Technical and Bibliographic Notes / Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

- [x] Coloured covers/ Couverture de couleur
- [ ] Covers damaged/ Couverture endommagée
- [ ] Covers restored and/or laminated/ Couverture restaurée et/ou pelliculée
- [ ] Cover title missing/ Le titre de couverture manque
- [ ] Coloured maps/ Cartes géographiques en couleur
- [x] Coloured ink (i.e. other than blue or black)/ Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations/ Planches et/ou illustrations en couleur
- [ ] Bound with other material/ Relié avec d'autres documents
- [ ] Tight binding may cause shadows or distortion along interior margin/ La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure
- [ ] Blank leaves added during restoration may appear within the text. Whenever possible, these have been omitted from filming/ Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- [ ] Coloured pages/ Pages de couleur
- [ ] Pages damaged/ Pages endommagées
- [ ] Pages restored and/or laminated/ Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed/ Pages décolorées, tachetées ou piquées
- [ ] Pages detached/ Pages détachées
- [ ] Showthrough/ Transparence
- [x] Quality of print varies/ Qualité inégale de l'impression
- [ ] Continuous pagination/ Pagination continue
- [ ] Includes index(es)/ Comprend un (des) index

Title on header taken from:/ Le titre de l'en-tête provient:

- [ ] Title page of issue/ Page de titre de la livraison
- [ ] Caption of issue/ Titre de départ de la livraison
- [ ] Masthead/ Générique (périodiques) de la livraison

- [ ] Additional comments:/ Commentaires supplémentaires:

This item is filmed at the reduction ratio checked below/
Ce document est filmé au taux de réduction indiqué ci-dessous.

10X	12X	14X	16X	18X	20X	22X	24X	26X	28X	30X	32X
							✓				

The copy filmed here has been reproduced thanks to the generosity of:

National Library of Canada

The images appearing here are the best quality possible considering the condition and legibility of the original copy and in keeping with the filming contract specifications.

Original copies in printed paper covers are filmed beginning with the front cover and ending on the last page with a printed or illustrated impression, or the back cover when appropriate. All other original copies are filmed beginning on the first page with a printed or illustrated impression, and ending on the last page with a printed or illustrated impression.

The last recorded frame on each microfiche shall contain the symbol —▶ (meaning "CONTINUED"), or the symbol ▼ (meaning "END"), whichever applies.

Maps, plates, charts, etc., may be filmed at different reduction ratios. Those too large to be entirely included in one exposure are filmed beginning in the upper left hand corner, left to right and top to bottom, as many frames as required. The following diagrams illustrate the method:

L'exemplaire filmé fut reproduit grâce à la générosité de:

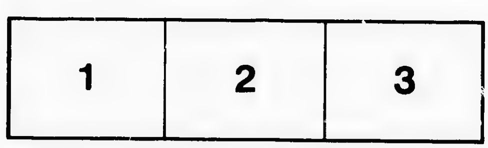
Bibliothèque nationale du Canada

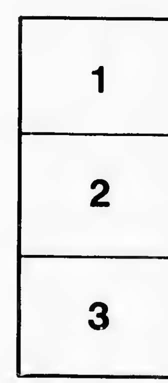
Les images suivantes ont été reproduites avec le plus grand soin, compte tenu de la condition et de la netteté de l'exemplaire filmé, et en conformité avec les conditions du contrat de filmage.

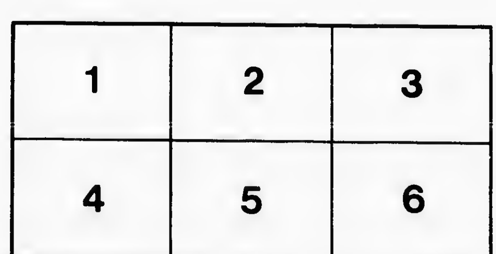
Les exemplaires originaux dont la couverture en papier est imprimée sont filmés en commençant par le premier plat et en terminant soit par la dernière page qui comporte une empreinte d'impression ou d'illustration, soit par le second plat, selon le cas. Tous les autres exemplaires originaux sont filmés en commençant par la première page qui comporte une empreinte d'impression ou d'illustration et en terminant par la dernière page qui comporte une telle empreinte.

Un des symboles suivants apparaîtra sur la dernière image de chaque microfiche, selon le cas: le symbole —▶ signifie "A SUIVRE", le symbole ▼ signifie "FIN".

Les cartes, planches, tableaux, etc., peuvent être filmés à des taux de réduction différents. Lorsque le document est trop grand pour être reproduit en un seul cliché, il est filmé à partir de l'angle supérieur gauche, de gauche à droite, et de haut en bas, en prenant le nombre d'images nécessaire. Les diagrammes suivants illustrent la méthode.







I

I

W

CO

METEOROLOGICAL SERVICE,

DOMINION OF CANADA.

INSTRUCTIONS

FOR

RECORDING RAIN, SNOW, WEATHER

AND

MISCELLANEOUS PHENOMENA,

WITH A SUPPLEMENTARY CHAPTER ON THE TEMPERATURE OF THE AIR.

BY G. T. KINGSTON, M.A.
SUPERINTENDENT.

TORONTO:
COPP, CLARK & CO., PRINTERS, 67 & 69 COLBORNE STREET.
1878.

INTRODUCTORY REMARKS.

A prominent object in Rainfall observations is the determination of the aggregate amount of rain that falls in any district of a country during any period of time.

Now, experience shews that the distribution of rain is very partial, one place being often visited by a heavy shower, while another, only a mile or two distant, receives little or none.

Hence, as regards short intervals of time, conclusions based on observations at a few points are liable to be very fallacious. In long periods the inequalities may probably to a great extent be balanced; but as far as they are due to permanent local causes, they would be made apparent also in the aggregate rainfall in long periods.

From what has been stated, it appears that in order that local inequalities, whether due to casual or permanent causes, may be eliminated from the results, and correct conclusions may be attained, the stations for rain observations should greatly exceed in number those at which observations of the other elements are necessary; so that for one station where a complete set of observations is made, three or more times daily, the rainfall should be measured at fifty points or more.

This pamphlet is designed chiefly to explain the mode of measuring the depth of the rain and snow which falls at any place in successive periods of twenty-four hours as well as in shorter intervals, with the method of registering the observations and of reporting them to the Central Meteorological Office of Canada; but it also relates to the registration of the *times* when rain and snow falls, as well as the weather that prevailed during each day, and the occurrence of atmospheric phenomena.

In order that intending observers who might be willing to devote a few minutes daily to the measurement of the rain, may not be deterred from doing so by the apparently large demand on them implied by the headings of the several columns and the explanations thereon, they are requested to notice that *the essential part of the work which they are invited to undertake is that of recording the depth of the rain or snow once each day in the morning*, and that at a station which is primarily a *Rain Station.* Information on the other matters named in the headings of the several columns, although very useful, is to be regarded as of secondary importance.

The following list of the other columns, placed in the order of their importance, is given for the general guidance of observers who may be willing to extend their work beyond the morning measurement of rain and snow:

(1). Times of beginning and ending of Rain or Snow.
(2). Total depth of Snow on the ground.
(3). Sleighing.
(4). Depth measured at 9 p.m.
(5). Duration in hours.
(6). Weather and phenomena.

As regards the relative importance of the different columns with respect to the *regularity* with which the entries are to be made, it is to be noticed that while an omission in the column, depth of rain or snow, renders the whole column comparatively worthless, occasional omissions in the other columns do not invalidate in the same degree those entries that are made in them; it should be borne in mind, however, that it is better to be regular in the use of one or two columns, the others being left blank, than to make only occasional entries in several.

Again, although a full description of the weather on every day would be very valuable, it would be better to select one or more conditions or phenomena, such as fog, thunder, lightning, Aurora, &c., &c., and to make a point of never failing to record examples of the selected class when they occur, than on some days to give a full and on others only a scanty statement or none.*

REMARKS RELATIVE TO THE SUPPLEMENTARY CHAPTER.

The general temperature of a district—an important element of its climate—is inferred from the temperature observed at various points within the district.

Now, although the temperature is not liable to vary from point to point to an extent comparable in any degree with that noticed in the case of rainfall, it is requisite, with a view to eliminate the effects of local circumstances, that the stations at which the temperature is observed should greatly exceed in number those where full observations are taken of the other elements.

For this reason thermometers are furnished to a few of the Rain Stations, where the observer is willing to take the additional observations with the requisite regularity.

It should be understood that these observations, to be of any use, should be made with the same regularity as those of rainfall.

In order that the observer may better appreciate the precautions enjoined as to the exposure of thermometers, a few explanatory remarks on certain properties of heat have been introduced in this chapter.

* This must not be understood to mean that fuller accounts during unusual weather would be otherwise than valuable, even although on ordinary occasions the record is limited to facts in the selected class.

CONTENTS.

CHAPTER VI.—SUPPLEMENTARY.

ON THERMOMETERS, AND THE MANNER OF EMPLOYING THEM FOR THE REGISTRATION OF THE TEMPERATURE OF THE AIR.

METEOROLOGICAL SERVICE,

DOMINION OF CANADA.

INSTRUCTIONS TO OBSERVERS WHO KEEP A REGISTER OF RAIN, SNOW, WEATHER AND MISCELLANEOUS PHENOMENA.

CHAPTER I.

