INSTRUCTIONS TO OBSERVERS

CONNECTED WITH

THE METEOROLOGICAL SERVICE

OF THE

DOMINION OF CANADA.

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SUPERINTENDENT.

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INTRODUCTORY REMARKS.

This volume has been prepared with the design of furnishing to Observers connected with the Meteorological Service of the Dominion of Canada, and to meteorological students generally, the means of obtaining an intelligent acquaintance with the objects, the principles, the construction, and the manner of using such meteorological instruments as are at present employed in the Canadian Meteorological System; and also to instruct Observers in the conventional regulations which have been adopted for the management of this service in Canada.

The Instructions consist of three Parts.

In Part I. are given the meaning of terms in frequent use, and simple statements of sundry physical facts to which reference is made in subsequent parts of the volume, or of which a knowledge would be useful in reading works on Meteorology. To facilitate such reference, and for convenience in answering the inquiries on meteorological questions frequently addressed to the Central Office by letter, a large portion of the paragraphs are numbered as separate articles.

Part II. is occupied chiefly in details relative to the various instruments, and the precautions to be taken in using them and in giving them proper exposure. This part contains also brief notices on Clouds, certain Optical Phenomena, Aurora Borealis, and Shooting Stars.

Part III. is principally concerned with the registration of observations; but it gives also, in a condensed form, the instructions relative to instruments which, in greater detail, have been before given in Part II.

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Superintendent.

METEOROLOGICAL OFFICE,
Toronto, January, 1878.

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INSTRUCTIONS TO OBSERVERS.

PART I.

BRIEF CONSIDERATION OF ELEMENTARY PRINCIPLES CONCERNED IN THE CONSTRUCTION AND USE OF METEOROLOGICAL INSTRUMENTS, WITH AN EXPLANATION OF THE MEANING OF CERTAIN TERMS.

CHAPTER I.

SECTION I.—DEFINITIONS.

(1) **Meaning of the Term "Unit."**—In meteorology, as in other sciences, it is necessary to have exact means of measuring various magnitudes with which that science is concerned. For this purpose, the various magnitudes should be referred to fixed standards, which are taken as units, and the magnitudes are numerically expressed by the number of times that they would contain the units to which they are referred.

Any convenient magnitude may be taken as unit. Thus in measuring a distance, we may express it either in miles, yards, or inches, &c.; and while, in some cases, the mile may be the most convenient unit, in others the yard, foot, &c., would be preferable.

Again for *surface* the unit may be a square inch, foot, yard, &c.;
for *volume*, a cubic inch, foot, yard, &c.;
for *time*, a second, a minute, an hour, &c.;
for *weight*, a grain, an ounce, a pound, &c.

MOTION.

(**2**) When a particle* occupies different positions in space at every successive instant of time, the particle is said to be in motion.

* By the word "particle" is here meant a body so small that every part of it may be considered as moving practically with the same velocity, which is not necessarily the case if the body is of large dimensions.

(3) **Uniform Motion.**—When the distances passed over by a particle are equal in equal times, whether the times be long or short, the motion is uniform, but if not, it is variable.

(4) **The Velocity or Rate of Uniform Motion** of a particle is expressed numerically by the number of units of space, or of distance, moved over by the particle, in a unit of time. Thus, the units of distance and time being one mile and one hour, the velocity of the particle moving ten miles in one hour would be expressed by the number 10.

As the units of distance and of time are not the same in all cases, it is necessary that they should be stated.

(5) **Velocity of Variable Motion.**—In this case the term velocity must have reference to some particular *point* of time, and, in strictness, should be expressed by the number of units of space or distance which the particle would describe in a unit of time, if it were to continue to move uniformly at the velocity that it had at that particular point of time.

An approximate measure of the velocity may be found from the distance moved over in a conveniently short time. Thus if the particle moves .3 of a mile in one minute, the velocity, if continued at that rate, would be $.3 \times 60$, or 18 miles per hour.

FORCE.

(6) By the term "Force" is understood any cause which produces or tends to produce motion.

(7) **Equilibrium of Two Forces.**—If two or more forces are so related, as regards the direction in which they act, as to produce no motion, they are said to balance, or be in equilibrium with each other.

(8) **Equality of Two Forces.**—Two forces are said to be *equal* when, acting in opposite directions along the same straight line, they balance each other.

(9) **Forces equal to the same Force are equal to one another.**—If several forces taken singly are found to balance or be equal to the same force, they will be found by experiment to be equal to each other; and any number of them, ten for example, applied together, will be ten times as great as one of them; so that if one be taken as the unit of force, the ten taken together will be expressed by the number 10.

MASS.

(10) A material body is one of whose existence we become conscious, in the first instance, by the sense of touch, or by the resistance which it offers to the muscular pressure exerted to move it; and we judge that a body (A) has the same mass as another body (B), if equal pressures, applied for a given time to the two bodies, produce in them the same velocity; and that the body A has a greater mass than B if a less velocity is given to A than to B, by the action of two equal pressures operating for the same length of time.

(11) The Mass of a Body Measured by its Weight.—It can be shown that the masses of bodies, as measured above, are proportional to their *weights;* so that if a body A has ten times the mass of B, according to the above mode of measuring mass, the weight of A will have also ten times the weight of B, provided they both be weighed at the same place.*

DENSITY.

(12) The term "Density" has reference in a general way to the quantity of matter contained in a given volume; a body being more or less dense, according as it has more or less mass or matter in it.

A body is said to be of uniform density when equal volumes, however small, taken from any part whatever of the body, have equal masses.

(13) Measure of Density.—Density is measured by comparing it with some substance chosen as a standard of density, so that if the substance A has ten times as much matter in a given volume as that contained in an *equal* volume of the standard† substance, A will have a density represented by 10.

SPECIFIC GRAVITY.

(14) This term has reference to the *weight* of a given volume; so that the body has a greater or less specific gravity, according as the weight of any given volume is greater or less.

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* While the mass or quantity of matter in a body is independent of its locality, its weight depends not only on the mass, but also on the force of gravitation, or the attraction of the earth, which is not the same at all places. Thus the weight of the body is greater at the level of the sea than at a great elevation, and greater near the poles than at the equator, as may be proved by weighing it with a delicate spring balance.

† The substance of standard density commonly chosen is distilled water at temperature 39°.2 Fahrenheit, at which temperature water is at its maximum density.

(15) Measure of Specific Gravity.—The specific gravity of a body is measured by comparing it with some substance chosen as a standard of specific gravity; so that if the substance *A* weighs ten times as much as an equal volume of the substance of standard specific gravity, *both being weighed at the same place*, *A* will have a specific gravity 10.*

(16) Other Definitions of Density and Specific Gravity.—Density and specific gravity are sometimes defined as the number of units of mass and of weight in a unit of volume of the proposed substance. These definitions necessitate an agreement as to units of volume, mass and weight, as well as to a standard substance; but if the units are suitably chosen, the density and specific gravity will be expressed by the same numbers, whichever of the definitions be used.

(17) Specific Gravities of certain Solids.—If distilled water at temperature† 39°.2 Fahrenheit, or 4 centigrade, be the standard of specific gravity, the following will be the specific gravities of certain solids:

Platinum (cast)	20.337
Gold "	19.258
Lead "	11.352
Copper "	8.788
Iron "	7.207
Melting Ice	0.930
Oak	0.845
Yellow Pine	0.657
Cork	0.240

(18) Specific Gravities of certain Liquids.—The following are the specific gravities of certain liquids at the temperature of 32° Fahrenheit, the standard being as before, distilled water at 39°.2 Fahrenheit:

Mercury	13.598
Sea Water	1.026
Distilled Water at 39°.2	1.000
Distilled Water at 32°	0.999
Alcohol	0.803
Ether	0.723

* If the standard or unit of density, as well as of specific gravity, be that of distilled water at 39°.2 Fahrenheit, it is clear that the density of a substance and its specific gravity will be numerically identical, the density being a ratio between two *masses*, and specific gravity a ratio between two *weights*. Moreover, as the masses of bodies are inferred from their weights in the same place, the density of a body and its specific gravity are identical also in the idea involved in the terms; and, in fact, in tables of specific gravity this identity is practically assumed. It is to be noticed, however, that the term "Specific Gravity" is not commonly applied to a body whose density is not uniform.

† It will be seen in Art. 67, on the Expansion of Liquids by Heat, that water attains its maximum density when at temperature 39°.2 Fahrenheit; that as the temperature rises from 32° to 39°.2, water contracts, and that from 39°.2 upwards it expands.

(19) Specific Gravity of Air.—The specific gravity of air of temperature 32°, *under a pressure of 30 inches of mercury*, is .000129 nearly.

CENTRE OF GRAVITY.

(20) If a body be suspended by a string attached to a fixed point, and also to some point in the body, the vertical straight line through the latter point, whatever be its position on the body, will pass through a certain definite point, either in or without the body. This point is called the *centre of gravity of the body.*

(21) Centre of Gravity of Part of a Body.—By the centre of gravity of *any portion of a body* is meant the centre of gravity, if that portion of it were detached from the whole body. The centre of gravity of a fluid body, or of a flexible body, is the centre of gravity which the body would have if all its parts were to be rigidly connected.

SECTION II.

FACTS RELATING TO FLUIDS, INCLUDING UNDER THAT TERM LIQUIDS AND GASES.

(22) Fluid Pressure.—The total pressure exerted by a fluid on a plane surface is equal to the pressure or force which must be applied in an opposite direction to balance it. Thus, if a piston sliding in an aperture in any part of a vessel containing water, air, or other fluid, be retained in its place by a pressure of ten pounds applied externally, the fluid pressure tending to drive the piston out will be ten pounds.

(23) Uniform Pressure.—The pressure on a surface is uniform when the pressures on equal portions of the surface are everywhere the same.

(24) Measure of Fluid Pressure, or Pressure referred to a Unit of Surface.—Fluid pressure, when uniform, is measured by the number of units of pressure exerted by the fluid on a unit of surface. Thus, the unit of pressure and surface being one pound and one square foot respectively, if the pressure on one square foot be ten pounds, the pressure referred to a unit of surface is 10. When the pressure of the surface is variable, it must be considered with reference to some point on the surface; in which case the pressure at that point is the pressure which would be exerted on a unit of surface if it had been uniform throughout that unit.*

* One pound and one square foot are chosen as units merely for illustration. The units are different in different cases, and depend on usage and convenience. A similar remark is applicable to the other cases, where units are arbitrarily chosen for purposes of illustration.

PROPERTIES OF FLUIDS COMMON TO GASES AS WELL AS TO LIQUIDS.

(25) Pressure in a Fluid the same in all Directions.—The pressure at any point in a fluid at rest is the same in all directions. Thus, if a very small plane surface placed at any part of a fluid be turned about a fixed point in itself, the whole pressure of the fluid on the small plane will continue invariable in all positions in which it can be turned.

(26) Additional Pressure propagated equally in every Direction.—If a fluid be contained in a vessel which it completely fills, so as to be kept at rest by the interior surface of the containing vessel, any additional pressure applied to any part of the surface will be propagated to all other parts of the fluid, and be added to the pressure which previously existed there. Thus, if the pressures at certain parts of the fluid were respectively 2, 3, 7, 9 pounds to the square inch, and an additional pressure of one pound were applied by means of a piston on the first of these, causing it to become 3 pounds, the pressure at the other parts would respectively become 4, 8, 10 pounds.

(27) Pressures equal throughout the same Horizontal Plane. If a fluid at rest be acted on by no extraneous forces but gravity, and the pressures of the bounding surfaces, the pressures at every point in the same horizontal plane will be equal.

(28) Equilibrium of a Body in a Fluid.—If a body,* or any part of a body, be immersed in a fluid at rest, the fluid pressures acting on it will be equivalent to a single pressure equal to the weight of the fluid displaced ; that is, to the weight of the fluid which, if the body had not been present, would have occupied its place, and acting vertically downwards through the centre of gravity of the fluid displaced. Consequently a body wholly or partially immersed in a fluid will have a tendency to rise, remain at rest, or sink, according as its weight is less, equal to, or greater than the fluid which it displaces.

* By the term "Body" is not necessarily meant a solid body. It may mean also a vessel filled or partly filled with liquid, or a fluid inclosed in a flexible envelope, such as a balloon, or a bladder containing a liquid, or a soap bubble, &c. The term is here applicable in a partial sense to a fluid that is not inclosed by any envelope. Thus, air heated by contact with the warm ground, and consequently expanded, will ascend, because the weight of any volume of it is less than that of the colder air which that volume displaces. The application is only partial, because the cold air partially penetrates and mixes with the warm, and thus alters the conditions. The heated water rising in a kettle on the fire is an example of a like process.

PROPERTIES OF NON-ELASTIC FLUIDS OR LIQUIDS, ON WHICH THE ONLY EXTRANEOUS FORCES ARE GRAVITY, THE PRESSURES EXERTED BY THE SIDES OF THE INCLOSING VESSEL, AND THE PRESSURE ON THE FREE LIMITING SURFACE OF THE FLUID.

(29) Pressure at any Point is Proportional to its Depth.—In a fluid of uniform specific gravity, the pressure at any given point exceeds the pressure at its highest point by a quantity which is proportional to the specific gravity and the depth of the given point below the highest point. If the pressure of the air on the upper surface of a tank of distilled water at its maximum density be 15 pounds on the square inch, the pressure on the square inch at a depth of 30 inches will exceed the pressure at the surface by 30 multiplied by the weight of one cubic inch of water in pounds. Now, the weight of one cubic inch of water at its maximum density = 252.5 grs. Troy, or = .03607 lbs. Avoirdupois.

Therefore pressure at depth 30 inches = 15 lbs. + 30 × .3607 lbs. = (15 + 1.082) lbs. = 16.082 lbs.

If the vessel had contained mercury at a temperature of 32°, since the specific gravity of mercury at 32° equals 13.598, the distilled water at maximum density being unit of specific gravity,

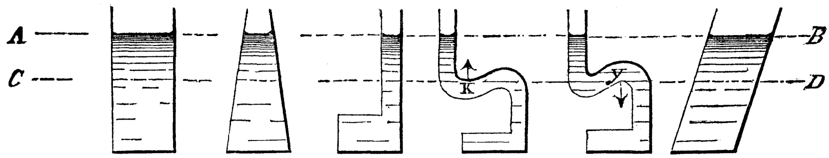
Weight of 1 cubic inch of mercury at 32° = .03607 × 13.598 lbs. = .4905 lbs.

Pressure at depth 30 inches = (15 + 30 × .4905) lbs. = (15 + 14.715) lbs. = 29.715 lbs.

(30) Pressure at any Depth not Influenced by the Form of the Vessel's Sides.—The total pressure on the horizontal surface of a fluid of uniform density is equal to the product of the number of units in that surface, and the common pressure on each unit, and is therefore independent of the form of the vessel; thus if the horizontal surface of the bottom of a vessel containing water measures 144 square inches, and the pressure at the bottom is 20 lbs. on the square inch, the total pressure on the bottom would be 144 × 20 = 2880 lbs.; and this pressure will be the same, whatever form the sides of the vessel may have.

Thus in the annexed figures, provided that the bases be equal in every case, and the water reaches to the level of the dotted line *A*, *B*, the whole pressure on each of the bases will be the same.*

* The pressure being proportional to the depth below the plane *A*, *B*, the pressures at every point of the horizontal plane *C*, *D* will be equal. Thus the pressure *upwards* at *x* is equal to the pressure downwards at *y*.



(31) The Free Surface of a Liquid at Rest is a Horizontal Plane.

(32) The Common Surface of two Fluids at Rest, and of different Densities, is a Horizontal Plane.—This is true also when the upper fluid is a gas.

CAPILLARITY.

(33) Meaning of Term "Capillarity."—The statement in Article 30 is subject to a modification occasioned by the mutual attraction between the liquid and the sides of the containing vessel, which becomes of sensible magnitude when the transverse section of the vessel is small. This action is called capillarity from the fact that it is most conspicuous in tubes which, from their small diameter, may be compared to hairs.

(34) Certain Phenomena of Capillarity.—(*a*) If a body be placed in a liquid which wets it (example: a glass rod in water), the water near the rod, instead of being horizontal, will be raised upwards against the sides of the rod, and be concave. If, on the contrary, the solid is one which is not moistened by the liquid, as glass by mercury, the liquid is depressed against the sides of the solid, and becomes convex.

(*b*) The surface of the liquid shows the same concavity and convexity against the sides of a vessel in which it is contained, according as the sides are or are not moistened by the liquid, and the effect is more apparent if the containing vessel is a tube of small diameter, the ascent or depression being greater as the diameter is less. When the tube is moistened by the liquid, as is the case of glass in water, its upper surface takes a concave form, which is called a concave meniscus; and when the tube is not moistened, as glass in mercury, the surface is convex, and forms what is called a convex meniscus.

(35) Laws of the Ascent and Depression in Capillary Tubes.—(*a*) When a capillary tube is placed in a liquid, the liquid is raised or depressed according as it wets or does not wet the tube.

(36)—(*b*) When the liquid is one which moistens the tube, and is therefore *raised*, the elevation, for the same liquid, is greater as the diameter is less; also the elevation varies with the nature of the liquid, and is independent of the nature or thickness of the tube.

(37)—(*c*) When liquids are in tubes which they do not moisten, and are therefore *depressed* (example: mercury in glass), the depression is greater as the diameter is less; but for tubes of the same diameter the depression depends on the substance of the tubes, for the depression of mercury in an iron tube is nearly twice as great as in a platinum tube of the same diameter.

(38) From what has been stated, it appears that the pressure at the base of a tube is not that due to the actual height, but to the height at which the liquid would stand if capillarity did not exist. At the base of a glass tube containing water, the pressure is less than that due to the depth of the water; but if the tube contain mercury, the actual pressure is greater than that due to the depth of the mercury.

CHAPTER II.—ON HEAT.

SECTION I.

FIRST NOTIONS OF HEAT, DEFINITION OF TEMPERATURE.

(39) The Bodily Sensations suggest the first Ideas of Heat, but are unsuited to Measure it.—By the term "Heat" is to be understood that agent which, in its various degrees of intensity, produces the familiar sensations of heat and cold.

The bodily sensations, though they furnish the first ideas of heat, are unsuited to be measures of its intensity. The same substance appears hot to one person and cold to another; or it may at one time appear hot and at another cold to the same person, according to his bodily condition; and if his two hands, after being held, the right in snow and the left in warm water, be transferred to ordinary cold water, it will appear warm to his right hand and cold to his left. These facts, and others of a similar kind, go to show the necessity of having recourse to other means for measuring heat than the bodily sensations.

(40) Temperature.—When two bodies appear equally warm to the touch, they are said, in common language, to have the same temperature; and if one appears to the touch to be warmer or colder than the other, it

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is said to have a higher or a lower temperature. Moreover, if the body appears to the touch to be becoming warmer or colder, it is said to be increasing or decreasing in temperature.

(41) Thermic Equilibrium.—If a small cylinder of thin metal containing hot water be stirred about in a somewhat larger vessel containing cold water, the hot water will become cooler and the cold water warmer, until each ceases to change its temperature (in the sense of the last paragraph). When that state is reached at which the two substances cease to change their temperature, or a balance of heat is attained, they are said to be in *thermic equilibrium*. Now, it will be found that the water in the two vessels appears of equal temperature to the touch. Hence, in this example, to be in thermic equilibrium is the same thing as to be of equal temperature.

Similar results occur if hot and cold oil, or any two similar liquids or two metals of the same kind, be thus brought together. It appears then, that when two bodies of a similar kind are brought together, thermic equilibrium is accompanied by equality of temperature in the sense above given. Now, as it has been seen that thermic equilibrium is accompanied by equality of temperature, as determined *by touch*, when the two bodies concerned are of the same material; and as the state of thermic equilibrium can be more accurately determined by other means to be described hereafter, it is more convenient to define equality of temperature as follows:

(42) Definition of the Term Temperature.—If two bodies in close proximity, not acted on by any external influence, be in thermic equilibrium, *i.e.*, if neither of them be gaining or losing heat, they are said to have *equal* temperatures.

If some mercury, inclosed in a small iron cylinder, be stirred in a vessel of water, it will be found, after a time, that the mercury and the water will be both in thermic equilibrium with, and therefore, according to the definition just given, of the same temperature as the iron. Now, if the mercury be poured out of the iron cylinder into the water, it will be found that the mercury is in thermic equilibrium with the water, and therefore of the same temperature with it. Similar results will follow if the experiment be tried with other bodies, unless interfered with by chemical action. It appears, then, that any two bodies which have the same temperature as a third body will also have the same temperature as one another, and that the definition of equilibrium of temperature may therefore be applied to all bodies, whether of like or unlike substances, unless chemical action take place between them.

(**43**) **Measure of Temperature.**—*Equality* of temperature having been defined, it is now necessary to fix on some method of measuring its differences. To do this, recourse is had to some easily recognized and easily measured effect of a rise or fall of the temperature of some body chosen as a standard of reference.

The effect most convenient for this purpose is the expansion which is found to take place in most bodies on the application of additional heat. But as the 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*.

SECTION II.

PRINCIPLE AND CONSTRUCTION OF MERCURIAL THERMOMETERS.

(**44**) The thermometer most frequently employed is the mercurial thermometer, which consists of a glass tube or stem formed with a very fine or capillary bore, as nearly uniform as possible throughout, with a bulb blown at one end of it, whose capacity is largely in excess of that of the bore. The bulb and part of the stem being filled with mercury, marks are placed on the stem for the purpose of indicating the expansion and contraction caused by changes of temperature.

(**45**) **Calibration of the Tube.**—The tube and bulb being formed as stated above, it is necessary before filling to calibrate the tube, that is, to ascertain that the bore is of uniform calibre, or that its cross sections are throughout of uniform area; and if not uniform, the extent of the variations in calibre at different parts of it. This is done by introducing into the tube a small portion of mercury, and causing it to occupy in succession different positions from one end to the other of the tube. The position of the two ends of the thread of mercury on each occasion being temporarily marked on the tube, and the distance between them measured as the volume of the mercury is constant, it is clear that the intervals between successive pairs of marks correspond to equal volumes, and that the longer intervals indicate smaller calibre, and *vice versa*. If the intervals differ much, the tube should be rejected; but if they be nearly of equal length, it is practicable, with due care, to divide the length of the tube into small portions which shall be of equal internal volume or capacity.

It is sometimes the practice to calibrate the tube after it has been filled, in which case a portion of the mercury is detached from the rest.

(46) To Fill a Thermometer.—Rarify the inclosed air by applying heat to the bulb, and insert the open end in a vessel of mercury, after which, as the air cools a little, the mercury will be forced into the tube by the pressure of the external air. This mercury is then boiled, and when the bulb and tube become full of either mercury or mercurial vapour, the open end is again plunged into a vessel of mercury, which, as the vapour cools, is forced into tube and bulb, and thus fills them. After leaving the instrument in this position until it has cooled to a temperature rather higher than any the thermometer is required to record, the open end is hermetically sealed.

(47) To Graduate the Thermometer.—For this purpose 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.*

(48) To find the Freezing Point, *i.e.*, the point on the tube at which the end of the mercurial column stands when it has the temperature of melting ice.

Procure a wooden cylindrical cup† about 2½ inches in diameter, and about a third of the length of the whole tube and bulb, perforated with holes small enough to exclude particles of ice, but which will freely admit water, and place it in a bucket full of snow or pounded ice with some water, in a room which,‡ when practicable, should not be much warmer than melting ice.

Stir the cup in the outer mixture of ice and water, that the water in the cup may have the temperature of melting ice. Place the bulb and as much of the tube as possible in the cup, and move it about that the mercury may speedily take up the temperature of the water.

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* Although the melting point of ice is appreciably constant, water, if *perfectly still,* may be cooled 8° or 10° below 32° F., and yet continue liquid. The slightest vibration, however, will cause the sudden conversion of a portion of the water into ice, when the temperature of the water will rise to 32°, in consequence of the latent heat given out by the ice in its formation. (See Arts. 106, 107.)

† The cup is used to guard the bulb from contact with particles of ice that may have a much lower temperature than that of melting; and it is made of wood, a bad conductor, to guard it from being unduly warmed by the heat of the room conducted down its sides, or from being unduly cooled by contact on its outer surface with any particles of very cold ice which the bucket might contain.

‡ It is of course not always possible to fulfil this condition, as it is necessary sometimes to perform the operation in summer.

When the mercurial column becomes stationary, mark the tube. This is the freezing point, which, according to Fahrenheit's scale (that ordinarily used in England, the British territories, and the United States), is called 32 degrees, and written 32°.

(**49**) **The Boiling Point.**—Water is said to boil when the steam rising from it has a pressure equal to the pressure of the atmosphere for the time being. When the atmosphere has a higher pressure, the steam from boiling water must have a greater pressure, and consequently (see Art. 52) be at a higher temperature.

(**50**) In Fahrenheit's scale the standard boiling point is the temperature of steam when its pressure is just sufficient to counterbalance the pressure of the atmosphere which is equal to that due to a column of pure mercury 29.905 inches in height, at a temperature 32°, the force of gravity being that found at the level of the sea, and on the parallel of London. The pressure of the atmosphere is known from the barometer. (See Arts. 124, 125, on the Barometer.)

(**51**) **To find the Boiling Point.**—Expose the bulb and stem to the *steam** issuing from boiling water, and mark on the stem the point to which the mercury rises and remains stationary. This is the boiling point for the time being. Ascertain also the corrected reading of the barometer.

If the corrected barometer reading is 29.905, the part of the tube intervening between the freezing and boiling points is to be divided into 180 parts representing equal volumes, which parts are called "degrees," and the boiling point will then be 180 degrees higher than the freezing point, and be designated as 212 degrees, or 212°. If the process of calibration has shown that the bore is uniform, the lengths of the degrees will be the same throughout; but if not, allowance must be made in the graduation for the varying capacity of the bore.

(**52**) **Boiling Point for Different Pressures.**—If the barometer shows that the atmosphere, and therefore the steam of boiling water, has a higher or a lower pressure than that corresponding to temperature 212°, the temperature corresponding to the actual pressure is found from a table which shows the temperature of steam for the different pressures

* The bulb should be exposed to the *steam*, and not be immersed in the water from which it issues; because it has been found that water boils under the same pressure at slightly different temperatures in different vessels; whereas the nature of the vessel does not affect the temperature of the steam.

as indicated by the barometer. The following is a portion of the table referred to:—

Temperature of the Boiling Point.	Pressure in Inches of Mercury reduced to Temperature 32° at Level of Sea in Latitude of London.
211°.0	29.315
211°.5	29.609
212°.0	29.905
212°.5	30.203
212°.9	30.444

If the barometer corrected should have a reading 29.315, the boiling point will be 211°, and the space between the freezing and boiling points must be divided into 179 degrees; on the other hand, should the corrected barometer reading be higher, say 30.203, the boiling point is 212°.5, and the space between it and the freezing point will contain 180°.5. 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 degrees 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 graduation for cold climates should extend down to nearly −40°, but it is useless to extend it lower, because mercury becomes solid at −37°.9.

(53) Other Thermometer Scales.—Besides Fahrenheit's scale there are two others, that of Celsius, usually called the Centigrade, which is used throughout France, and that of Reaumur, used commonly in Germany.

(54) To Convert a Temperature in Fahrenheit's Scale to the corresponding Centigrade, and the Converse.—As frequent reference is made in various books to Centigrade thermometers, an explanation of the mode of deducing from a temperature in the Centigrade scale the corresponding reading in Fahrenheit's scale, and *vice versa*, is called for.

In the Centigrade thermometer the freezing point of water is termed 0, or zero, and the boiling point 100; so that the interval between the freezing point and the boiling point contains 100 degrees Centigrade. The volumes of each degree Centigrade is therefore $\frac{180}{100}$, or $\frac{9}{5}$ of a degree Fahrenheit; and the volume of a degree Fahrenheit is $\frac{5}{9}$ of a degree Centigrade. From the above it is easily seen that if *F.* and *C.* represent the readings of a Fahrenheit and a Centigrade thermometer whose temperatures are the same, $C. = \frac{5}{9}$ (F. −32) and $F. = \frac{9}{5\,C}$ + 32.*

* There is in strictness a slight difference in the boiling points 212° F. and 100° C., owing to the fact that the latter is determined with a pressure corresponding to 29.914, instead of 29.905; but as the error thus occasioned does not exceed 0.015 in the boiling point, it may be disregarded.

Examples :—

If 50, 14, −13, be the readings of a Fahrenheit thermometer,
10, −10, −25, will be the corresponding readings of a Centigrade thermometer.

Also, if 20, −5, −20, be the readings of a Centigrade thermometer,
36, 23, −4, will be the corresponding readings of a Fahrenheit thermometer.

(55) **Change in the Position of the Freezing Point.**—If the freezing point be determined before and after boiling, its position after boiling will sometimes be found to be lower than before, in consequence of the slowness with which the glass returns to its ordinary condition after the expansion produced by boiling. On this account, when a thermometer has been boiled, it ought not to be used until experiment has shown that the freezing point has returned to the position which it had before the boiling experiment—a return which, although it may be accomplished in a few hours, will, for some instruments, require several weeks. If a thermometer is graduated soon after filling, *i.e.*, soon after the glass has been subjected to a very strong heat, and has therefore been unduly expanded, it will afterwards, by its contraction, force the mercury up the tube, it may be from 1° to 2°, and cause the freezing point to rise by that amount. For this reason a thermometer ought not to be graduated until several months after it has been filled; but even with this precaution there will sometimes, in the course of years, be a slow progressive contraction of the glass, which will cause a rise in the freezing point, and necessitate the subtraction of a correction throughout the scale, which will increase from time to time, until, after the lapse of several years, it will become constant.

(56) **Standard Thermometer.**—The term "Standard" is applied in strictness to a thermometer which, besides superiority in workmanship, and specially as regards the correspondence of the intervals between its divisions to equal volumes, is graduated from above the boiling point to below the freezing point. In a standard thermometer the correctness of the boiling point, as well as of the freezing point, can be verified, or, if these points have been displaced, their true position can be ascertained without reference to any other thermometer. As the chief use of a standard is to test the correctness of other thermometers, its range should extend each way as far as do those thermometers which are to be compared with it; and as these are sometimes wanted for very cold climates, it is better to extend the graduations down to the point where mercury becomes solid (−37°.9), or a little lower.

(**57**) **Thermometers which do not include the Boiling Point.**—The process of constructing thermometers described above is applicable as a whole to those only which include the boiling as well as the freezing points. Thermometers intended for meteorological purposes commonly have their graduations extending not much higher than 100°, unless designed for very hot climates. To graduate such thermometers, the position of some other fixed point, instead of the boiling point, is determined by comparison with a good standard, when the standard and the thermometer to be graduated are immersed in the same fluid.

INDEX CORRECTIONS.

(**58**) If the tube of a thermometer be calibrated throughout, and the length of a degree accurately known at all points of the scale, the true temperature of the thermometer would be obtained from its actual reading by the application of an "index correction," which would be constant, *i.e.*, of the same amount at all parts of the scale. Owing, however, to the difficulty of making tubes of equable bores, and the loss sustained by rejecting those whose bores are not equable, a large number of thermometers are sold which not only have large errors, but errors varying very considerably at different parts of their scales.

Such being their liability to error, 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. The true temperature of the thermometer is found from its actual reading, by applying the correction given in a table of corrections for the particular thermometer, which must be added or subtracted* from the actual reading, according as the correction is marked + or −.

(**59**) **Thermometer Certificates.**—It is a practice among English makers to supply to purchasers, with their thermometers, certified copies of index corrections. 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). Thermometers that have not been thus tested ought not to be accepted, however correct they may be at high temperatures, as it not unfrequently happens that thermometers, whose errors above 32° do not exceed 0°.2, are in error to the extent of 4° or more at or below zero.

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* This rule needs modification for temperatures near and below zero, for which see Arts. 177, 178. Part II.

SECTION III.

EXPANSION OR DILATATION.

(60) In describing the construction of a mercurial thermometer, it was stated that the *effect* of a rise or fall of temperature most convenient as a measure of the *amount* of the rise or fall, is the expansion produced by the application of additional heat. It is for the most part true, though not true universally, that when a body increases in its temperature, 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.

(61) Co-efficient of Cubic Expansion.—The term "Cubic Expansion" refers to its increase in volume; while the term "Linear Expansion" refers to the increase of one of its dimensions only, such as its length. The co-efficient of cubic expansion is the fraction or part of the volume of the body at temperature 32°, by which the volume of the body is increased when its temperature increases 1°. For example, if a body, whose volume is 1,000 cubic inches when at temperature 32°, were expanded so as to have a volume of 1,001 cubic inches at temperature 33°, or gain one cubic inch of volume when its temperature increases 1°, the co-efficient of cubic expansion would be $\frac{1}{1000}$, or .001 at the temperature 32°. If the expansion is uniform, the co-efficient of expansion may be also considered as the number by which the volume at 32° must be multiplied in order to produce the increase of volume corresponding to every additional degree of temperature.

Example:—Supposing the co-efficient of expansion to be as before, .001, a body which, at 32°, measured 100 cubic inches, would, at 42°, contain $100 + 100 \times .001 \times 10$, (or 101) cubic inches.

(62) Co-efficient of Linear Expansion.—The co-efficient of *linear* expansion is the fraction or part of one dimension of the body (its length, for instance) at temperature 32°, by which that dimension of the body is increased when its temperature increases 1°. The example above given will serve for illustration, if the word "length" be substituted for the word "volume."

(63) The Co-efficient of Cubic Expansion is approximately Three Times that of Linear Expansion for the same Body.—This is borne out by experiment, and its truth may also be tested by a numerical example, as follows:

Suppose a cube to be formed of a substance whose linear co-efficient is .001, and that at temperature 32° it measures 1 cubic foot. Then when its temperature is increased to 33°, each edge of the cube is increased from 1 foot to 1.001 of a foot, and the volume will increase to the cube of 1.001, *i.e.*, to 1.003003001, or 1.003 nearly, if the very small fraction 000003001 be neglected. Hence the co-efficient of cubic expansion is .003 nearly, which is three times the linear co-efficient .001.

(**64**) **Expansion greatest for Elastic Fluids, and least for Solids.**—The expansion is greatest for elastic fluids, and least for solids. For example, while air, under a constant pressure, will attain an increase of approximately .002 of its volume at 32° for every additional degree of temperature, the co-efficient of cubic expansion of mercury is approximately .0001, and that of iron .00002 nearly.

DILATATION OF SOLIDS.

