one another from the inside to the outside of the ring.

Brocken Spectre

It happens frequently on mountains that there is mist on one side of a ridge and not on the other. In such circumstances an observer standing with his back to the sun will sometimes see coloured rings of light round the shadow of his own head on the mist. Similar observations may be made from aircraft. The whole appearance has been called the "Brocken Spectre," and the rings are usually known as a "Glory." The colours are not caused by the shadow, they are due to light diffracted backwards in the same way as the corona is due to light diffracted forwards. A large outer ring, known as Ulloa's ring, which is essentially a white rainbow, is sometimes seen at the same time.

Iridescent Clouds

Green and red colours are occasionally seen on the edges of cirrus and cirro-cumulus clouds, at a distance from the sun or moon up to 25° or more. They are also seen at times on the edges of fracto-cumulus or strato-cumulus clouds. Frequently a number of them may be seen along a line passing through the sun. These patches are perhaps portions of coronae, in which case they are probably due to the local occurrence of exceedingly small drops of water. The most important point to note is the (angular) distance between the sun (or moon) and the patches showing irisation.

Rainbow; Double Rainbow

Rainbows are due to refraction and reflection of sunlight (occasionally moonlight) in falling drops of rain. They are circular arcs of coloured light centred at the anti-solar point (or point of the celestial sphere diametrically opposite to the sun). The primary bow is seen after one reflection and two refractions in the drops; the secondary bow is seen after two reflections and two refractions and so on.

The erroneous assumption that all rainbows show the same sequence of colours and have the same radius has caused the careful study of this phenomenon to be much neglected. It has been shown that the colours of a rainbow as well as their extent and the position of the greatest luminosity are very variable and depend on the size of the drops producing the bow. It is very desirable that greater attention be given to this subject.

Observers should note the sequence of colours, the relative width and intensity of the successive bands. The sequence of colours has been determined theoretically for bows formed by drops of certain sizes, and accordingly, when these sequences are observed, the size of the drops is identified.

The radius of the primary bow is about 42°. Red or orange is on the outside of the bow and violet inside. The order of the colours is reversed in the secondary bow, which appears outside the primary bow at a distance of about 12° from it.

Coloration of the Sky

A cloudless sky appears to be blue, but it may show all possible gradations between a deep blue and a whitish-blue shade. It is desirable to note the gradations of colour according to the scheme: deep blue, light blue and pale blue. Such observations give information regarding the purity of the air.

The most beautiful colours are seen at dusk. When the sky is cloudless, the colour and form of the first "purple light" is worth attention. It is approximately parabolic in shape and appears at a considerable elevation above the point where the sun disappeared soon after sunset. It varies in colour between pink and violet. Observers are also invited to note the colouring of the western sky and the appearance of the second "purple light" which develops soon after the disappearance of the first. The time of disappearance of the second light is also of importance. If "after glow" is associated with the sunset, the phenomenon should be noted.

The coloration of the clouds at sunset is often very beautiful and very striking, and is therefore frequently noted, although the phenomena observed when the sky is clear are more important.

All the above remarks apply also to sunrise but in the reverse order.

The Green Ray

When the sun sets under favourable conditions the last glimpse of it is coloured a brilliant green. The phenomenon and the corresponding one at sunrise are explained by the unequal refraction of light of different colours.

Mirage

The position and appearance of distant objects are always altered to some extent by refraction when the light which passes from the object to the observer traverses obliquely layers of air of different density, and sometimes the displacement of position or distortion of appearance is so great as to produce an illusion of apparent water, trees or buildings. Such phenomena are conspicuous when the variations of temperature close to the ground are very marked, as in desert countries when the ground is very strongly heated by the sun. Corresponding phenomena are to be noted occasionally in this country and are of definite importance in the study of visibility. Observers should therefore "remark" the occurrence.

Aurora Borealis

The Aurora usually appears as a bright arch beneath which the sky seems to be darker than in the surrounding regions. Frequently streamers of light shoot out radially from the arch and sometimes extend beyond the zenith. Occasionally the arch resembles a swaying sheet or curtain of light, and at times several arches can be seen simultaneously.

Observers should note such points as the direction in which the phenomenon appears to be most intense, the direction of the arches and their angular height above the horizon, the length and position of the most prominent streamers, etc. Attention should also be directed to the colour effects visible.

The Aurora is an electrical phenomenon and is usually associated with magnetic storms. It presents itself under six different forms:

(1) *Auroral Twilight.*—A light in the north, resembling the dawn of day, and of various degrees of intensity.

(2) *Arches.*—Arcs, or circles, or zones, formed at various altitudes, usually between Northeast and Northwest, being sometimes the mere boundary of a segment, at other times a dense pillar of light, forming a grand columnar arch, which spans the heavens from East to West. It frequently moves from North to South, usually advancing but little further than the Zenith.

(3) *Streamers.*—Acute cones or spindles, usually shooting up from an arch, or from a dark smoky cloud, which lies along the northern horizon, or rises a few degrees above. it.

(4) *Corona.*—A circular zone round the pole of the dipping needle, formed of wreaths of auroral vapour, either of pure white or of various prismatic colours, with streamers radiating from the circumference.

(5) *Waves.*—Undulations which commonly flow upwards towards the centre of the corona, along the line of the streamers, but sometimes course along the line of an arch from east to west.

(6) *Auroral Clouds.*—A milky and vapoury bank in the north, the quantity and apparent depth of which afford a prognostic of the intensity of the coming aurora. These clouds are sometimes of a smoky hue especially in front,while the margins are luminous.

Classification of Auroras.—From the preceding varieties, as described by Professor Olmsted, it will be found convenient to arrange auroras into four classes.

Class I.—This is characterized by the presence of at least *three* out of four of the most magnificent varieties of form, namely, arches, streamers, corona and waves. The distinct formation of the corona is the most important characteristic of this class; yet were the corona distinctly formed without auroral arches, or waves, or crimson vapour, it would not be considered as an aurora of the first class.

Class II.—The combination of *two* or more of the leading characteristics of the first class, but wanting in others, would serve to mark the second. Thus the exhibitions of arches with a corona, without streamers or columns (if such a case ever occurs), should be designated as an aurora of the second class.

Class III.—The presence of only *one* of the more rare characteristics, either streamers or an arch, or irregular coruscations, but without the formation of a corona, and with a moderate degree of intensity, would denote an aurora of the third class.

Class IV.—In this class are placed the most ordinary form of the aurora, as a mere northern twilight or a few streamers, with none of the characteristics that mark the grander exhibitions of the phenomenon.

Zodiacal Light

This is an astronomical phenomenon the visibility of which has been brought into use as a test of atmospheric transparency. The Light is probably sunlight diffused by minute particles. The nature of the particles is unknown; they extend from the sun to beyond the orbit of the earth. The axis of the Light appears to lie in the plane of the sun's equator.

The Light is observed as the extremity of an elongated ellipse of whitish light rising obliquely from the horizon in a westerly direction after sunset or an easterly direction before sunrise. The best time to see the phenomenon is when the stars and Milky Way become fully visible in the evening or just before they cease to be so in the morning; the Light is visible in faint twilight only in favourable conditions. As the evening advances the Light gradually sets, its position among the stars being retained. Observation in faint moonlight is possible but generally speaking only the period between about three days after full moon to three days after new moon is available for evening observation.

The centre of the ellipse is at the sun and the major axis is inclined a few degrees to the ecliptic. The Light is most readily seen when the ecliptic makes the largest angle with the horizontal; this occurs in the evenings from January to March and in the mornings from September to November. In February the Light lies between the constellations Pegasus and Cetus, the apex being near the Pleiades at an altitude of 50° or more in the early evening. The breadth near the horizon is 25° to 30°, the altitude of the brightest part being 20°–30°. As the season advances, the cone of light becomes blunter in form and makes a decreasing angle with the horizon. It can, however, be seen in favourable circumstances in this country to the middle of May.

The Light is ill-defined at its edges and is soft and homogeneous, thus differing from the Milky Way, with which it is comparable in brightness. It is more brilliantly and readily seen in the tropics; its visibility in this country depends on the observer's situation. In the open country the Light is too readily seen in the early evenings of spring to form a good test of atmospheric clearness, i.e., it will be visible on any reasonably clear starlight evening. Observations made later in the evening or later in the season form a much more stringent test. For this reason the hour of observation should always be noted. In the centre of large towns or industrial areas observation is very difficult. About the period of the winter solstice it is possible to observe the Light on the morning and evening of the same day.

CHAPTER IX

TIME

In order that observations should be strictly comparable with each other, it is necessary that they should be taken at the same time throughout the country; but there are three ways in which time may be reckoned: local apparent Solar time, local Mean time, and Standard time.

Apparent Solar Time

Time for civil use is derived from the earth's rotation. The interval between two successive transits of the centre of the sun's disk over the meridian is a true Solar Day, and the time based on the length of the true solar day is called "Apparent Time." A sundial or a sunshine recorder, when correctly set, indicates local apparent solar time.

Mean Time

The length of the true solar day is not the same throughout the year. To avoid the obvious inconveniences which would arise from a want of uniformity in the length of the civil day, time is referred to an imaginary body called the "mean sun" which may be supposed to revolve uniformly round the earth, and complete each revolution in a time equal to the average length of the true solar day. Time referred to this "mean sun" is called Mean Time; the days measured on this convention are all of equal length.

Standard Time

The instant that the sun is due south is not the same for all places, but depends on the geographical meridian of the place and is different for different meridians. The Equator is divided into 360 equal parts called degrees, and a line drawn through each degree and the poles is called a meridian, the distance between two meridians being known as a degree of longitude. As the earth makes a revolution on its axis in 24 hours it must turn through 360 degrees of longitude, or every hour through 15 degrees: hence every place distant 15° of longitude from another has the sun due south of it an hour before or after, as the case may be. If the time is reckoned from the instant that the mean sun is due south of the place, it is called local mean time, and it follows therefore that every place that is not on the same meridian has a different local mean time. Formerly every place had its own local time, but with the advent of the railway this became very troublesome, as it meant a change of time with every change of locality. To obviate this inconvenience the country was divided up into 15° zones, and every place within that zone has the same time. This is known as Standard Time, and is based on the meridian of Greenwich, which is 0° longitude. The different zones in order from East to West, with the meridian on which they are based, are as follows:

Atlantic time....................	60th meridian.
Eastern time....................	75th "
Central time....................	90th "
Mountain time..................	105th "
Pacific time....................	120th "

Hours of Observation

Meteorological stations reporting by telegraph instead of taking the observations at the local time of the place, take them at the same instant of time—8 a.m. and 8 p.m. Eastern Standard time; thus the time of observation

at Stations	using	Atlantic	time is	9 a.m.	and	9 p.m.
"	"	Eastern	"	8 a.m.	"	8 p.m.
"	"	Central	"	7 a.m.	"	7 p.m.
"	"	Mountain	"	6 a.m.	"	6 p.m.
"	"	Pacific	"	5 a.m.	"	5 p.m.