ON THE MEASUREMENT OF RAIN AND SNOW.

SECTION 1.

THE RAIN-GAUGE.

(1) The Rainfall expressed by its depth.—The rain that falls in a given time is commonly expressed by the *depth* of the rain which would be accumulated on any horizontal plane surface, if none of it were suffered to run off, or to be evaporated, or to be absorbed by the ground.

(2) General description of the Rain-Gauge.—This instrument is essentially a vessel open at the top to receive the rain as it falls, and having its rim, *i. e.*, the boundary which separates the rain that enters the vessel from the rain which falls beyond it, lying in a horizontal plane. That this separation may be complete, the rim should be sharply defined.

As rain, if left in an open vessel, would usually be diminished by evaporation, the bottom of the gauge is formed in the shape of a funnel, through which the rain passes to a receiver beneath.

The *volume* or the number of *cubic* inches in the receiver being ascertained by a graduated glass measure into which the contents of the receiver are poured, the *depth* of rain will be found by dividing this volume by the *area* of the mouth, *i. e.*, the number of square inches which it measures.

(3) Various forms of Rain-Gauge Mouths.—The mouths of rain-gauges may be of various forms, such as square, oblong, and circular.

Of these, circular mouths are to be preferred, for the reason that any local currents caused by the action of the wind on the side of the gauge, which may affect the quantity that enters the mouth, will be independent of the direction of the wind if the mouth is circular.

Circular mouths are, however, attended with the objection that the area will usually be expressed by a number having several decimal places, and therefore be an inconvenient divisor.

If an observer should have such a gauge in use, the labour of dividing the volume at every observation may be avoided by using a table that gives the depths corresponding to various volumes ; but even this labour may be escaped by employing the gauge in almost universal use at Canadian stations.

(4) Rain-Gauge used in the Canadian Meteorological Service.—The peculiarity of this instrument consists in its mouth having an area of 10 square inches, so that the depth is simply found by dividing the volume by 10, *i.e.*, by moving the decimal point one place to the left.

Thus, corresponding to a volume in cubic inches of 11.2, 4.3, 2, .4, 2.37,
the depth in inches will be 1.12, 0.43, 0.20, 0.04, 0.237.

The general appearance of the gauge and of its various parts is shewn in the photograph, where *A* represents the gauge complete, and *B* the measuring glass.

The rain-gauge apparatus is made up of the following parts :

(1) The upper part, which consists of a vertical cylinder whose cross section has an area of 10 square inches, and is open at the top to receive the rain, being connected at its lower part with a funnel and pipe, through which the rain passes to a receiver beneath.

This upper part is made either of brass or of sheet iron japanned ; but in either case the upper rim is of brass, and is formed into a well defined sharp edge. The vertical sides are high enough to prevent the rain when striking the funnel from rebounding out of the gauge. This part of the apparatus is shewn in an inverted position by *C* in the photograph.

(2) The large receiver on which the upper part is fitted. It is made either of brass or of sheet iron, and is shewn by *D*.

(3) The small receiver (*E*) which stands within the large receiver, and into which the rain enters directly from the funnel. It is made large enough to hold rather more than 5 cubic inches. It is sometimes

expanded a little at its upper end so as to fit nearly the outer surface of the funnel, and thus diminish the surface of water exposed to evaporation.*

(4) The outer stand (made of sheet iron), on which the large receiver rests by a sloping flange, designed to prevent the entrance of rain into the stand. The outer stand is represented by *F* in the photograph.

(5) Position or mode of exposing the Gauge.—The gauge should be in an open level space, out of reach of cattle or mischievous persons, and sufficiently removed from any building, fence, tree, or other object that might interfere with the free entrance of rain, even when it falls with considerable obliquity. The outer stand should be *tacked*† to the top of a post projecting about three inches above the ground, so that the mouth of the gauge may be about one foot above the ground.‡

It is essential that the mouth be *strictly level*, for otherwise the rain that enters it will not be the same as that which falls on a level area of 10 square inches.

Grass, weeds, &c., should not be suffered to grow above the level of the mouth of the gauge at a nearer distance than six feet.

A position for the gauge near the ground should always, when practicable, be used in preference to a higher elevation, as, for some as yet unexplained cause, a gauge on the top of a building commonly receives much less rain than when near the surface. If it is impracticable to obtain a suitable position near the ground, the height and circumstances of the position actually employed should be carefully noted.

(6) To take an observation with the Rain-Gauge.—Carry out from the house the second or spare small receiver. Take off the upper part of the gauge with the mouth and funnel. Lift out the small receiver that was in the gauge and replace it by the spare small receiver, unless the rain was more than sufficient to fill the small receiver that

---

* Two small receivers are commonly supplied.

† Some persons, by not *tacking* down the stand, expose it to the danger of being blown down in strong winds, or of being thrown out of level. If the stand is merely placed on the *ground*, without any fastening (which, very improperly, has been sometimes done), there is much danger of the mouth of the gauge becoming out of level; besides which, when placed on the ground, the stand is more liable to rust than if it is fastened to a post.

‡ At stations where, in consequence of habitually low temperatures in winter, a considerable depth of snow is liable to remain on the ground even during a fall of rain, it is better to place the gauge on a post of greater height than that named in the text.

was in the gauge; in which case, *if rain was not actually falling,** the large receiver and full small receiver should both be carried into the house or other place where the measuring glass is kept and the rain is measured.†

Measure the rain by the graduated glass to cubic inches, tenths, and estimated hundredths. If the rain be more than 5 cubic inches, fill the glass up to the 5 inch mark exactly, one or more times; then measure the remainder, and add together the separate measurements. Thus, if the rain twice fills the glass up to the 5 inch mark, and also 3 large and 4 small divisions, the whole cubic contents or volume of rain is 13.4 cubic inches, and the depth 1.34 inches.

In using the graduated vessel, let it stand on a level steady table in a good light, and place the eye on a level with the surface of the water.

(7) Sundry Precautions.—During the fall of dry snow the rain gauge may be covered by a lid supplied for that purpose; but if the snow be in a *melting* state, or if it be mixed with rain, so that it will probably not remain on the ground and be measured as snow, the rain gauge should be uncovered, and any mixture of rain and snow that it receives must be treated as if it were rain.

If the gauge be uncovered during the fall of dry snow, any that enters the gauge must be cleared out before the rain begins; but if this has been overlooked, the whole depth determined by the gauge must be diminished by one-tenth‡ of the depth of snow that fell on the level while the gauge was open.

As it would be impracticable to prevent the occasional entrance of dew, hail, &c., into the gauge, any moisture whatever that enters, except that derived from snow which entered the gauge in a dry state and subsequently melted, must be treated as if it were rain.

If a frost should have suddenly set in, or if a frost be expected, any rain that may be in the gauge should be measured without delay, instead of waiting for the usual hour, to save the receiver from being burst by the action of the ice.

* If rain is actually falling at the time of observation, and the observer anticipates that the rain will prove to be more than enough to fill the small receiver, he should carry out to the gauge a clean dry jug or other vessel for conveying the rain in doors for measurement. By this arrangement the observer may leave the gauge in working condition, and none of the newly falling rain will be lost.

† The measuring glass should never be placed in the receiver.

‡ For reasons explained in Art. 11, line 4, this deduction will be rather too great.

The measure and second small receiver should be carefully wiped out after each observation, and be kept in a dry place.*

(8) Hours for Measuring Rain.—If the observations were equally attainable at all hours, and the convenience of observers could be left out of consideration, the hour to be adopted, when only one observation is made in the twenty-four hours, would be at the termination of the meteorological day, *i. e.*, at midnight, so that the rain then measured would be that which had fallen during the day then terminated. At those stations, therefore, which include midnight as one of the regular hours for other kinds of observation, a measurement of the rain is made at midnight, in addition to that made at some hour common to all classes of stations. As regards the hour for general use, since a morning hour is best suited to the great majority of persons, who are then less likely to be absent from home, it is best, on the whole, when one observation only is taken in the day, to adopt 7 a.m. as the hour for measuring rain.

If the observer is willing to make *two* regular measurements of the rain in the day, the time for the second should be 9 p.m.†

SECTION II.

ON THE MEASUREMENT OF SNOW.

(9) In measuring Snow two objects are proposed:

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

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

(10) How the depth is measured.—The most ready method is by means of a rod divided to inches. The measurement should be taken from the surface of the newly-fallen snow to the surface of the ground, or (if there was any snow on the ground at the time for measurement on the preceding day) to the surface of the snow that was then on the ground. An experienced observer may estimate the depth fairly without the aid of a rod.

* It would tend to the preservation of the apparatus from rust if the observer were to make a practice of wiping every part of it after an observation, unless rain be actually falling. It would be desirable also, for the same reason, to expose the interior parts to the air occasionally in fine weather.

† Some observers measure the rain as soon as the weather has cleared up, or after some very heavy shower. Should this be done, the depth then found should be entered temporarily in a pocket book, and be added afterwards to the measurement taken at the *next regular hour*.

The depth should be measured at two or more places where the snow is fairly level and appears not to have much drifted, and the average may then be taken for the depth.