(**65**) The expansion of solids is commonly measured by their linear co-efficients. The following are the linear co-efficients of certain solids :

Glass	For the average of different kinds of glass the linear co-efficient is	.000005
	" " " " cubic "	.000015
Brass (standard scale) linear co-efficient		.00001030 6
Iron	Wrought	.0000066
	Soft	.0000068
Steel		.0000060
Lead		.0000156

DILATATION OF LIQUIDS.

(**66**) The co-efficient of expansion at a given temperature is different in different liquids, and for the same liquid it generally increases with the temperature. In speaking of the dilatation of a liquid, a distinction must be made between its *apparent* and its *real* dilatation. By apparent dilatation is meant the apparent increase of volume of a liquid in a vessel which itself also expands, but to a less extent than the liquid it incloses. Mercury furnishes an example of nearly equable expansion, as will be seen from the following numbers, which show the *true* co-efficients of expansion at certain temperatures :—

Temperature.	True Co-efficient of Expansion.
32°	.00009947
122°	.00010085
212°	.00010225
302°	.00010365
392°	.00010505

Between 32° and 212° the mean co-efficient is 00010085
" 212° " 392° " " 00010365

The apparent expansion of mercury in glass is very nearly uniform within the range required for meteorological purposes, except possibly for temperatures near the freezing point of mercury. Thus,

For certain samples	of glass	the apparent	expansion	at	150°	is .000085125
"	"	"	"	"	100°	is .000085040
"	"	"	"	"	50°	is .000084955
"	"	"	"	"	32°	is .000084924
"	"	"	"	"	0°	is .000084869
"	"	"	"	"	−30°	is .000084818

(**67**) **Water is an Example of Irregular Expansion.**—As its temperature rises from the freezing point, 32°, to 39°.2, water, instead of expanding, contracts. It attains its maximum density at the latter temperature, and continues to expand as the temperature rises beyond it. The irregularity in the rate of the expansion of water at different temperatures, and the rapid change in the rate as the temperature rises, are seen from the following co-efficients of expansion, extracted from a table formed from experiments by Deprez:

The mean	co-efficient	of expansion is	.000024	from temp.	39°.2	to temp. 50°
"	"	"	.000240	"	104°	" 122°
"	"	"	.000416	"	194°	" 212°

(**68**) **Alcohol has a Large Expansion.**—The co-efficient of expansion of alcohol is more than five times that of mercury. It is also very irregular. Thus,

At temperature	100°	Fahrenheit,	the co-efficient	of expansion is	.00065
"	50°	"	"	"	.00057
"	32°	"	"	"	.00055
"	0°	"	"	"	.00051

DILATATION OF ELASTIC FLUIDS OR GASES.

(**69**) For air and all permanently gaseous fluids, *under a constant pressure*, the co-efficient of expansion is nearly the same at all temperatures within very wide limits. Under the ordinary atmospheric pressure, the increase of volume attending an increase of temperature of 1° Fahrenheit is .002039 (or .002 nearly) of the volume which the gas had at a temperature of 32°. Thus, for example, if a gas under a constant pressure, say of 15 lbs. on the square inch, occupies a volume of 5 cubic feet at a temperature of 32°,

At temperature	33°	the volume will	become	$5\,(1+.002\times 1)$	cubic feet, or	5.01 cubic feet.
"	42°	"	"	$5\,(1+.002\times 10)$	"	5.10 "
"	22°	"	"	$5\,(1-.002\times 10)$	"	4.90 "

If the gas be subjected to a much higher constant pressure, the co-efficient of expansion will be somewhat increased.

(70) Dilatation in relation to Standards of Length.—A knowledge of the expansion of different bodies has a very important connection with the standards by which length, mass and time are measured; but it will be sufficient in this place to consider it only in relation to standards of length. Suppose that there is a certain absolute length called a yard, and that a rod when at a temperature of 62° measures exactly one such yard, it is clear that when the rod has a higher temperature than 62° it will be longer than one yard, and that when it has a lower temperature than 62° it will be shorter than a yard. Hence, if this rod be used to measure a length, it is necessary to know its temperature in order to make allowance for its expansion or contraction from its true standard length, *i.e.*, that which it has at a temperature of 62°, which in England is the standard temperature for measures of length.

Example: Suppose a certain length to be apparently 30 inches as measured by a brass scale whose temperature is 72°; then as the linear co-efficient of brass is .00001 nearly, the true length will be $30\ (1+.00001 \times 10)$ inches, or $(30+.003)$ inches, or (30.003) inches. Suppose the temperature of the scale to have been 32°, the true length will be $30\ (1-.00001 \times 30)$ inches, or $(30-.009)$ inches, or 29.991 inches.

SECTION IV.

ON THE DISTRIBUTION OF HEAT THROUGH SPACE.

(71) It has been before stated, that when bodies are in close proximity the heat existing in them has a tendency to distribute itself until a state of thermic equilibrium, or equality of temperature, has been attained by the bodies. This is true not only when the bodies are near together, but also when they are separated by great distances. It is true, in fact, that the heat existing in any part of the universe tends to diffuse itself throughout the universe in such a manner as to approach a state of thermic equilibrium. The distribution of heat through space is effected by the following three processes:—

(1) *By Conduction.*

(2) *By Convection.*

(3) *By Radiation.*

(72) Conduction Defined.—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 particle or the source of heat, the process is called "conduction." A familiar illustration 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 their turn transmit it by contact to still colder particles, and these latter to others, and so on, until after a time some of the heat reaches the hand.

(**73**) **Convection Defined.**—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."

(**74**) **Radiation Defined.**—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 communicated is called radiant heat. The heat received by a person standing before a fire, or from the sun, is an example of radiant heat; for the heat does not reach him by first heating the intervening air, as may be shown by the fact that the sensation of heat ceases when a screen is interposed.

CONDUCTION.

(**75**) As before stated, conduction of heat consists in the process whereby heat, emanating from a warm particle (source of heat in contact with the body), first warms the particles contiguous to it. These particles, as they receive heat, transmit part of it to the neighbouring particles, and these to other particles in succession, and so on, until the heat is distributed throughout the body.

(**76**) **Thermal Conductivity.**—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 in a substance 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 *conducting power*, or *conductivity*, or *thermal conductivity.*

Substances through which heat is transmitted *rapidly* are said to be *good conductors*, or to have a *high conducting power;* whereas those which transmit heat *slowly* are said to be *bad conductors*, or to have a *low conducting power.* The thermal conductivity of metals is the greatest. Next in order to the metals are stones and woods. Amongst bad conductors are wool, feathers, air and other gases, and most liquids.

(77) Conductivity of Metals.—A considerable difference exists between the conductivity of metals, as shown by the following table of the relative rates with which heat travels in different substances, the conductivity of silver, the best conductor, being expressed by 100:—

Silver	100	Brass	24
Copper	74	Iron	12
Gold	53	Lead	8

The conductivity of wood is greater in the direction of the fibre than across it.

(78) The conductivity of substances is usually diminished as their temperature increases.

(79) Conductivity of Liquids.—Little is known of the conductivity of liquids, further than that it is extremely small.

The conductivity of mercury is much greater than that of either water or alcohol.

CONVECTION.

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

(81) Process of Convection in a Liquid.—If heat be applied under a vessel of water, the particles in the lower strata become heated, expand, acquire a less specific gravity than the particles in the strata above them, and are raised towards the surface by the pressure of the cooler water from above. The cooler water, after its descent, becomes warm, and ascends in like manner, until the whole mass is warmed.

It may be seen that the process above described depends primarily on the extent to which the liquid expands by heat, and also on the force of gravity, and on the consequent difference between the specific gravity of the warmer and colder portions of the liquid. (See Art. 28, on Floating Bodies.)

(82) Convection in Air and other Gases.—Convection takes place in air and other gases more energetically than in liquids—the co-efficients of expansion in air and gases being much greater than those of liquids. It is by the process of convection that the warming of buildings by fires is chiefly effected. The air immediately heated by the fire being specifically lighter, or having a less specific gravity than the cooler air above and near it, and having therefore a less weight than that of the cooler air which it displaces (see Art. 28), is compelled to rise and to give place to that cooler air. The latter being warmed, also ascends to make room for a further descent of cooler air—the process of ascending warm air and descending cool air being continued, until a general distribution of temperature through the room has been accomplished.*

(83) Solar Heat Diffused by Convection.—The diffusion of solar heat through the atmosphere is due in a great measure to convection, which, as the ground is warmed by the sun, communicates its heat to the air in contact with it, and distributes that heat by a process similar to that described in the preceding article.

RADIATION.

(84) As stated in Art. 74, when heat is transferred from one body or particle to another more or less distant without the agency of intermediate particles, the heat is said to be transmitted by *radiation*, and the heat so transmitted is called *radiant heat.*

(85) Luminous and Dark Heat.—Radiant heat may be regarded as consisting of two kinds, designated as *luminous heat* and *dark heat*. Solar light is composed of rays of different kinds, which, by the aid of a prism, may be separated and examined separately. It is convenient to group these in three classes, designated, according to their predominant effects, as *heat* rays, *luminous* rays, and *chemical* rays. The heating influence exists in all three classes; but the luminous effect of heat rays being not powerful enough to affect the sense of sight, the heat derived from them is called *dark* heat, in contradistinction to the heat of the luminous rays, which is called *luminous* heat. The amount of heat in the chemical rays is comparatively insignificant. Although heat derived from other sources than the sun is not identical with solar heat as respects the quality of its component rays, these heat rays, like those of solar heat, may be also classed as luminous and dark.

(86) Velocity of Radiant Heat through Space.—It is probable that radiant heat traverses space with the velocity of light, namely, about 186,000 miles per second, and as its motion through air is not much less, its passage from point to point on the surface of the earth may be regarded as practically instantaneous. The motion of radiant heat being so enormous, the diffusion of heat by radiation would produce an almost instan-

* The process described is considerably modified by the influx of cool air under the doors, &c., and the escape of air, as it is warmed, by the chimney and other means.

taneous balance of temperature throughout nature, if it were not that heat leaves and enters bodies of a given temperature at a comparatively slow rate, and with a readiness depending on the condition of their surfaces, and on their internal conducting powers. The rate at which heat leaves a substance, as far as it depends on the nature of its surface, is called the radiating power of the surface. It is found that the absorbing power of a surface is nearly equal to its radiating power.

(87) The Radiating and Absorbing Powers of certain kinds of Surfaces:

RELATIVE RADIATING POWERS.

Lampblack	100	Tarnished lead	45
White lead	100	Mercury	20
Ordinary white glass	90	Polished lead	19
Isinglass	80	Tin, gold, and other metals	12

RELATIVE ABSORBING POWERS.

Lampblack	100	Isinglass	91
White lead	100	Metals	13

(88) Diathermanous, Athermanous.—If a substance be of such a nature as to allow radiant heat to pass freely through it without loss, the substance is said to be *diathermanous;* but if it be such as to stop all the rays, it is said to be *athermanous.* It may be seen that these terms are analogous to *transparent* and *opaque* with respect to light. The great majority of substances are athermanous; several are diathermanous to a partial extent; but very few are absolutely diathermanous.*

(89) When radiant heat encounters an athermanous body, part is *reflected* in conformity with definite laws similar to those of light, part is *diffused* or scattered by irregular reflection, and part is *absorbed.*

(90) Absolute Reflecting Power of a Surface.—By the absolute reflecting power of a surface is to be understood the number of rays which it reflects out of 100 rays that fall on the surface. The following table shows the *relative* number of rays reflected by certain substances, from which it is to be understood that while brass reflects 100 rays out of some unknown number falling on it, glass would reflect 10 rays out of the same number of incident rays:

Brass	100	Lead	60
Silver	90	Amalgamated tin	10
Tin	80	Glass	10
Steel	70	Lampblack	0

* Rock salt and certain sulphides are diathermanous.

The reflecting power of a surface is influenced by the angle at which the heat strikes it, the power being generally greater as the heat strikes the surface at a smaller angle.

(91) When radiant heat enters a screen formed of a partially diathermanous substance, a certain percentage of the rays is stopped, the amount stopped depending on the substance as well as on the thickness of the screen, and partly on the quality of the heat, the rest passing through.

It is found that if heat is transmitted through a succession of similar screens of the same material, the percentage lost on each screen will become less and less; or, as it may be stated, when heat has passed through a screen, it is better able than before to penetrate another screen of the same material.

(92) Atmosphere very Diathermanous to Solar Heat.—Atmospheric air is very diathermanous for the luminous heat from the sun; but is far less diathermanous for dark heat. The beneficial consequences of this property appear from the consideration that the luminous heat from the sun passes with but slightly diminished strength to the earth's surface, and according to the nature of the surface on which it falls, is partly reflected, partly diffused and partly absorbed.

Of the heat which is absorbed by the ground, and which serves to increase its temperature, a larger or smaller part, according to the greater or less conductivity of the soil below, is conducted downwards. While this is going on, the heat on the surface is radiated upwards; but as it is now *dark* heat, and air is less diathermanous for dark heat, it is in a great measure detained in the lower strata, and thus serves to add warmth to those strata. As the surface is cooled by radiation its heat is replenished from below by conduction, and the heating of the lower strata is continued. The vapour of water is less diathermanous than dry air to dark heat, and it is therefore very influential in detaining that heat in the lower strata.

(93) On the Rate at which a Body Cools by Radiation.—The rate at which a body radiates heat depends on the radiating power of its surface, on its internal conductivity, and on its temperature, (the rate of emission being greater as the temperature of the body is higher,) and is altogether independent of the action of other bodies.

(94) The rate at which a body acquires heat from external sources, depends on its own power of receiving, on the heat radiated from other bodies, and on the proximity of those bodies. The rate at which a body cools by radiation depends on the amount by which its losses of heat by radiation, exceed its gains obtained by absorbing the heat radiated by other bodies.

SECTION V.

SPECIFIC HEAT.

(**95**) **Measure of a "Quantity" of Heat.**—The quantity of heat imparted to or taken from a body may be inferred from any of the measurable effects which such change of heat produces; but the effect most conveniently employed for this purpose is the alteration in the temperature of a body consequent on the increase or diminution of its heat. A "quantity" of heat is usually expressed by the number of degrees to which it is capable of raising the temperature of a known weight of some substance, such as water, arbitrarily chosen for a standard. The heat unit being arbitrary, it will be here taken, for the sake of illustration, as the heat requisite for raising the temperature of 1 lb. of water from 32° to 33°.

(**96**) **Specific Heat, or Capacity for Heat.**—The quantity of heat that 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, and, even for the same substance, is not exactly the same at all temperatures. Of two bodies 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 greater "capacity for heat."

(**97**) **Measure of Specific Heat.**—The specific heat of a substance is numerically expressed by the ratio which the heat required to increase its temperature 1° bears to the heat required to raise the temperature of the same weight of distilled water from 32° to 33°. If the body weighs 1 lb., its specific heat will be numerically the same as the quantity of heat required to raise its temperature 1°. Although the specific heat of a body is not strictly constant for all temperatures, as in fact it increases somewhat as the temperature rises, it may for most bodies be considered constant within very wide limits.

(**98**) The following remarks and examples will further explain the meaning of the term "Specific heat."

If two substances of different temperatures, which do not act chemically on one another, be mixed so as to acquire a common temperature, it is clear that if they neither part with heat nor take in extraneous heat, the heat received by the cooler substance will exactly equal that which the warmer loses, and the common temperature will be something intermediate between the original temperatures of the two substances, supposing that no change of physical state from solid to liquid, or the converse, has taken place; also, the change of temperature in each will be inversely as its specific heat. If the two bodies be of similar nature and also of equal weights, and if the specific heat be supposed to be uniform, the temperature of the mixture will be exactly midway between the temperatures of the two substances before mixing.

If 1 lb. of water at 100° and 1 lb. of water at 40° be mixed, the temperature of the mixture will be very nearly 70°, and would be exactly 70°, were it not that the specific heat of water increases slightly with a rise of temperature. In this case the heat lost by the warmer water in falling 30°, is approximately that necessary to raise the temperature of the colder water by an equal amount.

If instead of water at 100°, 1 lb. of iron at 100° be stirred about in water at 40°, the common temperature will be 46° nearly. It appears then that while the temperature lost by the iron is 54°, the temperature gained by the water is only 6°. Hence the heat gained by the water is 6 units of heat, but the heat lost by the iron is the same as that gained by the water, therefore in falling 54° the iron loses also 6 units of heat, and in falling 1° the iron loses $\frac{6}{54}$ of a unit of heat. That is to say, the specific heat of iron is $\frac{6}{54}$, or .11 nearly. If 1 lb. of mercury 100° be stirred about in 1 lb. of water at 40°, the common temperature will be nearly 41°.92; or while the mercury loses in temperature 100°—41°.92, or 58°.08, the water only gains 1°.92. Hence the heat gained by the water is 1.92 units of heat. That is, in falling 58.08, mercury loses 1.92 units of heat, and in falling 1°, mercury loses $\frac{1.92}{58.08}$; *i.e.*, the specific heat of mercury is $\frac{1.92}{58.08}$, or .033 nearly.

(99) Specific Heat of Solids.—The following are the average specific heats of certain solid substances, water being unity:

Glass	0.1770
Iron	0.1098
Copper	0.0949
Zinc	0.0927
Silver	0.0557
Platinum	0.0355
Lead	0.0314

(100) Specific Heat of Liquids.—The specific heat of liquids is in most cases greater than that of solids. Taking water at 32° as the standard for specific heat, so that the specific heat of water at 32° is unity, or 1.0000, we have

Specific heat of water	1.0000
" " alcohol	0.5475
" " ether	0.529
" " mercury	0.033

(101) The Specific Heat of the same Liquid Increases with the Temperature.—Thus,

The specific heat of alcohol at 4° is	0.505
" " " at 176° is	0.769

(102) Specific Heat of Gases and Vapours.—The specific heat of air under a constant pressure, such as ordinarily prevails in the atmosphere, is for all temperatures 0.2375 nearly. The same substance has a higher specific heat when liquid, than when it is either in a solid or a gaseous state. Thus

Ice has a specific heat of	0.5046
Water	1.0000
Aqueous vapour	0.4805

A body which has a large specific heat requires a proportionately longer time to acquire the same addition to its temperature than one which has a small specific heat.

SECTION VI.

CHANGE OF STATE FROM HEAT.—LATENT HEAT.

(103) Most Bodies are Solid, Liquid, or Gaseous, according to the Heat which they Contain.—Many substances, according to the amount of heat communicated to them, may be made to appear in either a solid, a liquid, or a gaseous condition; but there are some that cannot, as far as is known, be made to change the state in which we find them. Thus we cannot freeze pure alcohol or liquefy atmospheric air.

(104) Liquefaction and Solidification.—At sufficiently high temperatures all solids, with very few exceptions, may be melted; and all liquids, alcohol excepted, are converted into solids, when their temperatures are reduced sufficiently low. The temperature of liquefaction or solidification is constant within extremely small limits for the same body.

It is commonly called the *melting* or the *freezing* point, according as the body at ordinary atmospheric temperatures is found in a solid or in a liquid state. Thus, while we speak of the melting point of iron and other metals, the temperature at which water becomes ice is most commonly called its freezing point.

(105) Melting Points of certain Substances.—The following are the temperatures at which certain substances pass from the solid to the liquid state, or the converse:

Mercury	$-37°.9$
Oil of vitriol	$-30°$
Ice	$32°$
Sulphur	$239°$
Lead	$620°$
Wrought iron	$2912°$

(106) Latent Heat of Liquefaction.—When the temperature of a solid body has reached its melting point, and additional heat is communicated to it, the temperature is not thereby increased until the melting is complete.* The heat thus expended in the liquefaction of a solid which has been previously heated up to its melting point, is called the "latent heat of liquefaction" for that solid. The latent heat is measured by the ratio which the heat required to liquefy a given weight of the substance bears to that required to raise the temperature of the same weight of water from 32° to 33°.

For example, the heat expended in converting 1 lb. of ice at 32° into 1 lb. of water at 32°, is about 142 times as much as that sufficient to raise the temperature of 1 lb. of water from 32° to 33°. It would raise the temperature of 1 lb. of water from 32° to 174° nearly, or it would raise the temperature of 142 lbs. of water from 32° to 33°. The latent heat of melting ice is therefore 142.†

(107) Heat given out in Solidification equals Heat Absorbed in Liquefaction.—In solidification heat is given out equal to that absorbed in liquefaction: thus, when snow is formed from condensed vapour, the heat given out for every pound of snow is sufficient to warm

* It is here assumed that the heat acquired is all taken up by the solid; as it is obvious that the liquid, when it has been removed from the cooling influence of the solid, will not retain the temperature of the melting point.

† It is sometimes the practice to express latent heat in degrees. This is merely a convenient way of shewing that the unit of heat is the heat which raises the temperature of the water, whose weight is equal to that of the proposed substance, from 32° to 33°. If the degrees had been in centigrade, the latent heat would have been $\frac{5}{9} \times 142 = 79$ nearly.

142 lbs. of water 1°; and as the specific heat of air is less than ¼ of that of water, the heat given out by the condensed vapour in turning into snow, is sufficient to warm about 568 lbs. of air 1°, or, more strictly, to retard its cooling to that extent.

(108) Vaporization and Condensation.—The temperature at which a liquid under a given pressure is converted into vapour, with an elastic force equal to that of the said given pressure, is called its *boiling point* for that pressure. The boiling point differs in different liquids; but, under the same pressure, it is constant for the same liquid. Thus under a pressure equal to that at the base of a column of mercury 29.905 inches in height, supposing the mercury to be of the specific gravity 13.598, and the force of gravity that in the latitude of London at sea-level—

Water boils	at	212°	Fahrenheit.
Alcohol	"	173°	"
Mercury	"	662°	"

(109) Latent Heat of Vapour.—When the temperature of a liquid has reached its boiling point, and additional heat is communicated to it, the temperature is not increased until the vaporization is complete. (See note to Art. 106.) The heat thus expended in the vaporization of a liquid previously heated up to its boiling point, is called the *latent heat of vapour at the boiling point.* It is measured by the ratio which the heat required to vaporize any given weight of the liquid bears to that expended in raising the temperature of an equal weight of water from 32° to 33°. Thus the heat required to convert 1 lb. of water at 212° into 1 lb. of steam at 212°, is about 966 times as great as the heat required to raise the temperature of 1 lb. of water from 32° to 33°, or the latent heat of steam at 212° is 966 nearly.

(110) Heat given out in Condensation equals Heat Absorbed in Vaporization.—In the process of condensation of a vapour to liquid, heat is given out equal to that absorbed in vaporization: thus the heat given out by 1 lb. of steam at 212°, in becoming water at 212°, is sufficient to raise the temperature of 966 lbs. of water from 32° to 33°.

The latent heat of the vapour of alcohol at its boiling point = 365 nearly.

(111) Latent Heat of Aqueous Vapour at Temperatures Different from that of the Boiling Point.—Vapour is formed from water at all temperatures, and also from the surface of ice. The amount of latent heat absorbed in the formation of vapour is less when the temperature of the liquid is high, and greater when the temperature is low, thus:

Ice at 32°	gives off vapour	whose latent	heat is	1234	nearly.
Water at 32°	"	"	"	1092	"
Water at 132°	"	"	"	1012	"
Water at 212°	"	"	"	966	"

(112) It has been seen that the cooling of the atmosphere is largely retarded by the formation of snow from cloud or condensed vapour. The conversion of vapour into cloud has an analogous and, on account of its large latent heat, a much more powerful effect. Thus the heat given out by 1 lb. of vapour at 32°, in becoming condensed vapour, or water at 32°, is sufficient to add 1° of temperature to 1092 lbs. of water at 32°. Also as the specific heat of air is less than $\frac{1}{4}$ that of water, the same heat is sufficient to add 1° of temperature to more than 1092×4 lbs., or 4368 lbs. of air.

Combining this with the result in Art. 107, the conversion of 1 lb. of vapour at 32° into snow at 32° gives out heat sufficient to add 1° of temperature to more than 4368 lbs. + 568 lbs., or 4936 lbs. of air, or 5000 lbs. of air nearly.

CHAPTER III.

FURTHER FACTS RELATIVE TO ELASTIC FLUIDS AND GASES.

SECTION I.

PERMANENT GASES.

(113) Law of Boyle or Marriotte.—This law is to the effect that if any given mass or quantity of gas be contained in a closed vessel, the pressure will be inversely proportional to the space or volume occupied by the gas, provided that the temperature remains unaltered, or, what comes to the same thing, the pressure will be directly proportional to the density. Thus, if gas confined in a cylinder, in which a piston can be made to slide so as to enlarge or diminish at pleasure the volume inclosed, has a pressure of 1 lb. on the square inch when the gas occupies a space or volume of 1 cubic foot, it will be found to have pressures 2 lbs., 3 lbs., 4 lbs., etc., when by pushing in the piston the volume is reduced to $\frac{1}{2}$ c. ft., $\frac{1}{3}$ c. ft., $\frac{1}{4}$ c. ft., etc., and the density therefore is increased to double, three times, &c., the original density. Also if the piston be drawn out so as to reduce the density by enlarging the volume to 2 c. ft., 3 c. ft., 4 c. ft., etc., it will be found that the corresponding pressures will become $\frac{1}{2}$ lb., $\frac{1}{3}$ lb., $\frac{1}{4}$ lb., etc, provided in every case that the temperature remains the same.*

(114) Increase of Pressure Proportional to Increase of Temperature.—If the temperature of gas inclosed in a vessel be increased or diminished while the gas is constrained to occupy the same space or volume, the pressure of the gas will be increased or diminished at the rate of .002036, or .002 nearly of the volume which it would have had at temperature 32° Fahrenheit, for every degree of temperature Fahrenheit added to or taken from its temperature. Thus, supposing the pressure to be 3 lbs. on the square inch at temperature 32°,

At 33° the pressure in lbs. will become $3+3\times.002\times\ 1=3.006$ lbs. nearly
At 42° " " " $3+3\times.002\times10=3.060$ lbs. "
At 22° " " " $3-3\times.002\times10=2.940$ lbs. "

It may be noticed that the co-efficient .002036, shewing the increase of pressure for each additional degree of temperature, is very nearly the same as the co-efficient of expansion for gas, which, as before stated, is .002039.

(115) If the density of a gas confined in a vessel be increased, either by reducing the volume or increasing the mass, and the temperature be also increased, the pressure will be increased from both causes, in conformity with the statements of the preceding articles.

(116) If a communication be opened between two closed vessels filled with different gases having the same temperature and pressure, it will be

* In order that the statement made above may hold good, it is necessary that the temperature which the gas had before compression or expansion be restored, if from any cause it has been altered. The density of the inclosed gas may either be increased by diminishing the size of the vessel or by introducing more gas. Thus if the air contained in two vessels having each a capacity of 1 cubic foot, with a pressure of 1 lb. on the square inch, be compelled to occupy one of these vessels, so that the density may be doubled, it will be found that the pressure also will be doubled, and become 2 lbs. on the square inch.

found, after a short time, provided that there be no chemical action between them, that the two gases will be uniformly diffused through the two vessels, and that the pressure will remain unaltered.

(**117**) If equal volumes of two or more gases of the same temperature be compelled to occupy the space occupied by one of them, the pressure of the mixed gas will be equal to the sum of the pressures of the separate gases.

SECTION II.

PROPERTIES OF VAPOUR.

(**118**) If a vessel from which the air has been withdrawn be partially filled with water, or any liquid capable of affording vapour, the part of the vessel unoccupied by the liquid will be quickly filled with vapour, whose density and pressure will depend on the temperature alone, *unless the whole of the liquid be turned into vapour.*

(**119**) If the temperature be increased, more of the liquid will become vapour, and the density and pressure will be increased. If the temperature be diminished, part of the vapour will resume the liquid state, and the pressure of the remainder, as well as its density, will be diminished. If the space be enlarged, (the temperature remaining the same,) more of the liquid will be converted into vapour, or if the space be diminished, some of the vapour will return to the liquid state; but in either case the density and pressure will not be altered.

(**120**) If all the liquid be converted into vapour, either by enlarging the space or elevating the temperature, the relations between temperature, density, and pressure will be nearly the same as for the permanent gases.

(**121**) If the vessel into which the liquid is introduced contains atmospheric air, the same effects are produced, but the vapour is formed more slowly, and its pressure is *slightly less.*

(**122**) **Saturation Defined.**—The space which a vapour occupies, or the air with which it is mixed, is said to be saturated when it contains as much vapour as it is capable of containing at the existing temperature. The amount of vapour requisite for saturating a given volume or space is not constant, but increases and diminishes with the temperature. It increases more rapidly than the temperature, as will be seen from the following tables:

Table derived from the experiments of Regnault, giving in grains Troy the weight of Vapour in a cubic foot of Saturated Air, for every ten degrees Fahrenheit, from 0 to 100.

Deg. Fahr.	0	10	20	30	40	50	60	70	80	90	100
Weight of Vapour in grains............	.545	.841	1.298	1.969	2.862	4.089	5.756	7.992	10.949	14.810	19.790

Table shewing the Pressure of the Vapour that Saturates Air at different Temperatures, given in Inches of Mercury.

Deg. Fahr.	0	10	20	30	40	50	60	70	80	90	100
Pressure in in. of Mercury..	0.0434	0.0684	0.1078	0.1668	0.2476	0.3608	0.5179	0.7329	1.0232	1.4097	1.9179

PART II.

ON THE

CONSTRUCTION AND USE OF METEOROLOGICAL INSTRUMENTS, WITH BRIEF DESCRIPTIONS OF CERTAIN PHENOMENA.

CHAPTER I.—BAROMETER.

SECTION I.

GENERAL DESCRIPTION OF A MERCURIAL BAROMETER.

(123) Measure of Atmospheric Pressure.—The pressure of the atmosphere at any time and place may be measured by the number of units of pressure exerted by the atmosphere on a unit of surface; for example, by the number of pounds on the square inch. It is customary, however, to measure the atmospheric pressure by the *depth* in inches of mercury in a vessel at the base of which the pressure referred to a unit of surface is the same as the pressure of the air, where the pressure on the upper surface of the mercury is supposed to be nothing, the density of the mercury, that proper to pure mercury at temperature 32°, namely, 13.598, and the force of gravity, that which exists at the mean level of the sea in latitude 45°.

(124) Barometers are instruments designed for measuring the pressure of the atmosphere. Those best adapted to this purpose, and most generally in use, are the various kinds of mercurial barometers. Their ordinary form may be described as follows: Let a glass tube, about 34 inches in length, closed at one end and open at the other, be filled with mercury; and when so filled let the open end be temporarily closed and be placed beneath the surface of some mercury in a cup or cistern, the tube being vertical. If the lower end be then opened, part of the mercury will flow through it from the tube into the cistern, and descend in the tube, leaving a vacant space above called the Torricellian vacuum, after Torricelli, inventor of the barometer; the quantity of mercury remaining in the tube being greater or less according as the pressure of the atmosphere is greater or less.

When the mercury has ceased to descend in the tube, it is maintained in equilibrium by the pressure of the air acting downwards on the surface of the mercury in the cistern, and the equal pressure of the mercury on that surface acting vertically upwards against the pressure of the atmosphere. Now as the pressures at every point of the same horizontal section are equal (Part I., Art. 27), the pressure of the mercury at the level of the cistern, and therefore the atmospheric pressure, is equal to the pressure within the tube at that level, namely, the pressure due to the depth of that level below the top of the mercurial column (Part I., Art. 29) or to the height of the mercurial column, measured from the level of the upper surface of the mercury in the cistern, provided that the tube be so large that capillarity may be regarded as insignificant. (Part I., Arts. 33–38.)

(125) Briefly, then, the atmospheric pressure at any instant is proportional to the height of the column of mercury above the level of the upper surface of the mercury in the cistern, provided that the diameter of the tube be sufficiently large, and provided also that the weight of a given volume of the mercury, as measured by *a spring balance*, be invariable.

SECTION II.

INSTRUMENTAL CORRECTIONS.

(126) Capillarity.—In the proposition (Part I., Art. 29) to the effect that pressure in a liquid is proportional to its depth, it is supposed that the liquid is acted on by *gravity only*. Now such would be the fact if the tube were of very large dimensions; but if the tube be of such dimensions as it is found convenient to employ, an additional force is introduced, namely, the force of *capillarity*, caused by the attraction between the glass of the tube and the mercury, which has the effect of keeping the mercury in the tube at a level lower than that at which it would stand if the tube were of a very large transverse section.

The upper surface of the mercury in a vessel of large dimensions, except close to the edges, will be horizontal, or rather will follow the general rotundity of the globe; but in a small tube, the mercury at its upper surface bulges upwards, so as to form a curved convex surface, called a *convex meniscus*. (Arts. 33–38.)

The form of the meniscus depends chiefly, but not entirely, on the internal diameter of the tube, being more protuberant for tubes of small than for tubes of large diameter.

The depression caused by capillarity is greater for tubes of small than for tubes of large diameter, and it is also greater for unboiled than for boiled tubes.*

(**127**) The depression caused by capillarity in tubes of different diameters, supposing in each case the meniscus to be of the ordinary dimensions proper to the diameter, is given in the following table for unboiled as well as for boiled tubes.

	CORRECTIONS.	
Diameter of Tube, Inches.	Unboiled Tubes, Inches of Mercury.	Boiled Tubes, Inches of Mercury.
0.60	0.004	0.002
0.50	0.007	0.003
0.45	0.010	0.005
0.40	0.014	0.007
0.35	0.020	0.010
0.30	0.028	0.014
0.25	0.040	0.020
0.20	0.060	0.029
0.15	0.088	0.044
0.10	0.142	0.070

CORRECTION FOR VARIATIONS OF THE DENSITY OF THE MERCURY DUE TO CHANGES OF TEMPERATURE.

(**128**) Supposing that correction for the effect of capillarity has been made, and the Toricellian vacuum to be perfect, the atmospheric pressure will be proportional to the height of the column measured from the cistern level, provided that the weight of any given volume of mercury (as measured by a spring balance) remains constant. Now at the same place the density of mercury, and therefore the weight of any volume of it, is subject to considerable changes owing to the variations of temperature; so that the same height of the column does not indicate the same pressure, and is therefore not a suitable measure for pressure.

It is therefore necessary to adopt some standard density for the mercury, and to calculate from the actual height of the mercury at the existing temperature, what the height would have been if the mercury had had its standard density. The standard density always taken is that which pure mercury has when at a temperature 32° Fahrenheit, or 0° centigrade, namely, 13.598 (Art. 18).