A sundial gives the true local apparent time of the place, and when this method is in use it should be remembered that it is local apparent time, not local mean time, that is obtained. If the true north-and-south direction is known, then by setting up a stake and marking a line from it towards the true north so that the shadow cast by the stake can be observed as it crosses this line, the local apparent time of noon may be obtained with considerable accuracy. In order to obtain the local mean time from the apparent time, the local mean time when the sun crosses the meridian (that is, when the shadow lies exactly on the marked line) is given in the following Table for every third day of each month in the year: that is, the local mean time for local apparent noon. For other hours given by apparent time, the local mean time will be at once obtained by taking the mean time as the same number of minutes before or after that hour as in the case of apparent noon.

LOCAL MEAN TIME AT LOCAL APPARENT NOON

Date of month	January	February	March	April	May	June
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
1	12 03½	12 14	12 12½	12 04	11 57	11 57½
4	12 05	12 14	12 12	12 03	11 56½	11 58
7	12 06½	12 14½	12 11	12 02	11 56½	11 58½
10	12 07½	12 14½	12 10½	12 01	11 56	11 59
13	12 09	12 14½	12 09½	12 00½	11 56	12 00
16	12 10	12 14½	12 08½	11 59½	11 56	12 00½
19	12 11	12 14	12 08	11 59	11 56½	12 01
22	12 11½	12 14	12 07	11 58½	11 56½	12 02
25	12 12½	12 13½	12 06	11 58	11 56½	12 02½
28	12 13	12 13	12 05	11 57½	11 57	12 03
31	12 13½	....	12 04	....	11 57½	

LOCAL MEAN TIME AT LOCAL APPARENT NOON—*Concluded*

Date of month	July		Aug.		Sept.		Oct.		Nov.		Dec.	
	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.
1	12	03½	12	06	11	59½	11	49½	11	43½	11	49½
4	12	04	12	06	11	58½	11	48½	11	43½	11	50½
7	12	04½	12	05½	11	57½	11	47½	11	44	11	52
10	12	05	12	05	11	56½	11	47	11	44	11	53
13	12	05½	12	04½	11	55½	11	46	11	44½	11	54½
16	12	06	12	04	11	54½	11	45½	11	45	11	56
19	12	06	12	03½	11	53½	11	45	11	45½	11	57½
22	12	06	12	02½	11	52½	11	44½	11	46½	11	59
25	12	06	12	02	11	51½	11	44	11	47½	12	00½
28	12	06	12	01	11	50½	11	44	11	48½	12	02
31	12	06	12	00	...	...	11	43½	...	...	12	03½

h signifies hours: m—minutes.

To obtain the standard time for the zone in which an observer is situated from the sundial or sunshine recorder when the longitude of the place is known, proceed as follows:—

Suppose the standard time is required on May 2nd and that your place of observation is in longitude 100° 45′ W. this is in the zone between 90° and 105°, the standard for which is the 90th meridian; the place is thus 10° 45′ west of longitude 90°. Time changes one hour for each 15°, that is at the rate of 4 minutes for every degree of longitude; hence the change for 10° 45′ will be 43 minutes. The easiest way to find the Central time from the sundial is to do so at local apparent noon (that is when the sun is exactly south of you, or as we say, "on your meridian"). Now you have found from the above calculation that your position is west of the Central Time meridian and the difference of time between the two is 43 minutes; in fact the sun crosses your meridian just that much later. The sun, therefore, crossed the 90th meridian 43 minutes before it crossed your meridian. But on May 2nd the table tells you that, at the moment when the sun crossed your meridian (local apparent noon), your local mean time was 11 hrs. 57 min.; hence the mean time of the 90th meridian (that is the "standard time") is: 43 minutes after 11 hrs. 57 min., which of course is 12 hrs. 40 min. This time, forty minutes past noon, is the standard time (for the Central zone)—or simply the Central time of the occurrence, namely, the crossing of your meridian by the sun. If you wished to set your watch to standard time you should set it 12.40 when the centre of the sun was on the meridian.

More frequently, however, it is required to find the reverse: the standard time of local apparent noon. Consider the case of a town in which you want to determine accurately when the sun will be on the meridian, or due south, by the standard time of the place. If you do not know your longitude take a good map and find it as accurately as possible; suppose that it is 113° 15′ W. That means that you are in the Mountain time zone, the time of which is the local mean time of the 105th meridian. Now all the railway and telegraph stations get the correct time every day from Montreal at 11 a.m. Eastern Standard time, which is 9 a.m. Mountain time; as soon as possible after 9 a.m. then, go to the station or get the time, to the nearest second, by telephone. You will thus have the correction of your watch, let us suppose it is 45 seconds slow and you want to know what time by your watch the sun will be on the meridian. You are 8° 15′ (or $8\frac{1}{4}$ degrees) west of the 105th meridian. Time changes 4 minutes for every degree, and the sun will therefore cross your meridian 33 minutes after it has crossed the 105th meridian. Supposing the date to be Feb. 17th we find from the table that the local mean time when the sun is on the meridian is, to the nearest half minute, 12 hours $14\frac{1}{2}$ minutes but you have already found out that the sun crosses your meridian 33 minutes after it crosses the meridian of Mountain time; that is to say, the sun will be on your meridian 33 minutes after 12 hrs. $14\frac{1}{2}$ min. or at 12 hrs. $47\frac{1}{2}$ min. Mountain time. But as your watch is 45 seconds slow it will be 45 seconds before this by your watch, or at 12 hrs. 46 min. 45 sec. p.m. (If your watch had been 45 seconds fast the time, according to your watch would have been 12 hrs. 48 min. 15 sec.) The sun will cross the meridian of 113° 15′ at 12 hrs. 46 min. 45 sec. by your watch on February 17th.

To determine the north-and-south line in places where this is not known accurately and instruments are not available, it may be determined with sufficient accuracy for meteorological purposes by means of (1) the sun at noon, or (2) the pole star.

(1) Having found the time when the sun is on the meridian as explained in the preceding paragraph, set up a stake and see that it is plumb or vertical; the direction of the shadow of this stake at the time when the sun is on the meridian is the true north and south line.

(2) The pole star is found, as you probably know, from the "Dipper," or "Great Bear." If the line that joins the two stars of the quadrilateral farthest from the handle be produced or extended it will very nearly pass through the pole star, fig 35. Having then

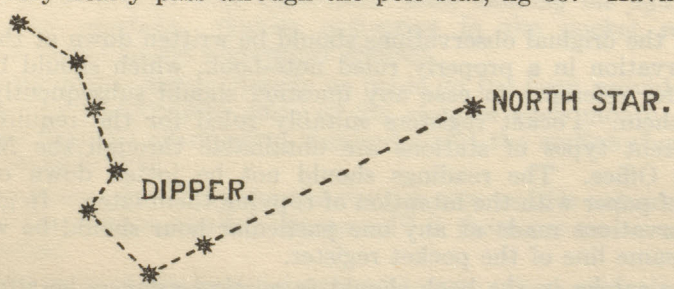


Fig. 35.

located the pole star, the north-and-south line may be obtained from it by taking the edge of a building or a picket and getting it in line with the eye and the pole star; then placing another picket at the point where your eye was, you fix or mark the line along which you were sighting on the pole star and this line is very nearly the true north and south line.

CHAPTER X

METEOROLOGICAL RECORDS

Instfument Register

This book should contain a history of the Observatory, its location, dates of all changes, heights above mean sea-level and how determined, the date of receipt of all instruments; with their numbers, the date on which they were brought into use and withdrawn from use, and their final disposal.

A map of the place should be kept showing the location of the observatory and a sketch plan, carefully drawn, giving the position of the thermometer shed and rain-gauge with the distance and height of the nearest buildings. The position of the anemometer and wind vane, its height above the ground, also above the nearest roof if it is on a roof, the type of tower used for its support, and the topographical features of the surrounding country as well as the distance and height of any buildings within 200 yards of the anemometer that are higher than the anemometer.

This register should contain a statement giving the height of the base of the thermometer shed and the top of the rim of the rain gauge above the level of the ground.

These facts may seem trivial at the time but they may be most important later and unless they are recorded at the time it would generally be impossible to obtain them afterwards.

Pocket Register

All the original observations should be written down at the time of observation in a properly ruled note-book, which should be preserved for reference in case any question should subsequently arise about them. Pocket registers suitably ruled for the requirements of different types of stations are obtainable through the Meteorological Office. The readings should not be jotted down on odd scraps of paper with the intention of copying them later. In general, all observations made at any one particular hour should be written on the same line of the pocket register.

The entries in the book should *in no circumstances* be altered or erased; errors should be noted in the margin. Doubtful entries should be marked with a query. Should observations be missed altogether, the words "no observations" should be written in the corresponding columns.

Punctuality is of the greatest importance. Should the observations be taken more than ten minutes earlier or later than the fixed hour, a note to that effect should be made in the margin.

In addition to the observations at fixed hours, unusual phenomena such as fogs, thunder or hail storms, etc., and the time and day of their occurrence and duration, should be noted in the "remarks" column at the time or as soon thereafter as practicable. It is important to state the standard of time used. (See page 104).

The pocket register should also contain a record of all changes of equipment of the station or in the exposure of the instruments, and of the times when the latter are inspected, cleaned or adjusted.

A clear record of changes in the hours of observation owing to the recurrence of "Summer time", if adopted in the locality in which the station is situated, should also be kept.

Meteorological Register

This is the permanent register of the observatory and all observations should be carefully copied, in ink, into it from the pocket register. The Meteorological Office issues to its observers the register suitable to the type of station. From these registers the various Forms that are required are filled in and despatched to the Central Office.

It should be remembered that this register forms a record which will retain its usefulness long after the officials who have had to do with it have yielded up their places to others. It is therefore most important that the position of the station, its height above mean sea-level, the standard of time to which the observations are referred, the number of the instruments in use and date of any changes should be entered on the first page in the place provided.

The headings of most of the columns are self-explanatory. In copying from the pocket register care should be exercised to enter the corresponding figures vertically under each other so that the columns may be added easily and especially to show clearly the decimal point. *This is of the very greatest importance when entering the figures for rainfall and sunshine.* Queries appearing in the pocket register should be copied on the permanent register.

A copy of the register has to be made on the form provided and forwarded to the District office at the close of each month. It is important that the information required about the station should be entered on each form.

Corrections.—In filling out the various returns it is not necessary to fill in the column headed "corrected" if there are no corrections to be applied.

While most of the barometers read to two places of decimals, it is quite easy to estimate with fair accuracy the third decimal figure. This should be done and the reading under the heading "Barometer as read" entered to three places of decimals; this column is not summed or meaned. Values under "Barometer reduced to 32°" should be given to three places of decimals. Under the heading "Barometer reduced to sea-level" the values are to be entered to two places of decimals and meaned to three places. The daily means are derived from the morning and night readings only. At stations where observations are also taken at other hours, they are not to be used in obtaining the mean for the day. Monthly means are derived from the daily means.