(11) Depth of Water to which the Snow is equivalent.— Some persons leave the rain-gauge open and assume that the snow which enters it is equal to that which falls on the level. This may be nearly true in a *perfect calm*; but if there be any wind, only a small part of the snow which would fall on the level will enter the gauge, as may be ascertained by watching the snow flakes as they approach the gauge. Dismissing this method as untrustworthy, there are two which may be employed:

(1) To measure the depth, as in Art. 10, and to assume that *ten* inches of snow would yield, if melted, *one* inch of water. A long series of experiments conducted by General Sir H. Lefroy, formerly Director of the Toronto Observatory, led to the conclusion that this relation (one to ten) is true on the average. It is not affirmed that it holds true in every case, as snow varies in density; but in the long run the error occasioned by assuming it to be true is not greater than such as attends other methods sometimes affirmed to be more accurate.

(2) The second method of finding the water equivalent, is by actually melting the snow collected by means of an apparatus called a *snow gauge*.

The Snow-gauge consists of a hollow metallic cylinder, open at both ends, about twelve inches long, and whose cross section has an area equal to the mouth of the rain-gauge.

To use the snow-gauge, plunge it vertically into the level snow till its lower edge reaches the upper surface of the snow that fell up to the commencement of the period concerned, or till the lower edge reaches the ground, if no snow had fallen before that period commenced.

Dig away some of the surrounding snow; slip a sheet of tinned iron under the gauge; lift up the gauge and its contained snow; melt the snow, and measure the water which it yields.

As the snow may be of unequal depth and density in different places, it is better to repeat the operation at two or more places and take the average of the results.

The snow should not be melted by the direct heat of a fire, on account of the loss from evaporation which it would sustain. It is better to put the snow in a tall narrow vessel in order to lessen the evaporating surface, and pour into it the *entire* contents of a vessel *exactly* filled with hot water. The hot water and snow should be then stirred until the snow is all melted, when water should be withdrawn just sufficient to fill the vessel from which the hot water was taken, and the water that remains is then to be measured as if it were rain.

(12) Hours for measuring Snow.—The times for measuring the snow should be precisely the same as those at which the rain is measured.*

CHAPTER II.

BRIEF DESCRIPTION OF CERTAIN PHENOMENA.

SECTION I.

OPTICAL PHENOMENA.

(13) The Rainbow.—The rainbow consists of two arches, the lower or primary bow, and the upper or secondary bow, each composed of concentric bands of the prismatic colours, in the order *violet, indigo, blue, green, yellow, orange, red,*† which overlap and blend into each other.

In the *primary* bow the *violet* band is the lowest and the red the highest, whereas in the secondary or upper bow the order is reversed, red being the lowest and violet the highest.

The bows are formed by the refraction and reflection of the light from the sun falling on drops of rain in that part of the sky which is most remote from the sun.

In forming the primary bow, the ray enters the *upper* part of the drop, is reflected internally from the back of the drop, and emerges from the lower part to the spectator's eye.

In forming the secondary bow, the ray enters the *lower* part of the drop, suffers two reflections at the back of the drop, and finally emerges

---

* Snow may be reduced by evaporation or melting, and may sometimes disappear altogether before the proper time for measuring it. On this account, and especially in soft weather, whenever the observer considers that circumstances make it necessary, he should ascertain, to the best of his judgment, how much snow fell during different parts of the day, and take the sum of these as the total fall.

† The order of the colours may be remembered by the word VIBGYOR, which is formed from the initial letters of their several names.

from the upper part towards the spectator's eye. It is owing to the loss of light occasioned by the *two* reflections that the secondary bow is much fainter than the primary.

The centre of both bows is at a point in the sky exactly opposite to the sun. It will therefore be below the horizon, except at sunset, when it will be on the horizon.

The radius or half the diameter of the primary bow is 42°, and that of the secondary bow 53°.

From what has been stated the following facts are deduced:

If the sun is on the horizon, complete semicircles of both bows may be seen.

If the sun has an altitude less than 42°, both bows may be seen.

If the sun's altitude be between 42° and 53°, the secondary bow only is seen.

If the sun is higher than 53°, neither bow can be seen.

If the spectator be in an elevated position, his visible horizon will be depressed, and it will be possible for him to see a larger portion of a bow than when he views it from a station near the level of the ground.

(14) Lunar Rainbow.—Rainbows are produced by the light of the moon in exactly the same manner as by the light of the sun; but when seen, which is very rarely, they are of a white or yellow appearance. The centre of a Lunar Rainbow must be at a point in the sky exactly opposite to the centre of the moon.

(15) Lunar and Solar Coronas.—Lunar coronas consist of faintly coloured rings round the moon. Sometimes two or more are seen at once, the diameter of the second being twice, and the diameter of the third three times the diameter of the interior ring. The diameter of the interior ring varies from 2° to 4°. In each ring the red is on the outer border and the violet on the inner.

A solar corona is not often seen by the naked eye, on account of the dazzling brightness of the sun. It may be made visible by viewing it through coloured glass.

(16) Halos, Parhelia, and Paraselenæ.—Halos are large circles of definite diameter, one of 45° and another of 92°, and which are seldom seen together. The colours are feeble, especially that of the larger, which is almost or quite white. The larger is very uncommon. Where they exhibit prismatic colours, which is rarely the case, the red is on the *inside.*

Sometimes the halo is intensified into two bright spots, one on each side of the central luminary. These are called *Parhelia* or *Paraselenæ* (mock suns or mock moons).

SECTION II.

AURORA BOREALIS.

(17) Different forms of Aurora.—The Aurora Borealis presents itself under six different forms.

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

(2) *Arches.*—Arcs, or circles, or zones, formed at various altitudes, usually between N.E. and N.W., 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.*—Sharp 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, *i.e.*, the point in the sky towards which the elevated end of the dipping needle is directed. This point for Toronto is about 15° south from the Zenith, but varies in position at other places. The corona is formed of wreaths of auroral vapour, either 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, vapoury bank in the North, the quantity and apparent depth of which afford a prognostic of the intensity of the coming aurora.

(18) Classification of Auroras.—From the preceding varieties it will be found convenient to arrange auroras in 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.

CLASS II.—The combination of *two* of the leading characteristics of the first class, would serve to mark the second.

CLASS III.—The presence of only *one* of the more rare characteristics, eithers streamers or an arch, or irregular corruscations, but without a corona, and with moderate 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.

CHAPTER III.

NOTATION FOR EXPRESSING WEATHER AND PHENOMENA.

(19) Preliminary Remarks.—The modifications of the aqueous condition of the atmosphere, which for the most part constitute what is commonly called the "state of the weather," and the appearances resulting from those modifications, to which the term "atmospheric phenomena" is applied, are so intimately connected that it is not practicable in every case to assign each to its proper class. The separation made in the following list must therefore be regarded to some extent as arbitrary. Some of the terms used as descriptive of the states of the weather might with equal propriety be applied to phenomena, while others are applicable not so much to weather as to certain *effects* of weather of which it is desirable to keep a record.

The state of the weather and the presence of the various phenomena may be indicated either by letters of the alphabet or by conventional symbols. The letters belong mostly to a system of notation introduced by Admiral Beaufort, while the symbols are principally those recommended by the Vienna Congress of 1873. It has, however, been found necessary to suppress some of the letters and replace them by symbols, and also to introduce new symbols.

(20) Letters and Symbols to denote the State of the Weather.

	Letter.	Symbol.	
	b		Blue sky.
	c		Cloudy, but detached opening clouds.
†		⊕	Overcast, the whole sky being covered with impervious cloud.
†		◎	Clearing weather.
	d		Drizzling rain.
	f	≋	Foggy.
†		∿∿	Misty; *i.e.*, hazy, caused by condensed vapour aloft.
		∞	Dust haze, or hazy from dust.
†		⌇⌇	Smoke.
	g		Gloomy, dark weather.
	h	▲	Hail.
		△	Soft hail.
	l	<	Lightning.
	p		Passing temporary showers.
	q		Squally.
	r	●	Rain; *i.e.*, continued rain.
	s	✱	Snow.
†		↕	Flurries of snow.
		→	Ice crystals.
		↦	Snow drift.
	t		Thunder.
		⊠	Thunderstorm.
	u		"Ugly." Threatening appearance.
†		ⓥ	Visibility of distant terrestrial objects, whether the sky be cloudy or not.
	w	⍝	Dew.
		⊔	Hoar frost.
		V	Silver thaw.
		~	Glazed frost.
		⫽	Strong wind.

In the above list the new symbols not included in those recommended at the Vienna Conference are those which express "Overcast," "Clearing weather," "Misty from condensed vapour," "Smoke," "Flurries of snow," and "Visibility of distant objects." They are indicated by † on the left of the column.

(21) Symbols to denote Phenomena.

⊕	Solar Corona.
○	Solar Halo.
⊔	Lunar Corona.
◡	Lunar Halo.
⌒	Rainbow.
♔	Aurora.

Remarks on the preceding Letters and Symbols.

(22) Degrees of intensity may be indicated by the exponents o or 2 attached to the symbols or letters, thus, $*^{0}$ means light snow; $*^{2}$ heavy snow.

(23) (*b*).—The letter (*b*), unaccompanied by any other letter or symbol, indicates a clear sky. Although originally chosen because a clear sky during daylight is ordinarily *blue*, the letter (*b*) may also be used when the sky is clear at night, or whenever from any cause the sky, though not blue, is clear.

(*b*) followed by (*c*) denotes the presence of a few detached clouds, the clear part of the sky being greatly in excess of the part that is clouded.