* The term boiled here has reference to the practice of boiling the mercury in a barometric tube in the process of filling, in order to expel bubbles of air and vapour.

Now as the co-efficient of cubic expansion of mercury is .0001 nearly (Art. 66), the mercury, which at a temperature 32° occupies a length of 1 inch in the tube of a barometer, will increase .0001 for every degree of temperature above 32°, and a height of 30 inches will increase in height 30 times as much, or .003 for each degree of temperature, so as to become............ 30.003 at temperature 33°;

to become	30.003	at temperature	33°;
	30.030	"	42°;
	30.060	"	52°;
	30.090	"	62°;
	30.120	"	72°.

In order then to obtain the height 30 inches, which is here the true measure of the pressure, it is necessary that the *observed* readings, as given in the column above, should be corrected by the *subtraction* of the decimal fractions, .003, .030, .060, &c.

Similarly, if the temperature of the mercury be below 32°, the observed height of the column will need the application of a correction to be *added.*

CORRECTIONS FOR GRAVITATION.

(**129**) If the barometer be furnished with a contrivance whereby the height of the top of the meniscus above the level surface of the mercury in the cistern can be measured, and that height be corrected for capillarity and for variation of temperature, the height so corrected will be a measure of the atmospheric pressure at any one place of observation; and the heights at different times will be adequate, without further correction, to shew the variations in pressure which occur at that place. If, however, it is desired to compare the pressures at different places, it is necessary to take into account the variations in gravitation, in virtue of which *equal* heights of the mercurial column, though in two similar barometers, and therefore equally affected by capillarity, and having the same temperature and density, do nevertheless *not indicate equal pressures.*

As the force of gravity is affected by the latitude and also by the elevation above sea-level, it is necessary to adopt some standard of gravitation to which the heights of the column of mercury in different localities may be reduced. The standard which has been adopted is the force of gravity *at sea-level, in latitude* 45°; so that the pressure of the atmosphere is correctly measured by the height at which the barometric column would have stood if the temperature of the mercury had been 32°, and if the force of gravity, and therefore the *absolute* weight of a cubic inch of mercury, had been that which it would have had at the level of the sea in latitude 45°.

(130) Correction for Gravity depending on Latitude.—A given mass, if weighed by a spring balance, weighs less at the equator and more at the poles than on the parallel of 45°. Hence the same atmospheric pressure will be balanced by a longer mercurial column at the equator, and a shorter mercurial column at the poles, than at latitude 45°. The correction, therefore, to be applied to an observed height in order to reduce it to what it would have been at 45°, must be subtracted at all places at the level of the sea, between the equator and the parallel of 45°; while they must be added between 45° and the poles.

The largest correction is −.077 nearly at the equator,
and +.077 nearly at the poles.

(131) Correction for Gravity depending on Altitude.—A given mass of mercury, when weighed by a spring balance, weighs less at a high elevation than at the sea level; hence the same absolute pressure will be balanced by a longer column of mercury at an elevated station than at sea level, and the correction therefore due to elevation that must be applied to the observed height of the mercury is always *subtractive.* The correction for gravitation in altitude is small, being about .002 for 1000 feet of altitude.*

SECTION III.

MODE OF MEASURING THE HEIGHT OF THE MERCURIAL COLUMN.

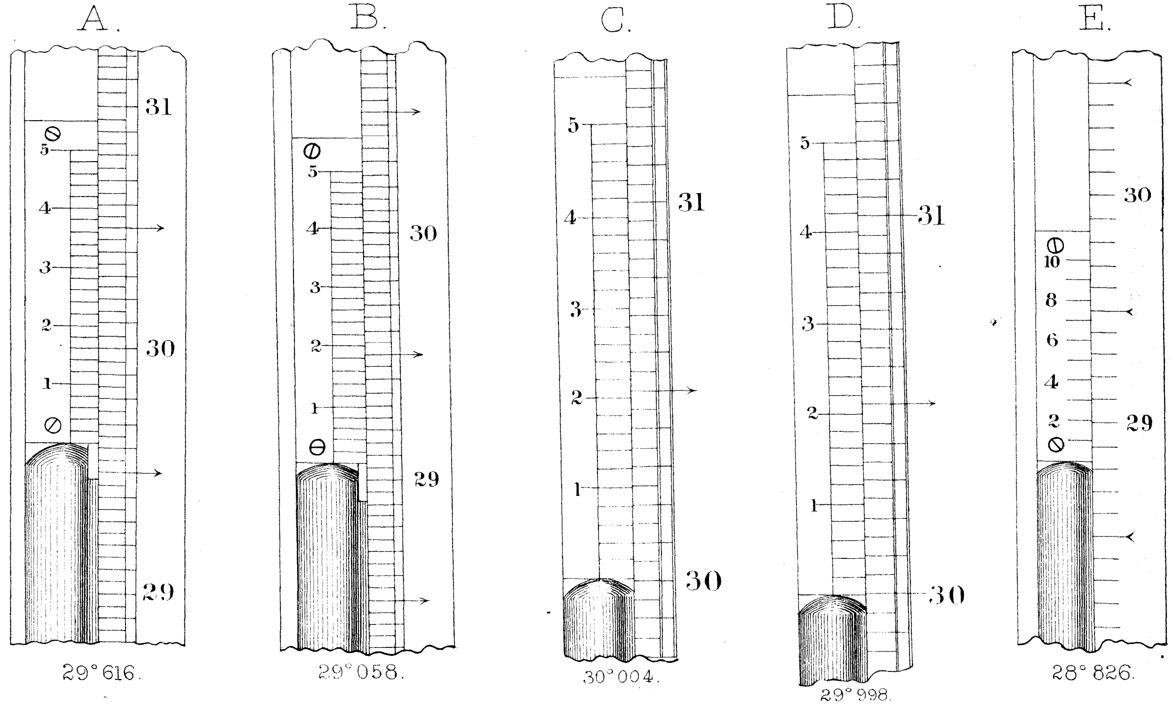
(132) The height of the barometric column is measured by a brass scale, whose lower end, or zero, from which the inches are reckoned, should just meet the level of the mercury in the cistern, while the point on the scale, which is on a level with the top of the meniscus, is read by means of a movable scale, called, after its inventor, a Vernier.

THE VERNIER.

(133) In employing a scale to measure any length, it happens more frequently than not that when one end of the length to be measured

* The "Correction for Gravitation in Altitude" must not be confounded with the "Reduction to Sea Level," which has a totally different meaning, and is moreover always *additive.*

Examples in setting and reading the vernier of a Barometer.



Copp, Clark & Co. Lith. Toronto.

(134) In the better class of barometers the principal scale is divided to inches, tenths and half-tenths, or twentieths, so that the intervals between the lines of graduation are .05. In these barometers the Verniers are graduated so as to measure the 500th part or .002 of an inch; the difference between the lengths of the intervals on the principal scale and those on the Vernier being .002.

There should be 25 intervals in all on the Vernier, each fifth division representing hundredths of an inch, and the intermediate division ·002.

The mode of reading the scale and Vernier of a barometer of this kind is precisely analogous to that already explained.

EXAMPLES IN READING THE SCALE AND VERNIER OF THE BAROMETER.

(See plate, Figures *A*, *B*, *C*, *D* and *E*.)

In Figure *A* the zero of the Vernier stands a little above the sixth *larger* division of the principal scale, counting from 29 inches. Hence as each of these divisions is one-tenth of an inch, the reading of that mark, which may be termed the *partial* reading of the principal scale, is expressed by 29.600. By examining the Vernier scale, it is seen that the third small division between the one-hundredth and the two-hundredth divisions, marked respectively 1 and 2, forms a continued line with one of the division lines of the principal scale; and as each of the small divisions is twice a thousandth, or .002, the Vernier reading is .016. Adding this to the partial reading of the scale 29.600, the complete reading is 29.616.

In Figure *B* the partial reading of the principal scale is 29.050; also the reading of the Vernier is .008; therefore, the complete reading of the scale is 29.058.

In Figure *C*, which is magnified in order to facilitate the reading, the partial reading of the principal scale is 30.000; also the reading of the Vernier is .004; and therefore the complete reading of the scale is 30.004.

In Figure *D*, which also is magnified, the partial scale reading is 29.950, the Vernier reading is .048, and the complete reading is 29.998.

In Figure *E*, of which the principal scale is divided to tenths only, and the Vernier to hundredths, the reading of the principal scale is 28.80. If the *second* division of the Vernier scale had formed a continued line with a division line of the principal scale, the Vernier reading would have been .02, and the complete reading 28.82; but as the second mark of the Vernier is a little above and the third a little below the marks on the principal scale nearest to them respectively, the position of the point of coincidence must be between .02 and .03. By estimation it is .026, and hence the complete reading of the scale is 28.826.

SECTION IV.

FURTHER INSTRUMENTAL CORRECTIONS.

(135) Correction for the Expansion of the Scale.—In measuring the height of the barometric column, allowance must be made for the expansion and contraction of the brass scale caused by variation in temperature, the distances between the inch marks not being *true* inches except when the scale has a temperature 62°.

It is seen in Art. 65 that the co-efficient of linear expansion of brass is .00001 nearly; hence if the temperature of the scale be 72°, a true length of 30 inches, and which at temperature 62° would be *marked* 30 inches, becomes 30 (1 + .00001 × 10), or 30.003.

Hence in using the scale at temperature 72° to measure the height of a mercurial column, a height which apparently, or, according to the scale, is 30 inches, would in truth be 30.003, and the scale reading 30 inches would require an additive correction of .003.

Similarly, if the temperature be 32°, *i.e.*, 30° below the standard temperature for the scale, the scale reading will need a subtractive correction of .00001 × 30 × 30, or .009.

(136) According to Art. 128, a correction must be applied to the true height of the mercurial column to reduce it to the height at which it would have stood if the temperature had been 32°. This correction is

–	when the	temperature	is	above 32°;
0	"	"	"	at 32°;
+	"	"	"	below 32°.

Again, by Art. 135 the correction for the dilatation of the scale is

+	when the	temperature	is	above 62°;
0	"	"	"	at 62°;
–	"	"	"	below 62°.

Between 62° and 32° the two corrections are both –; below 32° the correction for the contraction of mercury is +, and at 28°.5 nearly the two are equal, and of contrary signs, and the joint correction becomes 0, For the sake of simplicity, the two corrections are combined together in one table, of which the heading is—

"Corrections to be applied to barometers with *brass scales,* extending from the cistern to the top of the mercurial column, to reduce the observations to 32° Fahrenheit."

(137) The temperature of the mercury and of the scale is given by a small thermometer attached to the barometer, whose bulb is brought as near as possible to the mercury in the tube of the barometer.

As the volume of this thermometer is much smaller than that of the mercury in the barometer, and is also nearer to the body of the observer, there is some danger of its shewing a temperature higher than the true temperature of the barometer. For this reason the first act of the observer in approaching the barometer should be to *read the attached thermometer.*

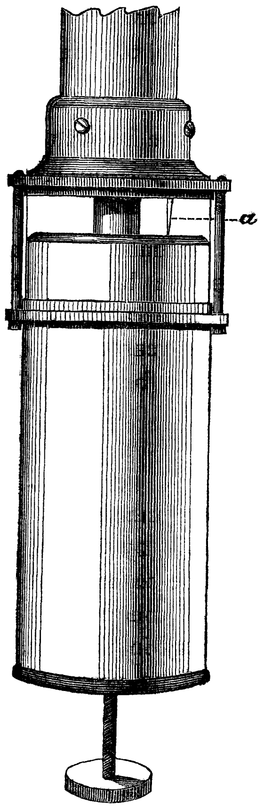
CORRECTION FOR CAPACITY.

(138) If the zero of the scale be at the level of the mercury in the cistern, when the reading of the top of the column is 29 inches, for example, and the mercury afterwards rises in the tube so as to stand at 30 inches, it is evident that this additional inch of mercury in the tube must cause a depression in the level of the mercury in the cistern, the amount of which depression must depend on, and be proportional to, the ratio of the cross sections of the tube (near the scale) and of the cistern, or the ratio of the squares of their diameters. Thus, if the diameters of the tube and cistern be .25 and 1.25, or $\frac{1}{4}$ and $\frac{5}{4}$, the ratio of the cross sections will be 1 to 25; so that if the mercury rises 1 inch in the tube, and gives a reading 30 inches, the level of the cistern will fall $\frac{1}{25}$ of an inch, or 0.040, and the true height will be 30.040. Similarly if the mercury in the tube falls to 28 inches, the level in the cistern will rise .040, and the true height will be 27.960.

(139) Neutral Point.—The reading of the mercurial column when the level of the mercury in the cistern coincides with the zero of the scale, is called the *Neutral Point,* because the actual reading is then neither above nor below the true height of the column. Thus in the example given above, 29 inches is the Neutral Point.

It is seen that the readings of the scale above the neutral point need a correction to be *added,* while readings below the neutral point need subtractive correction. These are called corrections for "capacity," because their amounts depend on the relative *capacity* of the cistern and tube.

(140) Correction for Capacity, how Avoided.—The necessity for a correction for capacity may be obviated in two ways. In the better



barometers, the capacity correction is avoided by a construction of cistern invented by Fortin, and represented by the annexed diagram. In these instruments the upper part of the cistern is made of glass, and the base is pliable, so as to admit of being raised or lowered by a screw beneath it, until the upper surface of the mercury in the cistern is brought to coincide with the zero of the scale, which is formed into a sharp ivory cone or point, called the *fiducial* point, marked *a* in the figure. The coincidence of this point with the surface of the mercury is ascertained by the apparent meeting of the point with its reflected image.

(141) The other mode of avoiding the capacity correction is by contracting the distances between the lines of graduation, both above and below the neutral point. Thus if 29 inches be the neutral point, as in the example given above, the mark on the scale one inch above 29 would be marked, not 30, but 30.040, the point marked 30 being truly less than one inch above the neutral point 29. Similarly the mark one inch below 29 is marked 27.960, the point marked 28 being less than one inch below the neutral point. This method of graduation is employed in the marine barometers constructed by Adie.

INDEX CORRECTIONS.

(142) The errors which necessitate index corrections are caused by defective graduation of the scale, or by a displacement of the zero point from which the inches are reckoned.

The corrections, which may vary slightly at different parts of the scale, should be added to or subtracted from the observed reading, according as the correction is marked + or −.

The index correction, as well as the corrections for capillarity and for capacity, if any, may be ascertained conjointly by comparison with a corrected standard, and be combined together so as to form one correction.*

* The joint correction for index error, capillarity, &c., is sometimes made to include also that depending on the error of the attached thermometer; but this is inconsistent with accuracy, unless the error of the attached thermometer is nearly the same throughout its scale.

These combined corrections belong to the individual instrument, and are independent of extraneous circumstances, such as temperature, locality, &c.

SUMMARY OF INSTRUMENTAL CORRECTIONS.

(**143**) The corrections for the instrumental errors of a mercurial barometer, of which detailed description has been given, are briefly as follows:

(*a*) Corrections which do not depend on extraneous circumstances. These are

Index correction,
Capillarity,
Capacity.

They may be conveniently combined in one correction, sometimes called, for brevity, "Index correction, &c."

(*b*) Correction for variations of the temperature of the mercury and scale, or reduction to temperature 32°.

(*c*) Correction for gravitation, depending on the latitude and elevation of the station.

This is not commonly applied to the separate observations.

SECTION V.

REDUCTION TO SEA LEVEL, SOMETIMES CALLED "THE CORRECTION FOR ALTITUDE ABOVE SEA LEVEL."

(**144**) The reduction to sea level is not properly a correction, as the barometer, when corrected for the various instrumental errors, indicates in a definite manner the pressure of the atmosphere at the time and place of observation, and needs no further correction.

By the reduction to sea level is to be understood the difference between the actual pressure at the place of observation and the pressure which would be found at a point immediately below it at the level of the sea, supposing that the space between the station and the sea level were occupied by air instead of earth.

It will be easily seen that the pressure, say on 1 square inch at the level of the sea, will exceed the pressure on 1 square inch at the station, by the weight of a column of air of 1 square inch cross section, whose height is that of the station above sea level.

The weight of such a column of a given length is proportional to the density of the air composing it, which density must increase as the pressure increases, and diminish as the temperature increases. (Arts. 113, 114).

The reduction to be applied in any case is found from a table computed for the particular station, and depending primarily on the height of the cistern above mean sea level, and also upon the barometric pressure at the station and the temperature of the external air.

(145) The table should be entered with the temperature of the *air*, as shewn by the thermometer exposed in the thermometer screen (see Part II, Chap. 11, Arts. 189–193), and the pressure in the table which is nearest to the barometric reading, *corrected for all instrumental errors.*

For stations of low elevation, the variations in the reduction depending on the thermometric and barometric readings are small, and the reductions nearly constant; while for very elevated stations, it is necessary to compute the reduction for every degree of temperature, and for every tenth of an inch of the barometric pressure.

SECTION VI.

POSITION OF A BAROMETER.

(146) The barometer should be suspended in a room or passage in a good light for observing, not subject to sudden changes of temperature, out of the reach of sunshine or the direct heat from a fire, and where it is not liable to be struck by persons passing by. As a precaution against accident and rapid changes of temperature, it is sometimes the practice to suspend the barometer in a wooden case screwed to the wall, and having folding doors, which are thrown open during the observation.*

(147) The hook by which the barometer is suspended, or, if it be a marine barometer, the socket into which the supporting arm is inserted, should be fixed to a firm wall, at such a height that the top of the scale may be about on a level with the observer's eye. If the barometer be suspended in a case, the hook or the socket will of course be attached to the inside of the back of the case.

It is necessary that the tube be strictly vertical when the reading is taken, for otherwise the reading obtained, although it is the *length* of the column, is not its *height*, and in fact will be greater than the true height.

Barometers are often suspended so as to hang vertically by their weight. Where this is done, care should be taken, after adjusting the

* A standard barometer by Negretti and Zambra, and a marine barometer by Adie, suspended in their cases, are shewn in the photograph, Figure 11.

level of the cistern to the zero point, to allow any oscillations of the tube to cease before setting the Vernier.

Sometimes the cistern is prevented from swinging by surrounding it by a ring of a greater diameter than its own, which is fixed in a horizontal position to the wall or box behind the cistern. Three horizontal screws pass through the circumference of the ring, which, by being gradually tightened up until their points bear against the cistern, serve to keep it steady.*

SECTION VII.

MOVING A BAROMETER.

(148) If a barometer be moved, *even across the room*, the cistern end should be kept higher than the other end; and if it has an adjustable cistern, the mercury should be kept screwed up to about ¼ of an inch from the top of the tube.

One object in keeping the cistern end higher than the other, is to diminish the range or space through which it is possible for the mercury to move in the tube, and so to diminish the risk of breakage. Thus if the diameters of the tube and cistern be as 1 to 5, the areas of their cross sections will be as 1 to 25; and the range or distance through which the mercury could move if the tube were uppermost, would be 25 times as great as the range with the barometer reversed, or cistern up.

Another object in keeping the cistern upwards while the barometer is being moved, is to diminish the risk of the intrusion of air into the tube.

In screwing up the mercury it should be done slowly and not too far, lest the leather of the cistern or the glass of the tube should be burst by the act of screwing up.

The screw of the cistern, moreover, should not be turned sufficiently to cause the mercury to fill or too nearly fill the tube, as room should be left to allow of expansion from an increase of temperature.

As soon as the barometer is suspended for use, the screw beneath the cistern should be reversed *slowly* until the surface of the mercury in the cistern sinks to the level of the ivory point.†

* When the scale is furnished with an ivory zero point, the verticality of the tube may be tested by turning it completely round, and noting whether the ivory point *just* maintains coincidence with the surface of the mercury during the whole revolution. This test should be repeated occasionally, and the verticality restored, if required, by the foot screws above mentioned.

† If the level should be lowered enough to expose the end of the tube, the instrument would become useless.

(149) When a barometer is packed for a journey or voyage, the mercury should be screwed up usually to about ¼ of an inch from the top of the tube; but if the instrument is liable to be exposed during transit to any very high temperature, whether from climate or from any other cause, a rather larger allowance for expansion would be better.

In marine barometers, the cisterns of which are not adjustable, the oscillations of the mercury in the tube are checked by the peculiar construction of the tube.

A barometer, when not supplied with a special travelling box, should be well wrapped round with soft cloth, and in either circumstances should be also inclosed in a packing case, and surrounded with three or four inches of elastic packing, such as hay, straw, paper cuttings, shavings, &c. The lid should be *screwed* and not *nailed* down. The address label should be *pasted* and not nailed, unless put on before the lid is fastened; and the cistern end of the box should be marked with the words, "keep this box flat," or "carry this end upwards."

(150) When a barometer is carried on horseback, it should be strapped in a slanting position, cistern up, across the back of the rider.

When carried in a carriage or sleigh on the road, it should be held in the hands, cistern end up, with the other end resting on the toe of the boot, which should be sloped upwards so as to serve as a spring; but in a railroad carriage the barometer may lie flat in its box on the floor or seat.

On board ship it is better to screw the box in a vertical position to a bulk-head, cistern up.

SECTION VIII.

DEFECTS TO WHICH BAROMETERS ARE LIABLE.

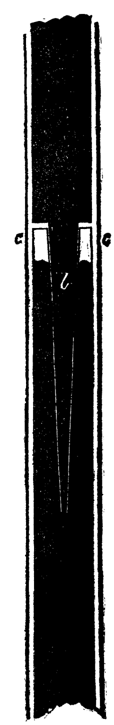
(151) A source of error for which, when it exists, it is difficult to make due allowance, is the intrusion of air into the tube.

When the height of the mercury is taken as a measure of the atmospheric pressure, it is assumed that the vacuum above the column is perfect. Should there be any air above the column, it is evident that by its expansive force it must keep the mercury in a position lower than that which it ought to occupy; and, moreover, the depression thus occasioned will be greater with a high atmospheric pressure, as the air above the mercury will then occupy a smaller space, and therefore exert a greater pressure. (Art. 113.) The depression will also be greater when the temperature is higher, as the tension of the confined air will be thereby increased. (Art. 114.)

(152) If vapour or moisture be in the tube, the error will be more irregular; moreover, moisture causes the mercury to adhere to the glass, and occasions sluggishness in the action of the instrument.

(153) Air and vapour should be removed from the tube by the maker in the process of filling, by boiling the mercury in the tube over a charcoal fire; and its subsequent introduction is sought to be guarded against by employing tubes of a peculiar form.

(154) Barometer tubes are usually contracted at the lower extremity so as to form an inverted cone, with a very small opening at the point. The risk of the intrusion of air is much diminished by this means; but if any should enter, it will either work its way to the top of the column, or, by adhering to the sides of the tube, it will impair the sensibility of the instrument. An additional precaution against the introduction of air, often used in the better kind of tubes, is the insertion of a funnel or pipette in some part of the tube well above the lower end. The rim of this funnel is attached to, and in fact forms part of the side of the tube, so that the only means of communication by which the mercury can pass from the lower to the upper part of the tube, and *vice versa*, is through a small opening at the point of the pipette or funnel. Now, as air bubbles entering near the cistern will be attracted to the side of the tube, it is most probable that instead of entering the pipette, they will work upwards to the air trap, as it is called, or the space between the outer surface of the pipette and the inner surface of the tube.



(155) The pipette is indicated by *b*, and the air trap by the white spaces *c c*, in the annexed diagram, which represents a longitudinal section of part of the tube of a marine barometer.

Any air that may be collected in the air trap at *c c* will be equivalent in effect to the introduction of as much additional mercury in the cistern as would fill the volume occupied by the air in the trap.

If the cistern is adjustable according to Fortin's method, the air in the trap will produce no error; but if there be no adjustment to the cistern, as in the marine barometers, the level of the mercury in the cistern will be raised above the zero of the scale, and the reading of the instrument will be somewhat too high.

(**156**) The marine barometers by Adie, of which kind there are several in use in Canada, are not so portable as those barometers which are furnished with adjustable cisterns; but owing to the peculiar form of the tube, of which the primary purpose is to prevent pumping, and so adapt the instrument to service on ship board, they are far more portable, *i.e.*, less liable to be damaged in moving, than other barometers with fixed cisterns.

In the marine barometer the tube is divided in three compartments. The upper compartment, which should be strictly cylindrical, extends from the top to below the lowest scale reading for which the instrument is designed. It is on the diameter of the upper compartment that the amount of capillarity depends.

The second compartment, which is connected with the first by a very fine capillary tube (*a*), terminates in a pipette, as before described, which protrudes into the third compartment (*b*), forming below and outside the rim of the funnel the air trap (*c*, *c*). The third compartment terminates at its lower extremity in a fine contracted bore extending to the cistern.

A longitudinal section of the tube of a marine barometer, as constructed by Adie, is shewn in the annexed, where the blackened parts shew the space occupied by the mercury.

(**157**) A tube of such a form is less subject than others to the introduction of air; but on the other hand, if any air should gain an entrance, it is more difficult to dislodge it than when the tube is more simple in its construction. A marine barometer, in conseqence of the peculiar construction upon which its fitness for a marine instrument depends, is liable to the defect of great sluggishness; so that, even though corrected for index error, it will often read too low when the pressure is rising and too high when it is falling.

(**158**) Sometimes, though rarely, the action of a marine barometer is stopped altogether in consequence of the lodgment of some particle of dirt or a bubble of air in the contracted part of the tube. Where an observer has reason to suspect the existence of this defect, or that air has found access to the tube, he should immediately notify the Central Office, and if he is furnished with a second barometer, he should immediately bring it into use, taking care to make frequent comparisons of the two instruments.

SECTION IX.

ANEROID BAROMETERS.

(159) The aneroid is an instrument by which the atmospheric pressure is caused to act in opposition to a spring inclosed in a hermetically sealed box, from which most of the air has been withdrawn, and which, by pressing against the lid, prevents it from collapsing.

When the atmospheric pressure rises the lid is forced inwards, and when it falls the lid is forced outwards, by the spring. The motions of the lid by certain mechanical arrangements, are transferred to a hand which moves on a dial, and thus indicates the atmospheric pressure, the divisions of the dial commonly representing changes equivalent to tenths of an inch in the mercurial barometer.

(160) Before an aneroid is brought into use, the hand on the dial, by aid of a small screw-driver applied to a screw head at the back of the instrument, should be set, so that its reading may be the same as that of a mercurial standard after correction *for all instrumental errors.* (Art. 143.) The aneroid ought also to be afterwards compared with the *corrected* standard at various atmospheric pressures and at various temperatures of the aneroid, and a table of corrections be thence formed from which the true pressures may be deduced from the readings of the aneroid. The corrections applicable to an aneroid, including those depending on temperature, are *special* corrections (Art. 143 *a*) applicable only to the *individual* instrument.

As the force opposed to the atmospheric pressure is derived from a *spring* and not from a *weight,* as in a mercurial barometer, the variations of gravitation consequent on changes of latitude and elevation do not affect it. (Arts. 129–131.)

When it is necessary to reduce the pressure to sea-level (Art. 144), the same table should be used as in the case of mercurial barometers.

The utility of aneroids is seriously impaired by their liability to spontaneous changes in their readings, without corresponding changes in atmospheric pressure; so that the same readings do not continue to indicate the same pressures, and corrections applicable at one time are found sometimes, even in a few days, to have become wholly inapplicable.

Occasionally, very good aneroids are met with; but such cases are exceptional, and though instruments of this class are valuable for service in boats, or even on shore if they are frequently compared, they are not suited, as a rule, for systematic scientific use.

CHAPTER II.—THERMOMETERS.

SECTION I.

SPIRIT THERMOMETERS.

(161) A description of the standard thermometer and the mode of constructing it has been given in Part I. When thermometers are designed for meteorological purposes, it is sufficient that the graduations extend from about 120° (except for very warm climates) to about the freezing point of mercury (—37°.9). For lower temperatures it is necessary to employ alcohol thermometers, as alcohol has not been known to become solid at any temperature, however low. (Art. 103.)

(162) Alcohol is not so well suited as mercury for the construction of thermometers, chiefly for two reasons: First, the *inferior sensibility* to changes of temperature possessed by a spirit thermometer, occasioned by its large specific heat and its very low conductivity; and secondly, the *inequality* of its expansion. (Arts. 100, 79, 68.)

(163) The large specific heat of alcohol would not be so detrimental to the sensibility of the thermometer, if it could be so constructed that the *volume* of spirit which it contains might be the same as the volume of mercury in a mercurial thermometer, because, owing to the relatively small *specific gravity* of spirit (Art. 18), the amount of heat required to effect a specified change in the temperatures of a mercurial and a spirit thermometer, when they have the same *volume*, is nearly the same in each.

Such equality, however, is hardly possible, as the weight of the spirit in a fine capillary tube, or its cohesion, if the tube be horizontal, would not be sufficient to overcome the adhesion to the glass, and the continuity of the column would be frequently broken. It is necessary therefore that the tube, and, in consequence, the bulb of a spirit thermometer, should be of much larger dimensions than those of a mercurial thermometer.

(164) Moreover, a spirit thermometer is slow in taking up the temperature of the surrounding medium (air or water, etc.), on account of its very *inferior conductivity;* in fact, the conduction of heat in a liquid is so slow (Art. 79), that it is likely that the distribution of the heat through the interior of the spirit is effected more by convection (Art. 81) than by conduction, and by the absorption of heat as it is radiated inwards from the interior of the glass. When there is a large difference between the temperature of the thermometer and that of the air, these agencies may be tolerably active; but as the thermometer approaches thermic equilibrium with the surrounding air, they will be extremely slow (Part I., Section iv.); and unless the temperature of the air remains the same for a considerable time, a spirit thermometer, constructed as these instruments mostly are at present, is nearly certain to lag behind the true temperature, so to speak; that is to say, it will shew too high a temperature if the temperature has been falling, and too low a temperature if it has been rising.

(165) Unequal Expansion of Alcohol.—The other objection to a spirit thermometer is that arising from the inequality in the expansion and contraction of spirit which accompany changes of temperature (Art. 68), and the consequent difficulty, in the process of graduating the tube, 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.

(166) In addition to the two principal objections given to the use of alcohol thermometers, there is a serious defect to which these instruments are liable, owing to the *volatility* of alcohol (Art. 108), of 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 consequences of this defect, 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 that have been detached from the main body may be reunited to it. To do this the thermometer may be swung about its upper end, bulb downwards, or jerked in the direction of its length, so as to break the adhesion of the spirit to the glass. A convenient and effective mode of performing this jerking is to strike the right wrist sharply on the palm of the left hand, the thermometer being firmly held, bulb downwards, in the right hand.

(167) The large capacity which it is found necessary to give to the bore of a spirit thermometer to avoid a break of continuity in the column would necessitate a considerable and inconvenient contraction in the distances between the degree marks, were it not that the expansion of alcohol is more than five times as great as that of mercury. (Art. 68.)

SECTION II.

MAXIMUM AND MINIMUM SELF-REGISTERING THERMOMETERS.*

(168) The object of these thermometers is to give the highest and the lowest temperatures that have occurred within any given interval of time. They are not adapted, however, to give the times when these extremes of temperature occurred.

THE MAXIMUM THERMOMETER.

(169) The only instrument of the kind to be referred to here is that devised by Negretti and 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, in such a manner that although the expansion of the mercury occasioned by a rise of temperature is sufficient to force the mercury upwards beyond the obstacle or contraction, its cohesion 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 will retreat into the bulb, leaving stationary the mercury 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 its reading has been taken, hold it by the upper end with the bulb downwards, and swing it gently, or jerk it 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 temperature thus acquired will continue to be the reading until it has been exceeded by the increasing temperature of the air. If the temperature of the air should not attain to the temperature artificially given by the hand, it is obvious that the instrument will give a false maximum higher than the true one.

(170) The maximum thermometer should be suspended in a nearly horizontal position, but with the bulb end sufficiently depressed to prevent the mercury from sliding towards the further end of the tube,

* These instruments must not be confounded with the automatic self-recording thermographs, by means of which the temperature of the air is recorded for every instant of time.

which might happen if that end were lower than the contracted part of the tube near the bulb.

Some observers recommend that the bulb end be raised, so that the mercury, as it flows out of the bulb past the contraction, may be permitted to slide towards the other end. The object of this method is to guard against the danger of any mercury that has risen beyond the obstruction being shaken back again by the vibration which is sometimes given during a strong wind to the supports of the thermometer. When the mercury is thus suffered to flow towards the end furthest from the bulb, it is evident that the reading cannot be taken until, by depressing the bulb, the separated mercury is permitted to flow back to the obstruction. It would seem, however, that by the act of depressing the bulb, there is some danger that the reading will be vitiated by the passage of some mercury past the obstruction into the bulb, unless the obstruction be so perfect as to render it needless to suspend the thermometer in the manner proposed, *i.e.*, with the bulb raised; moreover, as the instrument, when thus suspended, must be handled before it can be read, there is the further danger that more mercury may be forced by expansion out of the bulb. It is evident that the possible effects of the two sources of danger are of an opposite kind, the first making the reading too low and the latter too high.*

(171) Maximum thermometers of Negretti and Zambra's construction are affected by a small inaccuracy occasioned by the contraction of the column, due to the fall of temperature between the time when the maximum temperature occurs and the time when the reading is taken, which will of course cause the indication of the thermometer to be too low. The amount of error from this cause, which is always small, will depend on the length of the column between the obstruction, the number of degrees of fall in the interval between the time of maximum temperature and the time of reading, and the co-efficient of the apparent cubic expansion of mercury in glass. (Art. 66.) If the obstruction in the tube be at a point 45° below zero, and the true maximum 75°, the fall of temperature 20°, and the co-efficient of expansion be taken as approximately .0001; the length of the column contracted will be 120, and the error $.0001 \times 120 \times 20^\circ$, or $0^\circ.24$, that is, less than a quarter of a degree.

SELF-REGISTERING MINIMUM THERMOMETER.

(172) The minimum thermometer commonly used is a spirit thermometer, containing in the tube a small index, which consists of two minute

* It has been suggested that if the graduations were to be reckoned from the end of the tube furthest from the bulb, both errors would be obviated.

spheres connected by a fine short stem, and which slides with some little difficulty within the body of the spirit, by which it should be always perfectly enveloped. The thermometer is suspended in a horizontal position.

(173) When the column of spirit is unbroken, and the end of the index furthest from the bulb (and which for brevity 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 will contract, and draw 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, raise the bulb and allow the index to slide to the end of the column, and if necessary aid the motion by gently tapping the tube.