Temperature.

"Dry."—Under this heading enter the reading of the dry-bulb thermometer in the thermometer shed to one place of decimals, and mean to one place of decimals only. Daily means are derived from the MORNING and NIGHT readings only. At stations where observations are taken at noon, this value is to be entered but not used in striking the mean.

Monthly means are derived from the daily means of the maxima and minima as explained below.

"Wet."—Under this heading enter the readings of the wet bulb thermometer to one place of decimals. Mean in the same way as is done for the dry bulb.

"Extremes"; Minimum for the day.—Under this head is entered the lowest of the morning and night readings for the day. Maximum for the day; under this heading is entered the maximum temperature read at night unless, *as often happens in winter, the maximum temperature reading on the following morning is higher, in which case it is to be entered as the absolute highest for the previous day.* It is here assumed that the maximum temperature occurs between the time of the evening observation and midnight.

The following extract from a meteorological record illustrates this very clearly.

EXTREMES

Day	Read in morning Max.	Read in morning Min.	Read at night Max.	Read at night Min.	For the day Max.	For the day Min.	Daily Range
1	30·4	19·7	42·6	21·7	49·2	19·7	29·5
2	49·2	34·2	48·9	35·3	48·9	34·2	14·7
3	35·8	14·2	25·3	15·5	36·6	14·2	22·4
4	36·6	15·9	36·2	14·8	36·2	14·8	21·4
5	19·9	− 2·1	18·3	− 0·2	36·8	− 2·1	38·9
6	36·8	10·2	53·6	36·4	54·3	10·2	44·1
7	54·3	34·0	36·2	28·6	36·2	28·6	7·6
8	29·4	13·5	16·5	5·8	16·5	5·8	10·7
9	12·6	3·4	22·3	9·0	22·3	3·4	18·9
10	19·3	7·7	45·2	12·8	45·3	7·7	37·6
11	45·3	35·1	38·7	23·8	38·7	23·8	14·9
12	31·8	20·4	33·2	28·0	33·2	20·4	12·8
13	30·6	10·9	34·8	13·5	34·8	10·9	23·9
14	33·7	10·5	13·7	1·6	13·7	1·6	12·1
15	2·4	− 2·3	6·7	0·0	7·2	− 2·3	9·5
16	7·2	− 6·4	18·1	1·9	18·1	− 6·4	24·5

The maximum in the morning was higher than in the evening on the 2nd, 4th, 6th, 7th, and 16th, and consequently these readings are entered as the maximum for the 1st, 3rd, 5th, 6th and 15th.

At the end of the month add together all the maxima for the day and divide by the number of days. This is the mean maximum for the month. Similarly find the mean minimum. Then half the sum of these two gives the mean temperature for the month.

IT IS VERY IMPORTANT THAT TEMPERATURES BELOW ZERO SHOULD HAVE THE MINUS SIGN PREFIXED.

In totalling temperatures some of which are above zero and some below, add separately those above and those below, and then subtract the lesser sum from the greater. If the sum of those below zero is the greater, then the difference of the two sums is negative or below zero, and the corresponding mean temperature obtained by dividing this by the number of days is also below zero, and should have a minus sign prefixed.

"Humidity".—Sum and mean all columns to the nearest whole number, leaving out the decimals.

"Wind".—Sum and mean the velocities in the same manner as humidity.

"Clouds".—Total amounts—sum and mean the readings to one place of decimals.

"Footnotes."—Under the heading of "winds" the number of observations of each direction is to be taken from the data on the form. At stations supplied with anemometers, the number of days of moderate winds, strong winds, and gales, and the greatest velocity in one hour, are to be taken from the record on the anemograph sheet.

Location of Observatory

An ideal location for a meteorological observatory is an open level plain free from trees, as it would give an uninterrupted exposure for the wind instruments, thermometer shed and rain-gauge. It is however seldom possible to obtain such an exposure but in making a selection a site approaching as nearly as possible to this ideal situation should be chosen. Special consideration should be given to the exposure of the wind instruments if the true wind velocity and direction are to be obtained. For this reason places situated in a hollow even if the surrounding hills are low and at some distance cannot give a proper exposure. Nor should there be high buildings or trees close to the site. The thermometer shed and rain-gauge should be in an open space at a considerable distance from trees and buildings.

Classification of Stations

The first classification of stations was made at an International Congress of Meteorologists in Vienna in 1873. This classification is based on the observations that are taken and the equipment at the stations. The Canadian classification for meteorological purposes is a modification of the International and is as follows;—

Class I.—A station where eye-readings of pressure, temperature, humidity, cloudiness, wind (velocity and direction), and precipitation, are taken twice or thrice daily.

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Class II.—A station where the equipment consists of a maximum and a minimum thermometer and a rain-gauge, ordinarily, although at a few the equipment is more extensive.

Class IIb.—A station equipped with a mercurial thermometer, where readings are taken at certain local times. A rain-gauge completes the equipment.

Class IIm.—A station of the second class in operation during the summer months only, in order to telegraph results daily for the preparation of the morning bulletin during the growing season.

Class III.—Stations devoted entirely to the measurement of precipitation.

According to the Civil Service classification the stations are divided into six grades, grade 1 being stations where only precipitation is measured and grade 6 a chief station.

Brief Notes on Taking Observations

(1) Be punctual and take the observations on time.

(2) Be accurate; always read the instruments a second time as a check.

Punctuality and accuracy are the two essential qualifications for reliable and trustworthy observations, and all others are worthless.

(3) The order of taking the observations will depend largely on circumstances, but it is best to always follow the same order and, as far as possible, read each instrument at the same time each day.

(4) The observations should be entered in the pocket register at the time they are read and then checked. *They should not be written down on scraps of paper* or remembered until it is possible to write them down.

(5) The order of observing the barometer should be:

(a) Read the attached thermometer.

(b) In the Fortin type set the ivory point.
In the Kew pattern briskly tap the tube.

(c) Set the vernier.

(d) Read the vernier.

(e) Examine again setting of ivory point and vernier and note again the reading of the attached thermometer and vernier. This is to prevent the large mistake of 5 or 10 degrees or divisions that one might make.

(f) Lower the mercury a little in the cistern in the Fortin type, so that the ivory point will not become foul so soon.

(6) *(a)* In reading the thermometers, do not breathe on the bulbs, or hold a match, candle or other source of heat near them.

(b) If the arrangement of the thermometers in the screen permits, read in the following order: Dry bulb, wet bulb, maximum and minimum. If the maximum and minimum are so arranged that it is impossible to read the dry and wet without removing the maximum or minimum from the hooks, then read in the order: maximum, minimum, dry and wet.

(c) Check the readings.

(d) See that the wet bulb has a proper supply of distilled or rain water.

(e) Set the maximum and minimum. When set they should read very nearly the same as the dry bulb.

(6a) If there has been rain, measure it to the unit ·01 inch in the glass graduate. Note should be made of the beginning and ending of the rain; also as to its character, heavy, little, drizzle, showery, etc.

(7) Obtain the winds direction from the anemograph from the last direction mark or punch. To obtain the velocity count the number of miles during the previous fifteen minutes or half hour, or on the new anemograph the mileage can be obtained by reading the mileage at the ten-minute intervals and taking the difference.

(8) Observe the clouds very carefully as to kind, amount and direction.

(9) Make careful notes of the weather, particularly in regard to fog, thunderstorms, line squalls, hailstones, gales, etc.

(10) Visibility is now a most important observation and should be made with care.

(11) See that the muslin and wick on the wet bulb is always kept clean and change it whenever it becomes dirty. This should be done at least once a month.

(12) In the winter, or as soon as the temperature goes below the freezing point, remove the muslin and wick from the wet bulb and then put water on the bulb with a camel hair brush so that a thin coating of ice will form. Care must be taken to see that there is not a drop of water left on the end of the bulb, which may freeze and be difficult to get off. When the temperature goes below zero, the wet bulb readings may be omitted.

(13) Keep all your instruments clean.

(14) Report promptly all breakages or if instruments go out of order.

(15) Have all the returns filled in and mailed promptly at the close of each month.

CHAPTER XI

SELF-RECORDING INSTRUMENTS

The Campbell-Stokes Sunshine Recorder is the simplest form of self-recording instrument, as it gives both the record and the time on the chart, but in most of the instruments that give continuous records of the other meteorological elements the motion of the working parts is magnified by a system of multiplying levers to the end of which is attached a pen, which records on a chart fixed on a revolving drum driven by clockwork. A good self-recording instrument should afford the means of determining, either directly or indirectly, the absolute value of the element recorded for any instant. As a rule this end can only be attained by using the continuous record to interpolate between the values given by eye observations at fixed intervals taken with "standard" or "control" instruments.

General Precautions

Certain precautions and considerations which apply equally to all forms of recording instruments will now be discussed.

Dating of Charts

The date (time, day, month and year) of commencement and end of the record should be entered on each chart either before it is fixed on the instrument or immediately after it is taken off. The place at which the record is taken, and, if a number of instruments of the same kind are kept, the number of the instrument used should be entered on the chart. Should a record be missed in consequence of an accident (pen not marking, etc.) the chart should be filed with the successful records, and not be destroyed or used again. When recording rainfall or sunshine it will frequently happen that the chart, when taken out of the apparatus, is blank. In such cases it should always be dated and filed with the remaining records.

Friction

Friction between the working parts of the apparatus must be avoided as far as possible. The bearings should be cleaned occasionally and oiled with a good clock oil, care being take to remove excess of oil.

The most serious friction generally occurs between the pen and the paper on which it writes. The pressure of the pen on the paper should be reduced to the minimum consistent with a continuous trace for which simple contact with the paper will suffice.

Modern instruments are arranged so that the pen or the style which carries it, is suspended like a gate, and arrangements are made for the slope of the gate bearings to be adjustable. In this way it is possible to regulate the pressure of the pen on the chart from zero to a certain small value. The gate suspension of the thermograph is seen at C in fig. 42; the adjustment of the slope of the bearings is effected by means of the milled head D, which clamps the rod carrying the bearing in any desired position in its cylindrical socket. Similar adjustments are provided for the pen of the Anemograph, but the details are different.

In instruments in which the elasticity of the arm is used to keep the pen in contact with the paper the pressure should be adjusted by means of the milled head F near the base of the arm, fig. 43, so that the pen falls away from the paper when the instrument is tilted slightly forward.

The pen should be well washed from time to time in water or methylated spirit, and thoroughly dried.

A thin clear trace should be aimed at, for if the trace be thick and blurred many of the smaller variations which are most interesting meteorologically, become obliterated.