If the clearness of the sky be impaired by haze or smoke, the letter (*b*) should be followed by the symbol for haze caused by mist, *i.e.*, condensed vapour, or that for dust haze, or the symbol for smoke.

(24) (*c*) alone denotes detached clouds with clear spaces intervening; but it is not necessary that the cloudy part of the sky should exceed the part that is clear.

(25) *f* or ≋ to denote fog. These are to be used when the spectator is completely surrounded by fog.

A very thin fog or ground mist may be expressed by the exponent (*o*) attached to the letter or symbol for fog.

〰 This symbol is to be used only when mist or haze, consisting of condensed vapour, intervenes between the eye and the sky.

∞ The symbol for dust haze is to be used when the clearness of the sky is dimmed by dust floating aloft.

(26) On the letters (*d*), (*p*), (*q*), and (*r*).

(*d*) for drizzle, indicates that the rain is composed of very *small* drops, without reference to its being transient or continued, while (*p*), for passing showers, shews that the rain falls in *frequent* showers of short duration, which, while they last, may be either heavy or light. These are exemplified by what are commonly called "April showers."

The letter (*r*) in the weather column indicates the fact that rain is falling, without implying that the drops were exceptionally *small*, as in a drizzle, and also that the fall is fairly continuous, *i.e.*, not frequently interrupted; but (*r*) does not necessarily express rain of *long* duration.

(*q*) Expresses a squall or squalls, *i.e.*, rather strong wind of short duration, while the combination (*pq*) expresses squally with rain, and (p^2q^2) heavy squalls, accompanied by transient but heavy showers.

(27) On the letters (*g*), (*u*).

While (*g*) denotes weather that is gloomy but not necessarily *threatening* as to the future, (*u*) ("ugly") indicates that the weather is threatening without implying that it is necessarily dark, as the absence of sunshine is not a necessary element of a threatening aspect in the sky.

(28) Hail denoted by (*h*) or ▲. One of these is to be used for hail, whether the stones be large or small, provided that they be of crystalline structure.

Soft hail denoted by △. The stones are small, like snow pellets, without crystalline structure. The term "soft" is not so applicable in Canada as it is in England, where the name originated. When mixed with rain it often bears the name of "sleet."

(29) *Flurries of Snow.*—This term denotes passing showers of snow. Very light and very heavy flurries may be expressed by applying the exponents (0) and (2).

(30) *Ice Crystals.*—These are minute crystals of ice that are occasionally seen apparently floating in the air, and glistening in the sun's rays. They are chiefly observed during bright weather with hard frost.

(31) "*Visibility of distant objects.*"—This term has no reference to the clearness of the *sky*, as the condition which it expresses may exist whether the sky be cloudy or not, and is most frequent when the general character of the sky is *threatening*. It often occurs also between heavy rain showers. The symbol used above for "visibility" has been substituted for *v*, on account of the resemblance of the latter to that adopted for "*silver thaw*" by the Vienna Congress.

(32) Lightning without thunder, whether it be sheet lightning or of other kinds, is expressed by (*l*) or by ⚡.

(33) "*Silver thaw*" is the phenomenon of frozen moisture on trees or other objects when the weather suddenly becomes warm after great cold.

"*Glazed Frost.*"—This term is applied to the glazed surface formed on the ground, trees, and other objects by rain falling and immediately freezing thereon. It differs from "silver thaw" in this respect, that the latter is formed by the condensation of vapour, and consequently has not the same smooth surface.

CHAPTER IV.

REGISTRATION OF THE OBSERVATIONS.

SECTION I.

RECORD OF FACTS RELATIVE TO THE STATION AND APPARATUS.

(34) The conclusions to be derived from meteorological observations taken at a station are influenced in a great degree by the geographical position, elevation, and physical peculiarities of the district in which the station is placed; on the position in that district which the station occupies; on the character of the *premises* where the observations are taken; and on the quality and mode of exposure of the instruments. With a view of preserving at the various stations permanent records of the facts descriptive of the district, premises, and apparatus, a register book is supplied to each station, bearing the title, "RECORD OF FACTS relative to STATION AND APPARATUS." At the beginning of this book detailed directions are given relative to the facts to be entered, and the manner of entering them.

SECTION II.

DIRECTIONS FOR FILLING UP THE REGISTER OF RAIN, SNOW, WEATHER AND MISCELLANEOUS PHENOMENA. (FORM 23.)

(35) Heading of Page.—Enter on every page the month and year, also the names of the station, county, province and observer.

Columns headed "Rain."

(36) "Times of Beginning and Ending," &c.—In the first two columns write the times at which, or the hours between which, the *first* rain began and the *last* rain ended; such beginning and ending being between the midnight which began and the midnight which ended the actual meteorological day, *i.e.*, the ordinary civil day.

If the rain continued from the previous day *through* the midnight which began the day, the time of beginning should be written "through 0^h a," or "thr. 0^h a;" and if the rain continued *past* the midnight which ended the day, the time of ending should be written "through mid^t," or "thr. mid^t."

If the time of beginning be not known within an hour, the hours *between* which the beginning was known to have occurred should be written. Thus, if it began between midnight and 5 a.m., the entry should be $\frac{0\text{ a}}{5\text{ a}}$.

Similar remarks are applicable to the time of ending.

In the column "Duration in hours" should be given the total number of hours during which, *to the best of the observer's knowledge*, rain was actually falling.

Columns for Snow.

(37) "Times of Beginning," &c.—The entries in these columns are to be made in a manner precisely similar to that described for the corresponding rain columns.

Column for Depth at Morning Observation.

(38) Depth of Rain.—The depth of rain measured at the time for the morning observation should be entered for the day *in which it was measured*,* without reference to the times between which it may have fallen. Thus, the rain measured at 7 a.m. on the 10th of the month is to be entered on a line with the 10th, whether the rain actually fell on the 10th or during some part of the 9th.

The gauge should always be examined at the regular hour for observation, whether the observer supposed that rain had fallen or not.

If no appreciable rain was found in the gauge at the proper time for measuring it, and the observer was aware that some rain had fallen since

* If the observer should have taken one or more extra observations or measurements between two consecutive regular observation hours, the depth found at such intermediate or extra observations should be added to the depth measured at the next regular hour. (See note to Art. 8.)

the time for the previous rain observation, he should enter the letter (*r*) for the depth fallen; but if he had no reason to suppose that rain had fallen, he should leave the place *blank*.

(39) Depth of Snow to 7 a.m.—The depth of snow to be entered for the morning hour (7 a.m.) is the total depth that fell between the previous regular observation hour up to 7 a.m. This depth will usually be that measured at 7 a.m.; but in soft weather, or whenever there is a danger that the snow would disappear or be diminished if its measurement were postponed until the regular time for the observation, the observer should measure or estimate the depth of the snow that fell in different parts of the period, and enter the number found by adding together the several partial depths. This sum, supposing the estimation to have been correctly made, will be the same as the total depth which would have been made at 7 a.m., if none of the snow had disappeared. (See note to Art. 12.)

If the snow which fell be insufficient to whiten the ground, the letter (*s*) should be written for the depth.

40 Column "Melted Snow," sometimes called "*Water Equivalent.*"—If the observer is furnished with a snow-gauge, he should enter in this column the depth of water obtained by melting the snow; but if he is not furnished with a snow-gauge, the column is to be left blank.

(41) Column "Total Precipitation," sometimes written "*Rain and Melted Snow.*"—The entry to be made here will be the number found by adding together the "*water equivalent*" (if the preceding column be used) and the depth of rain. If the preceding column be blank, one-tenth of the depth of snow (not melted), as an approximate water equivalent (see Art. 11), should be added to the depth of the rain.

Example: If the depth of rain be 0.37 inches, and the depth of snow 3.2 inches, the approximate depth of water equivalent to the snow is 0.32 inches, and the total precipitation 0.69 inches.

Depth at Night Observation.

(42) If the rain and snow be measured *twice* in the 24 hours, the second observation should be at 9 p.m., when the practice to be followed will be precisely the same as that at the morning observation.

It is desirable that the observation be made every night as well as every morning; but if the observer does not measure the rain *systematically* every night, but does so on special occasions only, he should in every such case enter the depth found at 9 p.m. He should enter the rain as 0.0 when he examines the gauge at 9 p.m. and finds that no rain had fallen, and leave the column blank whenever he failed to examine the gauge at 9 p.m.

(43) If the rain be *systematically* measured at 9 p.m., as well as at 7 a.m., the column for 9 p.m. is to be left blank whenever, on examining the gauge, no rain is found in it.

(44) If the observer does not usually make an observation at 9 p.m., he is requested to do so on the *last* night of each month. He is also requested to enter the observation of rain for the first of the month at the foot of the page for month just completed, as well as at the top of the page for the new month.

(45) The remarks made in Articles 42, 43, 44, are applicable also to the record of snow up to 9 p.m.

(46) Column "Sleighing."—This column is to contain one of the figures 0, 1, 2, to denote the general state of the roads in the neighbourhood of the station, (0) representing no sleighing, (1) bad, and (2) good.

If sleighing is interrupted during its ordinary season, the entry should be (0); but when sleighing is completely at an end, the column may be left blank.