(174) The errors to which minimum thermometers, in common with other spirit thermometers, are subject in consequence of the evaporation of the spirit, must be provided against as already explained in Art. 166. But before jerking down the detached portions of spirit, the index must be suffered to slide down to the bulb. It will assist in the completion of the reunion of the spirit, if the thermometer be afterwards suffered to remain for a few hours suspended in a vertical position, bulb downwards.*

SECTION III.

REMARKS ON DIFFERENT FORMS OF THERMOMETER BULBS.

(175) Spherical bulbs are less liable to fracture than bulbs of other forms, and it is probable also that they are not so subject as others to irregular changes in their internal capacity; so that the freezing point of a thermometer with a spherical bulb is likely to change less, and sooner take up a permanent position. On the other hand, as a sphere is the form which, for a given internal volume, presents the smallest possible

* It is not unlikely that the liability of the column to be shortened by the separation of portions of the spirit has had occasionally some share in the exaggerated reports often given of extremely low temperatures; but it is more than probable that these alleged low temperatures are to be traced chiefly to the enormous errors, amounting to 5° or 6°, or upwards, which have often been found in thermometers at very low temperatures, and for which the owners, not having been furnished with corrections, made no allowance. Since the Kew Observatory adopted the practice of testing thermometers down to the freezing point of mercury, considerable improvement has been made in the accuracy of thermometers at low temperatures.

surface to the heating or cooling action of the surrounding medium, it is the very *worst* form for a bulb as regards *sensibility*,* or the readiness with which the instrument takes up the temperature of the air, or other medium by which it is surrounded. For the sake of superior sensibility, therefore, it is better that the bulb be of the form of an elongated cylinder, which presents a much larger external surface, through which the temperature of the air may be communicated to the liquid within; and if, moreover, the cylinder be constructed so as to inclose a hollow concentric tube, open at both ends, to allow a flow of air through it, the surface of the bulb exposed, and consequently the sensibility of the instrument, will be still further increased.

(176) Sometimes the bulb of a thermometer is made in a spiral form, resembling a cork-screw. As this presents a large surface to the air, it has the merit of sensibility; but as it is liable to considerable alteration in its internal volume, and consequent alteration in the position of the freezing point, it is not to be recommended.

A form different from the spherical is specially to be desired when the thermometer is of spirit, for the reasons explained in Arts. 162, 163, 164.

SECTION IV.

INDEX CORRECTIONS.

(177) A thermometer is liable to errors in graduation, so that its reading does not express the actual temperature of the instrument. This is due either to a defect in its original construction, or to the changes to which through age the internal capacity of the instrument is subject. The magnitude of the correction to be applied to an actual reading in any case, or the index correction as it is called, is obtained by comparison with a standard, when both instruments have the same temperature. The thermometers employed in the Meteorological Service 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 in order to provide against the changes which through age they are liable to acquire, until the glass composing them has taken up a permanent condition.

* That the minimum thermometers, commonly in use in the Canadian Meteorological Service, have mostly spherical bulbs, is owing to the difficulty in procuring good thermometers with bulbs of other forms, in sufficient quantities to meet the rapidly increasing demand for instruments throughout the Dominion; the very large majority of thermometers, even by the best makers, having their bulbs spherical.

(178) Rules for Applying Index Corrections.—When a thermometer reading is lower than the true temperature, the correction is marked + (plus), to shew that the true temperature is higher than the observed reading; and if the actual reading is too high, the correction is marked − (minus), to shew that the true temperature is lower than the observed or actual reading. If the reading of the thermometer be well above zero, the sign + indicates that the correction is to be *added* to the observed reading, and the sign − that the correction is to be *subtracted;* but a rule the reverse to this holds for temperatures well below zero; while for temperatures bordering on zero, the rule may or may not hold, according to the sign and the magnitude of the reading and of the correction.

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 less number of the two from the greater, and the corrected reading will be the difference obtained by the subtraction, with the same sign as the greater.

(179) Examples on the Application of Index Corrections.—

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

(180) 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 correction 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 in the table 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.

(181) It is sometimes noticed that a self-registering thermometer, even when the index correction has been applied, does not agree with a correct

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

ordinary mercurial, and the inference is therefore hastily made that the correction is itself incorrect.

With respect to the *maximum*, of which the corrected reading is sometimes found to be too high, the discrepancy is attributed to the undue heating of the instrument in the act of setting it, by contact with the hand and radiation from the body, and sometimes also to imperfect setting.

It is also to be noticed that the temperature of the air is usually affected by frequent minute oscillations, sometimes rising and sometimes falling, so that while an ordinary thermometer shews a *fall* as well as a *rise*, the maximum can shew a *rise only*. Hence if the two thermometers were both absolutely correct, and were also similar in sensibility, and exposed to precisely the same rises and falls of temperature, the ordinary thermometer, although it might often give the *same* reading as the maximum, could never give a *higher* reading.

(182) In the case of the *minimum thermometer*, the want of accordance with the ordinary mercurial when the minimum reads too high, is explained by its sluggishness in taking up the falling temperature of the air surrounding it.

In the experiments for determining the index corrections, the comparisons are made in water or in a freezing mixture, either of which, having a large specific heat, is better adapted than air to communicate its temperature to thermometers immersed in it. The temperature of liquid is more under control than the air, and can be kept constant or nearly so, for a time sufficiently long to allow the thermometer to acquire its temperature; and the experimentalist can wait until he is satisfied that an equilibrium of temperature has been attained. Moreover, it is in his power to hasten the attainment of that equilibrium by shaking the thermometers, in order to bring the different parts of the spirit into contact with the interior surface of the glass; a practice evidently incompatible with the action of a self-registering minimum thermometer.

In comparing a minimum with a mercurial standard by placing both in a liquid, the identity of the temperatures of the two instruments can be assured by due precautions; but when a spirit thermometer and a mercurial thermometer are side by side in the air, they will often not have the same temperature, because although the mercurial may have acquired the temperature of the air, the spirit thermometer, owing to sluggishness, may not have done so; and this trouble is not escaped by waiting, as the temperature of the air is liable itself to change. If the temperature of the air, since the minimum was previously set, never fell more than a few degrees below the temperature at the time of observation, and if the lowest temperature, or one a little above the lowest, continued only a *short time*, it is probable that the spirit may never have fallen lower or even so low as the actual temperature shewn by the mercurial thermometer. The defect can never disappear until a minimum thermometer, comparable in sensibility to a mercurial thermometer, has been devised.

If a minimum thermometer, though corrected for index error, reads too low, the fault is probably caused by the removal of some of the spirit to the end of the tube. (Art. 166.)

SECTION V.

TO READ A THERMOMETER.

(183) The better thermometers are graduated on the *stem*, and have also numbers indicating some of the degrees etched on the stem. Most thermometers in ordinary use are also furnished with an attached scale,* on which every degree is marked, and every tenth degree numbered. As the use of the attached scale is only to aid the eye in reading the scale on the tube, and to shew the position of the numbers, if any slight discrepancy be noticed between the marks on the tube and those on the attached scale, it is by the tube that the observer should be guided.

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

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* The scale commonly forms part of a frame, which is used as a means of attaching the thermometer to its supports. The frame ought to be light, and formed of a substance with small specific heat, that it may take up readily the temperature of the air, and not interfere with the sensibility of the instrument. The too common practice of partly surrounding the bulb with a mass of wood to protect it from breakage, diminishes very much the scientific value of the thermometer.

† 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.

(185) The observer should avoid touching* the thermometer before reading it, or breathing on it, or warming it by a too near 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 VI.

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

(186) By the temperature of the air at a station is to be understood the temperature of such air as may be taken as a fair average sample, as respects temperature, of the air in the neighbourhood, in a stratum extending to some as yet undefined height above the ground.

For some purposes it is advantageous to know the temperature of a stratum of air at a low elevation, while for other purposes a knowledge of the temperature of a higher stratum might be more useful.

(187) As no decision has yet been arrived at by Meteorological Conferences in reference to this question, it is sufficient to state the rule adopted for stations in connection with the Canadian Meteorological Service, namely, that where practicable the bulbs of thermometers are to be placed at a height of 4½ feet above the soil. On some occasions it has been found expedient to place them at a height of 10 to 12 feet. When the thermometers are thus placed, much the same results will be obtained if the thermometers be carefully protected from radiation from the ground. (Art. 74.)

(188) In selecting a position for the thermometers, it is a matter of primary importance that the air near the thermometers be not *stagnant;* for unless there be a free communication between the air round the thermometers and the general body of air in the neighbourhood, the temperature of the latter may possibly undergo considerable change, while the air surrounding the thermometers may have the temperature of some preceding time.

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* 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.

† It is sometimes the practice to read a thermometer, when its stem is vertical, by means of a telescope placed at a distance of a few feet, which is arranged to slide on a vertical rod and in such a manner as to be strictly horizontal, while it is raised or lowered to the level of the top of the column. By this contrivance the horizontality of the sight is secured, and the danger of unduly warming the thermometer by approaching it, is avoided.

If a thermometer be placed in a perfectly calm air, from whose temperature it differs very little, the bulb of the thermometer and the thin layer of air contiguous to it will acquire a common temperature, which is intermediate between the present temperature of the air and of its temperature at some preceding time; and as the communication of the temperature of the general body of air to the thermometer, by the arrival to it of other layers of air, *i.e.*, by convection, will in a calm be very slow (Art. 82), the thermometer will be very long in taking up the true temperature.

For the reasons just stated, it is desirable that thermometers be exposed at a considerable distance from any building, so as to be freely exposed to every wind.*

THERMOMETER SCREEN AND SHED.

(189) The Screen.—Supposing the thermometers to be placed in 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 may be warmer or cooler than the air, or from 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 closed to guard against drifting snow which might possibly settle on it, and in melting drop on the thermometers.

(190) Suspension of Thermometers.—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 at the ends of the frames to the ends of brass bows, which project forward, the centres of the bows being screwed to the horizontal frame; while the self-registering thermometers are suspended by hooks, which by means of pinching screws, can be fixed in positions suited for giving to the thermometers the requisite slope.

* It has been sometimes the practice to subject the thermometers to a current of air produced artificially by a bellows or otherwise.

(191) The Shed.—As the screen alone is insufficient to protect the thermometers from the 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 formed of wooden louvre slats, with louvre doors on the north face, and a back towards the south of close half-inch boarding.

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 face of the slats of the screen.

(192) Supports of Shed.—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 the photographs, Figures 1 and 2.

Figure 1 shews the appearance of the shed seen from the west, with an air space between the two walls of the fence, and also an air space between the northern face of the fence and the back of the shed.

Figure 2 is an oblique view of the shed with its doors closed, as seen from the north-west.

Figure 3 is a view of the interior of the screen as seen from the north, the door of the shed and screen being both open, and the thermometers in position.

Figure 4 gives a view of the interior of the screen as seen from the west, the slats having been temporarily removed.

The screen, shed, and fence are painted white.

The dimensions, expressed in inches, are as follows:

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

DOUBLE FENCE.

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

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

(194) When the premises are so circumstanced as to preclude such position as that just described for the thermometer shed, it must be attached to the north side of some building, in a position 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 composed of inch boards which are upright, and are nailed to and blocked out by two pieces of 4×4 scantling fastened horizontally to the wall.

The object of the partition is to guard the thermometer shed from radiation from the wall, which may be much hotter or much colder* than the air whose temperature it is desired to learn. The partition should therefore extend at least one foot above, below and beyond the sides of the shed. The screen should be placed if possible at such a height that the bulb of the principal thermometer may be 4½ feet nearly above the soil; but as this height is not always attainable, the height, which should never be under 4 feet, should be recorded on the page of the register devoted to such purposes.

(195) Window Exposures to be Avoided.—The practice of exposing thermometers where they can be read through a window is to be avoided if possible; but should the premises be unfitted for any other mode of exposure, so that the choice lies between observations made in such circumstances and no observations at all, the thermometer 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 the door may face 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.

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

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* The large mass of the wall, and the large specific heat and low conductivity of the material composing it, will hinder it from following closely the temperature of the surrounding air. It will therefore usually have too high a temperature when the temperature of the air is falling, and too low when the temperature is rising.

† The window must of course face the north or nearly so.

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 well before an observation is taken.*

(197) 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, or rubbish† of any kind, not only to avoid slovenliness, but also because their presence impedes the free introduction and circulation of the air from outside; and as they are liable to retain the temperature received from the air at some previous time, they may affect the thermometers by imparting to them that temperature by radiation and convection.

CHAPTER III.

HYGROMETRICAL OBSERVATIONS.

SECTION I.

OBJECT OF HYGROMETRICAL OBSERVATIONS—WET BULB THERMOMETER.

(198) Hygrometrical observations are those that are concerned with the moisture which, in a state of vapour, is ordinarily mixed up with and suspended in the atmosphere that surrounds the earth.

(199) Saturation.—It is stated (Arts. 118–122) that, corresponding to any given temperature of the air, there is a certain definite maximum of vapour which, for *that temperature*, cannot be exceeded. If the tem-

* Snow on the slats affects the readings of the thermometers by communicating to the air, as it passes over it, a temperature which may differ from that of the outer air. The thermometers are also liable to be unduly affected by *radiation*, when snow, with a temperature different from that of the air, it may be, is near to them. Moreover, snow on the slats may influence the temperature of the air in the screen by impeding the free introduction of the outside air. As snow is a slow conductor, if any be settled on the thermometers, it *may* vitiate their readings by preventing the air from imparting its temperature to them, and by giving to them *its own* temperature, which may or may not be the same as that of the air.

† The objection with reference to *rubbish* is applicable also to *any articles whatever* placed in the screen, or shed, or space between the partitions. The objection applies, for example, to rain glasses, rain receivers, note books, register papers, and even to spare thermometers unless suspended for use.

perature of the air increases, its capacity for vapour also increases, *i.e.*, the mass of the greatest quantity of vapour which a given volume of air is capable of containing, and the pressure of that vapour, also increases. If, on the contrary, the temperature of the air falls, its capacity for vapour grows less, *i.e.*, the greatest quantity of moisture which a given volume of the air is capable of retaining in a state of vapour, and the pressure of that vapour, becomes less.

When the quantity of vapour in a given volume, and the pressure of the vapour, have attained the maximum corresponding to the existing temperature of the air, the air is said to be saturated.

(200) Saturation of the Atmosphere with Vapour, and its opposite, absolute Dryness, rarely attained.—Although there is a maximum of vapour which, when the air is at the corresponding temperature, cannot be exceeded, the vapour found in the atmosphere very seldom reaches the maximum, or the state of saturation. It may vary in its mass and pressure from saturation, which, as just stated, it rarely attains, to absolute dryness, of which however there are probably no well authenticated examples.

(201) The Actual Pressure is found by aid of the Wet Bulb Thermometer.—It has been the practice of some observers to deduce from observation the *mass* of the vapour, or, what comes to the same thing, the *weight* in grains of the vapour actually existing in a cubic foot of air. At Canadian stations, as well as at the majority of stations elsewhere, hygrometrical observations are made primarily for determining the *pressure* of the vapour, or vapour tension, existing in the air at the time of observation, which it is the custom to express in inches and decimals of an inch of mercury. For ascertaining that pressure, the method most frequently employed is by the *wet bulb thermometer*, used in connection with the simultaneous reading of the *dry bulb thermometer*, *i.e.*, the thermometer which shews the temperature of the air.

(202) Description of the Wet Bulb Thermometer.—The wet bulb thermometer is an ordinary mercurial thermometer, as nearly as possible equal and similar in every respect to the dry bulb thermometer, but with its bulb and the ungraduated part of the stem inclosed in a tight-fitting bag of fine muslin. A few threads of cotton wick tied round the stem close to the bulb, and connected with the muslin, are led down so as to dip into a small vessel of distilled water or pure rain water, by which arrangement the water is drawn up by the capillary action of the cotton wick, and spread over the bulb, where it is evaporated.

(**203**) **Muslin and Wick to be kept Clean.**—The muslin and wick should be washed in a solution of carbonate of soda before being applied, and also occasionally when in use, and should be renewed every two or three months. No sediment should be allowed to accumulate in the water vessel.

(**204**) **Water Vessel not to be Replenished just before an Observation.**—When the vessel needs replenishing with water, it should be done *after* or a considerable time before an observation, in order that the water may acquire the temperature of the air.

(**205**) When the arrangements are properly made, the wet bulb thermometer, in consequence of the heat rendered latent by the formation of the vapour, will usually shew a temperature lower than that of the air, which is termed the *temperature of evaporation*.

SECTION II.

ACTION OF THE WET BULB THERMOMETER.

(**206**) The following is a general explanation of the mode of action of the wet bulb thermometer, and of the process by which the pressure of the vapour present in the air is derived from the temperature of evaporation (that given by the wet bulb) and the temperature of the air.

While the bulb remains wet, and provided that the air is *not already saturated*, vapour must necessarily be formed from the moisture on the surface of the wet bulb, to an extent depending on the quantity of additional vapour which the air must receive in order that it may become completely saturated.

The new vapour thus formed must absorb and render latent (Art. 109) a certain quantity of heat, of which part is derived from the surrounding air and vapour, and part from the wet bulb thermometer. During this process, the thin stratum of air and vapour immediately enveloping the bulb will become saturated, and will acquire the same temperature as the wet bulb—a temperature lower than that of the surrounding air, on account of the heat expended in the evaporation. (Art. 109.)

(**207**) In the first instance, the latent heat absorbed in evaporation will be derived chiefly from the thermometer; but as the envelopes of air successively reach the bulb, and bear with them the general temperature of the neighbouring air, less and less heat will be furnished by the thermometer for vaporization, until its temperature becomes stationary. When this state is reached, the latent heat absorbed in the formation of the vapour requisite for saturating a thin envelope of air and vapour which reaches the bulb, bearing with it the temperature of the surrounding atmosphere, and which when saturated has the temperature of the wet bulb, will be derived wholly from the cooling of that envelope.

(**208**) It appears, then, that the heat rendered latent in forming the *additional* vapour furnished by evaporation from the muslin to the envelope of air and vapour, in order that when it attains the temperature of the wet bulb it may be saturated, is equal to

the heat taken from the envelope of air in order to reduce it to the temperature of the wet bulb;

+ the heat in the vapour which the envelope of air previously contained, which heat is abstracted from that vapour in reducing it to the temperature of the wet bulb.

(**209**) The above relation, expressed in algebraical symbols, leads to a formula from which hygrometrical or psychrometrical tables are calculated. Those used in Canada are by Professor Guyot, from experiments by Regnault.

They give in the first place the pressure or vapour tension corresponding to the temperature of evaporation, *i.e.*, that shewn by the wet bulb, usually denoted by t' and to the depression $(t\text{-}t')$ of the temperature of the wet bulb below the temperature of the air, denoted by t'.

(**210**) **The greater the depression of the Temperature of the Wet Bulb, the less will be the Vapour, and vice versa.**—On examining the tables it will be seen that for any given temperature (t') of the wet bulb, a large pressure corresponds to a small depression $(t\text{-}t')$ and a small pressure to a large depression.

When the air has relatively much vapour in it, only a small additional quantity of vapour is required to saturate it. There is, therefore, only a *small* demand for heat to be made latent in forming new vapour, and there is but a *small* reduction in the temperature of the wet bulb. If, on the other hand, the air is comparatively dry, or has little vapour already in it, a larger additional quantity is required to produce saturation. The wet bulb must therefore yield a larger quantity of vapour, and this must absorb a larger quantity of latent heat, and occasion a larger depression $(t\text{-}t')$ of the temperature of the wet bulb below the temperature of the air.

Examples:

(*a*) If the temperature of the air be 74°, and the temperature of the wet bulb 72°, so that the depression of the latter is 2°, it is seen on p. 8 of psychrometrical tables in a line with temperature of wet bulb $(t')=72°$, and in the column headed with the depression $(t\text{-}t')=2°$, that the pressure of vapour is 0.757 of an inch of mercury.

(*b*) If the temperature of the air be as before, 74°, and that of the wet bulb 70°, so that the depression $(t\text{-}t')$ is 4°, it will be found on p. 8 that the pressure of vapour is 0.679.

It thus appears, the temperature of the air being 74° in each case, that with a depression of the wet bulb of 4°, the pressure of vapour is .078 less than when the depression is 2°. Further examples in the use of the tables are given in Part III.

SECTION III.

PRECAUTIONS RELATIVE TO THE WET BULB THERMOMETER.

(**211**) The film of water surrounding the bulb should be as thin as possible; but it is requisite that the whole surface of the bulb should be wetted; for if any part be dry, the temperature indicated will be *higher* than the true temperature of evaporation.

(**212**) As the cotton wick is sometimes defective in conducting power, many observers adopt the practice of wetting the muslin by using a camel-hair brush, or by immersion, the vessel containing the water being lifted up from beneath the bulb two or three times to insure perfect wetting.

For securing continuity in the film of water, either of these methods is preferable to the cotton wick; but on the other hand, as some time will commonly elapse before the temperature of evaporation is attained, the practice of wetting otherwise than by the cotton wick is attended by the inconvenience of requiring the presence of the observer some time before the hour of observation.

(**213**) The interval between wetting and reading depends much on the weather. In dry or windy weather two or three minutes may suffice; but in damp or calm weather twenty minutes or more may be needed. If the bulb be wetted too near the time of observation, the temperature will not have fallen sufficiently, and the reading will be delayed; while if it be wetted too soon, so that the bulb has become dry in some parts, and the temperature is found to be rising, it will be necessary to repeat the wetting, and thus delay the observation still longer.*

(**214**) When the wet bulb thermometer is read, it should be watched for a minute or two, to see if the lowest depression has been reached. If the temperature should continue falling, the observer must wait until it has ceased to fall, and then take the reading; but if it be decidedly rising, the wetting by immersion or otherwise must be repeated.†

(**215**) **The Cistern and Cotton Wick useless for Temperatures at or below 32°.**—If the temperature of the air be at or below 32° Fahrenheit, the cistern and conducting thread become useless, and the bulb must then be wetted by immersion or by a camel-hair brush, the water having a temperature as near to 32° as possible. A film of ice will then be found from which evaporation will proceed as before, and the thermometer will attain a stationary temperature lower than that of the air.

(**216**) The film of ice should be continuous, but as thin as possible, in order that the temperature of evaporation may be more speedily reached; but to secure the continuity of the film, it is usually desirable to wet the bulb some time before each observation.‡

(**217**) **Accumulation of Ice on the Bulb must not be Permitted.**—One consequence of frequently wetting the bulb, will be an undue accumulation of ice, which, if allowed to remain, would retard the attainment of the true temperature of evaporation by the thermometer. It will not unfrequently occur that while the outer surface of the ice has the temperature of evaporation, the bulb of the thermometer, in consequence of the low conductivity of the ice, will have a temperature different to that of the outer surface if the bulb be improperly protected by a thick coating of ice. This evil is to be avoided by melting off the

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* It has been sometimes the practice to hasten the production of the temperature of evaporation by an artificial current of air brought to bear on the wet bulb.

† The troubles which grow out of the practice of wetting by immersion, &c., should be avoided if possible by careful attention to the adjustment of the threads of the cotton wick, as well as to the cleanliness of the wick, the muslin, and the water.

‡ During a low temperature accompanied by calm, the fall of the temperature of the wet bulb, after wetting, to the temperature of evaporation, occupies a very long time. The necessity of attendance before the observation to wet the bulb may be avoided in such a case by wetting it soon after one observation in order that it may be in readiness for the next. To avoid the danger of the drying off of the film, the water should be liberally supplied; but it should be done gradually, in order that no *button* of ice may be formed under the bulb.

ice by immersing it in tepid water after an observation, or, if that has been neglected, at least half an hour before the next observation.*

(218) Sometimes it is Noticed that the Wet Bulb gives a Higher Reading than the Dry.—If this occurs in foggy weather and the temperature be falling, the anomaly may be attributed to the fact that both thermometers are equally wet, and that as the muslin retards the escape of heat from the wet bulb, the latter is kept at a higher temperature than that of the more exposed thermometer. This occurrence, which, however, is rare, should be taken as a case of saturation.

(219) If the wet bulb reads higher than the dry when the former is inclosed by ice—an event which probably only occurs when the temperature is falling—it is due to the fact that the so-called wet bulb is inclosed in a coating of slow conducting ice, which retards its cooling. This fault is to be guarded against by carefully avoiding an undue accumulation of ice on the bulb.

SECTION IV.

RELATIVE HUMIDITY.

(220) The term "Relative Humidity" Defined.—By the term "Relative Humidity" is understood the *ratio* of the pressure of the vapour actually present in the air to the pressure of the vapour which is required to saturate the air at its existing temperature. Thus, supposing the temperature of the air to be 49°, the pressure of the vapour required to saturate it is 0.348.† If now the actual pressure of vapour be 0.174, the relative humidity is the ratio $\frac{.174}{.348}$ or $\frac{1}{2}$. If the actual pressure be .087, the temperature still remaining 49°, the relative humidity is the ratio $\frac{.087}{.348}$ or $\frac{1}{4}$.

It is customary in hygrometric tables to express saturation by 100, in which case the ratio or fraction which the actual vapour is of the

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* In reading the wet thermometer during low temperatures, care must be taken not to be deceived by a *false minimum*. During frost the first effect of wetting the bulb will be a rise of temperature, because the water when in the vessel cannot be warmer than 32°. The film of water will then cool, partly by contact with the cooler air and partly by evaporation. On its conversion into ice, which, owing to a peculiar property of water (Part I., note to Art. 47), may possibly be at a temperature *many degrees below the freezing point*, the temperature suddenly rises to about 32°. It then begins to sink again by contact with the air and by evaporation, until it ultimately attains the true temperature of evaporation. That the temperature at or a little below which the water *flashes* into ice may not be mistaken for the temperature of evaporation, it is necessary to be assured that the bulb is surrounded by an envelope of *ice* and not an envelope of water below 32°, and which is about suddenly to become ice.

† See tables, p. 5, under difference t-$t' = 0$.

saturating vapour, *i.e.*, the relative humidity, is multiplied by 100. Thus in the above examples, the relative humidity, or, as it is often called for brevity, the "humidity," is expressed by the numbers 50 and 25. Humidity, in short, according to the ordinary mode of expressing it, is the *percentage* which the actual vapour is of the vapour required to saturate the air.

(221) The Relative Humidity Computed from the Pressure of Vapour.—When the pressure of the vapour has been found from the reading of the dry and wet thermometers, the relative humidity may be computed by dividing 100 times the said pressure by the pressure of the vapour which saturates the air at the existing temperature.

Example: From the example in Art. 210, it is seen that with temperature (t') of the air or dry bulb 74°, and temperature (t') of evaporation or wet bulb 72°, the pressure of vapour present is 0.757. Also, referring to page 6 of the tables, in column headed 0°.0 for the difference t-t' the pressure of the vapour which saturates air at temperature 74° is 0.839. Hence the relative humidity is $\frac{.757}{.839} \times 100$ or 90.3 nearly. It is not usually necessary to go through this computation, as the humidity is given in the tables side by side with the pressure of vapour.* Thus on p. 6, in a line with temperature of wet bulb 72°, and in column headed t-$t' = 2°$, the relative humidity given is 90.3.

SECTION V.

THE DEW POINT.

(222) Dew Point Defined.—By the temperature of the dew point, or, as it is called for brevity, the "Dew Point," is understood the temperature to which the actual temperature of the air must be reduced, in order that the vapour which it contains may be sufficient to saturate it. It is called the *dew point*, because it is the limit below which if the temperature were to fall, the air would no longer be capable of holding the vapour that it contained before the temperature was so reduced, and some of the vapour would be deposited as *dew*.

(223) Mode of Determining the Dew Point.—The dew point may be observed directly by Daniell's Hygrometer or by Regnault's Dew Point Apparatus, by either of which instruments the general process is to cool, by artificial means, a smooth surface exposed in the atmosphere,

* There is sometimes a very slight disagreement between the humidity in the tables and that computed from the pressure of vapour. This, when it occurs, is owing to the fact that the pressures from which the tabular humidity is calculated are carried out to more decimal places than are given in the pressures printed.

and to observe, by a thermometer inclosed in that surface, the temperature at which a deposit of condensed vapour on the cooled surface commences.

The temperature of the dew point may also be taken from the hygrometric tables, when the pressure of vapour has been found from observations with the dry and wet bulb thermometers. In the column at the head of which the difference (t-t') between the two thermometers is 0, and which for brevity may be called the column of saturation, find the pressure equal to the actual pressure of vapour just found, and take out the corresponding value of (t') the temperature immediately contiguous on the left. This value of t' is the dew point. If the exact actual pressure is not in the saturation column, take out the number next less to it. The corresponding value of t' will be the *full degrees* of the dew point. To find the *tenths*, subtract the pressure corresponding to the full degrees from the actual vapour pressure, and find by division how often the difference thus obtained contains the *change* for 0°.1 of t', as given in an adjoining column. The quotient will shew the *tenths* of the temperature of the dew point.

Examples in Finding the Dew Point from the Pressure of Vapour.—Referring again to the examples in Art. 210:

When the temperature of the air is..........				74°,
And	"	"	" wet bulb is	72°,
The pressure of vapour is				0.757.

In the saturation column the number nearest to this is 0.758, which differs from it by less than half .0023 the change for 0°.1 of t'. Hence 71°, the value of t', corresponding to the pressure 0.758, is the temperature of the dew point to the nearest tenth of a degree.

When the temperature of the air is..........				74°,
And	"	"	" wet bulb is	70°,
The pressure of vapour is				0.679.

In the saturation column the number next less to 0.679 is 0.662, which gives 67° as the full degrees of the dew point.

Proceeding according to rule:

Pressure of vapour 0.679
Pressure next less to it... 0.662

Change for 0°.1 = .0023) 0.017 (7 = tenths of dew pt. temperature
0.0161

Hence temperature of dew point = 67°.7.

CHAPTER IV.

ON THE MEASUREMENT OF RAIN AND SNOW.

SECTION I.

THE RAIN GAUGE.

(224) The primary object in rain observations should properly be that of learning the *mass* of rain which falls, in a given time, on a horizontal plane surface of known dimensions. The rain-fall should therefore be properly expressed by the number of units of mass, or of weight, which fall on a unit of horizontal surface, or by the number obtained by dividing the number of units of mass, or of weight, which fall on any horizontal plane, by the area of that plane, or the number of units of surface which it contains.

In conformity with this notion, it has been the practice with some observers, instead of measuring the *volume* or the number of cubic inches of rain, to *weigh* the rain received in the gauge. That this is the more accurate method of the two, is evident from the consideration that the volume of a given mass or weight of water changes considerably with the temperature (Art. 67); nevertheless, owing chiefly to the inconvenience of weighing the rain, and to the time that would be taken up if that practice were followed at every observation, it has been commonly superseded by that of measuring the *volume;* and the rain-fall is therefore ordinarily expressed by the number obtained by dividing the number of cubic inches of the rain which falls on a given horizontal plane, by the area of that plane. If the area be in square inches, the rain-fall will be given in linear inches, which will denote the depth of the rain falling in a given time on a horizontal plane, or the depth of water which would be accumulated if the surface of the earth were horizontal, and if none of the water were lost by running off, by evaporation, or by the absorption of the ground.

(225) Mode of Finding the Depth of Rain.—The general method of finding the depth of rain is as follows:

The rain, as it falls, is caught in a rain guage, which is essentially a vessel open at the top, whose rim, *i.e.*, the boundary which separates the rain which enters the vessel from that which falls beyond, must lie in a horizontal plane.

As rain, if left in an open vessel, would be diminished by evaporation, the bottom of the gauge is in the shape of a funnel, by which the rain is conducted into a receiver beneath.

If the number of cubic inches in the receiver, measured by a graduated glass, into which the rain is poured from the receiver, be divided by the area of the mouth of the gauge, *i.e.*, the plane surface bounded by its rim, and expressed in square inches, the number found by the division will be the depth of rain on the surface.

(**226**) **Various Forms of Rain Gauges.**—Rain gauges are made with mouths of various forms, square, oblong and circular. If the mouth be square, or of any other rectangular form, and if, moreover, its sides measure an exact number of inches, its area will be expressed by a whole number of square inches, and the operation of dividing the cubic inches of water will be easy. Thus, mouths measuring 8×8, 20×10, 10×10, have areas 64, 200, 100; each of which, and especially the latter, is a divisor that can be conveniently used.

(**227**) Circular mouths are to be preferred to rectangular ones, for the reason that any local currents of air, caused by the action of the wind on the sides of the gauge, and which may affect the quantity of rain that enters the gauge, will be similar, whatever be the direction of the wind, if the gauge be circular; whereas, a wind blowing directly on the side of a square will probably produce an effect different to that caused by a wind in the direction of a diagonal, and the correctness of the results would be affected by the direction of the wind.

(**228**) The employment of a circular gauge is attended with the inconvenience that if the diameter of the mouth is an exact number of inches, the area is expressed by a number containing several decimal places. Thus, if the diameter be 8 inches, the area is ¼ the square of 8, multiplied by the number 3.1416 nearly, *i.e.*,

$$16 \times 3.1416 = 50.2656.$$

(**229**) The labour of performing the division by such a number as 50.2656, on every occasion of measuring the rain, may be got over in two ways. One of these methods is to graduate the measuring glass so that its divisions, instead of indicating the cubic inches, &c., contained in the glass, represent the *depth* on the surface, to which the contents correspond *when a gauge of those dimensions is employed.* Thus, if the diameter be 8 inches, as a depth of 1 inch of rain will cause an accumulation of 50.2656 cubic inches in the receiver, a tenth of an inch will give 5.02656 cubic inches nearly. Hence, if the glass be properly graduated, the volumes intervening between the lines of graduation which represent tenths of an inch in depth will be 5.02656 cubic inches.

This method, which is employed extensively in England, is subject to the grave inconvenience that the gauge and the glass must be made each one for the other, so that if either gauge or glass be damaged, the observation is stopped until the damaged instrument is replaced by another precisely similar. Now, while a glass adapted for a particular gauge is probably not procurable except from the maker who furnished the gauge, a glass divided to cubic inches can be procured with greater readiness, and it can moreover be used with any gauge whatever.*

(230) It is much better to avoid altogether the use of glasses which are so graduated as to be adapted exclusively for gauges of certain diameters, and to employ those only which are divided to *cubic inches*, and which can be used with gauges of any area whatever. Where the area of the gauge is expressed by a number which is not a convenient divisor, the labour of performing the division may be avoided by constructing a table giving the quotients which would be obtained by dividing the cubic inches of rain received in the gauge, by the area of its mouth expressed in square inches. A portion of such a table, calculated for a gauge whose diameter is 10.1 inches, is given below:

Table giving the Depth of Rain, corresponding to the cubic contents received in a Gauge whose area is 10.1 square inches.