The point of the pen should be fine so as to give a narrow trace but it must not be so fine as to scratch or stick to the paper. A new pen may frequently be improved by drawing the point once or twice along an oil-stone, but any trace of oil should afterwards be carefully removed.

Excess of ink should be avoided. Special care must be taken not to let the ink come in contact with the metal style which carries the pen, as this will cause the pen to adhere firmly to the style so that it cannot be removed or cleaned. The ink may also cause the metal to become brittle and break.

Selection of Charts

In many instruments the recording pen is fixed on a lever which is pivoted at one end, so that the pen moves along an arc of a circle. The ordinates on the charts supplied for such instruments are, therefore, also arcs of circles, and it is essential that the radius of the arcs on the charts should be equal to the length of the pen arm, and that the centres of these arcs should be at the same level as the pivot on which the pen arm turns. In other words, the curve traced by the pen when the clock drum is at rest should coincide with the arcs on the charts. It is for the instrument maker rather than the observer to attend to these points; in most instruments no provision for adjustment is made. As the instruments of different firms, or even different patterns by the same firm, differ in dimensions, even though the size of the drum be the same, it is necessary to make sure that the charts are suitable for the particular instrument in use. When ordering a new supply of charts the maker's name, and, whenever it is given, the number of the chart should always be quoted, and a sample should accompany the order. The use of charts with arcs of wrong radius will throw the time scale very considerably wrong, even though the range may appear to be correct. The width of the lower margin of the chart is also of importance. If it be too narrow or too wide the centre of the arcs on the charts will not be at the same level as the pivot on which the pen arm turns.

The attention of the observer is once more directed to the fact that ink, if allowed to come in contact with the style which carries the pen may corrode it, with the result that the style breaks. A new style is then required as the use of a pen arm which is too short renders both time scale and range inaccurate.

Fixing the Charts on the Drum

The chart is placed around the drum containing the clock where it is held in position by a spring. When fixing on the drum, care must be taken that the horizontal lines printed on the chart are parallel to the flange at the base of the drum. If the chart is carefully cut so that its lower edge is parallel to the horizontal lines, this will be the case when the edge of the chart is in contact with the flange all round the drum.

Time Scale

It is important that the time when the pen is at any particular point on the record should be determinable accurately to the nearest minute. Three main causes of error exist:—

(a) Back-lash between the clock and the spindle on which it turns. This may be reduced to a minimum if the cylinder be turned on its spindle so as to bring the pen back to the required time from a point in advance of its proper setting.

(b) Error of clock. It may gain or lose. An error in the ruling of the time scale of the chart produces the same result. The rate of revolution of the cylinder can be adjusted to agree approximately with the time scale of the charts by means of the clock regulator.

(c) Errors due to the chart becoming too damp.

All these errors can be eliminated by making proper time marks at known instants by slightly moving the recording pen. Some barographs are now fitted with a "time-marker" for slightly depressing the pen arm and so causing it to record a time mark; when this is not provided a mark may be made by gently tapping the instrument, but, if that be done, care must be taken not to shake the drum on its spindle or otherwise to interfere with the record. In the case of thermographs and hygrographs there is no necessity for a special lever, as the pen-arm can be easily moved from the outside. If the instrument is as free from friction as it ought to be, no discontinuity need be caused in the trace by the time marks. The absence of discontinuity in the trace furnishes good evidence that the instrument is working well.

If possible, time marks should be made punctually to the minute at a fixed hour every day, preferably at the time when the standard instruments are read. If this is inconvenient, arbitrary times may be selected; they must be noted correctly to the nearest minute. These times should be entered on the records. Time marks should not be made on the record until some time after it has been put on the instrument in order to allow the clock to take up the back-lash.

It is a very great advantage to make the time marks on the even hour when the pen is on or very close to one of the time scale lines. Any error can then be much more easily detected.

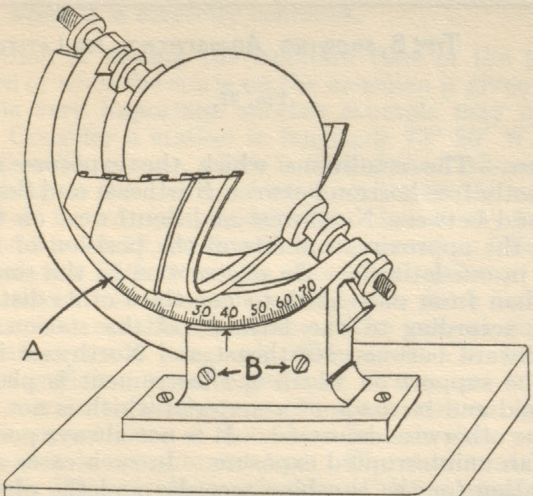
Sunshine Recorder

To get the number of hours of bright sunshine, the Canadian Service uses the Campbell-Stokes Sunshine Recorder. It consists essentially of two parts:—

(1) A glass sphere which brings the sun's rays to a focus.

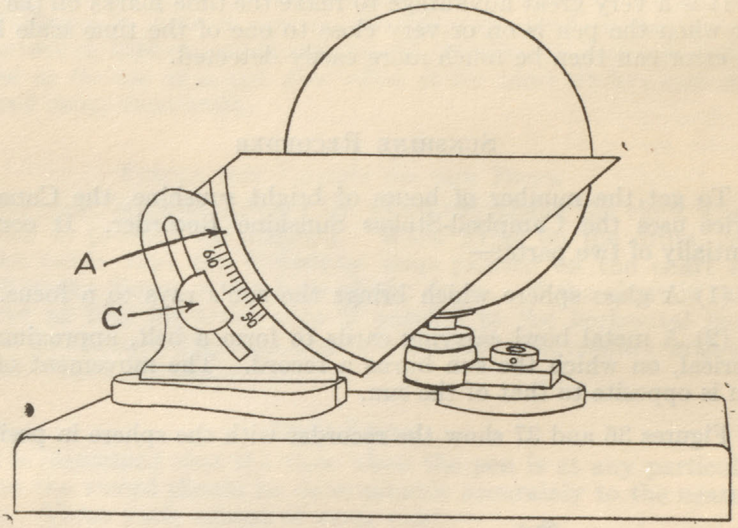
(2) A metal bowl carrying cards to form a belt, approximately spherical, on which the sun burns a record. The movement of the burn is opposite to that of the sun.

Figures 36 and 37 show the recorder with the sphere in position.



Type A, showing Adjustment for Latitude

Fig. 36.



TYPE B, SHOWING ADJUSTMENT FOR LATITUDE.

FIG. 37.

Exposure.—The conditions which the exposure should satisfy are: a perfectly free horizon between Northeast and Southeast on the East side, and between Northwest and Southwest on the West side, these being the approximate limits of the position of the rising and setting sun in our latitude. An obstruction to the south should not be higher than from one-eighth to one-third of its distance from the instrument, according to the latitude of the station. Obstruction to the northward between Northeast and Northwest is of no consequence. The support on which the instrument is placed should be perfectly rigid and be made of a material which is not liable to warp or to become otherwise deformed. It is not always possible to secure a site with an uninterrupted exposure. In such cases a sketch showing the location for the sunshine recorder and the obstruction, with distances, heights and directions, should be sent to the Central Office; when a table will be furnished showing the amount of possible sunshine cut off by the obstruction for each month of the year. This amount is then deducted from the total possible sunshine for the month.

The adjustment for level in the East and West direction may be made after placing the recorder in approximately the required position with a spirit level placed on the top of the metal bowl, care being taken that the level is parallel to the front edge of the recorder. The slate base should not be used for levelling as the bowl may not be attached to it quite symmetrically. It is not necessary to level the instrument very accurately in the North and South direction for reasons which will appear when considering the adjustment for latitude. There are no levelling screws provided, and consequently the levelling has to be done with packing of some sort, care being taken that it is well secured and that the instrument will not rock..

Adjustment for Latitude.—A very simple method of making this adjustment is provided in the instruments supplied to the Canadian stations: the brass scale A, figs. 36 and 37, is divided into degrees, and by loosening the screws B, Fig. 36, the bowl can be moved until the arrow head is at the latitude of the place, and then clamped there by tightening the screws. In Fig. 37 adjustment for latitude is made by means of the thumb nut C.

Adjustment for Meridian.—In making this adjustment we start from the consideration that the position of the burn on the card when the instrument is adjusted should indicate local apparent time on the time scale shown on the cards. The adjustment is most easily made at the moment the sun crosses the meridian as the defects in the adjustment for level are least at that hour and it is a simple matter to set the instrument so that the burn is right on the XII o'clock mark on the chart when it is correctly centered.

The method of finding the standard time of the place at local apparent noon or when the sun is on the meridian is given on page 106, but as this is very important another example may not be out of place here. Consider a station in longitude 73° 20′ W. This place is in the Eastern Time zone, which is that of the 75th meridian. The observer wishing to set the sunshine recorder on the meridian must necessarily wait for a bright, sunny day. Let us say he succeeds in getting this on March 12, he should then proceed as follows: Get the mean time of the 75th meridian from the railway or telegraph station at 11 a.m. if there is sufficient time to do so before having to go and adjust the sunshine recorder. The correct time is always sent to the railways and telegraph offices at 11 a.m. from Montreal. If there is not sufficient time to get it at 11 a.m. get it some time in the morning correct to the nearest minute; you can either set your watch to the correct time or note how fast or slow your watch is. Let us say that it is two minutes fast. The station at 73° 20′ W. is 1° 40′ east of the 75th meridian, or in time (1° being equal to 4 minutes) $6\frac{2}{3}$ minutes—which may be taken as 7 minutes—that is the sun will be due south of the station 7 minutes before it will be on the 75th meridian. Again we find from the table, page 106, that the local mean time when the sun is on the meridian March 12th is 12 hrs. 10 min. p.m., but as the sun is on the meridian of 73° 20′ 7 minutes before it is on the 75th meridian it will be due south at 12 hrs. 03 min. p.m., by Eastern Standard time, or 12 h. 05 m. in p.m. by your watch as it is 2 minutes fast.

The instrument should then be set so that the image of the sun is on the XII mark at 12 h. 05m. p.m. by your watch. Having set the instrument test it for a day or two of bright sun and if the burn is parallel to the edge of the card and the sun's image is on the XII hour mark at apparent noon, the instrument may be fastened securely in position by putting cement around it, or if it is on a wooden base by putting a small frame around it.

Management of the Instrument

When once the recorder has been set up, it requires little attention beyond that involved in changing the cards each day. The glass ball should be regularly cleaned with a wash-leather. It should not be cleaned with any cloth that will abrase the surface. If snow or hoar-frost settles on the recorder it should be removed at once.

A card should be inserted every day even if no sunshine has been recorded. A blank card affords surer evidence that the day has been overcast than a card on which the statement "no record" is written but which actually has a burn on the next day over the place where any record of the day in question would have been.