(47) Column "Total depth of Snow on Ground."—This column is to contain the total depth remaining on the ground, as distinct from that which fell in the interval between two consecutive observations. This would be equal to the sum of all the previous falls in the season, if no causes of diminution existed; but as the depth is reduced by compression, and by the waste attendant on evaporation and melting, the actual depth remaining at any time is usually very much less than the said sum or aggregate. It would be ufficient if this total depth were entered once or twice a week (say Mondays and Thursdays), the approximate depth in inches being given for the woods or open field as well as for the high road; the entries being made thus: "woods 20" or "field 20," and "road 8."

(48) Compartment "General State of the Weather."—In describing the state of the weather the observer is at liberty to use *words* instead of symbols,* provided that there be sufficient space.

* The term "symbol" is taken to include letters.

If two or more symbols are used to describe *co-existent* conditions, *i.e.*, conditions that are present at the same time, they should be written down without stops between them; but if it is intended to describe conditions at different parts of the whole period for which the compartment is provided, the symbols or groups of symbols which represent conditions which follow in succession are to be written in order of time with semicolons (;) between them.

It would add to the value of the description if the beginning and ending of the time to which each symbol or group relates were given. This may be done by writing the time of beginning on the left, and the time of ending on the right, of the symbol or group, and within the semicolons.

Very frequently the weather passes *gradually* from one condition to another, so that the time at which a certain condition begins cannot be definitely stated; or it may be that the precise time is unknown to the observer. In either such case the observer may express the time of beginning by writing down the hours *between* which the beginning occurred, in the form of a fraction, the earlier hour being uppermost. Thus, supposing that during a part of the morning, beginning between 6 and 8, and ending between 11 and noon, there was a blue sky rather dimmed by mist, the mode of describing it would be ; $\frac{6}{8}$ *b* ⁓ $\frac{11}{12}$; .

It is not necessary to affix (a) and (p) for a.m. and p.m., as the columns are adapted separately to these two periods.

As stated in Art. 19, certain terms reckoned among those descriptive of weather might be considered as equally appropriate to phenomena, as, for instance, when the state of weather referred to is comparatively rare or of very short duration, partaking more of the character of an *event* than of a *state* or condition, or when the *effects* of certain atmospheric conditions are described.

The following are cases in which, subject to the discretion of the observer, certain symbols in Art. 20 may be transferred to the column for phenomena:

Hail;

Thunder or lightning of short duration;

Dew, hoar frost, silver thaw, glazed frost, ice crystals.

When the symbol for strong wind is used, the *direction* of the wind may be shewn by the position of the arrow; the feather being uppermost with a north wind, and on the right with an east wind, and so on.

(49) Direction and Force of the Wind.—It is not expected that observers who use this form should keep a systematic record of the wind; but if any observer is willing to do so, he should rule in the compartment of "Remarks" a column for 7 a.m. and also one for 9 p.m., if the rain is measured at the latter hour, and enter therein the direction* from which the wind was blowing, at the time of observation, to the nearest of the eight points, with the words "light," "moderate," "fresh," "strong," &c., to express its force.

(50) Column "Phenomena and Time of Occurrence."—Enter in this column the symbols that express any phenomenon that occurred during the twenty-four hours, and indicate the time when it occurred, or the times between which it occurred, in the manner explained in Art. 48. It will be necessary, however, to affix the letters (a) or (p), for a.m. or p.m., to the figures that represent the time.

If an aurora is recorded, the class, according to Art. 18, should be given; the number of the class in Roman numerals being written under the aurora symbol.

(51) Column or Compartment "Remarks."—The following details should be entered in this compartment:

(1) Notices regarding instruments and observation, such as a breakage, a change of instrument, change of position, or a change in the time of the observation. If an observation be accidentally taken before or after the proper time, the fact should be stated in the Remarks.

(2) Notices regarding any phenomenon for which there is not sufficient space in the preceding column, with a reference to the place where a more detailed description is given, when such is thought necessary.

(3) Periodical events connected with the progress of the season, such as the following:

(*a*) First snow, or frost, or sleighing; ice formed or broken up; opening and closing of navigation; mill work begun or stopped; Indian summer, &c.

(*b*) Appearance or departure of migratory birds, first croaking of frogs, &c.

(*c*) Budding and flowering of plants, maturity of fruits, &c.

---

* The *true* and not the *compass* direction should always be given.

SECTION III.

ON METEOROLOGICAL RETURNS.

(52) Returns to be exact transcripts from Daily Register.—The observations, as soon as taken, are written by the observer in his daily register book. The reports or returns transmitted monthly to the Central Office are to be exact transcripts of these. As soon as the month is completed, the loose sheet, after careful comparison* with the original in the book, is to be forwarded by mail, addressed to "The Superintendent, Meteorological Office, Toronto."

Meteorological reports are transmitted by mail at the same rate as printed matter, *i.e.*, one cent for 4 oz., and on the same conditions.

The report may be inclosed in an envelope with a one cent stamp, provided that the envelope be *not sealed*, or in a one cent postal wrapper with the ends not inclosed. The envelope or wrapper must not contain any matter in the nature of a letter, and no communication that does not form part of the report must be written on the form.

(53) Rules for maintaining Uniformity and avoiding Ambiguity in the Returns.—The following should be observed alike in the register book and in the returns:

(1) Vulgar fractions are not to be used, but decimal fractions only. Thus, ten and a half should be written 10.5, and not 10½.

(2) Throughout the same column the entries should be made with the same number of decimal places; and if a figure in one of the decimal places be wanting, its place should be supplied with (0). Moreover, (0) ought to be entered in the units place, if the units be wanting.

Thus, if the numbers	6.23,	4.5,	7,	.47,	.6	
occur in the *same* column, they should be written	6.23,	4.50,	7.00,	0.47,	0.60;	

for although the former entries are not wrong, they are liable to lead to error.

(3) When an observation has been omitted, the place where it would have been entered is to be left *blank*. On no account should (0) be written for it.

(4) When the observations taken at the same hour, on two or more consecutive days, are identical, the entries should be repeated on each occasion. On no account should a repetition be indicated by a blank, or a dash, or any other sign.

* *Two* persons should be employed in this comparison, of whom one should read aloud.

(5) Figures, letters, &c., should be written in a plain, distinct manner, *without flourishes*, so as to be read without danger of mistakes.

(54) Conjectural Entries to be strictly avoided.—It is particularly requested that if an observation be accidentally omitted, no attempt be made to fill it up by conjecture, and that the observer strictly enters what he actually observes, however unlikely the observation may seem.

CHAPTER V.

MISCELLANEOUS MEMORANDA.

(55) Packing Cases to be preserved.—When an instrument is received at a station, the packing case, with its lid, is to be carefully preserved in a clean, dry place, and is not to be used for any but its proper purpose, so that it may be available in the event of its being needed for returning the instrument, or for transferring it elsewhere.

(56) Damaged Instruments not to be returned without Instructions.—When an instrument is injured, or is supposed to be injured, it is not to be returned to the Central Office, or sent elsewhere for repair, without instructions to that effect.

When a damage or defect, real or supposed, has been discovered, the fact should be reported to the Central Office on Form 26. This report may be inclosed with the next regular report, if the latter be due within three days, or with a letter, if the observer should have occasion to write on other business; but in other cases the report may be sent by mail in a one cent *open* envelope.

(57) Reports on Instruments, &c., to be on Separate Papers.—Any report to the Central Office of damage to an instrument, or of change in its position, or of circumstances affecting its exposure, or alteration in the time of observing with it, or remarks as to its mode of working, with suggestions for its improvement, should be transmitted on Form 26, as explained in Art. 56.

(58) Requisitions to be on Special Forms.—Requisitions to the Central Office for instruments, forms, &c., should *not* form *part of a letter*, but be written on a requisition postal card, or on some other requisition form, or on paper that contains no other matter.

Explanations of the special reasons for the requisition, when necessary, may be made in a letter with or without other matter.

(59) Instruments not to be sent away from a Station on Loan without Authority.—An observer having on loan an instrument the property of the Dominion of Canada, must not transfer it to another station without definite instructions from the Central Office, even though he may not (as he supposes) have need for it himself, as such action defeats the purposes for which the additional instrument was furnished to him; one of which is to guard against the stoppage of the observations by accidents to instruments in use.

If any observer should know of any qualified person in a suitable locality who desires to engage in meteorological work, he should report the case to the Central Office, Toronto; but he should not furnish the proposed station with instruments intended for his own use.

(60) Blank Forms to be Carefully Preserved.—Observers are requested to keep all articles of stationery connected with the observations in a safe place, and apart from other stationery, so to diminish the risk of loss.

(61) List of Books on Meteorology.—Observers who desire to engage in the study of Meteorology, are recommended to consult one or more of the following works:

Buchan, A. Handy Book on Meteorology.

Herschell, Sir John. Meteorology.

Loomis, Professor E. Treatise on Meteorology.

Scott, R. H. Weather Charts and Storm Warnings.

CHAPTER VI.—SUPPLEMENTARY.

ON THERMOMETERS, AND THE MANNER OF EMPLOYING THEM FOR THE REGISTRATION OF THE TEMPERATURE OF THE AIR.

SECTION I.

ON ORDINARY MERCURIAL THERMOMETERS AND CERTAIN PROPERTIES OF BODIES IN RELATION TO HEAT.