Cubic Inches.	Tenths of a Cubic Inch.									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	.0000	.0012	.0025	.0037	.0050	.0062	.0075	.0087	.0100	.0112
1	.0125	.0137	.0150	.0162	.0175	.0187	.0200	.0212	.0225	.0237
2	.0250	.0262	.0275	.0287	.0300	.0312	.0325	.0337	.0349	.0362
3	.0374	.0387	.0399	.0412	.0424	.0437	.0449	.0462	.0474	.0487
4	.0499	.0512	.0524	.0537	.0549	.0562	.0574	.0587	.0599	.0612
5	.0624	.0637	.0649	.0662	.0674	.0687	.0699	.0711	.0724	.0736
6	.0749	.0761	.0774	.0786	.0799	.0811	.0824	.0836	.0849	.0861
7	.0874	.0886	.0899	.0911	.0924	.0936	.0949	.0961	.0974	.0986
8	.0999	.1011	.1024	.1036	.1048	.1061	.1073	.1086	.1098	.1111
9	.1123	.1136	.1148	.1161	.1173	.1186	.1198	.1211	.1223	.1236
10	.1248	.1261	.1273	.1286	.1298	.1311	.1323	.1336	.1348	.1361

* In the event of an injury occurring to the gauge, there is no need to stop the observations while it is under repair, or until it has been replaced by another. Provided that the observer

Examples in the use of this table.*

Required the Depth to Three Decimal Places.

(1) When the volumes of rain are . . 5 cub. inches, 0.8 cub. inches, 7.3 cub. inches,
The depths are respectively . . . .062 inches, .010 inches, .091 inches,

(2) When the volume of rain is 45.4 cubic inches,

Depth for 10 inches		=	.1248 inches.
			4
" 40 "		=	.4992
" 5.4 "			.0674
Depth for 45.4 cubic inches			.567 inches.

(231) Comparative Advantages of Gauges with Large and Small Diameters.—Numerous experiments have led to the conclusion that gauges whose mouths are *small* give results more in accordance with each other than those whose mouths are *large*.

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possesses a glass divided to cubic inches, he may employ, as a temporary substitute for his gauge, a common funnel, round which a band of tinned sheet iron is soldered, extending 3 inches above and 3 inches below the edge of the funnel. The funnel should be rested on a common tin pot, of such a size as will allow the lower part of the band above named to overlap it on the outside. The diameter of the mouth of this temporary gauge can be taken as half the sum of two measurements, at right angles to each other, and the area can then be calculated therefrom. Thus, if two measured diameters are 4.24 and 4.28, the area $= \frac{1}{4}(4.26)^2 \times 3.1416$ nearly $= 14.2534$ nearly.

* The mode of constructing the table is as follows:

$$\text{Area of mouth} = \frac{3.1416 \times (10.1)^2}{4},$$

therefore the depth corresponding to 1 cubic inch of water will be found by dividing 1 by above area, or,

$$\text{Depth for 1 cubic inch} = \frac{4}{3.1416 \times (10.1)^2} = .012482.$$

By ten successive additions of .012482 to 0 we obtain, to five decimal places, the depth corresponding to 1, 2, 3, &c., 10 cubic inches, which form the left-hand column, under the heading 0 tenths. Again, the depths for .1, .2, .3, &c., .9 cubic inches, which form the upper row, are found from the left-hand column, by moving the decimal point one place to the left. Finally, the nine remaining columns are completed by ten successive additions of the number .01248 to each of the numbers in the upper row. In order that the depth may be correct to three decimal places, the table is calculated to *four*, and that the table may be correct to four decimal places, the constant addend .01248 should be correct to *five* places.

SECTION II.

THE RAIN GAUGE USED AT CANADIAN STATIONS.

(**232**) The necessity for a table to shew the depth corresponding to the measured volume of rain, or the labour of the division, is avoided in the gauge furnished by the Canadian Meteorological Office, whose essential peculiarity is that its mouth has an area of 10 square inches; so that the depth of rain is found by dividing the cubic contents by 10, *i.e.*, by moving the decimal point one place to the left. Thus,

Corresponding to a volume of cubic inches . . 11.2, 4.3, 2, .4, 2.37;
The depth will be in inches . . . . 1.12, 0.43, 0.20, 0.04, 0.237.

The general appearance of the gauge and of its various parts is shewn in photograph, Fig. 12, where *A* represents the gauge complete, and *B* represents the measuring glass.

(**233**) 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 runs 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 side of the cylinder is 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 in photograph, Fig. 12 (*C*).

(2) The large receiver on which the upper part is fitted. The large receiver is made either of brass or sheet iron. It is shewn in Fig. 12 (*D*).

(3) The small receiver which stands within the large receiver, and into which the rain enters directly by the down pipe. It is made large enough to hold rather more than 5 cubic inches. It is sometimes made to expand a little at its upper end so as nearly to fit the outer surface of the funnel, and thus diminish the surface of water exposed to evaporation. Fig. 12 (*E*).*

(4) The outer stand (made of sheet iron) on which the large receiver rests by a flange designed to prevent the entrance of rain or snow into the stand, which by freezing would cause the large receiver to adhere to the stand. Fig. 12 (*F*).

* Two small receivers are usually furnished.

(**234**) **Position of 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 access 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 be chosen when practicable, as for some as yet unexplained cause a gauge situated on the top of a building commonly receives much less than when near the surface. Where a position on the ground is unattainable, the height and circumstances of the position employed should be carefully noted.

(**235**) **To take an Observation,** 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 has been in use and replace it by the spare small receiver, unless the rain was more than sufficient to fill the small receiver that was in use; in which case, *if rain is 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.

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 fill the glass twice 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, place it on a level, steady table, and place the eye on a level with the surface of the water in it.

(**236**) During dry snow the rain gauge may be covered by a lid supplied for the purpose; but if it be in a *melting* state, or if it be mixed with rain so that it will probably not remain on the ground and be

* If rain is actually falling, 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 all the water in doors for measurement.

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 rain begins.

If this has been overlooked, so that what was dry snow has been mixed with rain in the gauge, the whole depth determined by the gauge must be diminished by one-tenth of the depth of the 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 the gauge, except dry snow, must be measured as if it were rain.

(**237**) If after rain a sudden frost should set in, any rain that happens to be in the gauge should be measured without delay to save the receiver from being burst.

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

The measuring glass should *on no account* be placed in the rain gauge as a substitute for a small receiver.

SECTION III.

ON THE MEASUREMENT OF SNOW.

(**238**) In measuring snow there are two objects proposed:

(1) To ascertain the average depth of snow on the level; and

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

(**239**) To find the depth, the obvious and most ready method is, by means of a rod divided to inches, to measure the depth at a few places where the snow does not appear to have much drifted, and to assume the average of these measurements to be the true depth. The measurement should be taken between the surface of the last fallen snow and the surface of the ground or of the old snow, *i.e.*, that which was on the ground at the beginning of the period concerned, such as on the preceding day. An experienced observer may estimate the depth very fairly without the aid of a rod.

(**240**) To find the depth of water to which the snow is equivalent:

It is sometimes the practice to leave the rain gauge open, and to 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 when there is any wind the snow that enters the gauge is likely to be only a small part of that which actually falls on the level, as may be verified by any one who will be at the pains to watch the course of the descending snow flakes as they approach the gauge.

(241) Dismissing this method as unsuited for the purpose, there are two which may be employed :

To measure the *depth* in the manner above stated, and to infer the depth of water by assuming that the depth of water bears a certain definite ratio to the depth of snow from which it is produced by melting. A long series of experiments made under the former director of the Toronto Observatory (General Lefroy), led to the conclusion that *ten* inches of snow is equivalent, *on an average*, to *one* inch of water. It is not affirmed that this holds true in every case, as the snow varies in density; but in the long run, the error occasioned by assuming this average relation, is not greater than that which attends other methods supposed to be more accurate.

THE SNOW GAUGE.

(242) The second method of ascertaining the depth of water that is equivalent to the snow which has fallen is by means of the snow gauge.

This instrument consists of a hollow metallic cylinder, open at both ends, about 12 inches high, and whose cross section has an area equal to the mouth of the rain gauge.

To use it, plunge it vertically into the level snow till its lower edge reaches either the ground or the upper surface of the snow that fell before the commencement of the period concerned.

Dig away some of the surrounding snow; slip a sheet of tinned iron under the gauge; lift up the gauge; melt the contained snow, and measure the water as so much rain.

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

(243) The snow should not be melted by the direct heat of a fire, on account of the great loss from evaporation. It is better to pack the snow in a tall, narrow vessel, and pour into it the *entire* contents of a vessel *exactly* filled with hot water. Stir the water and snow till the snow is melted, than pour back water just sufficient to fill again the vessel from which the hot water was taken, and measure the remainder as if it were rain.

CHAPTER V.

OBSERVATIONS FOR DETERMINING THE DIRECTION OF THE WIND.

SECTION I.

PRELIMINARY REMARKS.

(244) Observations relative to the wind embrace two classes:

(*a*) Observations on the *direction* in which the motion of the air takes place at a station.

(*b*) Observations for finding either the *velocity* with which the air passes through the station, or the *pressure* which the wind exerts at any instant on a plane surface of known dimensions on which it blows directly.

It is with the former of these two classes that the present chapter is concerned.

(245) The direction in which a particle of air moves is not always horizontal, but is sometimes compounded of *two* directions: first and chiefly, the direction of the *horizontal* motion; and secondly, that which the particle may have in virtue of its forming part of an ascending or descending current.

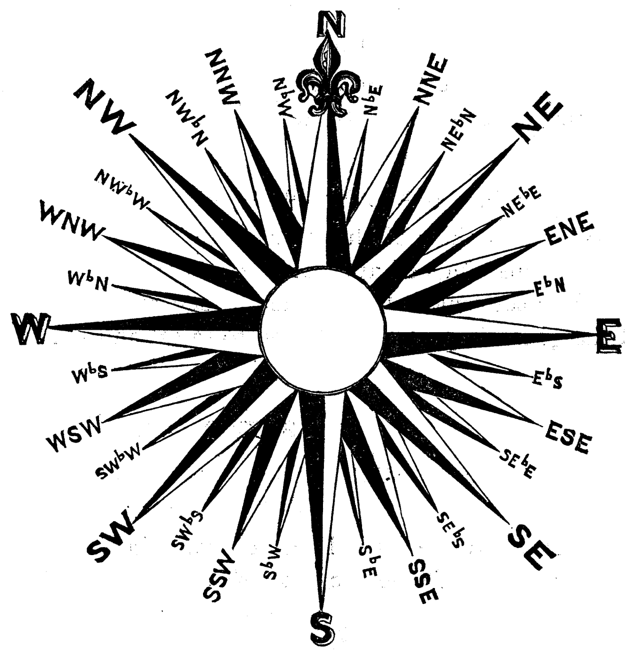
In this and the following chapters it must be understood that the observations described have reference only to the *horizontal* part of the motion.

(246) In order to express the direction of a line in a horizontal plane, it is necessary to have some fixed line to which to refer it. The line chosen for this purpose is the *true* or *astronomical* north and south line, or that formed by the intersection of the horizontal plane by a vertical plane through the axis of the earth. The north and south line shewn by a *compass* is affected by the magnetic declination, or, as it is popularly termed, "The Variation of the Compass," which differs in various places, and also at different times at the same place, and should never be used as a standard line from which to measure the wind's direction.

Such terms as "Compass North-East," or "North-East by Compass" always express the direction shewn by a compass, and therefore affected by the variation of the compass; nevertheless, when in the following pages, for the sake of brevity, the expression "Points of the Compass" is employed, the point stated must be understood to refer not to the *compass* but to the *true* direction.

(**247**) The direction of the wind is expressed by the point of the horizon *from* which it is blowing; and the position of that point is reckoned always from the *true* and not from the *compass* north.

(**248**) The compass with its thirty-two points is shewn in the annexed figure, where North, East, South and West are denoted by the capitals N., E., S., W., and the word "by" by the small *b*.



It is often sufficient to record that one of the eight principal points which is nearest to the actual direction of the wind; but sometimes greater precision is required.

GENERAL DESCRIPTION OF THE VANE.

(**249**) The term "Vane," in its more limited sense, is applied to the well-known contrivance which in a general way resembles an arrow, movable in a horizontal plane about a vertical line, which passes through it at a point nearer to the head than to the feathered end or tail, in order that the action of the wind on the latter may sufficiently exceed the pressure on the head to cause the arrow to take a direction parallel to that of the wind.

By a simple extension of the use of the word, the term "vane" may be taken to denote any contrivance or machine by which, through the action of the wind upon it, some line in the machine is brought into a direction parallel to that of the wind.

(**250**) **Further Extension of the term "Vane."**—The meaning of the term is frequently extended still further, so as to include not only the vane in the two preceding senses, but also the whole apparatus by which the direction of the wind is indicated on a dial or otherwise.

When the direction, in conjunction with the velocity, is shewn by an automatic or self-recording process, the apparatus by which this is effected is termed an "anemograph."

(**251**) Used in the wider sense of the term, a vane consists of two parts:

(*a*) The part on which the wind acts so as to bring a certain line in the machine to coincide with the direction of the wind, and which it may be convenient sometimes, for the sake of brevity, to call the "vane proper."

(*b*) The apparatus by which the direction is indicated.

As various kinds of the "vane proper" may be used in combination with various kinds of apparatus for recording the direction of the vane, it will be convenient to consider in separate sections the two portions of the general apparatus referred to in (*a*) and (*b*).

SECTION II.

ON THE PART OF THE VANE APPARATUS ON WHICH THE WIND DIRECTLY ACTS.

(**252**) There are two kinds of vane in common use, namely, the "*Ordinary Vane*," and the "*Windmill Vane*."

THE ORDINARY VANE.

(**253**) The ordinary vane, in its general form, resembles that referred to in Art. 249, the feather or tail being commonly formed of a thin oblong piece of metal, whose length greatly exceeds its width. It is however much better to use a *double* tail, consisting of two equal pieces of metal, equally inclined to the general middle line of the arrow.

(**254**) **Advantage of the Double Tail.**—The object of making the tail double is to diminish the oscillations to which ordinary vanes are subject when the direction is variable, and to increase their sensibility. If a sudden change occurs in the direction of the wind, and the tail is *single*, it is probable that when the wind is *in the act* of changing, its pressure on the side of the tail will be insufficient to move the vane, and that it will not begin to move until the new direction of the wind is attained. The vane will then begin to move; and although the pressure of the wind on the tail is becoming less and less as it approaches the position of rest, namely, a position parallel to the new direction of the wind, its velocity will continue to increase until it has reached that position; after which it will continue to move with diminishing velocity until the action of the wind on the opposite side of the feather causes a return towards and beyond the position of rest. Thus a series of oscillations will be kept up for a considerable time, the duration and extent of which will be much increased if the wind varies frequently and rapidly in its strength as well as in direction.

If the tail be double, the case will be as follows:

Suppose, for illustration, that the two tails are each inclined to the middle line of the vane at angles of 10°, so that they include an angle of 20°; and suppose also that the wind was from north and has changed 10° towards the east: it is clear that the new direction of the wind will make an angle with the right hand tail not of 10°, as it would have done if the tail had been single, but of 20°, and that the pressure on the *left* tail will be nothing.

The action of the wind to bring the vane to its new position will be greater and the effect more immediate; in other words, the vane will be more *sensible.* Moreover, as the vane swings beyond the line of rest the wind will blow with an angle of at least 10° on the left hand tail, and thus take immediate effect in checking the swing and in causing it to return to its position of rest.

(255) An ordinary vane may either turn about a *fixed* rod or spindle, as is common with vanes on steeples, or it may be fixed to the spindle, which itself turns within a fixed ring or bearing, and with its lower end formed into a point resting in a step or socket. The latter method is usually employed in vanes designed for meteorological purposes.

(256) Vanes Must be Counterpoised.—Whether the rod, about which the vane turns, be fixed, or whether the rod be attached to the vane and turns with it, the vane must be accurately counterpoised, *i.e.* the axis about which it turns must pass through the centre of gravity of the whole mass.

(257) The necessity of counterpoising the vane depends on the following facts:

If a body is capable of being turned about any fixed line in it which passes through the centre of gravity of the body, the body will rest in any position whatever in which it is placed, whether the line be vertical or have any other position; but if the line does *not* pass through the centre of gravity, and is not vertical, the body will not remain at rest unless a vertical line through the centre of gravity passes through the fixed line; and if the body be turned from the position of rest, the effect of gravity will be to restore it to that position. If the fixed line be itself vertical, the body will rest in any position, whether the centre of gravity be in the fixed line or not.

(258) To apply to the case of the vane what has been just stated.

Suppose that the rod or spindle, instead of being vertical, has an inclination to the south, and that the centre of gravity, instead of being in the spindle, is somewhere on the tail of the vane: it is evident that if there be no wind the arrow head will point to north; that if the wind is from north the arrow head will point correctly, but that if the wind be from any other quarter, and the arrow head be directed to another point instead of north, the tendency of the centre of gravity to seek its lowest position, namely, that immediately south of the spindle, will occasion a deflection of the arrow head from the true direction of the wind, whose magnitude will depend on the distance of the centre of gravity from the axis of the spindle, on the direction of the wind, and on its force.

If the spindle be vertical, and the centre of gravity be not in the axis of rotation, the displacement of the centre of gravity will not affect the direction of the vane in the same manner, but it will do so *indirectly* and *eventually*. In the first place, the weight, instead of acting along the length of the spindle, will press unequally on the upper and lower bearings, and cause an undue wear at certain parts, which will depend in some measure on the prevalent wind, and on the direction about which the wind is most liable to make frequent and rapid oscillations. Thus, if west were a prevalent wind, the upper bearing would be most worn on its east side, and the step on its west side. There would be also a similar wear on the spindle on its side and near the step. One effect of this undue wear is to *increase* the apparent duration of the *prevalent wind.* Thus if the prevalent wind be west, and there has been a light wind from that quarter, there is a danger that the vane will not yield to a light wind from another direction, but will continue to point to the west. Another effect of the unequal wear will be to destroy the verticality of the spindle, and thus indirectly occasion the fault already explained. Independently of the indirect influence on the apparent direction through undue *wear* on the bearings, the undue pressure caused by the displacement of the centre of gravity will add much to the friction, and thus impair the *sensibility* of the vane, or the readiness with which it takes up a change of wind.

(259) The Spindle of the Vane should be as nearly Vertical as Possible.—Provided that the vane be counterpoised, the want of perfect verticality in the spindle will not occasion an undue preference in the vane for any one direction; but it will impair its sensibility. There will also be an undue friction and wear of the bearings, which will also indirectly affect its sensibility.

(260) Mode of Testing the Counterpoising of a Vane.—Before a vane is placed in position, it should be ascertained, in the following manner, whether it is properly counterpoised:

Place the rod or spindle in a perfectly horizontal position; *fixing* the spindle, if the vane is movable about it; and *resting* it on two parallel edges in the same horizontal plane, if the spindle is attached to and forms part of the vane. If the vane is counterpoised, *i.e.* if the centre of gravity is in the axis of the rod, the vane will have no tendency to turn, but will remain at rest in *any position* in which it is placed; but if it be not counterpoised—if, for example, the centre of gravity be somewhere on the tail side of the spindle—it is evident that the tail will fall, and that the arrow will rest point upwards.

In trying this experiment, it is better to place the arrow in a horizontal position, as any error in the position of the centre of gravity is then most easily detected; whereas, if the arrow be nearly vertical, the tendency of the centre of gravity to take the lowest position and bring the arrow vertical may be insufficient to overcome friction, and an error may thus pass unobserved.

THE WINDMILL VANE.

(261) The oscillations to which ordinary vanes are subject, are in a great measure avoided by the employment of a windmill vane.

This instrument derives its name from the fact that the arrow head is brought to the wind by the action of two side wheels, with fans similar in form to those used for adjusting to the wind the axis about which the sail yards of a windmill revolve. It may be thus described:

The windmill vane consists of a cast-iron box and pillar, bearing on its top rim a fixed toothed wheel, through the centre of which the spindle works. Attached to the head of the spindle is a circular brass box carrying a pointer or arrow head to shew the direction of the wind.

Across the back of the brass box, or that part of it which is opposite to the arrow head, is a horizontal shaft, at right angles to the direction of the pointer, which gears by means of an endless screw into the fixed toothed wheel, and which, on being turned in one or in the opposite direction, produces a corresponding motion in the brass box and its arrow point. The axis of the endless screw projects both ways beyond the brass box, and at each end bears a wheel of fans formed of thin metal, and which are adjusted at such an angle that if the arrow points to the wind, *i.e.*, if the axis of the endless screw be perpendicular to the direction of the wind, the action of the wind on the opposite arms of each pair of fans exactly balances, and the fan remains at rest; but if the direction of the wind forms an acute angle with the axis of the endless screw, the fan turns in such a manner as to bring back the arrow to a position in which it points to the wind. If the wind suddenly shifts through a large angle, the fans will begin to turn rapidly; but they will turn more and more slowly, until the arrow again points to the wind, when their motion will again cease.

The superiority of the windmill vane over those of the ordinary form is manifest from the consideration that when a change of wind occurs the latter does not take up its true position until after it has made several violent oscillations, which are liable to be renewed whenever any small and temporary change occurs in the wind's direction.

The windmill vane should be counterpoised in order that its weight may be equally distributed on the toothed wheel, and that the cap may thus move more freely.

Windmill vanes are shewn in the photographs, Figs. 8, 9, 10.

SECTION III.

VARIOUS MODES BY WHICH THE DIRECTION OF THE VANE IS COMMUNICATED TO AND RECORDED BY A DIAL OR OTHER REGISTERING ARRANGEMENT.

(262) For steeple vanes it is common to place, a little below the vane, four fixed points to indicate the four cardinal points of the compass, N., E., S., W., and the direction of the vane is ascertained by referring it to the fixed points.

This plan is attended with the great inconvenience, that it is necessary for the observer to place himself somewhere in a line with the middle line of the vane, a position which the circumstances of the building may not always permit.

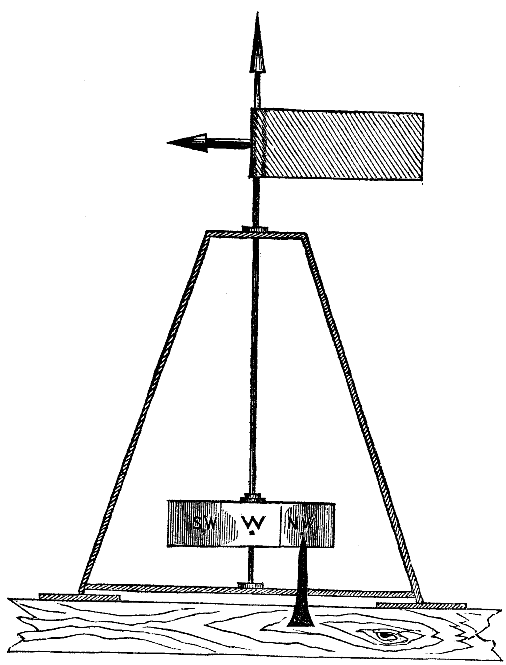
THE DRUM VANE.

(263) Description.—The apparatus for indicating the direction of the vane by aid of a drum, can be fitted, if required, to a vane which turns about a fixed rod ; but as it is better in every case that the rod should itself turn, the following description must be understood to refer to the latter plan only.

A little above its step the spindle is made to pass through the axis of a narrow cylinder or drum about 6 inches in diameter and 2 or 3 inches high, which is capable of being turned about the spindle, and also of being clamped to it in any position that may be desired.

On the outer surface of the drum the eight principal points are lettered, so that if the drum is properly adjusted with reference to the vane, the direction of the vane is shewn by a stationary pointer or hand, which is fixed in such a position that as the drum revolves, its lettered rim may be in close proximity to, but without actually touching the fixed pointer.

It is sometimes the practice to place the vertical division lines on the drum at the intermediate points N.N.E., E.N.E., &c., and the letters N., N.E., E., &c., in the spaces between the lines of division. When the drum is thus marked, the wind is regarded as north. When the hand points to any part of the space that lies between N.N.W. and N.N.E., while N.E. is shewn by the hand pointing to any part of the space between N.N.E. and E.N.E., and so on.



When the vane rod is in its frame, it is prevented from rising out of its step by a washer and pin just below the upper bearing. Care must be taken so to adjust the thickness of the washer as to make it impossible for the end of the spindle to leave the step.

The drum vane, with a short spindle with its frame, is shewn in the annexed diagram.

(264) To Adjust the Drum Vane.—(1) Secure the frame to its support in the position (as regards the points of the compass) which is most in accordance with appearance and convenience.

(2) Place the fixed index in a position in which it can be easily seen by the observer.

(3) Turn the vane until the arrow points to some distant object whose true bearing is known, and hold it in that position.

(4) Unclamp the drum and turn it about the spindle until the mark on the drum, which corresponds to the direction which the vane then has, may be coincident with the fixed index.

(5) Clamp the drum to the spindle, and the instrument is in adjustment.

The shaft may be lengthened to bring the drum within a convenient distance for reading; but if a longer shaft than 6 feet is needed, as much weight on the step would impair the sensibility, it is better to employ the instrument now to be described.

THE LONG SHAFT WINDMILL VANE.

(265) Description.—Just above the step of the spindle (which is at the base of the vane box), and surrounding and attached to the spindle, is a horizontal toothed wheel or disc, gearing into the teeth of another equal and similar wheel, which rests on friction rollers working at the bottom of the box. From the centre of this disc is *suspended* by a universal joint a shaft of such a length as may be desired. The shaft is formed of very light tubing in lengths of 2 and 4 feet, together with a telescopic length of 1 foot, which are connected by clamps adapted to resist the tendency to untwist, to which, in the event of a sudden change of the wind's direction, a screw joint is liable.

At its lower extremity the shaft is connected by a universal joint to a short vertical piece of rod, bearing a spur wheel, which gears into the circumference of another vertical cogged wheel, with the same number of cogs, and with a hand or pointer at its centre to indicate on the face of a dial the direction of the wind.

The dial is supported by a table or bracket in any position that may be convenient to the observer.

The arrangement is shewn in the photograph, Fig. 8, where the shaft is made very short to admit of its being included in the paper. Each instrument is furnished with a telescopic joint 1 foot in length, besides several pieces of 4 feet and 2 feet; so that by a suitable combination of these pieces, and by properly placing the bracket on which the dial box stands, the shaft may be accurately adjusted to the required length.

The shaft between the dial and the disc, to which it is suspended, should be as nearly vertical as possible; but if there be any slight deviation from verticality, the necessary freedom of motion is secured by the two universal joints.* †

(266) To Set a Long Shaft Vane.—(1) Unclamp the joint next to the dial.

(2) Turn the fans until the arrow head points to some distant object whose bearing is known.‡

(3) Turn the short rod or joint which acts on the hand of the recording dial, until the hand indicates on the dial the same point as that to which the arrow head of the vane is directed.

(4) Clamp the joint next to the dial, and the instrument will be in adjustment.||

ELECTRICAL WINDMILL VANE.

(267) Description.—The instrument here to be described is one by which the observer is enabled at any instant to ascertain by *sound* the direction of the wind to the nearest of the eight chief points of the compass. It is designed to meet the case where the vane, if suitably exposed, is too distant to admit of being connected by a shaft with a dial in any conveniently accessible position.

Surrounding the step of the vane, and attached to the bottom of the box which incloses the step and lower part of the spindle, is a flat brass ring divided by radial lines into four equal arcs (direction arcs they may be called) corresponding to, but not necessarily in the direction of the four cardinal points of the compass, and separated by small equal intervals. The direction arcs, as well as the step, are insulated, except as regards connection with their screw cups.

Clamped to the spindle a little above the step, but capable when unclamped of being turned round the spindle, is a contrivance which may not unfitly be termed a "circuit maker." It consists of an arm bearing an arc of brass which by means of a spring is made to press

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* By employing one or more universal joints at other parts of the shaft, it may be made to take a gradually curved direction, and thus avoid any obstacles that may lie in its vertical course; but any but a direct vertical course should be avoided as much as possible.

† It is practicable to apply the long shaft arrangement to an ordinary vane; but on account of the violent oscillations to which those vanes are liable, which might injure the dial, and by twisting the tube cause the dial to mark incorrectly, it is not desirable to use a long shaft with any but a windmill vane.

‡ The attempt to turn the brass box otherwise than by the fans should *never* be made.

|| For adjusting any kind of vane a time should be chosen when the weather is calm or nearly so.

down on the fixed brass ring. The length of the movable arc is 45° + the interval between the fixed arcs.

The step of the vane is connected by wire with one pole of a battery, and the direction arcs with four screw cups in proximity to a brass plate attached to the wall in the office, and so contrived that by means of a brass plug metallic connection can be made at will between the brass plate and any one of the direction wires.

Finally, two wires from the poles of a small telegraph sounder are attached, one to the brass plate, and the other to the other pole of the battery.

The electric windmill vane is shewn in photograph, Fig. 9, where *A* is the circuit maker, *B* the set of direction arcs (placed outside the box to be better seen), *C* the brass plate or direction indicator, and *D* the sounder.

C and *D*, which are placed near to the vane in the figure, would be in the observer's office when in actual use.

(268) To Adjust the Electric Vane.—Fix the vane box to its support, its position with reference to the points of the compass being governed only by regard to the direction of the building on which the vane is placed, and to the place of the door of the vane box, which should be of easy access to the observer. Unclamp the circuit maker and turn it until its middle point is immediately over the middle of the arc on the left of the box, and temporarily fix it in that position by inserting a pin provided for the purpose through two holes in the circuit maker and arc.

The arc on the left of the box may represent any one of the four cardinal points.

Turn the arrow head of the vane to the point to which the arc on the left of the box corresponds; clamp the circuit maker to the spindle; remove the pin, and the adjustment is complete.

(269) To take an Observation with an Electric Vane.—To ascertain the direction of the wind, notice by the sound, which direction arc or pair of arcs is placed in circuit, as the brass plate is connected by the plug with the four wires in succession.

If connection made by the brass plate with the *north* wire, *i.e.* the wire proceeding from the north arc, produces a click of the sounder, and connection of the brass plate with the other wires produces no sound, the direction is nearer to north than to either N.W. or N.E., unless it be exactly N.N.W. or N.N.E.; but if connection made separately with the

N. and with the E. wires produces a click of the sounder, the direction is nearer to N.E. than either to N. or E., unless it be N.N.E., or E.N.E. exactly.

(**270**) The apparatus is found to work well with a single gravity battery when the vane is 60 feet or more from the battery and sounder. With a strong battery it works well at the distance of a mile or more.

(**271**) The electrical arrangement above described can be applied to ordinary vanes as well as to those of the windmill construction; but it is better to limit its use to vanes of the latter kind, as the extensive oscillations to which ordinary vanes are liable, often make it difficult to decide nearer than to 45° the true direction of the wind, when an ordinary vane is employed with electrical connections.

(**272**) Further suggestions relative to setting wind vanes.

In Arts. 264, 266, 269, the observer is instructed to turn the vane until the arrow head points to some distant object or mark whose true bearing is known. In this operation there is sometimes a practical difficulty in obtaining a suitable mark, and also in placing the eye in a position that is convenient for judging whether the arrow head is truly pointed to it. When such difficulty exists, the following method of setting a vane or of testing it, will be found convenient:

Fix a picket on the ground, or what is better, make a mark on a wall or fence immediately south of the centre of the vane at a distance of about 100 yards or more.

The place for this picket or mark may be found approximately by suspending a plumb line near to the supposed place of the picket, and in such a position between the eye and the centre of the vane, that it may be brought into apparent coincidence with the pole star and the centre of the vane.*

(**273**) For suspending the plummet, it will be convenient to employ a rough stand, consisting of two uprights about 6 or 7 feet high and 3 feet apart, one placed east of the other, with a cross piece having one of its sides in the shape of a wedge, so that the line may hang freely, and admit of being easily moved to the east or to the west.

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* The pole star, of course, bears strictly north only when at its upper or lower transit; but, except in very high latitudes, the error caused by taking it as bearing north in setting the vane, is inconsiderable. Thus, at the equator the *greatest* error is about 1°20′;

in latitude 45° ..... 1°54′;

50° ..... 2°6′.

Even in latitude 70° the greatest error is under 4°.

Having placed the stand and suspended the plummet in its approximate position, move the plumb line along the cross piece until the desired coincidence is nearly obtained. Lengthen the line and lower the plummet into a bucket of water to check the oscillations, and make the apparent coincidence of the star with the centre of the vane more complete. Then mark the point on the horizontal bar at which the line was finally suspended, remove the bucket and lower the plummet to the ground. The point where the plummet meets the ground should then be marked by a picket, or, if possible, by something more permanent.

If there be a wall, or fence, or any fixed object at a sufficient distance due south from the vane on which a mark can be placed, the observer may determine the position for the mark by placing himself close to the wall, and in such a manner as to bring the star, vane, and plummet in one.

The operation for finding the position for the mark must of course be performed at night. A time should also be selected when there is not much wind and when the night is clear, so that the vane may be easily seen.

The operation of setting the vane or of testing it, should be always performed by daylight, and in fine and very calm weather.

In using the mark found in the manner described, three persons should be employed. Of these one (A) should stand over the picket or close to the mark on the wall, and hold up a plumb line before his eye, so as to make it appear to pass through the centre of the vane. Another (B) should adjust the vane until the arrow head and tail appear to A to be in one line. A third person (C), when informed by B that the arrow head is pointed north, should then set the drum or dial hand to the north mark, when the adjustment will be completed.

(274) When a windmill vane is used, as the arrow head when pointed north will be hidden by the vane box, the centre of the top of the box should be brought into the same vertical line with a mark on the side of the vane box immediately opposite to the arrow head.

(275) As the adjustment of the vane is liable to be disturbed by the loosening of clamps, and by the twisting of the shaft if it be a long one, it is desirable to test the vane once a month, or at any time when there is reason to suspect that a disagreement exists between the vane and its dial, or other recording contrivance.

(276) Directions on selecting positions suitable for the erection of vanes are given in Chapter VII.

CHAPTER VI.—ANEMOMETERS.

SECTION I.

PRELIMINARY REMARKS.