If possible the cards should be changed after sunset each day. If this be impracticable any other hour may be selected, but an hour having been once fixed upon, it should be adhered to as far as possible. If the cards are changed before sunset there is danger of two traces overlapping and to prevent confusion the exact local apparent time of insertion, as indicated by the burn, should be indicated by a pencil line passing transversely across the card. If the sun is shining at the time when a fresh card is being inserted, the observer should shade the ball in order to prevent a false score being made.

When inserting a card care must be taken that the XII-hour line on it coincides with the "noon" mark on the bowl.

If after rain, a card cannot be withdrawn without tearing it, it should be cut out carefully by drawing a sharp knife along the edge of one of the flanges.

Every card should have written clearly on it the name of the station, the date (day, month and year) of the record and, if the cards are changed before sunset, the time of insertion and withdrawal. This should be done immediately after the card has been withdrawn from the instrument.

Observers in connection with the Meteorological Office are requested to forward their cards as soon as possible after the close of each month to the district office.

In packing for transmission through the mail the cards should be kept flat and should not be folded. Suitable boxes or envelopes can be obtained from the Office.

Types of Cards

Three types of card are supplied for use with the instruments:

(1) The long curved cards are to be used during summer from the 13th of April to the 31st of August inclusive; they should be inserted with their convex edge uppermost, beneath the flanges marked "summer card" in fig. 38.

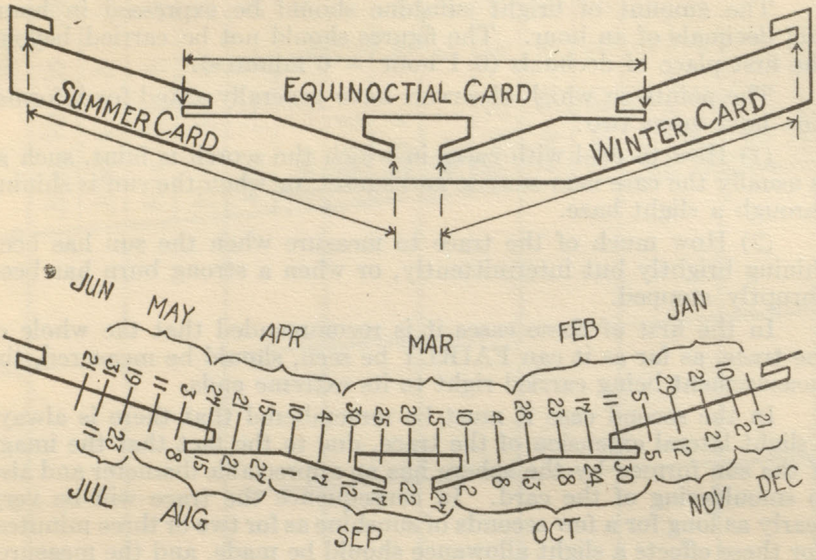


Fig. 38.

(2) The short curved cards are to be used during winter from the 13th of October to the last day of February inclusive; they should be inserted with their concave edges uppermost, beneath the flanges marked "winter card" in fig. 38.

(3) The straight cards are for use about the times of the equinoxes from the 1st of March to the 12th of April and again from the 1st of September to the 12th of October, both periods inclusive; they should be inserted beneath the central pair of flanges marked "equinoctial card" in fig. 38. When inserting the equinoctial cards care must be taken that the *hour figures are erect* otherwise the morning sunshine will be recorded on the portion of the card intended to receive the afternoon record and vice versa.

Before bringing a new type of card into use it is desirable to clean away any dirt which may have accumulated in the grooves into which the cards will be placed.

Tabulation of the Cards

Observers must bear in mind that the duration of "bright sunshine" to be published is not the number of hours and tenths during which the sun is visible to the human eye, but the number of hours and tenths which can be estimated from the record according to long-established practice; this duration is approximately the duration of sunshine of sufficient intensity to scorch the standard card when it is concentrated by the standard glass sphere.

The amount of bright sunshine should be expressed in hours and decimals of an hour. The figures should not be carried beyond the first place of decimals (0·1 hour = 6 minutes).

The points on which observers have generally asked for information have been two:

(1) How to deal with cases in which the scorch is faint, such as is usually the case near sunrise and sunset, or when the sun is shining through a slight haze.

(2) How much of the trace to measure when the sun has been shining brightly but intermittently, or when a strong burn has been abruptly stopped.

In the first of these cases it is recommended that the whole of the trace, as far as it can FAIRLY be seen, should be measured, the measurement being carried right to its extreme ends.

In the second case it must be remembered that there is always a slight lateral extension of the trace, due to the fact that the image of the sun formed by the sphere has an appreciable diameter and also to smouldering of the card. In consequence the trace will be very nearly as long for a few seconds of sunshine as for two or three minutes. For these effects a slight allowance should be made, and the measurement should not in such cases be carried to the extreme limits of each of the burns.

It has been found that a close approximation to the true duration of bright sunshine can be obtained if the measurement is carried to the centre of the semicircular end of each part of the trace, but in practice the allowance made for the latter extension of the burn is considerably smaller than this. To introduce a change in the method of procedure would involve inconvenience to observers, and moreover, the results obtained would not be comparable with those for previous years from which the adopted normal values have been computed. As one of the primary objects of sunshine measurements is to enable us to compare the results from different places or for different periods, it is not considered desirable to modify the practice which has prevailed hitherto. In order to secure uniformity in the method of estimating, it is desirable that a central authority should have an opportunity of examining the tabulations made at different stations and for this reason observers who desire their returns to be included in official publications are required to send their cards to the Meteorological Office for inspection at the end of each month.

A convenient method of evaluating a trace is to place the edge of a sheet of paper along it and to mark on the paper with a sharp pencil, lengths equal to the lengths of successive burns. The paper is slid along the trace so that these lengths form a continuous line, the addition being thus done mechanically. The length of the line is then read off on the special scale shown in fig. 39. When reading off, the paper must be placed against the line on the diagram corresponding with the date of the record. All records on equinoctial cards must be measured along the line so marked. The length of the burn may also be read off on the time scale shown on the cards, but in

SCALE FOR MEASURING THE DURATION OF BRIGHT SUNSHINE RECORDED BY CAMPBELL-STOKES RECORDERS OF STANDARD DIMENSIONS

WINTER CARD	SOLAR DECLINATION	HOURS 0	1	2	3	4	5	6	SUMMER CARD
DEC 11 to JAN 1	23°								JUNE 10 to JULY 3
DEC 2 & JAN 10	22°								JUNE 1 & JULY 12
NOV 26 & JAN 16	21°								MAY 25 & JULY 18
NOV 21 & JAN 21	20°								MAY 20 & JULY 24
NOV 17 & JAN 25	19°								MAY 16 & JULY 28
NOV 13 & JAN 29	18°								MAY 12 & AUG 1
NOV 9 & FEB 1	17°								MAY 8 & AUG 5
NOV 6 & FEB 5	16°								MAY 4 & AUG 8
NOV 3 & FEB 8	15°								MAY 1 & AUG 12
OCT 31 & FEB 11	14°								APR 28 & AUG 15
OCT 28 & FEB 14	13°								APR 24 & AUG 18
OCT 25 & FEB 17	12°								APR 21 & AUG 21
OCT 22 & FEB 20	11°								APR 19 & AUG 24
OCT 19 & FEB 23	10°								APR 16 & AUG 27
OCT 16 & FEB 25	9°								APR 13 & AUG 30
EQUINOCTIAL CARD									EQUINOCTIAL CARD

EQUINOCTIAL CARD, 6 HOURS = 4.50 INS. *CURVED CARDS* { *DECLINATION 8° 6 HOURS = 4.50 INS.* / *DECLINATION 24° 6 HOURS = 4.15 INS.*

FIG. 39.

the cases of the curved summer and winter cards, on which the length of an hour space is not the same throughout the whole width of the card, care must be taken to measure along the portion of the card on which the burn falls on the day in question. On this account it is better to use the specially constructed scale of fig. 39.

The trace can also be evaluated by another scale; the makers have now ruled a glass scale that enables one to evaluate the trace quickly and easily to the nearest tenth of an hour (6 minutes). Care must be exercised in using the proper scale for the type of card used and also to see that the scale covers the whole width of the card, by doing this the correct result for the position of the burn will be obtained.

Self-Recording Rain-gauges

The self-recording rain-gauge in use at some of the Canadian Stations is of the tilting bucket pattern registering electrically. The receiver A, fig. 40, for collecting the rain is 12 inches in diameter

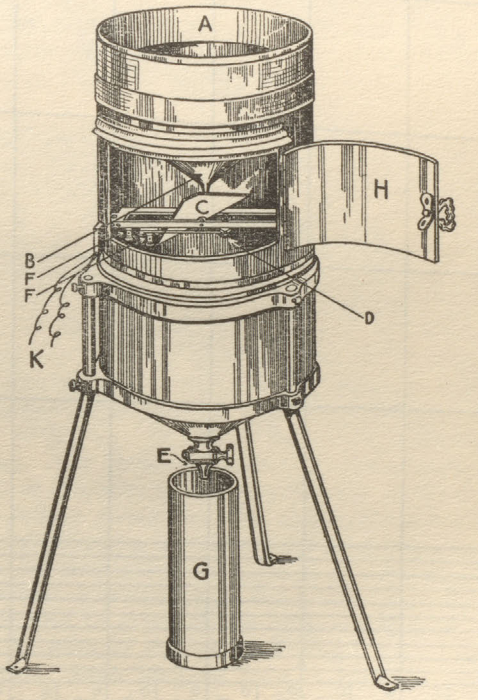


Fig. 40.

and is mounted in two rings supported on three legs. In setting up the receiver the exposure should be the same as for the ordinary rain-gauge (page 58), and the legs should be buried in the ground or fastened to posts driven into the ground so that it may be held rigid. The bucket C is of triangular shape, has a portion across the centre which divides it into two equal parts, and is mounted on pivots about its central point. The funnel B is directly above the centre of the bucket and the rain runs down through it into one side of the bucket. The bucket is so adjusted that when the weight of rain water collected is equal to ·01 inch of rain it tips over and empties the rain into the bottom of the gauge: at the same time the other division of the bucket comes under the funnel and the rain runs into it until ·01 inch has been collected when the bucket again tips. Each tip of the bucket registers ·01 inch of rain. When the bucket tips the two prongs on the bottom of the bucket depress the long strips of metal on the under side of the framework, closing an electric circuit. The circuit is closed just below the post D, which can be adjusted so that when the bucket is in position, it is at the top of the slot and when the bucket is tipped the end of the arm is pressed down on the bottom of the slot and closes the electric circuit. If D is screwed too far down, the arm will not touch the bottom part and will not close the circuit; and again if D is screwed up too far, the circuit will be closed all the time, or the bucket in tipping will stick on the long metal strips and simply let the rain water run out without registering it. The wires K to the gauge are led in through an opening to the binding screws F on the bar. The wires which should be not less than No. 18 copper, well insulated are carried to the office, preferably in a conduit pipe, or a two wire lead cable may be used. The