(62) Measure of Temperature.—To measure changes of temperature recourse is had to an easily recognized and easily measured effect of changes of temperature, namely, the expansion which is found to take place in most bodies on the application of additional heat; but as expansion differs in different substances, it is requisite that some one substance should be chosen for this purpose. An instrument furnished with a contrivance for measuring the expansion or contraction which accompanies changes of temperature *in the substance chosen as a standard*, is called a *thermometer.*

Mercury is the substance ordinarily used as a standard of reference for the construction of thermometers, chiefly because the *apparent** increase to the volume of mercury inclosed in a glass tube is proportional† to the increase of its temperature as measured on rigid principles, so that apparently equal additions to the volume of the mercury indicate equal additions to its temperature.

(63) The Mercurial Thermometer.—This instrument consists of a glass tube or stem with a fine or capillary bore, as nearly as possible uniform throughout, with a bulb at one end, whose capacity is largely in excess of that of the bore. The bulb and part of the stem are filled with mercury, and marks are placed on the stem to indicate the expansion and contraction caused by changes of temperature.

Before the mercury is introduced into the tube, the tube is calibrated, that is, it is ascertained that the bore is of uniform calibre, or that its cross sections are throughout of uniform area; and if not uniform, the

---

* The actual is not identical with the apparent increase, on account of the expansion of the glass.

† The proportionality is not absolutely perfect; but the error occasioned by regarding it as such is too minute to be worthy of consideration.

extent of the variations in calibre at different parts. This calibration is necessary in order that equal *lengths* in the column of mercury may correspond to equal *volumes*, and thence to equal *changes* of temperature.

For graduating the thermometer it is necessary to determine two fixed points on the scale, so that the unit of temperature may have a known relation to the interval between them.

These points are the freezing point of water, or rather the melting point of ice, and the boiling point of water. The former of these has been ascertained to be appreciably constant, and the latter constant under the *same atmospheric pressure.*

In England, the British Colonies, and the United States, Fahrenheit's scale is used, wherein the freezing point is called 32 degrees and written 32°, and the boiling point 212° when the atmosphere has a *certain definite pressure.*

The part of the tube intervening between the freezing and boiling points is divided into 180 parts, representing *equal volumes*, which parts are called "degrees." If the bore is uniform, the *lengths* of the degrees will be the same throughout; but if not, allowance is made in the graduation for the varying capacity of the bore.

The graduation should be continued below the freezing point, and sometimes above the boiling point, by setting off on the stem portions representing volumes equal to those between the freezing and boiling points. In Fahrenheit's scale, as the freezing point is marked 32°, it follows that the point 32° lower than the freezing point must be marked 0°, or, as it is called, zero; also, a temperature ten degrees colder is called ten degrees below zero, or minus ten, which is written —10°. The graduations for cold climates should extend down to nearly —40°; but it is useless to extend them lower, because mercury becomes solid at —37°.9.

(64) Standard and Ordinary Mercurial Thermometers.—The term "standard" is applied in strictness to a thermometer which, besides being of superior workmanship, and specially as regards the correspondence of the intervals between its divisions to equal volumes of mercury, is graduated from above the boiling point to below the freezing point.

In a standard the correctness of the boiling point, as well as of the freezing point, can be verified by direct experiment, without reference to any other thermometer.

As the chief use of a standard is to test other thermometers, its range should extend each way as far as those of any thermometers to be compared with it; and as these are wanted sometimes for very cold climates, it is better to extend the graduations to the point where mercury becomes solid (—37°.9).

Thermometers for meteorological purposes commonly have their graduations extending not much higher than 100°, unless they are designed for very hot climates.

(65) Change in the Position of the Freezing Point.—If a thermometer is graduated soon after filling, *i.e.*, soon after the glass has been subjected to a very strong heat, and has been thus unduly expanded, it will afterwards, by its contraction, force the mercury up the tube, it may be from 1° to 2°, and cause the *true* freezing point to rise by that amount above the mark 32°. For this reason a thermometer ought not to be graduated until several months after it has been filled; but even when this precaution has been used, there will often, in the course of several years, be a slow progressive contraction of the bulb, and a consequent rise of the freezing point, necessitating the subtraction of a correction throughout the scale, which will increase from time to time, and finally become constant.

(66) Index Corrections and Rules for applying them.—Owing to the difficulty of making tubes of equable bores, and the loss sustained by rejecting those whose bores are not equable, thermometers are often sold having not only large errors, but errors varying considerably at different parts of their scales. On this account thermometers should not be used until their "index corrections," or the corrections to be applied at different parts of their scales, have been ascertained by comparison with a standard.

It is a practice among English makers to supply to purchasers certified copies of the index corrections of their thermometers.

Of late years thermometers certified by the Observatory of the Royal Society at Kew, are examined as low as the freezing point of mercury (—37°.9). Those which have not been thus tested ought not to be accepted, however correct they may be at ordinary temperatures, as it not unfrequently happens that thermometers, whose errors above 32° do not exceed 0°.2, are in error 4° or more at or below zero.

The thermometers employed in the Meteorological Service of the Dominion of Canada are first compared at Kew; they are again compared at the Canadian Central Office before they are issued, and should be compared afterwards from time to time to provide against the changes to which they may be subsequently liable.

When the true temperature of a thermometer is higher than the reading, the correction is marked + (plus); and if the true temperature is lower than the reading, the correction is marked — (minus).

The rule for applying index corrections, which covers all cases, is the following:

If the reading of the thermometer and the index correction have the *same* sign*, either both + or both —, *add* the two together, and the corrected reading will be the sum with the common sign.

If the reading and the index correction have *contrary* signs, one being + and the other —, subtract the smaller number of the two from the greater, and the corrected reading will be the difference obtained by the subtraction, with the same sign as that of the greater.

Examples:

Observed thermometer readings† ..	50°.4	-10°.3	46°.6	-12°.5	0°.8	-1°.2
Index corrections	+1°.2	-0°.5	-0°.8	+1°.0	-1°.4	+2°.0
Corrected thermometer readings ..	51°.6	-10°.8	45°.8	-11°.5	-0°.6	0°.8

Index correction papers are made up for temperatures at longer or shorter intervals, according as the change in the correction, in proceeding from temperature to temperature, is slow or fast. If the index corrections for two temperatures consecutively placed in the table should differ by more than 0°.1, the correction for any intermediate temperature must be made by estimation. If the thermometer reading should lie between two temperatures for which the index corrections only differ 0°.1, that correction must be used which corresponds to the temperature in the table which is nearest to the thermometer reading.

Sundry Properties of Bodies with Respect to Heat.

(67) Expansion or Dilatation.—It is for the most part true, although not true universally, that when the temperature of a body increases, it expands, or its dimensions increase; when its temperature decreases, its dimensions also decrease; and when it returns to its former temperature, it returns also to its original dimensions.

* The reading is understood to be above zero, and to have the sign +, unless otherwise stated. It is not the practice to prefix the positive or plus sign (+) to a thermometer reading.

† The reading is understood to be above zero, and to have the sign +, unless otherwise stated. It is not the practice to prefix the positive or plus sign (+) to a thermometer reading.

There is considerable difference in the expansion produced in different kinds of bodies by the same increase of temperature. The expansion is least for solids, it is greater for liquids, and greatest for elastic fluids, such as air. Thus ordinary glass acquires an increase of about .000015 of its volume when its temperature increases 1°, while for an increase of 1° mercury expands about .0001 of its bulk, alcohol about .0006, and ordinary atmospheric air .002.

The expansion of water is irregular. As the temperature of water rises from 32° to 39°.2, instead of expanding it *contracts;* but above the latter temperature it expands, although at an unequal rate.

(68) On the Distribution of Heat among Bodies by Conduction, Convection and Radiation.—Whether bodies be in close proximity with each other, or be separated by distances small or great, the heat existing in them has a tendency to distribute itself among them until they attain an equality of, temperature. This distribution of heat is effected by the following three modes:

(1) *By Conduction.*

(2) *By Convection.*

(3) *By Radiation.*

(69) Conduction, and Conductivity or Conducting Power.—When the transmission of heat from one particle or body to another is effected by the successive heating of the intermediate particles by contact communication, in the order reckoned from the warmer to the colder, the process is called "conduction." A familiar example is that of a metal rod held with one end in the fire, while the other is in the hand. When the particles contiguous to those in the fire receive heat from them, they in turn transmit it by contact to adjacent colder particles, and these latter to others, and so on, until after a time some of the heat reaches the hand. Substances differ greatly in the facility with which they conduct heat. If a spoon of metal be kept dipped in boiling water, the handle will soon become inconveniently hot; while if the spoon be of wood or earthenware it may be held without inconvenience, because the wood and earthenware have not such a facility as metals for conducting heat. While the process by which heat is transmitted from particle to particle is called conduction, the substance in relation to that process is called a *conductor*, and the property whereby the body conducts heat with greater or less rapidity is its *conductivity* or *conducting power*.

Substances through which heat is transmitted *rapidly* are said to be *good conductors*, or to have *high conducting powers;* whereas those which transmit heat *slowly* are said to be *bad conductors*, or to have *low conducting powers.*

The conductivity of metals is the greatest. Next in order to the metals are stones and woods. Among bad conductors are wool, feathers, air and other gases, and most liquids. The conductivity of mercury is much greater than that of either water or alcohol.

(70) Convection.—While it is by conduction that heat is transferred from particle to particle, the particles being at rest, the mode of transmission whereby the heated particles are *themselves* transferred is called "convection."