(**277**) Anemometers, or wind measurers, consist of two general classes:

(1) *Velocity Anemometers*, by which we learn the *distance* moved over by the wind in a given interval of time, and the *rate* or *velocity* of its motion, usually expressed in miles per hour.

(2) *Pressure Anemometers*, which give the pressure of the wind on a plane surface placed at right angles to its direction, and expressed in pounds on the square foot, or by other units of pressure and surface.

(**278**) A velocity anemometer only enables us to learn the *average* rate during a given interval of time; but it is incapable of shewing the *instantaneous* velocity at any *point* of time, although the instantaneous velocity may be inferred approximately from the distance moved over by the wind in a short interval of time. (Art. 5.)

(**279**) A pressure anemometer, on the other hand, gives the pressure at any *instant*, but cannot give the general average pressure during an interval of time, although that average may be inferred approximately from several pressures observed at short equal intervals.

(**280**) For general meteorological purposes a knowledge of the *velocity* of the wind is more useful than a knowledge of its *pressure;* but as velocity anemometers cannot give the velocity of momentary gusts, it would be desirable, in order to ascertain the greatest strain which any structure is required to sustain from the action of the wind, that instruments which measure the *pressure* should be employed in addition to those which measure the velocity.

(**281**) **Principle of Velocity Anemometers.**—The anemometers in all but universal use at the present time are various modifications (as regards mode of registration) of Robinson's anemometer, so called after its inventor, Dr. Robinson, Dean of Armagh, in Ireland.

The portion of the instrument on which the wind immediately acts, and of which Dr. Robinson was the inventor, consists of four hollow hemispheres or cups, attached, as shewn in photographs, Figures 7 and 10, to the extremities of four arms of equal length, which project horizontally from a vertical shaft or spindle, in such a manner as to make with each other equal angles of 90°. The shaft passes through a collar, and terminates at its lower end in a well tempered point working in a step or socket, and is caused to turn by the action of the wind on the cups.

From theoretical considerations, Dr. Robinson arrived at the conclusion that the distance passed through by the centres of the revolving cups is one-third of the distance passed over by the wind in the same time, and that this proportion is maintained whatever be the length of the arms and the diameter of the cups. There is reason to doubt the perfect accuracy of these conclusions; in fact, it has been found that short arms give results somewhat lower than when the arms are long. Experiments are yet needed for determining the precise relations between the length of the arms and the diameter of the cups, and the most advantageous size of each. In the meantime, in the absence of more exact knowledge, it is necessary to assume, as approximately correct, that the linear velocity of the centres of the cups is one-third that of the wind.

For registration, the motion of the shaft is communicated by gearing to a dial or system of dials, which being read at the beginning and end of an interval of time, shews the number of miles moved over by the wind in that interval; or the motion of the shaft may be communicated to a marker whose motion is proportional to that of the wind, and which traces a line on paper caused to move by clock-work in a direction perpendicular to that of the marker.

Instruments of the former kind are usually designated dial anemometers, while the others are called anemographs.*

SECTION II.

DIAL ANEMOMETERS IN WHICH THE DIAL IS VERY NEAR TO THE REVOLVING CUPS.

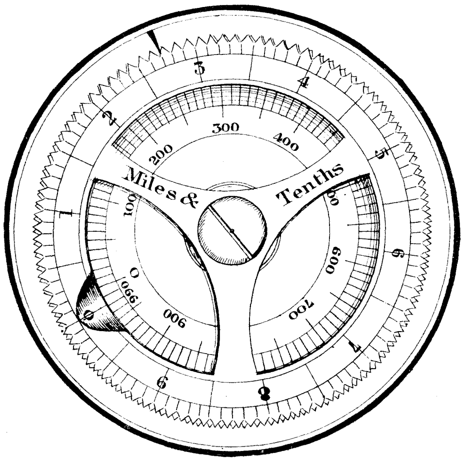
(282) Among the various kinds of dial anemometers, one constructed by Green, of New York, is extensively used on the North American continent.

In this instrument, an endless screw on the shaft, just above the step, gears on the circumference of a vertical cogged wheel, whose axis, formed into a second endless screw, gives motion to a cogged cylinder, which turns about a horizontal axis at the rate of one cog for one-tenth of a mile of wind, and acts on the toothed edges of the two dial wheels now to be described. Movable round a common horizontal axis, and in close

* With some anemographs the marker, instead of tracing a continuous line, makes a dot or mark at the end of each mile or some definite fraction of a mile.

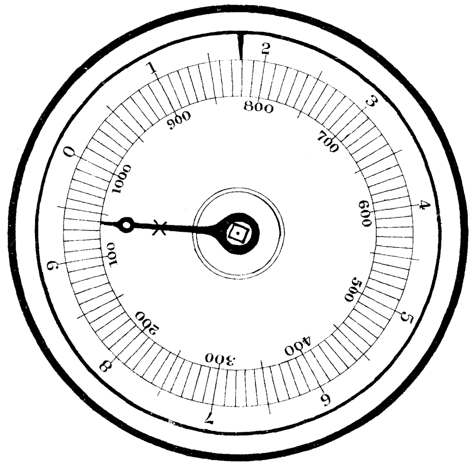
Examples in reading Anemometer Dials.

A.



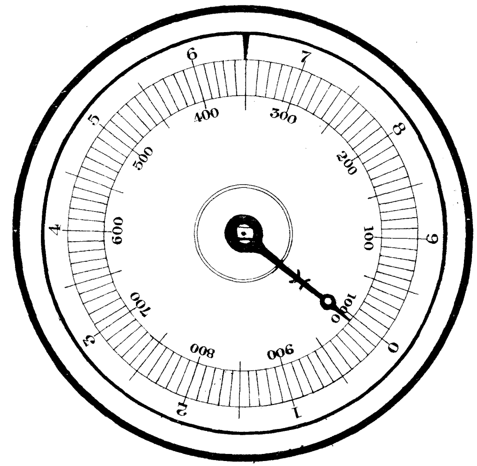
972° 7.

B.



61° 8.

C.



996°5.

Copp. Clark & Co. Lith. Toronto.

proximity to each other, are two equal graduated circles. The front or outer circle or dial, containing 100 divisions on its face, with 100 teeth on its edge, revolves past a fixed index. The back or inner circle or dial contains 99 divisions on its face and 99 teeth on its edge. Portions of the front circle are cut away to expose to view the graduations on the inner circle.

(**283**) **Principle of the Dial in Green's Anemometer.**—Suppose that the dials both read zero, in other words, that the zero marks of both and the fixed index are in one line.

As the cogged wheel revolves, each cog sends forward both dials one tooth, that is, one division, or the 100th part of the front dial (representing one-tenth of a mile), and one 99th part of the back dial. Hence when the front dial has made one complete turn, equivalent to ten miles, the back dial will have made a complete turn, and will in addition have advanced one tooth, or one of its own divisions, which therefore represents ten miles.

The position of the zero of the front dial with respect to the zero of the inner dial, and read on the *inner* dial, gives the number of *complete* turns of the outer circle, *i.e.*, the number of tens of miles; while the position of the *fixed* index with respect to the zero of the outer circle, and read on the outer circle, gives the whole number of miles and tenths of a mile.

TO READ GREEN'S ANEMOMETER.

(**284**) First see what is the reading of the inner circle which corresponds to the zero of the outer circle. This reading shews the number of hundreds and tens of miles which have passed the instrument. Thus in the lithographed diagram marked *A*, the number of miles lies between 970 and 980.

To find the units and tenths, see what reading to the nearest tenth is opposite to the pointer. In this case we see that the reading is rather nearer to 2.7 than to 2.8, so that the complete reading is 972.7.

In photograph, Figure 5, the zero of the outer circle lies between 580 and 590 of the inner circle, and the fixed hand points to 9.3 of the outer circle; hence the whole reading is 589.3.*

As the total number of divisions in the inner dial is 99, the total number of turns of the front dial which the inner dial can record is 99, and the highest reading 990 miles. Hence, in obtaining the miles passed

* Owing to some fault in setting, the zero of the outer circle is too far to the left. It should be much nearer to 590.

over during an interval of time in which the zero of the inner circle has been passed, 990 miles must be added to the second reading before the subtraction is performed. For example, if the first reading be 864.2 miles, and the second 25.7 miles, the interval is 990+25.7 miles−864.2 miles, or 51.5 miles.

(285) Foster's Small Anemometer.—If the circles be made with 101 and 100 teeth instead of 100 and 99, and each dial be graduated to 100 divisions, the instrument will read to 1000 miles instead of to 990 miles, the length of the arms bearing the cups being shortened so that the shaft may make 101 turns instead of 100 turns for the same motion of the wind.

This arrangement is made in some instruments constructed for the use of the Canadian Meteorological Service, by Foster of Toronto, who, instead of graduating the back circle of 100 teeth, has attached to it a movable hand or index, which shews the number of complete turns made by the front or ten mile circle, and therefore indicates the number of hundreds and tens of miles. In this construction there is but one graduated circle, containing 100 lines of graduation, of which the outer ends measure tenths of miles from 0 to 10 complete miles, while the inner ends of the same lines measure 10 miles each, from 0 to 1000 miles, and reckoned *in the reverse order*. The position of the front circle is shewn, as in Green's anemometer, by a fixed index, while the number of complete turns of the outer circle is shewn by the movable hand.

Examples in Reading Foster's Small Anemometer.—In lithographed plate, Figure B, the movable hand lies between 60 and 70, while the fixed hand points to 1.8; hence the whole reading is 61.8 miles.

In Figure C, the movable hand lies between 990 and 1000, and the fixed hand points to 6.5; hence the whole reading is 996.5 miles.

In photograph, Figure 6, the movable hand lies between 760 and 770, and the fixed hand is at 5.0; hence the whole reading is 765.0 miles.*

If the fixed hand lies between two marks, the reading of that mark should be taken to which the hand is nearer.

THE CLOCK ANEMOMETER.

(286) The clock anemometer is a contrivance† whereby the works of a common wooden clock can be utilized for the purpose of registering the motion of the wind.

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* Owing to faulty setting in the photographed dial, the movable hand is too near 770. It should be midway between 760 and 770.

† This instrument was suggested by Mr. W. Menzies, a carpenter in Toronto.

The peculiarity of this instrument consists in the arrangement by which the wind, instead of *moving* the recording dial or dial hand, only *regulates* its motion, the motion being effected by the weight or spring of the clock.

(287) Description.—In the clock anemometer, the shaft, bearing a set of Robinson's cups, is connected with the escapement of a common clock in such a manner that for each revolution of the cups the escapement wheel advances one tooth. There are various modes by which the connection may be made between the shaft and the escapement wheel.

The earliest plan adopted was to bend the shaft into the form of a crank, which, connected with the escapement by a horizontal wire, and working to and fro, acted on the escapement in the manner of a pendulum. This arrangement was simple and not apt to get out of order; but it was only suitable for stations where the dial could be placed at a very short distance from the cups, as the motion of a shaft of any considerable length would be impeded by its friction on the step.

A less simple contrivance, but one which has the advantage of admitting of a greater distance between the cups and the dial, is the clock anemometer, with an oscillating vertical lever, of which the following is a description:

The shaft or spindle, which is of metal, and extends about 9 inches* below the arms which bear the cups, terminates at its lower extremity in a well tempered steel cone, working in a step. The recording clock is so placed that when a spectator stands opposite to and views its face, the step will be a few inches to the right of the clock, and at a distance above it of two or more feet, according to circumstances. Just above the step, the shaft or spindle passes excentrically through and is rigidly attached to a small horizontal disc, which of course revolves with the shaft. Between the disc and a point at the side of and near the level of the escapement is a nearly vertical lever, which oscillates about a horizontal axis, resting on two angular supports, or Y's (as they are called, from their resemblance to the letter Y). The upper end of the lever is formed into a pair of jaws, between which the disc revolves, and thus causes the lever to oscillate, the lower end moving towards and receding from the side of the clock, and in a vertical plane coincident with the plane of the escapement wheel. Projecting from the lower extremity of the lever is a brass plate, to which is attached a small rod connected

* A somewhat greater length would be beneficial.

with the escapement wheel. The rod is flattened at the end next to the lever, and has two or more screw holes in it to allow the length of the horizontal rod to be altered in case the lever should warp.

The arms bearing the cups are made of such a length that a movement of 1 mile of the wind is indicated by an advance of 4 minutes of the clock. Hence one hour on the clock represents 15 miles, and one whole revolution of the hour hand, 180 miles.

In some of these instruments there is an additional small dial on the face of the clock, divided into twelve equal arcs, numbered from 1 to 12, and which is made to turn one division at the completion of a whole revolution of the hour hand. With this auxiliary dial the clock anemometer is capable of registering up to 144 hours (as indicated by the hour hand) or 2,160 miles.

(288) To Determine the number of Miles passed over by the Wind between two Given Times.—Read the dial at both times as if it were a common clock, and write down the readings to hours, minutes, and estimated tenths of a minute, and also the readings of the small dial, shewing the number of revolutions (R) of the hour hand. Subtract the first from the second reading, adding 12 revolutions, or 12 R, to the latter if it should be less than the first. Reduce the difference to minutes and decimals of a minute, and divide the difference thus reduced by 4. The result will be the number of miles which the wind has travelled between the observations. The average velocity will, of course, be found by dividing the number of miles which the wind has travelled by the hours and decimals of an hour in the interval.

Examples:

	R.	h.	m.
(1) 1st reading of anemometer clock..........	2	4	10.5
2nd " "	2	10	15.8
Difference..........		6	5.3
		60	
	4)365.3 minutes of clock.		
	91.3 miles nearly.		

	R.	h.	m.
(2) 1st reading of anemometer clock..........	3	10	16.6
2nd " "	4	2	20.2
Difference..........		4	3.6
		60	
	243.6 minutes of clock.		
	60.9 miles.		

	R.	h.	m.
(3) 1st reading of anemometer clock..........	6	9	20.4
2nd " "	8	4	30.4
Difference..........	1	7	10
		19	10
		60	
		1150	minutes of clock.
		287.5	miles.

	R.	h.	m.
(4) 1st reading of anemometer clock..........	12	10	30.6
2nd " "	1	6	40.8
Difference..........		8	10.2
		60	
		490.2	minutes of clock
		122.55	miles.

(289) Winding the Clock Anemometer.—As the motion of the hands is *regulated* only and not maintained by the motion of the wind, it is necessary that the clock should be wound up from time to time. The number of turns must depend on the number of miles passed over since the previous winding; but to avoid the risk of the clock running down, it is safe to wind it up after each observation, taking care not to wind too tightly.

SECTION III.

DIAL ANEMOMETERS IN WHICH THE DIAL IS AT A GREATER DISTANCE FROM THE CUPS.

(290) Good Exposure and Accessibility of Dials Antagonistic.—The anemometers that have been described are so constructed as to require the dial to be very near to the revolving cups. Now it will easily be seen that in order that a good measure of the wind's motion may be obtained, it is essential that the cups be in a lofty, unsheltered position, freely exposed to the wind; and also that, if not essential, it is at least very desirable that the dial be easy of access to the observer. These two conditions, however—namely, good exposure and accessibility—unless in very exceptional circumstances, are incompatible, and one or other of them has to be sacrificed if the dial is near to the cups. It is necessary therefore to devise methods by which the dial may be placed at a greater distance from the cups than is possible with the ordinary small anemometer.

(291) Old and Modern Long Shaft Anemometers Compared.—In the instruments of older construction it was sought to increase the distance between the cups and dial by lengthening the shaft or spindle;

but this method was attended with the objection that the additional weight, as well as the irregular action on the step, increased the friction, and materially impeded the motion. In all contrivances for recording motion by dials, the original motion, which is comparatively quick, is reduced by a system of cog wheels, &c., to the slow motion of the dial. *In the older* anemometers the reduction of the motion was made *close to the dial*, the quick motion being transmitted down by a long shaft, which moved with the speed of the cups, and was much retarded by the friction. In the anemometers of *newer construction* the reduction from the rapid to the slow motion is made in a box *very near to the revolving cups*, so that the shaft which communicates with the recording apparatus has a relatively slow motion. For example, the descending shaft of the anemometer used at the principal British observatories makes *one turn only* when the wind passes over *fifty miles.*

CLOCK ANEMOMETER WITH LONG LEVER.

(**292**) This differs from the clock anemometer described in Art. 287 in no respect but in the length of the oscillating lever.

In the hands of very careful observers it may be made to give fair results; but on account of the liability of the long lever to become warped, and thus occasion a stoppage, it is not desirable to extend the use of these instruments when the length of the lever exceeds 6 feet.

DIAL ANEMOMETER WITH LONG SHAFT.

(**293**) In this instrument a short spindle, bearing a set of Robinson's cups, gears by means of an endless screw on the cogs of a wheel which turns about a horizontal axle. The horizontal axle also by means of an endless screw gears into the cogs on the circumference of a horizontal wheel or disc resting on friction rollers, and having suspended from its centre a shaft formed of very light tubing, the separate lengths of which are connected by screw joints.* It is so contrived that the shaft makes $50\frac{1}{2}$ turns for a motion of the wind of 100 miles.

The action of the shaft on the dial is as follows:

At the lower end of the shaft is an endless screw with a double action, and gearing into the circumferences of two toothed wheels of equal diameter, which turn in vertical planes about a common axis, and have 101 and 100 teeth respectively.

The face of the front wheel (which has 101 teeth) is graduated, being divided into 100 equal parts, which on the outer edge of the graduated rim represent miles, and on the inner edge of the same rim, but reckoned in an inverse order, represent hundreds of miles.

* The screw joints are such that the effect of the motion of the shaft is to tighten them.

The back wheel gives motion to a hand or pointer, which moves about the centre, and points to the inner ends of the lines of graduation.

The endless screw near the dial, being one of double action, causes both wheels to advance *two* teeth for every turn of the shaft; so that for 100 miles of wind, or 50½ turns of the shaft, the front wheel advances 101 teeth, or makes a complete turn, while the back wheel also advances 101 teeth, and so moves one complete turn and one tooth, and thus advances one division with respect to the front wheel.

The miles up to 100 are shewn by a *fixed* pointer, and the complete turns of the front wheel, or the hundreds, by the movable hand on the inner edge of the graduated circle.

Examples in reading the dial:

Referring to Art. 285, Figs. *B* and *C*, representing the dials of Foster's small anemometer, may be adapted to the present purpose, if tenths be taken as miles and tens as hundreds.

In Fig. *B* the movable hand lies between 600 and 700, and the fixed hand points to 18; hence the whole reading is 618 miles.

In Fig. *C* the movable hand lies between 9,900 and 10,000, and the fixed hand points to 65; hence the whole reading is 9,965 miles.

In instruments of this class, furnished with a Vernier in place of a simple fixed index, the reading may be taken to the nearest tenth of a mile; but in those first constructed the tenths are read approximately (subject to an error of 1 per cent. in the tenths) by means of a small graduated cylinder or rim, which surrounds the shaft just above the place where it gears on the dial wheels. The graduated cylinder is attached by a spring to the shaft, and turns with it; but it can also be turned round the shaft and adjusted in any position with respect to a fixed pointer, past which the lines of graduation move. There are 20 divisions, each of which represents a tenth of a mile *nearly*, and are reckoned from *two* zeros, marked 0_a and 0_b.

This contrivance may be used in the following manner for reading the anemometer to the nearest tenth:

Set the graduated cylinder to the nearest zero; then having waited until the fixed index of the dial points to a full mile, count the number of divisions between the index of the cylinder and the *other* zero to which it is then approaching. This number will be the tenths required. As the above method is tedious, especially during light winds, it is better, when there is no Vernier, to *estimate* the tenths. Estimation will give the reading with sufficient exactness except when it is desired to learn the distance moved through in a small interval of time for the purpose of computing the velocity during that time. The mode of employing the graduated cylinder for finding the velocity about a point of time will be explained in Part III.

For adjusting the length of the shaft to the circumstances of the station, each instrument is furnished with a telescopic joint 1 foot long, besides several pieces of 4 feet and 2 feet; so that, by a suitable combination of those pieces and by properly placing the support of the dial box, the shaft may be accurately adapted to the required length. To remedy any want of strict verticality of the shaft, there are, as in the long shaft vane, two universal joints, one at the upper and one at the lower end of the shaft.

The long shaft anemometer is shewn in photograph, Fig. 7, where the shaft is shortened to suit the size of the paper.

(294) Long Shaft Anemometer and Long Shaft Windmill Vane Combined.—The Robinson's cups of this instrument revolve immediately above the centre of the windmill vane, their spindle passing down through the interior of a tube which represents the spindle of the vane. The two long shafts may be inclosed in the same casing, and their dials may be placed near together.

SECTION IV.

ELECTRICAL ANEMOMETERS.

(295) When the circumstances of a station do not afford for the anemometer a position at once well exposed and accessible, nor one to which the observer can with convenience approach nearer than 40 feet in a vertical line, recourse must be had to an electrical anemometer.

In all instruments of this class the registration of the motion of the hemispheres is effected by means of an electric circuit, which includes in its course a battery, an electro magnet placed near to the recording dial, and certain metallic parts of the case or frame that supports the revolving hemispheres. Near to the spindle there is a contrivance whereby, after a certain number of turns of the cups or hemispheres, the circuit, which is ordinarily broken, becomes completed for a very short time, when the electro magnet attracts its armature, and thus, through the intervention of some mechanical contrivance, either moves forward the dial hand, or *regulates* its movement. An instrument of which the dial hand is moved by the electro magnet requires a stronger battery than where the electro magnet only regulates the movement, and its action is more liable to be stopped. For this the anemometers constructed on the principle of the clock anemometer are preferable to other instruments that have been devised.

THE ELECTRICAL CLOCK ANEMOMETER.

(**296**) This instrument differs from the *ordinary* clock anemometer solely in the mode by which the motion of the hemispheres is transmitted to the escapement wheel.

At each turn of the arms bearing the hemispheres a projection from the spindle presses on a common telegraph key in the box which encloses the step of the spindle, and thus alternately completes and opens the electrical circuit connected with an electro magnet near to and at the side of the recording clock.

As the armature alternately approaches the magnet and is withdrawn from it by a spring, a lever with which it is connected suffers the escapement wheel to advance one tooth, and thus to act on the hands, as explained in Art. 287.

The electrical clock anemometer is commonly combined with an electrical vane, the electro magnet of the clock serving as a sounder to indicate the direction. The circuit of the anemometer can be broken at will by removing a brass plug which ordinarily completes the circuit, and be diverted to the direction indicator by inserting the plug in one or in two of the holes referred to in Art. 269.

The clock anemometer alone would require *two* wires, but for the combined instrument six wires are needed; namely, one for each direction arc, one for the anemometer key, and one return wire common to both instruments.

The electrical clock anemometer is liable to occasional interruptions in common with other kinds of telegraphic apparatus; but there is also a special cause of error to which the instrument as above described is subject when the wind is very strong, namely, that the action of the spring may not always be sufficiently rapid to withdraw the armature when the circuit is interrupted, so that a revolution of the hemispheres will sometimes occur without a corresponding motion of the escapement wheel.

In some instruments this defect is removed by a modification, whereby the circuit is completed only at the end of every fourth revolution of the hemispheres.*

* If circuit were made at every tenth of a mile, and the clock were constructed with one dial divided into 100 parts, and a hand moving one division for each tooth of the escapement, this hand would shew every tenth of a mile of wind up to 10 miles. If there were also another dial divided into 10 parts, and with *two* hands, the first moving one division during each turn on the first dial, and the other hand moving one division for each complete turn of the first hand on the same dial, the wind would be recorded by it for every tenth of a mile up to 10,000 miles.

SECTION V.

ANEMOGRAPHS.

(**297**) The term Anemograph is applied to a modification of an anemometer and vane, by which the velocity and direction of the wind are recorded on paper in such a manner that the number of miles moved over by the wind, as well as the direction during any interval of time, may be known from the paper without requiring the presence of the observer at the beginning and end of that interval.

For recording the velocity of the wind the machine is so contrived as to give motion to two separate and independent parts, of which one is moved uniformly by clockwork, while the other is moved through the action of the revolving hemispheres, and therefore with a variable velocity.

In some instruments the paper is stretched on a cylinder or on a disc moving with a variable rate, while the marker is moved by the clock; but in the anemographs with which the following remarks are concerned it is the *paper* that is moved by the clock, the *rate* with which the marker moves on the paper, or the *frequency* with which it marks (when its action is intermittent), being regulated by the velocity of the wind.

BECKLEY'S ANEMOGRAPH.

(**298**) This apparatus, which was devised by Mr. R. Beckley, the mechanician formerly attached to the Kew Observatory, and is used very extensively in England, consists of the following parts:

(*a*) A set of Robinson's cups with a windmill vane, each fitted with a descending shaft, in the manner described in Arts. 293, 294, but with the motion of the velocity shaft reduced to one turn for every 50 miles of wind.

(*b*) A cylinder, called the clock cylinder, round which the registration paper is wrapped, and which moves about a horizontal axis once in 24 hours. The paper is divided into 24 equal portions by straight lines, which may be termed hour lines, which, when the paper is on the cylinder, are parallel to the axis of rotation. There are also on the paper lines at right angles to the preceding, which divide the paper into five equal parts, each representing 10 miles.

(*c*) A marker, consisting of a strip of brass wrapped round a cylinder in such a manner as to form a screw with a very thin but projecting thread extending from end to end of the marking cylinder, and forming one whole turn on the cylinder.

The marking cylinder is placed with its axis parallel to that of the clock cylinder, and sufficiently close to it to allow the brass marker (the thread of the marking cylinder) to press continuously on the paper, and thus touch it at one point. It is connected with the descending shaft, so as to make one complete turn for 50 miles of wind. The paper used for registration is the metallic paper by De La Rue, which has the property of receiving a mark from a brass pencil.

If the clock cylinder were *stationary*, the marking cylinder as it revolves would trace out a *straight* line parallel to the axis of the clock cylinder, or to the hour lines. On the completion of 50 miles of wind, as one end of the marker is lifted off the paper the other end comes in contact with it, and thus commences another line, representing, when complete, 50 miles of wind.

As the clock cylinder revolves uniformly, the traces, *i.e.*, lines traced by the marker, instead of being parallel to the hour lines, are inclined to them, and are straight or otherwise according as the velocity of the wind is uniform or variable. It is evident that the inclination of the trace to the hour lines is greater or less according as the velocity is less or greater, a calm being represented by a straight line perpendicular to the hour lines.

(*d*) The paper on which the direction is traced is also wrapped round a cylinder which makes one turn in 24 hours, and the marker, of a form precisely the same as that of the velocity marker, is connected by a spur wheel with the descending shaft proceeding from the vane.

The paper is divided into 24 equal compartments by hour lines; but the transverse lines in the direction of the rotatory motion divide the paper into *eight* compartments, each corresponding to 45° of the wind's direction.

GIBBON'S ELECTRICAL ANEMOGRAPH.

(**299**) This apparatus, devised by Lieutenant Gibbon of the U. S. Signal Service, and constructed by Hahl, now of Baltimore, has undergone several changes since it first came into use.

In the earliest form of the apparatus the velocity only was recorded, a mark being made at the end of every mile on a revolving clock cylinder bearing the register paper.

The anemometer was subsequently combined with an electrical vane, such as described in Art. 267. In the combined anemograph, the velocity and direction are recorded on one sheet of paper, which is wrapped round a cylinder of about 4 inches in diameter and 6½ inches in length. By means of a clock, the cylinder is made to revolve *four* times in 24 hours, and also to move longitudinally at a uniform rate through a distance nearly half the width of the paper or length of the cylinder. One half of the paper is designed for recording the velocity, and the rest for the direction.

The velocity marks are made by a pencil attached by a lever to the armature of an electro magnet, which pencil is pressed down on the paper and withdrawn from it as the circuit is made and broken; and as the circuit is completed at the end of every mile of wind, the number of marks on the paper between two consecutive hour lines indicate the number of miles passed over by the wind in the interval.

The record of the *direction* is made by means of four electro magnets, each of which acts on an armature corresponding to one of the four quadrants, and is furnished with a marker so placed that the *position* of the mark made on the trace paper by each marker indicates the direction to which that mark corresponds.

Five wires only are needed for this form of Gibbon's anemograph, namely, one for the anemometer, and one for each of the four direction arcs. The vane and the anemometer are connected by a wire in such a manner that the office of return wire for each instrument is performed by the wire or wires of the other instrument.

As the current is closed only at the completion of each mile of wind, no marks are made by the direction markers, except at the instant when the mile is finished; so that if the wind be light, some time will elapse for which no record of the direction is preserved. The defect just stated is obviated in the following manner in the anemographs constructed since 1873:

In addition to the five wires above named, there is a return wire common to the vane and anemometer, and also a wire from the battery to the four direction magnets, being connected with the latter by four branch wires.

This wire, after leaving the battery, passes through the clock, in which there is a contrivance whereby the circuit, which is ordinarily kept open, is completed at the end of every five minutes. The direction markers moreover consist of dies, which *print* on the paper the *letters* N, E, S, W; so that by this arrangement a nearly continuous record of the direction is printed.

The general appearance of Gibbon's anemograph is shewn in photograph, Fig. 10.

Detailed instructions will be furnished to stations at which self-recording anemographs are in use.

CHAPTER VII.

ON THE EXPOSURE AND MODE OF MOUNTING VANES AND ANEMOMETERS.

SECTION I.

GENERAL CONSIDERATIONS RELATING TO POSITIONS SUITABLE FOR VANES AND ANEMOMETERS.

(300) It is essential that both instruments be placed in such positions that the wind, before reaching them, may neither be deflected from its true direction, nor retarded in its velocity, by neighbouring objects near or above the level of the instruments. As such objects are usually more numerous near the ground, a lofty position is, on the whole, to be preferred.

It is not sufficient, however, that the instruments be not sheltered by loftier buildings or by trees; they should also be placed at such a height above the building on which they stand as to escape the eddies caused by the reaction of these buildings on the wind.

If an anemometer be a little above the deck roof of a square tower, it is probable that it will not receive its due share of wind. When the wind blows directly on a wall, there will be collected close to the wall a mass of compressed air, which, in escaping, will form currents parallel to the wall, both horizontally and upwards. The effect of the ascending current thus formed will be to deflect the wind upwards and cause it to pass over the anemometer, which will thus receive a current whose velocity is less than that of the wind.

If the anemometer or vane be above the deck roof of a house or hove the ridge, or in other positions over any part of the roof of a 'ing, and at an insufficient height, effects of a similar nature, though ., be in different degrees, will follow.

The effects of buildings and other objects on the direction and velocity of the wind, depending as they do on a great variety of circumstances, are extremely complicated, and can not be determined without very great difficulty. It is better therefore to avoid these complications by exposing the instruments at a sufficient height above the building. The nature of the structure to be used will depend on its position and on the kind of vane and anemometer to be placed on it.

(301) Different Exposures Enumerated.—For the exposure of these instruments there are various positions more or less suitable, of which the following are examples. For the sake of reference, they are designated by the letters *A*, *B*, *C*, &c.

(*A*) Above the deck roof of a tower which does not exceed 12 feet square.

(*B*) Above the deck roof of a larger building, when the whole roof is flat, and either level or nearly so.

(*C*) Above a deck roof which forms only a part of a larger roof, the rest being on a slope.

(*D*) Above the ridge of a roof.

(*E*) In the same vertical plane with the ridge, or a little on the side of that plane, but extending outside the gable.

(*F*) A little beyond or outside one of the eaves of the house, but higher of course than the ridge.

(*G*) At some position between the ridge and the eave, but higher than the ridge.

(*H*) On a mast or post in a field or garden, away from all shelter from trees or buildings, and if possible on rising ground.

(*I*) Above the deck roof of a tower specially erected, at some distance from trees and buildings.

(*J*) A chimney, *if it be not used as such,* and be conveniently accessible, will form a suitable exposure; but it must be closed, in order to avoid the effect of ascending currents of air from below.

(**302**) In choosing one of the positions included in the classes (*A*) to (*G*) the proximity of chimneys should be avoided, partly on account of the shelter which they afford, partly on account of the deflection given to the wind by the currents of hot air and smoke ascending from them, and partly also from the damage to the instruments which the smoke may occasion.

SECTION II.

ON THE STRUCTURES USED FOR SUPPORTING VANES AND ANEMOMETERS IN DIFFERENT CIRCUMSTANCES.

(**303**) **Cross Head.**—The support most frequently employed is a cross head, mortised or otherwise secured to the top of a post. The cross head consists of a plank from 4 to 5 feet long, about 6 inches wide, and 2 inches in thickness, the precise dimensions depending on the size and weight of the instruments which it is designed to place on it. Sometimes for a solid post a hollow pillar formed of four boards may be substituted.

In cases where a vane only is used the cross head may be replaced by a square board.

Care must be taken that the cross head be *strictly horizontal*, as unless the vane and the arms of the anemometer move in a horizontal plane, erroneous indications will be given.

Height at which the anemometer cups should revolve in each of the various cases named in Art. 301, or the height at which the acting part of the vane should be placed when there is no anemometer.

(304) (*A*) Height, 7 to 9 feet. Diameter of post, 8 to 10 inches if solid, but rather greater if hollow.

The post must be well stayed. Its security would be increased if it were to penetrate the roof.

(*B, C*) Height, 8 to 12 feet.

(305) (*D*) For a very small building a height of 4 to 5 feet would be sufficient. In such a case a hollow pillar would be preferable. The opposite sides of the pillar, instead of being parallel, might taper upwards to a square of 6 inches, the spread towards the slope of the roof being greater than in the direction of the ridge. The lower ends of the sides of the pillar, where they cross the ridge, should be cut somewhat in the shape of the letter V, inverted so as to fit the ridge.

The four sides of the pillar should be secured by angle irons well screwed to the ridge and sloping roof.

For the ridge of a building of greater extent, a height of 5 to 8 feet might be necessary, and if there be chimneys which exceed the height of the ridge by more than those amounts, a greater elevation is desirable for the cups than would be otherwise required; but it is not *necessary* that the height should exceed that of the chimney.

If a post be used its lower end should be cut to fit the ridge and slope of the roof, and in either case the post or hollow pillar should be securely stayed.

Near to the post, for the convenience of the observer when he has occasion to visit the instrument, should be placed a little platform resting on and secured to the ridge, to consist either of a single board, or of one or more steps according to the height of the post.

(306) (*E*) A gable end exposure is adapted for an instrument with a long shaft reaching down to its dial, which may be secured to a bracket attached to the wall, and be read either from a window in an upper room near the gable, or from a ladder outside.