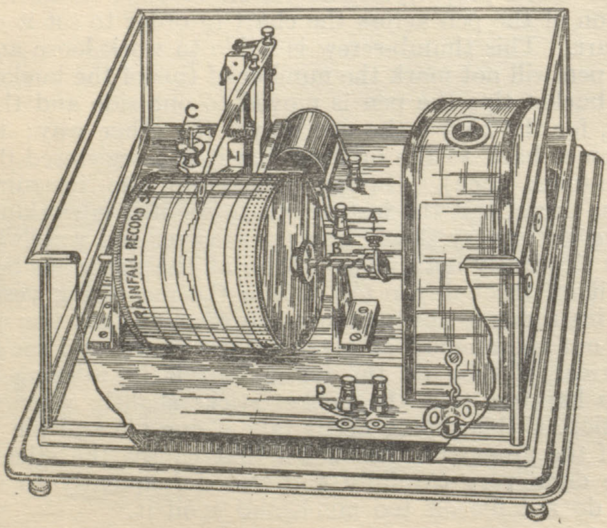


FIG. 41.

distance from the office is immaterial as far as length of wire is concerned, and the rule as regards distance of the rain-gauge from trees, buildings, etc., is the same as for the ordinary gauge; in fact it is better to put the self-recording gauge a few feet from the ordinary gauge. In the office the recording part, fig. 41 is set up wherever convenient and one of the wires is joined direct to one of the binding posts D on the recorder; the other is connected to one of the terminals of the battery; the other battery terminal is connected to the other binding posts A on the recorder. The simplest form of battery, as very little current is required, is two or three dry cells connected in series. To remove the drum loosen the thumb-screw A on the bar B and slide back the bar until the drum is free, when it can be removed. The chart should be put on straight, and as tight as possible, with one edge against the flange; care being taken to put it on the right way and with the right edge underneath. After putting on the chart set the drum by turning it until the pen is set at the correct time. The drum revolves once every 6 hours, or four times a day, and if no rain has fallen during the day the chart should be dated and filed away for reference. To ink the pen use only the special ink sent with the instrument and when it is finished write to the Central Office for more; ordinary ink must never be used, as it will simply blot the paper and spoil the pen. After putting the ink in a new pen a little trouble may be experienced in getting it to write; if that is so just open the pen point by slipping the point of a pen-knife down through the pen and that will generally bring the ink down. The pressure of the pen on the chart is regulated by the screw B, and it should be as light as possible, being just sufficient for the pen to mark properly. The thumb-screw C is used to adjust the position of the pen across the chart in order to set it on the line of the chart. This thumb-screw is liable to work loose and when it does, the pen will not mark the number of tips of the bucket. Every time the bucket tips the pen is moved to one side and this goes on for 5 tips, for the next 5 the pen moves the other way; thus every time it comes back to the original line it has registered 0·1 inch of rain (one-tenth inch). Having joined up the instruments and started the drum, test the instrument to see if it is working properly by pouring water very slowly into the receiver and watch the bucket to see if it tips freely both ways. After all the water has been poured in, draw it off through the tap E into the measuring vessel G sent with the instrument, and measure the amount that you poured in; next find out the amount as given by the chart, and see if the two results agree: if they do the instrument is in working order. It sometimes happens that the bucket sticks slightly when tipping in one direction, if this should occur take a fine file and file a little off the end of the prongs on the bucket that causes the sticking. This should be done very carefully and tested frequently to make sure that you do not file off too much and spoil it.

You should always keep the tap E closed and after each rainfall measure the amount of rain that has fallen with the measuring rod and enter the amount on the back of the chart.

In winter when the gauge cannot be used, the top of the receiver should be covered with a board so that the snow and water cannot get into the gauge, otherwise on freezing it might burst some of the parts.

If you cannot get the instrument to work satisfactorily write to the Central Office telling what you have done and what the trouble is; then instructions will be sent to you.

The Barograph

Barometers, as we know, are instruments designed for measuring the pressure of the air and in Chapter I some of the forms of mercurial barometers are described. There is, however, another class of instrument known as the "Aneroid" barometer, which can also be used to measure the air pressure. The essential part of the aneroid is a thin circular air-tight box (closely resembling two lids of a can soldered together at their edges), with a system of levers to magnify the movement of the box. The box is made of thin metal sheets, corrugated to give greater flexibility, and as the air exerts a pressure over the whole surface of the box it forces the two sides together until the resistance of the sides to collapse is equal to the air pressure; if then the air pressure is increased the sides come closer together, while if it is decreased they open out. The aneroid thus acts something like a bellows, and by magnifying the movement the pressure can be read on a dial, or by a system of levers the movement can be recorded on a chart turned by a clock, thus giving a continuous record of the pressure. The instrument in this form is a barograph and generally instead of one aneroid chamber, there are several in order to give greater movement to the aneroids with less magnification by the system of levers; the aneroid chambers are usually exhausted of air and, in the barograph, they are prevented from collapse by a spring inserted in each chamber. A typical barograph, as used in the Canadian Service, is shown in fig 42. The

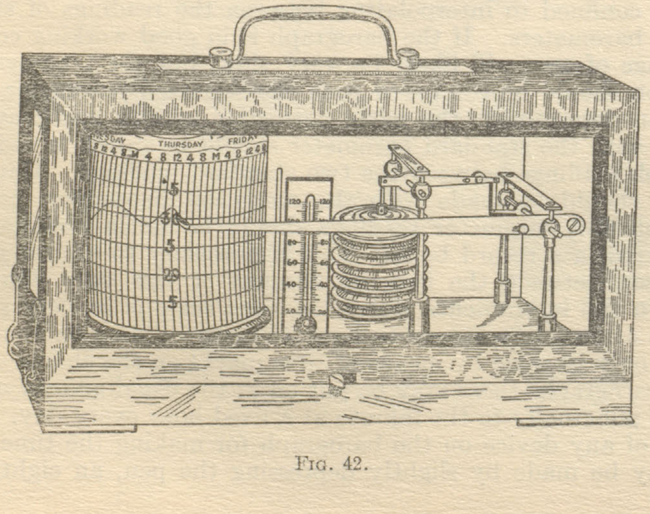


Fig. 42.

drum for the chart is usually about 3 inches in diameter, 3·6 inches high, and makes one revolution in a week. The charts have a small margin at the top and bottom with a space of 3 inches ruled for the record. The curved lines give the time scale and the horizontal lines the pressure. The curved lines have a radius equal to the length of the pen arm from the pivot to the tip of the pen. Thus any change in the length of the pen arm will introduce an error in the magnification of the system, and consequently in the pressure readings. It is therefore necessary to take great care not to alter the length of the pen arm when the pen is changed.

The charts are usually graduated to take in a range of three inches of pressure, the most common being 28 to 31 inches. This is the standard graduation for instruments near sea-level, but for those at higher elevations different graduations are required.

The aneroid barometer will record pressure changes, but it cannot, of itself, give absolute pressures as does the mercurial barometer. For this reason it is necessary to set the aneroid to the reading of the mercurial barometer, corrected for instrumental error and reduced to 32°, or, if near sea-level, it may be set to the sea-level value.

Manufacturers have their own devices for setting the position of the pen on the chart. One of the most common methods is to adjust the pen by means of a screw underneath the case just below the aneroid; the screw is turned by one end of the clock key; some of the new forms have for the setting device a milled head screw on the central bridge.

As regards the adjustment of the pressure of the pen on the paper, see under "Friction" on page 114.

The barograph should be set to the reading of the standard barometer corrected for index error and reduced to 32° F., Barographs in which aneroid chambers are used are subject to change of zero, so that when absolute pressure values are required, their use must be confined to interpolating between the readings of standard mercury barometers. If the barograph is in good working condition the change of zero will likely be very slow, but the readings of the barograph should be compared with the standard barometer and its correction determined; the mean correction of two successive comparisons with the standard barometer should be taken to reduce the barograph readings between the two standard readings. Daily comparisons should be made with the mercurial barometer, and both barograph and barometer readings should be taken simultaneously and entered in a record book. This is necessary to ensure a proper comparison between the two, on account of the very short time scale. In the instruments where the time scale is so very short, it is of the utmost importance to have the correct time on the charts; this can only be done by means of time marks on the charts. In the case of barographs these may be put on at the usual hour of observation and punctually to the minute at a fixed hour every day. In the absence of any device on the barograph for making the time marks, they may be made by slightly depressing the pen, an eighth of an inch is ample; this must be done very carefully so as not to strain the instrument; the weight of an ordinary lead pencil is sufficient to give the mark. (See note regarding Time Scale and setting the drum, page 116.)

It is better to apply the proper correction even if it changes frequently, rather than alter the position of the pen, in fact the position of the pen should not be moved, except when it is likely to go beyond the limits of the chart. Modern barographs are now quite accurate and the proper correction to apply would be the mean correction for the month, provided the corrections do not differ by more than ·02 inch from the mean.

The Thermograph

The Thermograph is an instrument that gives a continuous record of the temperature by means of a special type of thermometer, to which is attached a system of levers by which its expansions and contractions are recorded on a chart attached to the drum. One of the types in use in this Service has a thermometer made from a

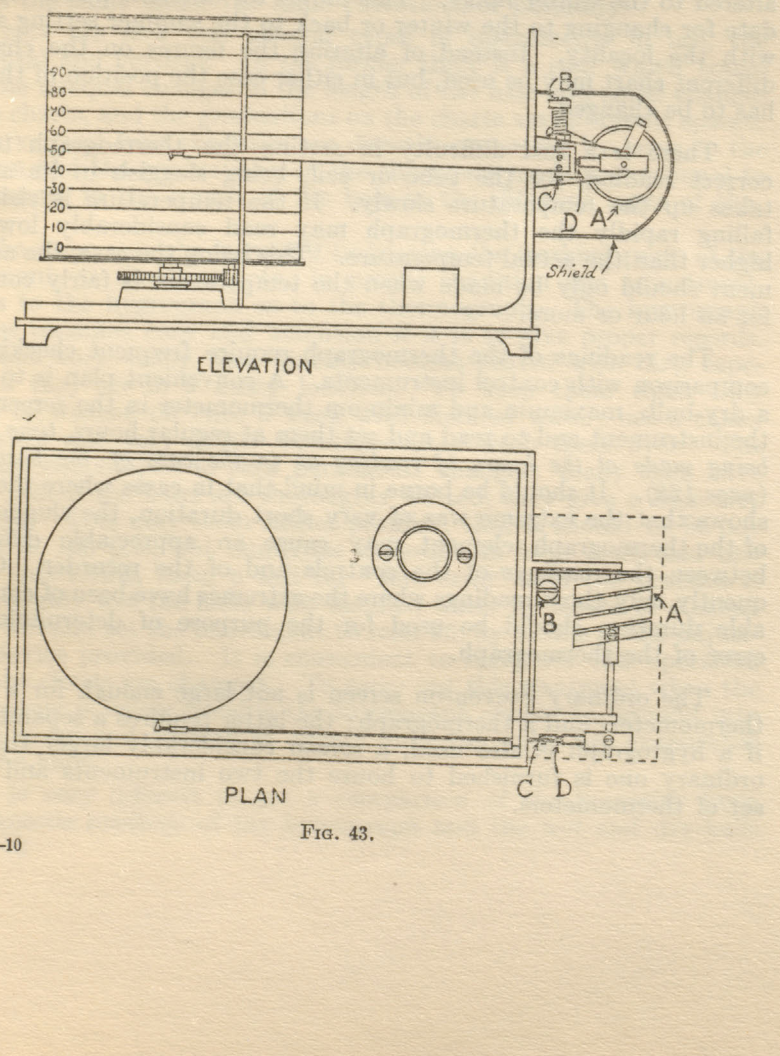


Fig. 43.

slightly curved metal tube filled with spirit (Bourdon tube). The spirit on expanding or contracting with change of temperature causes the Bourdon tube to change its curvature, and thus record the temperature. The other type (shown diagrammatically in Fig. 43) consists of a metal spiral made from strips of two different metals that expand unequally when heated; these, when soldered together and made into a spiral, will cause the spiral to coil or uncoil with change of temperature, so recording the temperature.