It is chiefly by convection, or the transfer of heated particles from place to place, that heat is distributed through liquids and gases.

If heat be applied under a vessel containing water, the particles in the lower strata become heated, expand, become lighter then the particles above them, and are raised towards the surface by the action of the cooler and heavier water. The cooler water, after its descent becomes warm and ascends in like manner, until the whole mass is warmed. It may be seen that this process depends on the extent to which the liquid expands by heat, and also on the force of gravity and the consequent difference between the weight of the warmer and colder portions of the liquid.

Convection takes place in air and other gases more energetically than in liquids, because the expansion of air and gases is much greater than that of liquids, (Art. 67.)

The diffusion of solar heat through the atmosphere is due in a great measure to convection. As the ground is warmed by the sun, it communicates its heat to the air in contact with it, which air becoming lighter than the cooler air immediately above it, is compelled to rise and to give place to that cooler air. The latter being warmed ascends in its turn and makes room for a further descent of cool air, and so on.

(71) Radiation and Radiant Heat.—When the passage of heat from one particle or body to another more or less distant is effected ***directly***, without the agency of intervening particles, the heat is said to be transmitted by "radiation," and the heat so transmitted is called "radiant heat." The heat received by a person standing before a fire is an example of radiant heat, for the heat does not reach him by first heating the intervening air, as may be shewn by the fact that the sensation of heat ceases when a screen is interposed.

The motion of radiant heat is so enormously rapid (probably the same as that of light), that the diffusion of heat by radiation would produce an almost instantaneous balance of temperature throughout nature, if it were not that heat leaves and enters bodies at a comparatively slow rate.

The rate with which a body of a given temperature radiates heat is much the same as that with which it absorbs heat radiated from other bodies, and this depends much on the nature of the surface. Lampblack radiates heat quickly, and the metals slowly.

The rate with which a body cools by radiation throughout its mass, apart from the effect produced by other bodies, depends not only on the rate with which heat leaves the surface, but also on the rate with which its internal heat reaches the surface, *i.e.*, on its internal conductivity. The actual rate at which a body cools depends on the amount by which its losses of heat by radiation exceed the gains obtained by absorbing the heat radiated from other bodies.

(72) Specific Heat and Capacity for Heat.—The quantity of heat which must be communicated to or abstracted from a given weight of a substance to produce a given change in its temperature, differs in different substances. Of two bodies of different material but of equal weight, that which requires more heat to effect a given change in its temperature is said to have a greater "specific heat," or a greater "capacity for heat."

The heat necessary to add a certain temperature to water greatly exceeds that required for giving the same increase of temperature to an equal weight of iron or of mercury.

Thus the heat by which the temperature of 1 lb. of iron is increased 1°, is only about 0.11 of that necessary to add 1° to the temperature of 1 lb. of water; or, as it is termed, the specific heat of iron as compared with water is about 0.11.

The specific heat of	mercury is	0.033
" "	alcohol about	0.6
" "	ice about	0.5
	aqueous vapour about	0.5

A body which has a large specific heat requires a proportionately longer time to acquire the same change in its temperature than one of a small specific heat; hence alcohol, whose specific heat or capacity for heat is nearly 20 times that of mercury, is vastly more slow than mercury in taking up the temperature of the surrounding medium.

SECTION II.

ON SPIRIT THERMOMETERS AND SELF-REGISTERING THERMOM

Spirit Thermometers.

(73) Mercury becomes solid at —37°.9: when, therefore, a thermometer is required for lower temperatures, it is necessary to employ alcohol for its construction, as alcohol has not been known to become solid at any temperature, however low.

Alcohol is not so well suited as mercury for the construction of thermometers, chiefly for the following reasons: First, its *inferior sensibility*, occasioned by its large specific heat and low conductivity; secondly, on account of the *inequality* in its expansion; and thirdly, from its *volatility*.

(74) Inferior Sensibility.—The *sensibility* of a spirit thermometer, *i.e.*, the readiness with which it takes up the temperature of the surrounding medium, is impaired by the *large specific heat* of alcohol, and its *low conductivity*.

The former of these causes would not be so detrimental to sensibility (see Art. 72), if it were possible to give to the spirit the same volume as that of a mercurial thermometer, as, in consequence of the lightness of spirit as compared with mercury, the quantity of heat required to effect the same change of temperature would be nearly the same in each case. It is not, however, possible so to reduce the volume of the spirit thermometer, as the weight of the spirit if the tube were vertical, or its cohesion if the tube were horizontal, would be insufficient to overcome the adhesion of the spirit to the glass, and the continuity of the column would be frequently broken.

Moreover, a spirit thermometer is slow in taking up the temperature of the surrounding medium (air or water, &c.), on account of the very inferior *conductivity* of spirit as compared with mercury; in fact, the conduction of heat in alcohol, as in other liquids (except mercury), is so slow that it is likely that the distribution of heat through the spirit is effected more by convection (Art. 70) than by conduction, and by the radiation inwards from the interior of the glass.

(75) Unequal Expansion of Alcohol.—The inequality at different parts of the scale in the expansion and contraction of spirit which accompany changes of temperature, increases the difficulty of adapting the interior volumes of the tube between the degree marks to the true change of volume corresponding to a change of one degree.

(76) Volatility of Alcohol.—A serious defect in spirit thermometers is that caused through the *volatility* of alcohol, by which portions are sometimes evaporated and condensed in the further end of the tube, thus causing the instrument to give readings too low, it may be, by several degrees.

To guard against the error thus produced, the readings should be frequently compared with those of a good mercurial thermometer; and if it is found that the spirit thermometer gives too low a reading, its tube should be carefully examined, in order that any portions of spirit, or "*blebs*," as they are called, that have been detached from the main body, may be re-united to it. To do this the thermometer may be swung about its upper end, bulb down, or jerked in the direction of its length, so as to break the adhesion of the spirit to the glass.

(77) Incidental Advantage of the large Expansion of Alcohol.—The large capacity which it is found necessary to give to the bore of a spirit thermometer, relatively to that of the bulb, to avoid a break in the column would necessitate a considerable contraction between the degree marks, were it not that the expansion of alcohol is more than five times that of mercury.

(78) Self-Registering Maximum Thermometer.—The object of this instrument is to give the highest temperature that has occurred within any given interval of time. It is not capable, however, of giving the *time* when the highest temperature occurred.

There are various kinds of maximum thermometers, but the instrument with which we are here concerned is that devised by Negrette & Zambra. In this instrument, which is a mercurial thermometer, the bore of the tube near the bulb is contracted or obstructed by the insertion of a piece of porcelain, such that, although the expansion of the mercury occasioned by a rise of temperature is sufficient to force the mercury upwards beyond the obstruction, the cohesion of the mercury is not sufficient to draw it back again when, in consequence of a fall of temperature, it contracts.

When the mercury forms an unbroken column the instrument is said to be *set*. If the temperature remains constant, or if it rises, the column will continue unbroken; but if the temperature falls, the mercury below the obstacle, as it contracts, will retreat into the bulb, leaving stationary the column above. The reading of the upper extremity of the column will then be the maximum temperature that has occurred during the interval which commenced with the time of setting and ended with the time of reading.

To set the instrument, which should be done as soon as it has been read, it is to be held by the upper end with the bulb down, and swung gently, or jerked in the direction of its length, till the continuity of the column has been restored. Care must be taken to raise the temperature of the thermometer as little as possible by the heat of the hand, as the thermometer will continue to indicate the temperature thus acquired, until its temperature has been exceeded by the increasing temperature of the air. If the temperature of the air should not attain to the temperature thus artificially given, the instrument will obviously give a false maximum which is higher than the true one.

The maximum thermometer should be suspended in a nearly horizontal position, but with the bulb end slightly depressed to prevent the mercury from sliding towards the further end of the tube, which might happen if that end were lower than the contracted part of the tube.

(79) Self-Registering Minimum Thermometer.—A minimum thermometer is designed to shew the lowest temperature that has occurred within a given interval of time.

The minimum thermometer commonly used is a spirit thermometer, containing in the tube a small index, which consists of two minute spheres connected by a fine short stem, and which slides within the body of the spirit, by which it should be always perfectly enveloped. The thermometer is suspended in a horizontal position.

When the column is unbroken, and the end of the index furthest from the bulb (and which may be called the upper end of the index) coincides with the end of the column of spirit, the index is said to be *set*. If the temperature becomes lower the column contracts and draws the index with it, the upper end of the index still coinciding with the end of the column. If the temperature afterwards becomes higher, the index will remain stationary, and the spirit will expand beyond it. The upper end of the index will then shew the lowest temperature that has occurred since the index was set.

To set the index, the bulb should be raised and the index allowed to slide to the upper end of the column, the motion being aided, if necessary, by gently tapping the tube.

The errors to which a minimum, in common with other spirit thermometers, is subject from the evaporation of the spirit, must be provided against as explained in Art. 76; but before jerking down the detached portions of spirit, the index must be suffered to slide down to the bulb. It will assist the re-union of the spirit, if the thermometer be afterwards suffered to remain for a few hours suspended in a vertical position, bulb downwards.

SECTION III.

ON THE DETERMINATION OF THE TEMPERATURE OF THE AIR AND THE MODE OF EXPOSING AND READING THERMOMETERS.