For a gable exposure a height of 4 feet above the ridge is sufficient. The support might be constructed by attaching a piece of 4 × 6 scantling, placed parallel to the ridge, to the top of a post secured to the ridge near the gable end. If a vane only is to be used, this scantling would be sufficient; but if provision is to be made for both instruments, a cross head for supporting them should be half-checked to the above named scantling.

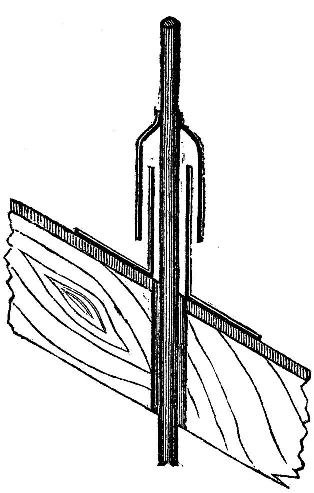
(**307**) (*F*) The eaves exposure would be employed in circumstances similar to those just stated, and when from any cause the gable exposure is not attainable. It is objectionable on account of the difficulty of giving adequate firmness to the support, but still more on account of the great inconvenience of obtaining access to the instruments, to oil them or to rectify defects.

The height of the cups above the ridge should be about the same as in the case (*D*).

For an eaves exposure the support of the instruments might rest on one or on two poles fixed in the ground, and stayed to the wall and to the frame of the roof.

(**308**) (*G*) A position between the ridge and the eaves is adapted either for the case when it is desired to read the dials from an attic window, or for that of an anemometer or vane with long shafts intended to penetrate the roof, and with their dials or other recording apparatus in a room below.

When provision for a vane only is to be made, a drum vane with a lengthened shaft may be employed. To guard against the intrusion of rain through the hole in the roof, a short pipe just large enough to admit the shaft, and with a broad flange adapted to the slant of the roof, should be securely fastened over the hole. There must also be a short piece of pipe soldered to the shaft, with its internal diameter a little greater than the external diameter of the other, and placed at such a position on the shaft as to serve the purpose of an umbrella.



The annexed diagram is a vertical section of the pipe, with its flange and the umbrella.

The height of the cups or vane should be about the same as in the case of the ridge exposure.

(**309**) (*H*) When a mast in open ground is employed for supporting a vane or anemometer, it should be from 12 to 20 feet or upwards in height according to the circumstances of its position and surroundings, with a diameter from 10 to 14 inches, and be well stayed with four wire ropes set up to posts firmly fixed in the ground.

To enable the observer to read the dials and to rectify defects when they occur, a substantial step-ladder is required, the pressure of which against the mast is be counteracted by a strut on the opposite side.

The ladder should not rest directly against the mast, but on the edge of a platform attached to the mast and partly surrounded by a railing.

The cross head is similar to that used in the various cases before named.

If a post not exceeding 12 feet in height be sufficient, the stays may be dispensed with; but to prevent the mast from being thrown out of perpendicular by the pressure of the ladder, the platform, instead of being attached to the post, might rest on four legs of 4 × 4 scantling, and be near to without touching the post.

The following mode of erecting and securing the mast will be found convenient, and especially when the mast is of considerable length.

The mast, instead of being itself sunk in the ground, is supported between two square posts securely fixed in the ground about 6 feet high and of a width and distance apart the same as the width of the mast. Through the mast and the two posts, near to their top, is passed a stout iron bolt, about which the mast can be made to turn in the act of raising or lowering it.

The holes through which the bolt passes are protected by iron.

The posts are braced together by a stout piece of timber bolted to them near the ground on the side from which the mast is raised.

When the mast is raised to the vertical position, this brace will prevent it from going further. The mast is retained in its vertical position by a stout batten across the two posts near their upper ends, and secured by two strong iron cleats opening upwards, between which and the mast the batten is driven down.

(**310**) When the mast is required for an instrument with a long shaft, additional height may be given to it without increasing the distance to which the observer is obliged to ascend in order to read the dial; but that provision may be made for his occasional access to the instruments to oil them or rectify defects, the whole height of the mast may be divided into *two parts*, the upper being arranged so as to slide like a topmast on the lower. In order that this arrangement may be adapted to the circumstances of the case, the ordinary mode of fitting topmasts will need modification.

(311) When an anemometer is exposed above a roof and to be read by ascending a ladder, an additional height may be given to the instrument by dividing the mast into two parts, of which the lower may be hollow, and receive the upper part, which slides in it like the joints of a telescope; or it may consist of two parallel pieces, between which the upper length slides on guides. When this contrivance is employed, it is requisite to lower the upper joint of the mast when the anemometer is read. On this account, it is not adapted for the method of deducing the velocity from two readings taken at an interval of a few minutes, unless the anemometer can be promptly raised to its proper position immediately after the first reading.

(312) (*I*) The following are some of the occasions when it may be necessary to erect a tower as a substitute for a mast:

(*a*) When a height of about 20 feet is not sufficient to secure good exposure.

(*b*) When the observer is unwilling to encounter the inconvenience or danger of ascending a mast to such a height whenever an observation is taken.

(*c*) When the vane and anemometer are to be used in connection with a long shaft anemograph, in which case a building is necessary, that the recording apparatus may be protected from the weather.*

The tower may be in the form of a pyramid on a square base, the top of the pyramid being cut off so as to form a deck roof about 5 feet square, to be surrounded by a railing.†

(313) It must be understood that the heights that have been stated as necessary for the anemometer and vane over roofs of different kinds, have reference only to the effects which the buildings themselves have on the direction and velocity of the wind that passes over them. If there be buildings or trees within a distance of 50 yards from the place selected for the anemometer and vane, these instruments should be raised to a height exceeding that of the neighbouring trees and buildings.

* A tower 30 feet high, adapted for an ordinary vane and anemometer, could be constructed for about $150. If the tower be required for an anemograph, as provision for warming it would be necessary, the cost would be much greater.

† Detailed directions for the erection of a tower can be furnished when necessary.

SECTION III.

CHOICE OF THE VANES AND ANEMOMETERS SUITABLE FOR DIFFERENT CIRCUMSTANCES.

Stations where the Velocity is estimated, and Vanes only are used.

(314) Vanes with Short Shafts.—If adequate exposure is attainable over a deck roof or ridge to which the observer has safe and convenient access, a Drum Vane with a short shaft, or with a shaft a little lengthened, may be used. The necessity of approaching very near to the drum to read it at night may be obviated by a contrivance by which the bull's eye lantern may be hoisted up on guides so as to throw its light on the drum.

(315) Long Shaft Vanes over Buildings.—If the only available position for the vane be above some building, to the roof of which access cannot be conveniently obtained, a vane with a long shaft must be used. The shaft may either penetrate the roof, so that the drum or dial may be in a room below, or it may pass down outside the wall at the gable end, or at the eaves. When it passes through the roof, the entrance of rain must be guarded against by an umbrella such as that described in Art. 308 (*G*), the flange being horizontal or sloping, according as it is to be used on a level or sloping roof.

(316) Long Shaft Vane on a Mast.—If the building at the disposal of the observer cannot be made available for exposing a vane by any of the modes stated in the two preceding paragraphs, the vane may be supported on a mast, if a position suitable for a mast can be found. The vane may be one with a long shaft, if a mast low enough for the convenient use of a short shaft vane would not insure adequate exposure.

(317) Electric Vane and Indicator.—If the methods stated in the three preceding paragraphs for exposing vanes be unsuitable or inconvenient, the electric vane and indicator may be employed. (Art. 267, and photograph, Fig. 9.)

Stations where Anemometers as well as Vanes are employed.

As it is necessary to approach much nearer to the dial of an anemometer than to the dial of a vane in order to read it, positions suitable as regards accessibility are more difficult to obtain when an anemometer as well as a vane is used.

(318) Positions for Exposure that are of Easy Access.—(See Art. 301, *A*, *B*, *C*.) The anemometer to be used in such positions is one of the following:

Green's small anemometer, reading to tenths up to 990 miles; Art. 283.

Foster's small anemometer, reading to tenths up to 1,000 miles; Art. 285.

The clock anemometer without electric connections; Art. 286.

Some other small dial anemometer.

The vane to be used in combination with either of the above named anemometers is the "Drum Vane."

(319) Positions that are not conveniently Accessible, but which admit of a Long Shaft Connection.—The anemometer and vane to be used in such cases are the long shaft anemometer and long shaft windmill vane, or these two instruments combined in one.

Whenever these instruments are used, the shafts should be carefully protected by a wooden tube, one side of which must be kept in its place by screws, so as to allow of being opened in the event of the shaft needing examination.

The dials should be supported on firm brackets, and be well protected from the weather or dust, and from injury of any kind.

(320) Positions which do not admit of a Long Shaft Connection.—The instruments to be used in such cases are one of the following combinations:

The electrical clock anemometer, and a vane with electrical connections;

A modified form of the electrical clock anemometer with the vane;

Self-recording anemograph, connected electrically with a small anemometer by Green or Foster, and with a windmill vane.

(321) Vanes and Anemometers secured by Square Headed Brass Screws.—To facilitate the process of securing vanes and anemometers to their supports, and of taking them down when necessary, they are *usually* attached by square headed brass screws, which are tightened up or loosened by a wrench or key. The necessity of applying a screwdriver—a very inconvenient tool to use in positions such as those required for anemometers—is thus obviated; and as the screw is moreover of brass, and is therefore less liable to rust than iron, its removal is comparatively easy.*

* Bolts and nuts may be used instead of screws, the nut being tightened up below the support of the instrument.

(322) On Keeping Vanes and Anemometers in Order.—Care should be taken to prevent dust, sand, or smoke from reaching the working parts of the instrument, by tightly closing up the openings to the interior when they are not wanted for examination, cleaning, or oiling.

As regards ordinary drum vanes and clock anemometers, the principal bearings, as a general rule, should be wiped clean and oiled with *watchmaker's oil*, once a month in *summer*, but less often in *winter*, as the evaporation and accumulation of dust is not so great in that season.

An oil can, such as is commonly used in oiling machinery, should not be employed, as there is thus a danger of pouring on too much. It is better to apply the oil by a thin iron wire, one or two drops from the end of which to each bearing being sufficient for a month's work. When too much oil is applied, it forms with any dust that may have intruded a glutinous paste, which is very detrimental to the free action of the instrument.

For lubricating the bearings and steps of the more delicate instruments, it is usually sufficient to apply the oil once in every two months.

Directions applicable to the different classes of instruments, for applying the oil and for cleaning the bearings when necessary, are furnished with each instrument.

CHAPTER VIII.

PHENOMENA FOR THE OBSERVATION OF WHICH INSTRUMENTS ARE NOT COMMONLY EMPLOYED.

SECTION I.

CLOUDS.

(323) Immediate Cause of the Formation of Clouds.—When from any cause the air at any part of the atmosphere is cooled below its Dew Point, a portion of the vapour suspended in it becomes condensed or converted into minute drops of water, forming what is called a fog or a cloud, according as the condensation takes place near the ground or in some higher region.

CLASSIFICATION OF CLOUDS.

(324) The system of classification commonly adopted is that first proposed in the early part of the century by Luke Howard, and described in detail in his work on the climate of London.

In the following description, Howard's definitions are given in inverted commas.

According to Howard, clouds consist of three primary forms, namely:

Cirrus, or Curl Cloud ;
Cumulus ;
Stratus.

From the combination of these are derived the four modifications :

Cirro-cumulus ;
Cirro-stratus ;
Cumulo-stratus ;
Cirro-cumulo-stratus, or Nimbus.*

DEFINITIONS, DESCRIPTION, AND MODE OF FORMATION.

(325) Cirrus.—"Parallel, flexuous, or diverging fibres, extensible by increase in any or in all directions."

This is the very lofty cloud, which sometimes has the appearance of hair or feathers; but it varies greatly in extent and figure. It varies also greatly in height, sometimes attaining the height of ten miles.

It is usually of very small density, and is probably composed of minute snow crystals.

Its duration varies from a few minutes to several hours, according as it is formed in a lower region and in the neighbourhood of other clouds, or in a lofty and isolated position.

The motions of the cirrus, which often differ in direction from those of the surface winds, shew the general movements of the upper atmospheric strata, and are often indicative of coming changes.

(326) Cumulus.—"Convex or conical heaps, increasing upwards from a horizontal base."

Clouds of this modification are commonly of the most dense structure, and include all those of a rounded or globular form. They are formed

* Plates in illustration of the different forms of cloud are bound up herewith. As the plates were prepared for other works, the numbers on them have no reference to the text of these "Instructions."

in the lower atmosphere, and move with the current next to the earth. They are caused by the ascending currents of warm air which rise from the heated ground, which air, as it reaches a stratum sufficiently cold to reduce its temperature below the Dew Point, becomes condensed into visible cloud, in a manner analogous to that of condensed steam as it issues from a kettle or boiler, and forms what in the distance resembles mountains of snow. The rounded top results from the fact that an ascending current is stronger near its centre than at its external parts, and carries up the vapour to a greater height.

In fair weather the cumulus often forms a few hours after sunrise, goes on increasing until the hottest part of the day, and disappears about sunset.

It is sometimes called the "cloud of the day," from the fact that the conditions necessary for its formation are more commonly present in the day; nevertheless, although commonly formed in the day, it often continues through the night.

(327) Stratus.—"A widely extended, continuous, horizontal sheet, increasing from below upwards."

This, as its name implies, is a continuous layer of cloud, or a horizontal sheet of uniform thickness, often covering the earth with a uniform veil. When seen near the horizon, and therefore in profile, it has the appearance of a horizontal band. Although frequently seen through the day, it is often called the "cloud of the night," as, more commonly than not, it forms about sunset, grows denser during the night, and is dissipated by the morning sun. It is caused by the vapours which have risen during the day, and which, as the ascending currents become weaker towards evening, approach the earth. As the cooling of the air during the night begins near the ground, and thence proceeds upwards, the condensation of the vapour first appears near the ground, and thence increases from below upwards, as successive layers of air are cooled below the Dew Point. Smoke and particles of dust that have been carried up by the ascending currents, contribute, when they descend, to the density of the stratus clouds; not apparently only, which they do by their mere presence, but because each particle, as it is cooled by its own radiation, receives a deposit of water from the surrounding air.

(328) Cirro-Cumulus.—"Small, well defined, roundish masses, in close horizontal arrangement or contact." This cloud is formed from the cirrus by the fibres breaking and collapsing into small roundish masses, sometimes resembling a flock of sheep, and when the masses are very small, forming what is often called a mackerel sky. It occurs very frequently in summer, and is attendant on dry and warm weather.

(**329**) **Cirro-Stratus.**—" Horizontal or slightly inclined masses attenuated towards a part or the whole of their circumferences, bent downwards or undulated, separate, or in groups consisting of small clouds having this character."

From the form and relative position of these clouds when in groups, they resemble shoals of fish. It appears to result from the settling down of the cirrus. If the cloud descends to a very low level, it ceases to be a snow cloud and becomes a water cloud.

Cirro-stratus possesses great extent and continuity of substance with little vertical depth, and is the cloud through which are exhibited Parhelia, or mock suns, Paraselenæ, Coronas, and Solar and Lunar Halos.

(**330**) **Cumulo-Stratus.**—" The cirro-stratus blended with the cumulus, and either appearing intermixed with the heaps of the latter, *or superadding a wide-spread structure to its base.*"

This variety has for its base a horizontal stratum or layer, from which rise large overhanging masses of cumulus. It is often traversed by horizontal lines of dark cloud, and sometimes assumes the form of a mushroom with a thick, short stem.

(**331**) **Nimbus.**—" The rain cloud. A cloud or system of clouds from which rain is falling. It is a horizontal sheet, above which the 'cirrus' spreads, while the 'cumulus' enters it laterally and from beneath."

Whilst on the horizon, or as it advances towards the observer, its front frequently presents a marked outline, like that of a very heavy *cumulo-stratus* with rain falling from it, and with some *cirrus* above, so that Howard has called it the *cirro-cumulo-stratus.* When it has overspread the whole sky, it is usually so mixed up with or concealed by the falling rain, that it generally assumes a uniform dark appearance.

(**332**) **Scud** is a term used to indicate loosely formed, detached clouds, drifting rapidly before the wind. They may be detached fragments either of *cirro-stratus* or *cirro-cumulus*, and moving at a high level, or of *stratus*, and moving at a low level.

SECTION II.

OPTICAL PHENOMENA.

(333) 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 of the colours is reversed, the red in the secondary bow being lowest and the violet 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 from the back, and emerges from the lower part of the drop towards the spectator's eye.

In the formation of the secondary bow, the ray enters the *lower* part of the drop, suffers *two* reflections at the back of the drop, and finally emerges from the upper part towards the eye of the spectator.

The centre of both bows is at a point in the sky exactly opposite to the sun, *i.e.* in the prolongation of a line from the sun to the spectator's eye. 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 middle part of the primary bow is approximately 42°; hence when the sun is 42° or more above the horizon, no part of the primary bow is visible.

The radius of the secondary bow is approximately 53°; hence, whenever the sun has an altitude of 53° or more, neither primary nor secondary bow will be seen.

To sum up the results of the statements in the three preceding paragraphs.

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 its altitude is between 42° and 53°, the secondary bow only is seen.

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

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

If the spectator be in an elevated position, his visible horizon may be considerably depressed below the horizontal plane through his eye, and the bow become extended below that plane, so as to form, when the sun is near the horizon, an arch exceeding a semicircle, more or less, according to the greater or less depression of the visible horizon.

(**334**) **Lunar Rainbow.**—Rainbows are produced by the light of the moon in exactly the same manner as by the light of the sun; but they are usually 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, *i.e.*, at the point where the prolongation of a straight line from the moon through the spectator's eye meets the sky.

CORONAS ROUND THE MOON OR SUN.

(**335**) 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 that of the third triple the diameter of the interior ring. The diameter of the interior ring varies from 2° to 4°. In each ring or corona the red is on the outer border, and the violet on the inner. The coloured circles arise from the interference of rays passing on either side of minute globules of water, nearly all of which have at the time very nearly the same size. The diameters of the rings depend on the size of the globules, being greater or less according as the globules are less or greater. Coronas are seen whenever light clouds pass between the moon and the spectator; but if the globules of water be too numerous, the light will be intercepted, and no corona will be visible.

(**336**) A solar corona is not often seen, on account of the dazzling brightness of the sun. It may however be made visible by viewing it through coloured glass.

HALOS, PARHELIA, AND PARASELENÆ.*

(**337**) **Halos.**—These are large circles of definite and constant diameter, one of 45°, the other of 92°, and which are seldom both seen together. The colours are very feeble, especially of the larger, which is usually almost or quite white. The larger is very uncommon. Where they exhibit prismatic colours, which is rarely the case, the red is *inside.* They arise from the existence of minute prisms of ice in the atmosphere, and consist of refracted light.

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).

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* Quoted from "Instructions," by Robert H. Scott.

At times the phenomena are even more complicated, and other circles, arcs, and lines are observed, usually intersecting the primary halo symmetrically. At the intersections these multiple images appear. The lines and arcs probably form parts of circles of 45°, 90°, and 180° diameter.

These appearances are exceedingly rare except in high latitudes.

SECTION III.

AURORA BOREALIS.

(**338**) The Aurora Borealis 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 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.*—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.‡

* The contents of Art. 338 are from "Remarks," by Professor Olmsted, in the Smithsonian Contributions to Knowledge.

† A dipping needle, or magnetised needle, which is free to turn in a vertical plane about a horizontal line through its centre of gravity, will take up a position of rest such that the end containing its north pole will be depressed below the horizon through an angle which is called the "Dip," or "Magnetic Inclination." At Toronto the Dip is somewhat over 75°. It becomes greater and greater as the place of observation approaches the Magnetic Pole of the earth. It is the opposite or elevated pole of the needle to which reference is made in the text; so that the point about which the corona is formed is about 15° south of the Zenith. It will not be due south from the Zenith; but will be *east* or *west* from the meridian according as the magnetic *declination* or variation of the compass is to the *west* or *east* of north.

‡ In some comparatively rare instances, the waves to which Professor Olmsted refers are propagated in such a manner as to give to the arch the appearance of a phosphorescent stream, rushing tumultuously, and with prodigious velocity, 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.

(**339**) **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 and streamers, both of superior brilliancy, with a corona, or 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 corruscations, 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.

SECTION IV.

SHOOTING STARS.

(**340**) The term shooting or falling star, or meteor, is applied to those well known luminous bodies which at night often appear suddenly, and, darting across the sky, again suddenly vanish.

Although meteors undoubtedly belong chiefly to Astronomy, the common practice of considering them as being within the province of Meteorology—a practice which may be traced to the opinion which at one time prevailed, that they had an atmospheric or terrestrial origin—

* The classification in Art. 339 is that adopted many years ago by the Smithsonian Institution.

is still justifiable on the ground that during the time when they are visible, they are within the limits of the atmosphere. Their luminosity is due to the heat developed by the compression of the atmosphere which their rapid passage through it occasions; and it is in consequence of this luminosity that they have been employed as a means of ascertaining the height to which a perceptible atmosphere extends.

Shooting stars or meteors may be seen with greater or less frequency during every clear night; but there are certain seasons and hours at which they are much more numerous than at others; thus the *average* number seen during one hour about midnight is much greater from July to November than in the other months of the year, and they also increase in frequency from the evening twilight throughout the night until the morning twilight; and, when daylight does not interfere, are usually most numerous about 6 a.m.

The motion of meteors may be in every direction with respect to the horizon; but the meteors which move downwards vastly exceed in number those which have a direction upwards.

There is satisfactory proof that a very large number of these bodies move round the sun in elliptic orbits which are inclined at various degrees of obliquity to the orbit of the earth; so that a meteor can only pass through the atmosphere when the meteor and the earth arrive nearly at the same time at the *node* of the meteor's orbit, *i.e.*, the point where its path and that of the earth intersect one another.

The paths or orbits of many meteors are arranged in groups, the individual orbits in each group being in comparatively close proximity and nearly parallel to each other; from which it follows that when the meteors occupy very different positions in their respective orbits, they constitute a meteoric stream, or, as it is called when seen from the earth, a "meteoric shower."

The showers of August and November are remarkable examples of this grouping.

In the meteoric shower of August, which occurs about the 10th, the meteors are distributed with fair uniformity throughout different parts of their orbits. Hence, approximately, much the same number of meteors are seen in every year when the earth arrives at the nodes of their orbits, or crosses the stream on Aug. 10th.

In the case of the November meteoric showers, which the earth encounters about Nov. 14, although no part of the *group* of orbits is unoccupied by numerous meteors, these bodies, instead of being nearly uniformly distributed in different parts of the stream, are for the most part collected into one dense group of such a length as to require nearly *four* years to cross the node, the most dense part being about two years in passing that point. The periodic time of the November meteors, or the time taken in completing a revolution round the sun, from the node to the same node again, is about 33 years.

From the facts above stated, it follows that while an unusual number of meteors (as compared with those in other days) may be expected every 14th of November, the greatest number will be seen at the end of a period of 33 years, that the numbers will be unusually great (as compared with other years) for probably four years in succession, and that the display will be greatest in the two middle years of these four. In the years 1866 and 1867 the November meteors were remarkably numerous and brilliant. The next great display will be in 1899 and 1900.

PART III.

DIRECTIONS FOR TAKING AND RECORDING METEOROLOGICAL OBSERVATIONS, WITH BRIEF NOTICES RELATIVE TO THE INSTRUMENTS AND THEIR MANAGEMENT.

CHAPTER I.

ON METEOROLOGICAL INSTRUMENTS AND THEIR MANAGEMENT.

SECTION I.

THE BAROMETER.

(341) Atmospheric Pressure, how Measured.—The pressure of the air at the time and place of observation is measured by the reading of a barometer after that reading has been corrected for all instrumental errors, or has had all instrumental corrections applied to it. Read Arts. 123 to 125.

(342) Meaning of term "Instrumental Corrections."—By "instrumental corrections" are understood those corrections which must be applied to the reading of a barometer, in order that the same *corrected* reading may always indicate the same pressure, whatever be the barometer used, whatever be its temperature, and to whatever latitude or elevation above the sea it may be carried.

(343) Instrumental Corrections for a Mercurial Barometer Enumerated.

(*a*) Corrections which do not depend on extraneous circumstances, such as temperature and locality, but are peculiar to the individual barometer, or to barometers of the same class and dimensions. These corrections are as follows:

Index Correction. Art. 142.
Correction for Capillarity. Arts. 126, 127.
Correction for Capacity. Arts. 138, 139.

The above are frequently combined so as to form one correction.

(*b*) Correction for variations of the temperature of the mercury and of the measuring scale, or, as it is often called, "*The reduction to temperature* 32°." Arts. 128, 136, 137.

(*c*) *Correction for Gravitation.*—This consists of two parts, which depend respectively on the latitude and elevation above sea level.* See Arts. 129, 130, 131.†

(344) Reduction to Sea Level.—The Reduction to Sea Level is the difference between the pressure at the place of observation and the pressure which would be found at a place immediately below it at the level of the sea, supposing that the intervening space were occupied by air. The magnitude of the reduction depends primarily on the height of the station, and secondarily on the temperature of the *external* air and the atmospheric pressure. It increases with the height of the station, and, for a given height, increases with the atmospheric pressure, and diminishes as the temperature of the air increases.

(345) Use of Tables of Barometric Corrections.

(*a*) The combined correction for index error, capillarity, and capacity for some barometers is constant at all pressures, but for others is different in amount at different pressures or readings of the instrument. The correction is to be added or subtracted according as it is marked (+) or (−).

(*b*) The reduction to temperature 32° is taken from the table of which the title is "Corrections to be applied to Barometers with *Brass Scales* extending from the cistern to the top of the mercurial column to reduce the observations to 32° Fahrenheit."

The correction corresponding to the temperature shewn by the attached thermometer is found in the same horizontal line with that temperature at the side of the table, and in the column the heading of which is nearest in amount to the reading of the barometer after it has been corrected for index error, &c. The correction is to be subtracted when the temperature is 29° and upwards, and added when the temperature is below 29°. Thus:

For temperature	40°	and corrected Bar.	29.526,	the correction	is	−.030 ;
"	16	"	30.124,	"		+ 034.

* This must not be confounded with "Reduction to sea level." See Arts. 144, 145. The correction for gravitation in *altitude* is always *subtracted*, whereas the reduction to sea level is always *added*.

† *All* the corrections above named should in *strictness* be applied ; but, as a matter of fact, it is not the usual practice to correct the separate observations for gravitation.

When the change in the correction corresponding to consecutive half inches of the barometer exceeds .001, which it often does at temperatures above 52°, it is sometimes necessary to use a correction intermediate to those given in consecutive columns of the table. Thus, if the corrected barometer be 29.725 and the temp. 71°, the correction to be used is −.113, the corrections corresponding to 29.5 and 30, about midway between which 29.725 lies, being −.112 and −.114.

When the reading of the attached thermometer is known to tenths, the correction may be obtained in a similar manner: thus, if the barometric reading be 30.236, and the reading of the attached thermometer 60°.3, the correction is −0.086.

(*c*) Reduction to Sea Level. The table to be used at any station depends on the height of the barometer cistern above sea level. It is to be entered with *the temperature of the air,* as shewn by the principal mercurial thermometer inside the thermometer screen (Arts. 189–193), and the pressure in the table, which is most nearly equal to the barometer reading when *corrected for all instrumental errors.* The reduction is always *added.**

For the purpose of illustration, *portions* of three tables are given herewith, calculated for stations having elevations 87 feet, 351 feet, and 1,186 feet.

Table of Reductions to Sea Level to be added to Barometric Pressures at a Station having an Elevation of 87 feet.

Temp. of Air.	Approximate Pressure at Station.						
	28.0	28.5	29.0	29.5	30.0	30.5	31.0
° −20	0.105	0.107	0.109	0.111	0.112	0.114	0.116
−10	0.102	0.104	0.106	0.108	0.110	0.111	0.113
0	0.100	0.102	0.103	0.105	0.107	0.109	0.111
10	0.098	0.099	0.101	0.103	0.105	0.106	0.108
20	0 095	0.097	0.099	0.100	0.102	0.104	0.106
30	0.093	0.095	0.097	0.098	0.100	0.102	0.103
40	0.091	0.093	0.094	0.096	0.098	0.099	0.101
50	0.089	0.091	0.092	0.094	0.096	0.097	0.099
60	0.087	0.089	0.090	0.092	0.094	0.095	0.097
70	0.086	0.087	0.089	0.090	0.092	0.093	0.095
80	0.084	0.085	0.087	0.088	0.090	0.091	0.093
90	0.082	0.084	0.085	0.087	0.088	0.090	0.091

* The pressures referred to are given in the upper row of figures in each table.

Portion of a Table of Reductions to Sea Level to be added to Barometric Pressures at a Station having an Elevation of 351 feet.

Temp. of Air.	Approximate Pressure at Station.								
	28.8	29.0	29.2	29.4	29.6	29.8	30.0	30.2	30.4
—8°	0.427	0.430	0.432	0.435	0.438	0.441	0.444	0.447	0.450
—6	0.425	0.427	0.430	0.433	0.436	0.439	0.442	0.445	0.448
—4	0.422	0.425	0.428	0.431	0.434	0.437	0.440	0.443	0.446
—2	0.420	0.423	0.426	0.429	0.432	0.435	0.438	0.441	0.444
0	0.418	0.421	0.424	0.427	0.430	0.433	0.436	0.439	0.442
2	0.416	0.419	0.422	0.425	0.428	0.431	0.434	0.437	0.440
4	0.414	0.417	0.420	0.423	0.426	0.429	0.432	0.435	0.437
......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......
24	0.395	0.398	0.401	0.404	0.406	0.409	0.412	0.415	0.417
26	0.394	0.396	0.399	0.402	0.405	0.407	0.410	0.413	0.415
28	0.392	0.395	0.397	0.400	0.403	0.406	0.408	0.411	0.414
30	0.390	0.393	0.396	0.398	0.401	0.404	0.406	0.409	0.412
32	0.388	0.391	0.394	0.396	0.399	0.402	0.405	0.408	0.410
34	0.387	0.389	0.392	0.395	0.397	0.400	0.403	0.406	0.408
36	0.385	0.388	0.390	0.393	0.396	0.398	0.401	0.404	0.406
38	0.383	0.386	0.389	0.391	0.394	0.396	0.399	0.402	0.405
......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......
64	0.362	0.365	0.367	0.370	0.373	0.375	0.378	0.380	0.383
66	0.361	0.364	0.366	0.368	0.371	0.373	0.376	0.378	0.381
68	0.359	0.362	0.364	0.367	0.369	0.372	0.374	0.377	0.379
70	0.358	0.360	0.363	0.365	0.368	0.370	0.373	0.375	0.378
72	0.356	0.359	0.361	0.364	0.366	0.369	0.371	0.374	0.376
74	0.355	0.357	0.360	0.362	0.365	0.367	0.370	0.372	0.375
76	0.354	0.356	0.358	0.361	0.363	0.366	0.368	0.371	0.373
78	0.352	0.355	0.357	0.359	0.362	0.364	0.367	0.369	0.372

Portion of a Table of Reductions to Sea Level to be added to Barometric Pressures at a Station whose Elevation is 1,186 feet.

Temp. of Air.	Approximate Pressure at Station.								
	28.5	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3
—8°	1.451	1.456	1,461	1.466	1.471	1.476	1.481	1.486	1.492
—6	1.444	1.449	1.454	1.459	1.464	1.469	1.474	1.479	1.484
—4	1.437	1.442	1.447	1.452	1.457	1.462	1.467	1.472	1.477
—2	1.430	1.435	1,440	1.445	1.450	1.455	1.460	1.457	1.470
0	1.423	1.428	1.433	1.438	1.443	1.447	1.453	1.450	1.463
2	1.416	1.421	1.426	1.430	1.435	1.440	1.445	1.443	1.455
......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......
24	1.344	1.348	1.353	1.358	1.362	1.367	1.372	1.376	1.381
26	1.337	1.342	1.347	1.352	1.356	1.361	1.366	1.370	1.375
28	1.331	1.336	1.341	1.345	1.350	1.354	1.359	1.364	1.369
30	1.325	1.330	1.334	1.339	1.344	1.348	1.353	1.358	1.362
32	1.319	1.324	1.328	1.333	1.338	1.342	1.347	1.351	1.356
34	1.313	1.318	1.322	1.327	1.332	1.336	1.341	1.345	1.359
36	1.307	1.312	1.316	1.321	1.326	1.330	1.335	1.339	1.344
......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......
64	1.230	1.234	1.238	1.243	1.247	1.252	1.256	1.260	1.264
66	1.224	1.229	1.233	1.237	1.242	1.246	1.250	1.254	1.259
68	1.219	1.224	1.228	1.232	1.237	1.241	1.245	1.249	1.254
70	1.214	1.218	1.223	1.227	1.231	1.236	1.240	1.244	1.248
72	1.209	1.213	1.218	1.222	1.226	1.230	1.235	1.239	1.243
74	1.204	1.208	1.213	1.217	1.221	1.225	1.230	1.234	1.238
76	1.199	1.203	1.208	1.212	1.216	1.220	1.224	1.229	1.233
78	1.194	1.198	1.203	1.207	1.211	1.215	1.219	1.224	1.228

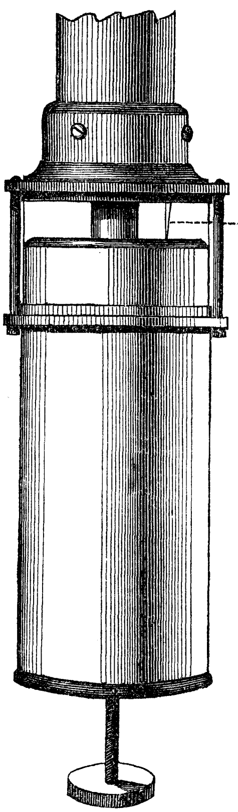
Examples:

(1) If the elevation be 87 feet,
The barometric reading, corrected for all instrumental errors, 29.628,
And the temperature of the air.......................... 35°,
The reduction to sea level will be........................ 0.097.

(2) If the elevation be 351 feet,
The corrected barometer................................. 29.470,
And the temperature of the air.......................... 28°,
The reduction to sea level will be........................ 0.401.

(3) Elevation, 1,186 feet,
Corrected barometer.................................... 28.850,
Temperature of the air.................................. 64°,
The reduction to sea level will be........................ 1.245.