From the nature of the case, thermographs for meteorological use must be exposed out of doors in a Stevenson screen; hence it is necessary to clean and oil their bearings much more frequently than is the case with barographs, expecially in towns where dirt accumulates rapidly. In this instrument there is a device for altering the position of the pen on the chart; in the illustration the screw B is for this purpose. The charts are usually graduated for a range of 100° in temperature. the most common graduation for those used in Canada being from 0° to 100°. During the winter when lower temperatures are recorded, the pen is raised and the figures on the chart altered to the winter range. This differs for different places and the date for changing to the winter or back to the summer setting varies with the locality. Instead of altering the figures on the chart, a different chart may be used, but in either case the position of the pen has to be changed.

There is a real difficulty in setting the thermograph to the correct reading, for the tube or coil, being sluggish in its action, takes up the temperature slowly. If the temperature is rising or falling rapidly the thermograph may read considerably lower or higher than the actual temperature. This being the case, the adjustment should only be made when the temperature is fairly constant for an hour or more.

The readings of the thermograph require frequent checking by comparison with control instruments. A convenient plan is to place a dry-bulb, maximum and minimum thermometer in the screen with the instrument and to read and set them at regular hours, *time marks being made at the hours of reading as in the case of the barograph* (*page 128*). It should be borne in mind that in cases where the trace shows that the extreme was of very short duration, the sluggishness of the thermograph element may cause an appreciable difference between the readings of the controls and of the recorder. Consequently only those readings where the extremes have been of considerable duration should be used for the purpose of determining the error of the thermograph.

The ordinary Stevenson screen is not large enough for a set of thermometers and a thermograph; the latter requires a separate one; if a hygrograph is also used, a screen considerably larger than the ordinary one is furnished to house the two instruments and a full set of thermometers.

The Hair Hygrograph

This instrument measures the relative humidity of the air and depends for its action on the fact that the length of a human hair, which has been freed from oil by boiling in caustic soda, or potash, varies considerably with the relative humidity, but only very little with other meteorological elements. It increases in length as the humidity increases and vice versa, but the changes are not in proportion. A change of 5 per cent, in the relative humidity at the top of the scale, say from 90 to 95 per cent, gives a much smaller change in the length of the hair than an equal change lower in the scale, say from 40 to 45 per cent. In practice, a small bundle of hair is used for actuating the lever bearing the recording pen.

As in the case of the thermograph, the instrument must be exposed out of doors (in a Stevenson screen), so that frequent cleaning and oiling of the bearings are necessary. After exposure to wind carrying salt spray the hygrograph reads too high. In these circumstances the hairs should be washed. Unfortunately the properties of the hair are subject to gradual changes, so that the reading is not always the same under the same conditions of humidity.

There are now two general types of instruments in use, the horizontal and vertical. In the former there is a cam which translates the unequal changes in the length of the hair into equal changes on the charts, and the graduations on the charts are all equally spaced. In the vertical type the hairs are directly connected by lever to the pen arm and the graduations on the charts are made proportional to the changes in the length of the hair at the different parts of the scale.

The same remarks in regard to keeping the working parts of the instrument, as the clock, etc., in proper condition and adjustment, applies to the hygrograph as to the thermograph. The hygrograph requires constant care and attention if it is to give proper records. The hairs very easily and quickly become coated with dirt, especially if they are in a dusty location. To keep them clean they should be washed off once a week with distilled water; use a camel hair brush and very gently but thoroughly wash them over. The hairs are also subject to slow permanent changes; many tests have shown that if the hairs are thoroughly wetted, they give a humidity of 95 p.c. This may seem rather peculiar, that it should be 95 p.c. instead of 100 p.c., but numerous experiments have confirmed this fact. This forms, then, a test for "zero error" and the practice is to thoroughly wet the hairs with distilled water by means of a camel hair brush and set the instrument to read 95, by means of the adjustment device provided. It is convenient to carry out this operation when the charts are changed. To carry out this treatment when the temperature is below freezing the hygrograph should be brought into the office, set and allowed to remain until the water has evaporated from the hairs.

It is very difficult to get a comparison of the humidity from simultaneous readings of the hygrograph and the wet and dry-bulb thermometers. Sluggishness in either instrument may give rise to discrepancies; this is especially true when the humidity is changing rapidly. Such comparisons should only be made when humidity conditions are steady, and only from the mean result of several observations.

A little experience with the hygrograph will show that the humidity of the air varies very rapidly, so that small errors in the time scale may become very serious. Accurate time marks are therefore very important and should be put on by slightly depressing the pen.

Registers for Self-Recording Instruments

All comparisons of self-recording instruments with the standard instruments, as well as the time when the comparisons were made, should be entered in the pocket register provided for the purpose. The comparative readings should be entered at the time of observation. These should then be copied on to the Forms provided for tabulating the readings of the instruments. These forms are self-explanatory.

Fineman's Nephoscope

A modified form of the nephoscope, fig. 44, consists of a disk

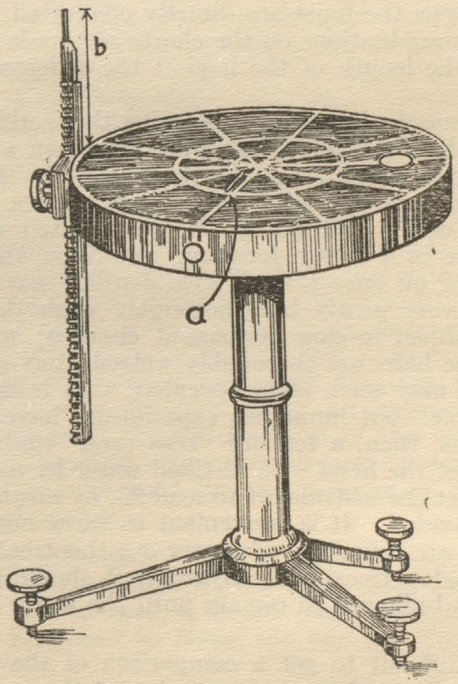


Fig. 44.

of black glass mounted on a tripod stand which allows of accurate levelling. A vertical pointer which can be raised or lowered by a rack and pinion motion is attached to a collar which can be rotated independently of the mirror. A scale of millimetres engraved on the edge of the pointer gives the height of its tip above the glass surface.

The method of observing is as follows: The mirror is levelled and then oriented by means of the scale of degrees engraved on the circular frame and a compass needle mounted below the mirror, and then clamped. The observer must bear in mind that the compass needle does not, in most parts of this country, point to the true north, but the correction to be applied in each locality is known. The orientation is made in such a manner as to bring the zero of the engraved scale into the direction true north of the centre of the disk. After orienting, the observer stations himself in such a position that the image of the cloud in the glass and the central point of the mirror are seen in the same straight line. He then rotates the pointer and adjusts its length until the image of its tip is also brought into this straight line. This done, he moves his head so as to keep the images of the cloud and of the tip of the pointer in coincidence. The point on the circumference at which the image of the cloud appears to leave the dial gives the direction from which the cloud is coming.

The velocity-height ratio of the cloud may be determined by noting the number of seconds required for the image to travel from one circle to the next. If "a" be the difference between the radii of the circles, "b" be the height of the tip of the pointer above the reflecting surface and "t" be the time required for the cloud image to traverse the distance "a" (both "a" and "b" being measured in the same units, e.g., millimetres), the value of the velocity-height ratio is given by the formula "a/bt".

In the particular type described, the difference between the radii of the circles engraved on the glass is 25 mm.