(80) Temperature of the Air Defined.—By the temperature of the air at a station at any time, is to be understood the temperature of such air as may be taken as a fair average sample, as repects temperature, of the air in the neighbourhood at that time, within a few feet above the ground. It is a matter of primary importance that the air near the thermometers be not *stagnant;* as such stagnant air is likely to have the temperature which the air in the neighbourhood had at some *previous* time, and not the temperature at the *actual* time of observation. It is desirable therefore that thermometers be suspended at a distance from any building, so as to be freely exposed to every wind.

(81) Thermometer Screen.—Supposing the thermometers to be placed in the air whose temperature it is desired to know, it is further necessary that they be so exposed as to take up the temperature of the air by contact with that air, while they are guarded from being heated or cooled by interchange of heat through radiation with the ground and other surrounding objects (which are liable to be warmer or colder than the air), or by parting with heat by radiation to the sky.

This is effected to a great extent, although not perfectly, by suspending the thermometers in a *screen*, which is a rectangular case formed on its four sides and bottom by thin louvre slats of sheet iron, which intercept heat rays, but freely admit air. The top is close, to guard against drifting snow which might possibly settle on it, and drop on the thermometers as it melts.

The thermometers are attached to a frame formed of two strips of hoop iron stretched from end to end between the front and back of the screen. The ordinary mercurial thermometers are fastened to brass bows, the ends of which project forward, while the middle of the bows are screwed to the horizontal frame. The self-registering thermometers are suspended horizontally by hooks, which by pinching screws can be so fixed as to give the requisite level.

(82) Thermometer Shed and its Supports.—As the screen alone is insufficient to protect the thermometers from sun and rain, it is placed under a thermometer *shed*, which has a double roof, with an air space open to the east and west, with sides of wooden louvre slats, with louvre doors on the north face, and a back of close half-inch boarding towards the south.

Within the shed and to the north side of its back, the screen is attached by four iron holdfasts, with an interval of two inches between the back of the shed and the southern slats of the screen.

To protect the thermometer shed from the southern sun, it is attached at a distance of two inches to a double fence as represented in Photographs, figures 2 and 3 at the end of the book.

Figure 2 gives a view of the shed with its doors closed as seen from the North-West.

Figure 3 gives a view of the interior of the screen as seen from the North.

The screen, shed and fence are painted white.

The dimensions in inches are as follows:

	Screen.		Shed.
Length from east to west	24		37
Depth from north to south	8		18
Height	18	front	29
		back	31

Double fence:

Length from east to west	72
Interval between front and back	4
Height	84

(83) Locality of Thermometer Shed.—The shed, if possible, should be in an open space, away from all buildings, walls, fences, &c., which might interfere with the free circulation of the air, or by which stores of heat could be accumulated, from whence the thermometer sheds, &c., might be unduly affected by radiation.

Wall Exposure.—When the premises are so circumstanced as to preclude such a position as that just described, the outer shed must be attached to the north side of some building, in a position that is not exposed to draughts from doors or windows, and where no high building stands within 20 feet from the thermometers, and to the north of the line of wall to which the shed is attached.

When the shed is thus placed, the iron holdfasts of the shed, instead of being screwed directly to the wall, should be screwed to a partition formed of upright inch boards, which are nailed to and blocked out by two pieces of 4 x 4 scantling, fastened horizontally to the wall. The object of this partition is to guard the shed from radiation from the wall, which may be much hotter or colder than the air whose temperature it is desired to know. The partition should therefore extend at least one foot above, below, and beyond the sides of the shed.

Window Exposures to be Avoided if Possible.—The practice of exposing thermometers where they can be read through a window is to be avoided if possible; but if the premises be not adapted for other modes of exposure, so that the choice lies between observations through a window and no observations at all, the shed may be attached to two scantlings stretched across the window,* with a sliding door fitted to the back of the shed, the screen being turned round so that its doors may face the south. It would be well also to fit a sliding pane to the window, which should be kept open as short a time as possible, when the self-registering thermometers are set.

(84) Snow to be removed from the Screen, &c.—More snow must not be allowed to accumulate near the thermometer shed than is found elsewhere in the immediate neighbourhood; and if snow has disappeared generally from the ground near at hand, snow and ice close to the shed should be removed.

Snow that settles on the slats of the shed or screen should be kept brushed away; and if snow settles on the thermometers, it should be carefully removed some time before an observation is taken.

(85) No Rubbish allowed in or about Thermometer Sheds.—The thermometers, as well as the screen and shed, &c., should be kept free from dust, cobwebs and rubbish of any kind, not only to avoid slovenliness, but because their presence impedes the free introduction and circulation of the air from outside. This objection is applicable to *any articles whatever* placed in the screen between the partitions, such as rain-glasses, note books, and even spare thermometers, unless suspended for use.

---

* The windows must of course face north, or nearly so.

(86) To Read a Thermometer.—The better kind of thermometers are graduated on the *stem*, and have also numbers indicating some of the degrees etched on the stem. Most thermometers have also an attached scale on which every degree is marked, and every tenth degree numbered. As the chief use of the attached scale is to aid the eye in reading the scale on the tube, if any slight discrepancy be noticed between the marks on the tube and those on the attached scale, it is by the scale on the *tube* that the observer must be guided.

In reading a thermometer, it is necessary that the eye be placed on a line from the end of the column of liquid perpendicular to the column.* If the column be in an upright position, this line will be horizontal, and the eye will be in the same level with the top of the column. Inattention to this precaution may cause an error of 2° or more.

The observer should avoid touching† the thermometer before reading it, or breathing on it, or warming it by a too close approach of the person; and at night he should not allow the light from the reading lamp to fall on the bulb, or on more of the stem than is necessary.

SECTION IV.

ON THE REGISTRATION OF TEMPERATURE OBSERVATIONS.

(87) Hours of Observation.—At stations which are primarily *Rain Stations*, but at which certain observations of temperature are also taken, the temperature observations consist either of readings of the ordinary thermometer made twice daily, or of readings once daily of the self-registering maximum and minimum thermometers.

For the ordinary thermometers the readings are 9 a.m. and 9 p.m., while the self-registering thermometers are both to be read and set at 9 p.m.

(88) Rules for filling up the Columns of the Register.—The actual reading of each thermometer, without modification or correction, should always be entered in the Register, as the risk of error is thereby much diminished.‡

---

* The observer must not mistake for a degree mark the reflection of that mark on the back of the tube. If he brings the mark, its reflected image, and the end of the column into apparent coincidence, his eye will be correctly placed.

† If the thermometer has been wetted by driving rain or snow, it must be wiped sufficiently long before the observation to allow it to recover its proper temperature.

‡ Instead of entering the readings in the columns from memory, it is better to write them in a pocket-book before leaving the instrument, and to transfer them from the pocket-book to the register book.

In the columns headed "observed" enter to tenths the actual readings of the thermometers, prefixing the sign (—) if the reading be below zero.

Under these readings write the index corrections, with their proper signs (+) or (—), and apply them according to the rules explained in Art. 66, and enter the corrected readings in the columns headed "corrected."

Examples:

Observed.	Corrected.	Observed.	Corrected.
35°.2	34°.8	32°.4	32°.6
−.4		+.2	

Column "range." When a column for the range is provided, enter in it the difference between the corrected readings of the maximum and minimum thermometers.

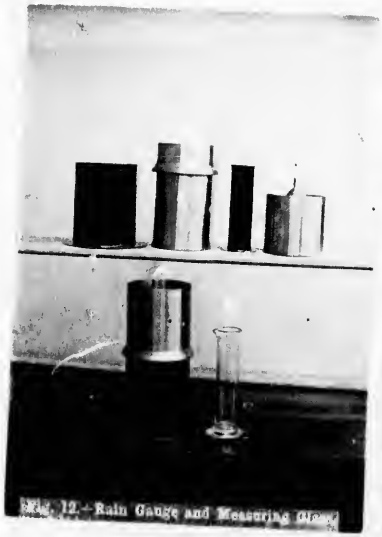


Fig. 12.—Rain Gauge and Measuring Glass

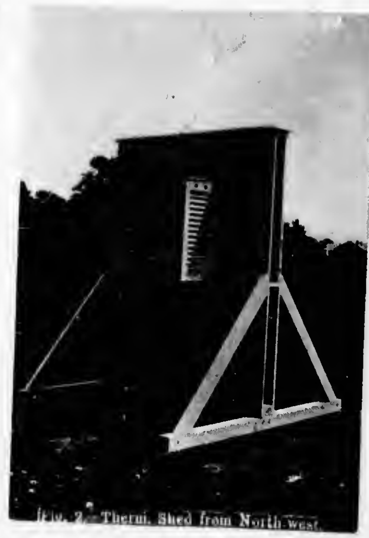


Fig. 2.—Therm. Shed from North-west.

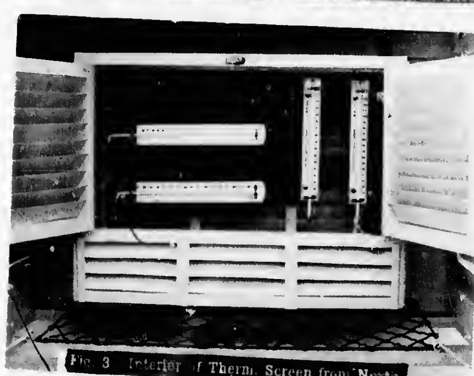


Fig. 3.—Interior of Therm. Screen from North