CONVERSION OF DEGREES ABSOLUTE INTO DEGREES FAHRENHEIT

Abs.	·0	·2	·4	·6	·8	Abs.	·0	·2	·4	·6	·8
	F.	F.	F.	F.	F.		F.	F.	F	F.	F.
220..........	−63·4	−63·0	−62·7	−62·3	−62·0	270.....	26·6	27·0	27·3	27·7	28·0
221..........	−61·6	−61·2	−60·9	−60·5	−60·2	271.....	28·4	28·8	29·1	29·5	29·8
222..........	−59·8	−59·4	−59·1	−58·7	−58·4	272.....	30·2	30·6	30·9	31·3	31·6
223..........	−58·0	−57·6	−57·3	−56·9	−56·6	273.....	32·0	32·4	32·7	33·1	33·4
224..........	−56·2	−55·8	−55·5	−55·1	−54·8	274.....	33·8	34·2	34·5	34·9	35·2
225..........	−54·4	−54·0	−53·7	−53·3	−53·0	275.....	35·6	36·0	36·3	36·7	37·0
226..........	−52·6	−52·2	−51·9	−51·5	−51·2	276.....	37·4	37·8	38·1	38·5	38·8
227..........	−50·8	−50·4	−50·1	−49·7	−49·4	277.....	39·2	39·6	39·9	40·3	40·6
228..........	−49·0	−48·6	−48·3	−47·9	−47·6	278.....	41·0	41·4	41·7	42·1	42·4
229..........	−47·2	−46·8	−46·5	−46·1	−45·8	279.....	42·8	43·2	43·5	43·9	44·2
230..........	−45·4	−45·0	−44·7	−44·3	−44·0	280.....	44·6	45·0	45·3	45·7	46·0
231..........	−43·6	−43·2	−42·9	−42·5	−42·2	281.....	46·4	46·8	47·1	47·5	47·8
232..........	−41·8	−41·4	−41·1	−40·7	−40·4	282.....	48·2	48·6	48·9	49·3	49·6
233..........	−40·0	−39·6	−39·3	−38·9	−38·6	283.....	50·0	50·4	50·7	51·1	51·4
234..........	−38·2	−37·8	−37·5	−37·1	−36·8	284.....	51·8	52·2	52·5	52·9	53·2
235..........	−36·4	−36·0	−35·7	−35·3	−35·0	285.....	53·6	54·0	54·3	54·7	55·0
236..........	−34·6	−34·2	−33·9	−33·5	−33·2	286.....	55·4	55·8	56·1	56·5	56·8
237..........	−32·8	−32·4	−32·1	−31·7	−31·4	287.....	57·2	57·6	57·9	58·3	58·6
238..........	−31·0	−30·6	−30·3	−29·9	−29·6	288.....	59·0	59·4	59·7	60·1	60·4
239..........	−29·2	−28·8	−28·5	−28·1	−27·8	289.....	60·8	61·2	61·5	61·9	62·2
240..........	−27·4	−27·0	−26·7	−26·3	−26·0	290.....	62·6	63·0	63·3	63·7	64·0
241..........	−25·6	−25·2	−24·9	−24·5	−24·2	291.....	64·4	64·8	65·1	65·5	65·8
242..........	−23·8	−23·4	−23·1	−22·7	−22·4	292.....	66·2	66·6	66·9	67·3	67·6
243..........	−22·0	−21·6	−21·3	−20·9	−20·6	293.....	68·0	68·4	68·7	69·1	69·4
244..........	−20·2	−19·8	−19·5	−19·1	−18·8	294.....	69·8	70·2	70·5	70·9	71·2
245..........	−18·4	−18·0	−17·7	−17·3	−17·0	295.....	71·6	72·0	72·3	72·7	73·0
246..........	−16·6	−16·2	−15·9	−15·5	−15·2	296.....	73·4	73·8	74·1	74·5	74·8
247..........	−14·8	−14·4	−14·1	−13·7	−13·4	297.....	75·2	75·6	75·9	76·3	76·6
248..........	−13·0	−12·6	−12·3	−11·9	−11·6	298.....	77·0	77·4	77·7	78·1	78·4
249..........	−11·2	−10·8	−10·5	−10·1	− 9·8	299.....	78·8	79·2	79·5	79·9	80·2
250..........	− 9·4	− 9·0	− 8·7	− 8·3	− 8·0	300.....	80·6	81·0	81·3	81·7	82·0
251..........	− 7·6	− 7·2	− 6·9	− 6·5	− 6·2	301.....	82·4	82·8	83·1	83·5	83·8
252..........	− 5·8	− 5·4	− 5·1	− 4·7	− 4·4	302.....	84·2	84·6	84·9	85·3	85·6
253..........	− 4·0	− 3·6	− 3·3	− 2·9	− 2·6	303.....	86·0	86·4	86·7	87·1	87·4
254..........	− 2·2	− 1·8	− 1·5	− 1·1	− 0·8	304.....	87·8	88·2	88·5	88·9	89·2
255..........	− 0·4	0·0	0·3	0·7	1·0	305.....	89·6	90·0	90·3	90·7	91·0
256..........	1·4	1·8	2·1	2·5	2·8	306.....	91·4	91·8	92·1	92·5	92·8
257..........	3·2	3·6	3·9	4·3	4·6	307.....	93·2	93·6	93·9	94·3	94·6
258..........	5·0	5·4	5·7	6·1	6·4	308.....	95·0	95·4	95·7	96·1	96·4
259..........	6·8	7·2	7·5	7·9	8·2	309.....	96·8	97·2	97·5	97·9	98·2
260..........	8·6	9·0	9·3	9·7	10·0	310.....	98·6	99·0	99·3	99·7	100·0
261..........	10·4	10·8	11·1	11·5	11·8	311.....	100·4	100·7	101·1	101·5	101·8
262..........	12·2	12·6	12·9	13·3	13·6	312.....	102·2	102·5	102·9	103·3	103·6
263..........	14·0	14·4	14·7	15·1	15·4	313.....	104·0	104·3	104·7	105·1	105·4
264..........	15·8	16·2	16·5	16·9	17·2	314.....	105·8	106·1	106·5	106·9	107·2
265..........	17·6	18·0	18·3	18·7	19·0	315.....	107·6	107·9	108·3	108·7	109·0
266..........	19·4	19·8	20·1	20·5	20·8	316.....	109·4	109·7	110·1	110·5	110·8
267..........	21·2	21·6	21·9	22·3	22·6	317.....	111·2	111·5	111·9	112·3	112·6
268..........	23·0	23·4	23·7	24·1	24·4	318.....	113·0	113·3	113·7	114·1	114·4
269..........	24·8	25·2	25·5	25·9	26·2	319.....	114·8	115·1	115·5	115·9	116·2

EQUIVALENT IN MILLIBARS OF INCHES OF MERCURY AT 32° F. AND LATITUDE 45°.

Mercury Inches and Tenths.	·00	.01	.02	·03	·04	·05	·06	·07	·08	·09
	mb	mb	mb	mb	mb	mb	mb	mb	mb	mb
27·0	914·3	914·6	915·0	915·3	915·7	916·0	916·3	916·7	917·0	917·4
27·1	917·7	918·0	918·4	918·7	919·0	919·4	919·7	920·1	920·4	920·7
27·2	921·1	921·4	921·8	922·1	922·4	922·8	923·1	923·4	923·8	924·1
27·3	924·5	924·8	925·1	925·5	925·8	926·2	926·5	926·8	927·5	927·5
27·4	927·9	928·2	928·5	928·9	929·2	929·5	929·9	930·2	930·6	930·9
27·5	931·2	931·6	931·9	932·3	932·6	932·9	933·3	933·6	933·9	934·3
27·6	934·6	935·0	935·3	935·6	936·0	936·3	936·7	937·0	937·3	937·7
27·7	938·0	938·3	938·7	939·0	939·4	939·7	940·0	940·4	940·7	941·1
27·8	941·4	941·7	942·1	942·4	942·8	943·1	943·4	943·8	944·1	944·4
27·9	944·8	945·1	945·5	945·8	946·1	946·5	946·8	947·2	947·5	947·8
28·0	948·2	948·5	948·8	949·2	949·5	949·9	950·2	950·5	950·9	951·2
28·1	951·6	951·9	952·2	952·6	952·9	953·2	953·6	953·9	954·3	954·6
28·2	954·9	955·3	955·6	956·0	956·3	956·6	957·0	957·3	957·7	958·0
28·3	958·3	958·7	959·0	959·3	959·7	960·0	960·4	960·7	961·0	961·4
28·4	961·7	962·1	962·4	962·7	963·1	963·4	963·7	964·1	964·4	964·8
28·5	965·1	965·4	965·8	966·1	966·5	966·8	967·1	967·5	967·8	968·1
28·6	968·5	968·8	969·2	969·5	969·8	970·2	970·5	970·9	971·2	971·5
28·7	971·9	972·2	972·6	972·9	973·2	973·6	973·9	974·2	974·6	974·9
28·8	975·3	975·6	975·9	976·3	976·6	977·0	977·3	977·6	978·0	978·3
28·9	978·6	979·0	979·3	979·7	980·0	980·3	980·7	981·0	981·4	981·7
29·0	982·0	982·4	982·7	983·0	983·4	983·7	984·1	984·4	984·7	985·1
29·1	985·4	985·8	986·1	986·4	986·8	987·1	987·5	987·8	988·1	988·5
29·2	988·8	989·1	989·5	989·8	990·2	990·5	990·8	991·2	991·5	991·9
29·3	992·2	992·5	992·9	993·2	993·5	993·9	994·2	994·6	994·9	995·2
29·4	995·6	995·9	996·3	996·6	996·9	997·3	997·6	997·9	998·3	998·6
29·5	999·0	999·3	999·6	1000·0	1000·3	1000·7	1001·0	1001·3	1001·7	1002·0
29·6	1002·4	1002·7	1003·0	1003·4	1003·7	1004·0	1004·4	1004·7	1005·1	1005·4
29·7	1005·7	1006·1	1006·4	1006·8	1007·1	1007·4	1007·8	1008·1	1008·4	1008·8
29·8	1009·1	1009·5	1009·8	1010·1	1010·5	1010·8	1011·2	1011·5	1011·8	1012·2
29·9	1012·5	1012·8	1013·2	1013·5	1013·9	1014·2	1014·5	1014·9	1015·2	1015·6
30·0	1015·9	1016·2	1016·6	1016·9	1017·3	1017·6	1017·9	1018·3	1018·6	1018·9
30·1	1019·3	1019·6	1020·0	1020·3	1020·6	1021·0	1021·3	1021·7	1022·0	1022·3
30·2	1022·7	1023·0	1023·3	1023·7	1024·0	1024·4	1024·7	1025·0	1025·4	1025·7
30·3	1026·1	1026·4	1026·7	1027·1	1027·4	1027·7	1028·1	1028·4	1028·8	1029·1
30·4	1029·4	1029·8	1030·1	1030·5	1030·8	1031·1	1031·5	1031·8	1032·2	1032·5
30·5	1032·8	1033·2	1033·5	1033·8	1034·2	1034·5	1034·9	1035·2	1035·5	1035·9
30·6	1036·2	1036·6	1036·9	1037·2	1037·6	1037·9	1038·2	1038·6	1038·9	1039·3
30·7	1039·6	1039·9	1040·3	1040·6	1041·0	1041·3	1041·6	1042·0	1042·3	1042·6
30·8	1043·0	1043·3	1043·7	1044·0	1044·3	1044·7	1045·0	1045·4	1045·7	1046·0
30·9	1046·4	1046·7	1047·1	1047·4	1047·7	1048·1	1048·4	1048·7	1049·1	1049·4

APPROXIMATE CORRECTION OF BAROMETER FOR SMALL CHANGES IN HEIGHT

Change of height in feet	Mean of thermometer readings in screen						
	−40° F.	−20° F.	0° F.	20° F.	40° F.	60° F.	80° F.
	"	"	"	"	"	"	"
10	0·01	0·01	0·01	0·01	0·01	0·01	0·01
20	0·03	0·03	0·03	0·02	0·02	0·02	0·02
30	0·04	0·04	0·04	0·04	0·03	0·03	0·03
40	0·05	0·05	0·05	0·05	0·05	0·04	0·04
50	0·07	0·06	0·06	0·06	0·06	0·05	0·05
60	0·08	0·08	0·07	0·07	0·07	0·07	0·06
70	0·09	0·09	0·09	0·08	0·08	0·08	0·07
80	0·11	0·10	0·10	0·09	0·09	0·09	0·08
90	0·12	0·12	0·11	0·11	0·10	0·10	0·09
100	0·13	0·13	0·12	0·12	0·11	0·11	0·10

NOTE.—These values apply for heights up to 2,500 feet. If the barometer is moved higher, add the above values to the corresponding values in the existing table. If the barometer is moved lower, subtract them.

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