(346) Choice of a Position for a Barometer.—For choosing a place for suspending the barometer, and for placing it in position, see Arts. 146, 147. It is imperative that the tube be *strictly vertical.* See Art. 147.*


a

(347) Moving a Barometer.—In moving a barometer, *even across the room,* the cistern end should be higher than the other end, and, *if the cistern be adjustable,* the mercury, before the instrument is moved from where it was hanging, should be screwed up to about ¼ of an inch from the top of the tube, and be kept there until the barometer is again suspended. Care must be taken not to screw up too high lest the tube or leather bag be burst. When the barometer is suspended, if the cistern be adjustable, the screw beneath it should be *slowly* reversed until the level of the mercury in the cistern sinks to the level of the ivory point, which is the zero from which the scale is measured. It is very important not to reverse the screw so rapidly as to endanger the fall of the mercury below the lower end of the tube; for if the end of the tube be exposed, air will enter through it to the vacuum above, and the instrument for the time will be

* Some observers are in the habit of hanging up their barometers in an open shed, or of otherwise exposing them, much in the way in which thermometers are exposed. This practice is much to be condemned. When the barometer is subjected to the rapid changes of the atmospheric temperature, there is a danger, owing to the larger volume of mercury which the barometer contains, that it will not take up those changes so rapidly as the attached thermometer, and

useless. The adjustable cistern, with its adjusting screw beneath it, and the ivory point (*a*), is shewn in the preceding diagram.*

If the barometer be one whose cistern is *not* adjustable, it should be taken down, reversed, restored to the vertical, and suspended, in a slow careful manner; and before it is read should be suspended at least half an hour, in order to allow ample time for the flow of the mercury down through the contracted passages in the tube. See diagram, Art. 156. For directions relative to packing a barometer, and for moving it from place to place by conveyances of different kinds, see Arts. 148 to 150.

(348) To Take an Observation with a Barometer, proceed in the following order:

(*a*) Read the attached thermometer, and enter the reading to the nearest degree in the pocket book.

(*b*) Slightly tap the instrument near the top of the column, to prevent the adhesion of the mercury to the tube.

(*c*) Raise or lower the cistern by the screw below it until the surface of the mercury in the cistern *just* meets the ivory zero point, or until the ivory point appears to meet its image reflected by the mercury.† See diagram, Art. 347.

(*d*) Bring the eye to the level of the front and back edges of the Vernier, and adjust the Vernier by the rack and pinion, raising or lowering it until the two edges of the Vernier, brought into one, appear *just to touch* the top of the meniscus or curved surface of the mercury in the tube, the eye being raised or lowered so as to maintain the apparent coincidence of the front and back lower edges of the Vernier.

(*e*) Read the scale and Vernier as explained in Art. 134, and enter the reading in the pocket book.

SECTION II.

THERMOMETERS FOR OBSERVING THE TEMPERATURE OF THE AIR.

(349) Temperature of the Air.—By the temperature of the air at a station is understood the temperature of such air as may be regarded as a fair average sample (as respects temperature) of the air in the neighbourhood.

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that the temperature correction, which corresponds to the reading of the attached thermometer, will in consequence be erroneous.

The needless damage to the metallic parts of the barometer, occasioned by the alternations of dry and moist weather, is an additional reason for not exposing it in the manner above stated.

* The diagram differs slightly in its details from some patterns.

† This step in the process must of course be omitted when the cistern is not adjustable.

(350) Exposure of Thermometers.—The thermometers should be exposed where the air is not *stagnant* (Art. 188), and where the air, having the general temperature of the air in the neighbourhood, may obtain perfectly free access to them. As far as practicable, they should be protected from radiation from objects that are hotter or colder than the air, and from loss of heat by radiation to the sky.

This protection is afforded by the thermometer screen and shed described in Arts. 189 to 192, and shewn in photographs, Figs. 1, 2, 3, 4. The screen and shed should be at such a height that the bulb of the ordinary thermometer may, if possible, be about 4½ feet above the soil. See Art. 187.

It is better that the shed be away from all buildings, walls, trees, &c.; but when the premises do not admit of this, it must be attached to the north side of some building where it is not exposed to warm draughts from doors or windows, and where no high building stands within 20 feet from the shed and on the north of the line of wall to which the shed is attached. For the mode of attaching the shed, see Art. 194.

Window exposures should be avoided if possible. See Art. 195.*

Snow is to be removed from slats, &c. See Art. 196 and note.

The shed and screen should be kept clean and free from dust, cobwebs, &c., and no articles whatever should be allowed to remain inside them except the thermometers in actual use. See Art. 197 and note.

(351) To take an Observation with the Thermometer.—Place the eye so that a straight line from the eye to the top of the column may be perpendicular to the stem, or, what is the same thing, place the eye on the same level with the top of the column when the stem is vertical. Disregard to this precaution may cause an error of 2° or more in the reading.

Read the division mark on the *stem*† at which the top of the column stands, to the nearest tenth of a degree (the tenths being estimated), and enter the reading in the pocket book.

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* Cases have occurred where the thermometer shed has been placed over the flat roof of a lofty building. If the station be in a crowded city, this is perhaps the best available position; and if moreover the observer's office be immediately below the roof, it has the important advantage of allowing all the instruments to be within convenient reach. It is not however, on the whole, a desirable position for giving the true temperature.

† If the division marks on the attached scale (if there be one) do not quite agree with those on the stem, it is by the *stem* that the reading must be determined. The same remark is applicable to maximum and minimum thermometers. See note to Art. 184.

The observer should avoid touching the thermometer just before he reads it,* or breathing on it, or warming it by approaching it too nearly. He should also not allow the light of the reading lantern to fall on the bulb, or on more of the stem than is necessary.

(352) Self-Registering Maximum Thermometer.—The object of this instrument is to ascertain the *highest* temperature that has occurred within a specified period of time. (Arts. 169, 170, 171.) It is suspended in the screen with the other thermometers, with its stem in a nearly horizontal position, but with the bulb end very slightly depressed. (Art. 170.) The requisite inclination may be maintained by adjustable suspension hooks, which can be clamped in any position that may be necessary.

In reading the scale, the eye must be placed in a line from the end of the column at right angles to the stem, and attention must be given to the precautions stated in Arts. 183, 184, 185, and to the notes to those articles.

When the time for observing has arrived the scale must be read to the nearest tenth of a degree, and the reading entered in the pocket book, care being taken not to touch the instrument until after the reading has been entered and verified.

After reading the maximum thermometer, it is to be set as explained in the last paragraph of Art. 169.

(353) Self-Registering Minimum Thermometer.—The object of this instrument is to ascertain the *lowest* temperature that has occurred within a specified period of time. For description and explanation see Arts. 172, 173, 174.

The minimum thermometer is suspended in a horizontal position in the thermometer screen by adjustable hooks.

In reading the scale the precautions stated in Arts. 183, 184, 185, must be carefully attended to. The point on the scale to be read is that which coincides with the end of the index that is farthest from the bulb.

Before reading the minimum, the observer should notice if there be any *bleb* or detached portion of spirit in the tube. If there be such bleb, and it be somewhere in the *graduated* part of the tube, he should enter in the pocket book the readings at each end of the bleb, in order that

* If the thermometer has been wetted by rain or snow, it must be wiped dry sufficiently long before the observation to allow the thermometer to recover the temperature of the air.

the difference between the two readings may be *subsequently* added to the reading as an extra index correction. As soon as convenient, after the completion of the various observations of the hour, the observer should endeavour to reunite the detached spirit as explained in Art. 166. If the detached spirit be in the ungraduated, or in the expanded part of the tube at the end furthest from the bulb, the correction to be applied to the reading of the minimum should be approximately determined at the time of the observation by comparing the reading of that point in the scale at which the *end of the column* of spirit stands with the corrected reading of the mercurial standard. The difference between the reading of the spirit and the mercurial thermometers (the latter being corrected) will be the *whole* index correction for the minimum. When this latter is required the ordinary tabulated index correction must not be employed.

The reading of the index is to be entered in the pocket book, and immediately afterwards the index is to be set by raising the bulb until the index, aided if necessary by a gentle tapping on the tube, slides to the end of the column of spirit.

(354) **Index Corrections.**—Rules for applying index corrections to thermometric readings, with examples, are given in Arts. 178, 179, 180.

It is not an unfrequent custom with some observers to apply index corrections mentally, and to enter in the register the corrected reading only, without the actual reading of the instrument.

As this practice very greatly increases the risk of error, it should be invariably avoided, not only in the case of thermometers, but also with respect to all instruments, except the ordinary rain gauge with a mouth whose area is 10 square inches.*

With this exception, and such others as may be hereafter stated, the *actual reading of every instrument is to be entered in the pocket book, in the daily register, and in the returns sent to the central office.*

SECTION III.

HYGROMETRIC OBSERVATIONS.

(355) **The Pressure of Vapour** in decimals of an inch of mercury, and the RELATIVE HUMIDITY, are determined by the temperature of evaporation (the temperature of the wet-bulb thermometer), together with the simultaneous temperature of the air. Arts. 198 to 201.

* The mode of entering the readings of rain gauges of other dimensions will be explained in its proper place.

(356) The Wet-Bulb Thermometer.—For a description of this instrument and of its mode of action, see Arts. 202 to 210.

For precautions to be taken in using the wet-bulb thermometer when the temperature is above 32°, see Arts. 211 to 214.

It is better to avoid the delays occasioned by wetting otherwise than by the cotton wick, by giving careful attention to the adjustment of the threads of the wick, and to the cleanliness of the wick, the muslin, and the water.

When the temperature is below 32°, the bulb must be wetted either by immersion, or by a camel hair brush. Arts. 212 and 215.

The film of ice must be continuous, but as thin as possible. No accumulation of ice must be allowed, as from its low conductivity it would impair the sensibility of the thermometer. Arts. 217, 75, 76.

For an explanation of the anomaly that sometimes occurs, when the wet-bulb thermometer shews a reading higher than the temperature of the air, see Arts. 218, 219.*

When the wet-bulb thermometer has been read, its reading is to be entered in the rough pocket book.

(357) RULES FOR DEDUCING THE FORCE OR PRESSURE OF VAPOUR, THE RELATIVE HUMIDITY AND THE DEW POINT FROM THE CORRECTED READINGS OF THE DRY AND WET THERMOMETERS BY MEANS OF THE PSYCHROMETRIC TABLES.

Pressure or Tension, or Force of Vapour.

In the same horizontal line with the full degrees of the temperature t' of the wet-bulb, and under the full degrees of the difference (t-t') at the head of the column, between the readings of the wet and dry thermometers, take out the corresponding force of vapour.

If the tenths of t' and of t-t' be o in each case, the number just found is the force of vapour required.

If the tenths of t-t' be exactly .5, the force of vapour can be found directly from the column midway between those corresponding to two consecutive full degrees of t-t'.

* When this occurs it should be treated as a case of *saturation*, the pressure taken from the tables being that which is found in the saturation column under t-t' (or the difference between the wet and dry) = o, and in a line with t' = the *temperature of the air*. Thus, if the temperature of the air be 40°, and the *corrected* reading of the wet-bulb 40°.5, the pressure of vapour will be that corresponding to t' = 40°, and *not* that corresponding to t' = 40°.5. Also, the humidity will be 100.

Attention should be called to such an occurrence by a special note in the register.

To find the increase in the force of vapour corresponding to the tenths of t', look in the column at the side headed "mean vertical differences," &c., and taking therefrom the decimal fraction in the horizontal line nearest to but a little lower than the pressure just found, multiply it by the number of tenths of t'. The product so found is to be *added** to the force of vapour corresponding to the full degrees.

The decrease in the force of vapour corresponding to the tenths of the difference t-t', is the product of the mean horizontal difference at the foot of the page by the tenths of the difference t-t'.

Examples:

(1) Given $t'=78°$ t-$t'=9°$ force of vapour $=0.836$

(2) Given $t'=78°$ t-$t'=9°.5$ .... $=0.829$

(3) Given $t'=78°.3$ t-$t'=9°.7$

For full degrees. force of vapour $=0.836$

for tenths of t', corr^n $=+.0032\times3$ $=+.010$

for tenths of t-t', corr^n $=-0013\times7$ $=-.009$

Hence for $t'=78°.3$, and t-$t'=9°.7$, the force of vapour $=0.837$

(4) Given $t'=78°.2$ t-$t'=9°.5$

For full degree of t' and for t-$t'=9°.5$ force of vapour $=0.829$

for tenths of t' corr^n $=+0032\times2$ .... $=+0.006$

Hence for $t'=78°.2$; and t-$t'=9°.5$, the force of vapour $=0.835$

(5) Given $t'=78°$ t-$t'=11°.2$

for $t'=78°$ and t-$t'=11°.0$ force of vapour $=0.809$

for tenths of t-t', corr^n $=-0013\times2$ .... $=-0.003$

Hence for $t'=78°$, and t-$t'=11°.2$, the force of vapour $=0.806$

The labour of performing the multiplication of the vertical and horizontal differences by the tenths of t' and of t-t' may be avoided by a table of proportional parts, which is furnished to all Canadian observers.

Relative Humidity.

When the temperature t' is an exact number of degrees, and the difference t-t' either an exact number of degrees or of half degrees, the Relative Humidity may be taken from the column in the tables immediately on the right of the Force of Vapour.

Although the Relative Humidity is printed to tenths, it is usually sufficient to take it out to the nearest unit, which is done by omitting the tenths, and, if they exceed .5, by adding unity to the right hand

* When t' is zero, or below zero, as the additional tenths then indicate a lower temperature, and therefore a lower pressure, the product is to be *subtracted*.

figure of the whole number. If the tenths be exactly .5, to increase the whole number by unity or to leave it unaltered is equally correct. Thus, 72.3 and 72.7, when taken to the nearest unit, should be written 72 and 73; whereas 72.5 may with equal correctness be written either 72 or 73.

Examples:

Referring to Nos. (1) and (2) of preceding examples, the relative humidities given in the tables are respectively..	65.2 and 63.7
Which, to the nearest unit, should be written	65 and 64

When, as is more frequently the case, neither t' nor t-t' are given exactly in the tables, the Relative Humidity is to be obtained by interpolating between the tabulated values, which process, as these latter are printed to tenths, can be performed with great facility.

Example:

(3) Let $t'=36°.4$ and t-$t'=10°.3$.			
For $t'=36°$ and t-$t'=10°$, the Relative Humidity			$=26.0$
Difference for 1° of $t'=$	$+1.6$		
Difference for .4 of $t'=$		$+0.64$	
Difference for 1° of t-$t'=$	-4.9		
Difference for .3 of t-$t'=$		-1.47	
Whole difference=			-0.8
Therefore, Required Humidity			$=25.2$
			or $=25$ nearly.

A little practice will enable an observer to interpolate mentally, and to write down the result to a sufficient degree of accuracy, without going through the calculation in detail.

Dew Point.

The mode of determining the temperature of the Dew Point is sufficiently explained and illustrated in Article 223.

Further examples:

t'.	t-t'.	Pressure.	Humidity.	Dew Point.
42°	2°.0	0.241	84	39°.3
68°	1°.5	0.665	92	67°.1
—11°	1°.5	0.009	32 or 33	—31°.0
50°.2	6°.3	0.281	61	43°.3
25°.6	4°.4	0.088	53	15°.5
— 4°.7	1°.2	0.021	59	—15°.0

[NOTE.—The directions in the above article have reference to Table No. VII. of the Psychrometrical Tables, or Class B, in the Smithsonian Meteorological and Physical Tables, compiled by Professor Guyot. Should other tables be supplied to observers at any time, they will be accompanied by such explanations as may be necessary.]

SECTION IV.

ON THE MEASUREMENT OF RAIN AND SNOW.

The Rain Gauge.

(358) **Depth of Rain on the Surface.**—By the depth of rain on the surface is understood the depth of the water that would be accumulated in a given time if the surface of the ground were horizontal, and if none of the water were lost by running off, by evaporation, or by the absorption of the ground.

(359) **Mode of Measuring the Depth of the Rain.**—The measurement is effected by means of a Rain Gauge, which is essentially a vessel with an open mouth, bounded by a sharply defined edge or rim that lies in a horizontal plane.

If the gauge be properly exposed to receive the rain, the depth which falls in a given time on the surface, and expressed in inches, will be found by dividing the number of cubic inches of water received in the gauge by the number of square inches which expresses the area of the mouth. The number of cubic inches of water is ascertained by a glass, graduated to cubic inches and tenths.

(360) **The Rain Gauge Commonly used at Canadian Stations.**—The essential peculiarity of this gauge consists in its having a mouth whose area measures *exactly 10 square inches*, so that the depth on the surface is found by dividing the cubic inches of water by 10, *i.e.*, by moving the decimal point one place to the left. See examples in Art. 232.

This Rain Gauge is fully described in Art. 233. The general appearance of the gauge and of its several parts is shewn in photograph, Fig. 12.

In those few cases where the station is provided with a gauge whose mouth does *not* measure 10 square inches, the exact area of the mouth must be ascertained, and a table similar to that in Article 230 must be constructed, so as to avoid the necessity of dividing the cubic inches of water by the area of the mouth.

The mode of calculating the area of the mouth and constructing the table is explained in the note to Art. 230.*

* If any observer has been provided with a gauge with a glass so graduated as to be adapted *exclusively* to that gauge (see Art. 229), it is desirable that he should measure the diameter of the mouth of his gauge, and construct a table similar to that in Art. 230, so that in the event of the breakage of the special glass, he may be provided with the means of using one graduated to cubic inches.

(361) Position of the Gauge.—The gauge must be in a level place and well exposed, and, if possible, with its mouth one foot above the soil. It is essential that the mouth be *strictly level.* For particulars read Art. 234.*

(362) To take an Observation with a Rain Gauge. — Follow carefully the directions in Art. 235, and enter the measurement in the pocket-book. If the area of the mouth be not 10 square inches, the *cubic* inches should be also entered.

For the mode of proceeding when snow falls as well as rain, or during frost, see Arts. 236, 237.

The measuring glass should never be placed in the receiver.

ON THE MEASUREMENT OF SNOW.

(363) The *depth* of the snow that has fallen during any given time is measured by a rod divided to inches, the measurement being taken between the surface of the newly fallen snow and the surface of the old snow.† The operation should be repeated in two or three places where the snow is fairly level and does not appear to have drifted much, and the average of these measurements is to be taken as the true depth. An experienced observer may estimate the depth very fairly without using a rod.

(364) Water Equivalent to the Snow.—The water equivalent to the snow is found by regarding one inch of water as the equivalent of ten inches of snow, *i.e.*, by dividing the depth of the snow by 10, or by moving one place to the left the decimal point of the number which expresses the depth of snow in inches. For an explanation of the snow gauge, &c., see Arts. 242, 243.

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* Attention is called to the directions to *tack* the outer stand to the top of a post projecting about 3 inches above the ground. Some persons, by neglecting the use of tacks, expose the gauge to be blown down during strong winds, or to be thrown out of the level. If the stand of the gauge is merely placed on the *ground*, without any fastening (which, very improperly, has been sometimes done), there is much danger of its being occasionally thrown out of level; besides which, when placed on the ground, the stand is more liable to be damaged by rust than when fastened to a post.

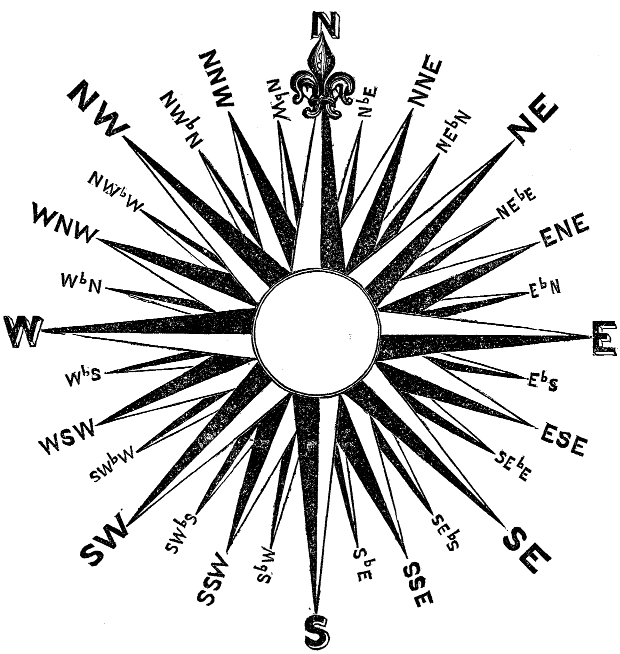
† If the surface of the old snow be not well defined, and the depth of the old snow be known, either to the ground or to the surface of some previous fall, the depth of the *new* fall may be found by subtracting the depth of the old snow from the *whole* depth measured from the upper surface of the new fall to the lower surface of the old snow.

SECTION V.

VANES AND ANEMOMETERS FOR DETERMINING THE DIRECTION AND THE VELOCITY OF THE WIND.

(365) **The Direction of the Wind** is expressed by the point of the horizon *from* which it is blowing; and the position of that point is always reckoned from the *true* and not from the *compass* north. See Art. 246.

It is usually sufficient to record that one of the *eight* principal points which is nearest to the actual direction; but if greater precision be required, the direction may be given to the nearest of the sixteen or of the thirty-two points.



The compass with its thirty-two points is shewn in the annexed figure, where North, East, South, and West are denoted by the capitals N, E, S, W, and the word "by" by the small letter b.

The direction of the wind is ascertained by a vane, for a description of the various kinds of which, and for precautions to be used in adjusting them, see Arts. 249 to 275.

(366) **The Velocity of the Wind** at any point of time, in miles per hour, is the number of miles which a particle* of air *then passing the station* would move through in one hour, if it were to move uniformly throughout that hour with the velocity which it had at that particular point of time. Arts. 2 to 5.

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* It must be assumed that all the particles which pass the anemometer at any instant are moving in parallel lines and at equal rates.

The velocity, though not given directly, is *inferred* from readings of an anemometer, for descriptions of the various kinds of which see Arts. 282 to 299.

The difference in miles between the reading of an anemometer and a second reading taken at the end of some given interval of time, is commonly said to be the *space* or *distance* moved through by the wind in that time.

By this space or distance must be understood the aggregate of the small distances moved over by each individual of a line of particles that pass through the station during the interval of time, or, what is the same thing, it is the distance which the leading particle of the line would move through, if its motion were in a straight line, and at a rate always equal to that of a particle which at the same instant is passing the station.

(367) Choice of a Position for the Vane and Anemometer.—The choice of the particular kind of vane or anemometer to be used at a station depends much on the facilities which the station possesses for giving to these instruments a suitable exposure.

It is essential that the vane and the cups of the anemometer be in a well exposed position, not sheltered by loftier buildings, trees, high land, &c., and one to which the wind will have free access, without being liable to be deflected from its true direction, or to have its velocity modified by roofs of buildings or other objects in the neighbourhood, or by the building on which it stands.

It is desirable, if not essential, that the dials or other arrangements for indicating the direction and velocity be in such positions that the observer may approach them near enough to read them without danger or inconvenience.

It is easily seen that good exposure to the wind and convenient accessibility of the dials are to a great extent antagonistic conditions, and that in many cases they cannot be reconciled except by connecting the vane or the cups with their dials, either by long shafts or by electrical wires.

As vanes and anemometers with long connections, whether by shaft or by electricity, are more expensive and more liable to get out of order than those of which the dials are close to the vane or cups, the latter, when it is practicable, should be employed in preference.

For a description of different kinds of exposure and for the structures suitable to them, read Arts. 300 to 313.

VANES AND ANEMOMETERS SUITED FOR VARIOUS CIRCUMSTANCES.

Stations where Vanes only are used.

(**368**) **Drum Vanes.**—If a position can be found which is well exposed, and which can be approached so as to be seen at night with the aid of a bull's-eye lantern, the Drum Vane, with a short spindle, may be used. Arts. 263, 264.

For suitable positions, see Art. 301, *A, B, C, H.*

(**369**) **Long Shaft Vane.**—If the only available position be one to which the observer cannot obtain convenient access, such as those named in Art. 301, *D, E, F, G, a long shaft vane,* either of the ordinary or windmill kind, may be used, provided that there be a room or a window immediately below the vane which can be made available for the dial. See Arts. 265, 266.

(**370**) **Electrical Vane.**—When the circumstances of the station make it necessary to place the vane on a hill or building, or in any position which is neither accessible to the observer nor admits of the adaptation of a long shaft, the electric vane and indicator must be employed. For a description of the electric vane, and the mode of adjusting and using it, see Arts. 267, 268, 269, and photograph, Fig. 9.*

(**371**) Whichever vane be employed, the direction should be read to the nearest of the eight principal points, and entered in the pocket book. Unless the vane be of the electrical kind, the direction should also be entered to the nearest of the sixteen points.

If there be much oscillation, the average position of the index or drum must be taken as indicating the direction.

Stations at which Anemometers as well as Vanes are Employed.

(**372**) As it is necessary to approach much nearer to the dial of an anemometer than to the dial of a vane in order to read it, positions suitable as regards accessibility are more difficult to obtain when an anemometer as well as a vane is used.

(**373**) **Positions which can be Closely Approached.**—The anemometer to be used in such cases would be one of the following:

Green's small anemometer. Arts. 283, 284.

Foster's small anemometer. Art. 285.

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* For suggestions relative to setting vanes, see Arts. 272 to 275.

Clock anemometer, without electric connections. Arts. 286 to 289.

Some other small dial anemometer.

The vane to be used in combination with any one of the above-named anemometers is the Drum Vane, with a short spindle. Art. 263.

(374) Positions of Inconvenient Approach, but which Admit of a Long Shaft Connection.—The long shaft anemometer and long shaft vane, or the two combined in one (Art. 294), are to be used in such cases, the dials being fixed on a table or bracket in the room below, or on a bracket outside the window. For descriptions of long shaft vane and long shaft anemometer, read Arts. 265 and 293.

(375) Positions on a Hill or distant Building, or other Positions Unsuitable for a Long Shaft Connection.—In such cases one of the following combinations are to be used:

Clock anemometer and a vane, both with electric connections. Arts. 296, 267 to 271.

Modified clock anemometer and vane, with electric connections.

Self-recording anemograph, connected electrically with a small anemometer and a windmill vane. Art. 299.

[NOTE TO ARTS. 365 TO 375.—It is sometimes found that water finds its way between the bottom of the iron box of the electric vane, or of the long shaft vane or anemometer, and the top of the cross head or other support. To obviate this a piece of thin felt, well greased, should be placed under the edge of the box before it is screwed down. The intrusion of water round the edges of the door may be avoided by a similar precaution.]

VELOCITY OF THE WIND ABOUT ANY POINT OF TIME.

(376) The velocity at or about a proposed *point* of time (Art. 5) is inferred from the difference between the readings of an anemometer taken at the beginning and end of a short interval of time, of which the proposed point of time is the middle point, or the distance passed over by the wind in that interval, the velocity required being the whole distance which would have been passed over by the wind in one hour, if throughout that hour equal distances were described in equal times. Art. 3.

If the interval of time between the readings be very short, there is a danger that the result may be vitiated by transient gusts or transient lulls; while on the other hand, unless a self-recording anemograph be employed, a long interval (30 minutes or more) would necessitate too long an attendance of the observer to be conveniently practicable.

On the whole, it is better to take the readings at some interval not less than 5 minutes and not greater than 10 minutes; and as 5 minutes,

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6 minutes, or 10 minutes, are exact divisors of 60 minutes, the calculation will be more simple if one of these intervals, and especially an interval of 6 minutes, be employed.

(377) Rule for Finding the Velocity.—Read the anemometer 3 minutes before and 3 minutes after the proposed time; subtract the first of these reading from the second (adding, if necessary, the whole range of the instrument to the second reading, which is 990 miles in Green's and 1000 miles in Foster's anemometer); reduce the difference to miles and decimals of a mile, if they are not already so expressed, and multiply the difference by 10. The result will be the velocity required.

If the interval of time, instead of being 6 minutes, be 5 minutes or 10 minutes, the differences between the readings are to be multiplied by 12 or 6 respectively.

If the interval of time be not an exact divisor of 60 minutes, such, for instance, as 7 minutes, the velocity is found by dividing the difference between the anemometer readings by the interval expressed in minutes and by multiplying the quotient thus obtained by 60.*

If it were only desired to ascertain the velocity at or about a certain point of time, it would be sufficient to take the readings of that part of the dial which gives miles and tenths, without taking into account the tens and hundreds; but that the readings may be also utilized for finding the whole number of miles since the previous observation, it is better to take the entire reading on each occasion.

Examples of the above Rules as Applied to Anemometers of Different Kinds—Green's Anemometer, or Foster's Small Anemometer.

(1) To find the velocity at or about 7h. 48m. a.m.:

	h.	m.		
1st reading made at	7	45 a.m.	432.6	miles.
2nd "	7	51 a.m.	434.2	"
Difference, or miles in 6 minutes			1.6	"
Velocity, or miles in 60 minutes			16	"

* While an interval of 6 minutes is on the whole the best, it may be sometimes necessary or convenient to use an interval of some other length; thus, if the 6th minute has been suffered by accident to pass, the second reading would be taken at the 7th, or at some subsequent minute. An interval of 10 minutes might sometimes be chosen to allow time for the completion of some other observation in the interval. An interval of 5 minutes would be used when the first reading was accidentally late, or in case of special rapidity being necessary.

The length of the interval will have some reference to the position of the dial. If the dial be difficult of access, so that the time between the readings could not be utilized, (unless it were employed in taking note of the state of the sky,) an interval of less than 6 minutes might be preferable.

(2) Required the velocity about 2h. 8m. p.m.* Suppose that by an oversight the 6th minute had just passed when the observer prepared for the second reading:

	h.	m.			
1st reading made at	2	5 p.m.	723.2	miles.	
2nd "	2	12 p.m.	724.7	"	
Difference, or miles in 7 minutes................			1.5	"	
" " 1 minute			0.21	"	nearly.
Velocity, or miles in 60 minutes			12.6	"	

(3) Required the velocity about 3h. 50m. p.m. from Foster's small anemometer, supposing that time was required to complete some other observation between the readings of the anemometer:

	h.	m.		
1st reading made at	3	45 p.m.	996.4	miles.
2nd "	3	55 p.m.	2.8	"
Difference, or miles in 10 minutes			6.4	"
Velocity			38.4	"

In this example 1000 miles is added to the 2nd reading.

Examples in finding the Velocity about a point of Time from the Clock Anemometer, in which 4 minutes of the Clock Dial represents 1 mile of Wind.

(1) To find the velocity at or about 7 a.m.:

	h.	m.	R.	h.	m.
1st reading made at	6	57 a.m.............	3	6	14.2
2nd "	7	3 a.m.............	3	6	26.2
Difference in 6 minutes				12	minutes of clock,
				or 3	miles.
Velocity, or distance in 60 minutes				30	"

(2) Find the velocity at or about 11h. 48m. p.m., allowing an interval of 10 minutes between the readings:

	h.	m.	R.	h.	m.
1st reading made at	11	43 p.m.	11	11	58.6
2nd "	11	53 p.m.	0	0	7.4
Difference in 10 minutes				8.8	minutes by clock,
				or 2.2	miles.
Velocity, or distance in 60 minutes				13.2	"

In this example 12 R, *i.e.* 12 complete revolutions of the hour hand, is added to the second reading.

* Although the result, 12.6 miles, is strictly the velocity about 2h. 8m. 30s., it may be taken with sufficient accuracy as that proper to 2h. 8m.

(378) Long Shaft Anemometer.—The rule in Art. 377, when applied to the long shaft anemometer, will need modification.

If the dial of the long shaft anemometer be fitted with a *Vernier*, the velocity about a point of time is found by the same process as that used in the case of Foster's small anemometer; but if the instrument be *not* fitted with a Vernier, the velocity may be obtained in the following manner:

Having read the dial to complete miles and estimated tenths, at exactly 3 minutes before the proposed time, *set* the small graduated cylinder, so that its fixed index may point at that one of the two zeros *Oa* or *Ob* which is nearest to it (*Oa*, for example).

At the completion of the 6 minutes, take the reading of the cylinder at which the index is then pointing, and again read the dial to miles and estimated tenths.

Subtract the first reading of the dial from the second, and thus obtain an *approximate* value of the distance moved over by the wind during the interval.

The reading of the small cylinder reckoned from the zero (*Oa* or *Ob*) which was set to the index, increased, if necessary, by 2 miles, or, in some rare cases, by 4 miles, in order that it may become more nearly equal to the approximate value, will be the required distance nearly.*

Examples:

(1) Required the velocity about 11h. 30m. p.m.:

	h.	m.	Dial.	Small Cylinder.
1st reading made at	11	27	8327.4	0
2nd "	11	33	8329.2	1.7
Difference			1.8	1.7
Velocity				17 miles.

(2) Required the velocity about 7h. 20m. a.m.:

	h.	m.	Dial.	Small Cylinder.
1st reading made at	7	15	9997.2	0
2nd "	7	25	0.4	1.1
Difference			3.2	3.1
Velocity				18.6 miles.

In the above example, 10,000 miles is added to the second reading of the dial. Also 2 miles is added to the reading of the small cylinder, in order to make it more nearly equal to the difference derived from the dial.

* The readings given by the small cylinder are nearly 1 per cent. too great, as half a turn is not strictly 1 mile, but 1 mile $- \frac{1}{101}$ of a mile.

(**379**) If the measurement of the velocity were the only object to occupy the observer at the observation hour,* the readings of the anemometer should be taken at equal intervals before and after that hour. There are, however, observations of other kinds to be taken near the same time, so that, if due attention be given to the latter, it is often impracticable to measure the velocity about the observation hour, and it becomes necessary to take the two readings of the anemometer either *both* before or *both* after the hour, the times of reading being so chosen as to allow time for other observations more near to the observation hour, and without any reference to the middle point between the readings.

It is usually required to record at each observation hour the number of miles passed over by the wind since the preceding observation hour, or the difference between the readings of the anemometer at those hours reduced to miles. That the number of miles may be accurately obtained, the readings should be taken *exactly* at the observation hours; but this, as before stated, not being ordinarily practicable, the reading which is taken most near to the observation hour on each occasion may be employed.†

CHAPTER II.

REGISTRATION OF METEOROLOGICAL OBSERVATIONS.

SECTION I.

RECORD OF FACTS RELATIVE TO THE STATION AND THE APPARATUS.

(**380**) The conclusions to be derived from the meteorological observations taken at a station are influenced in a great degree by the geographical position, elevation, and physical features of the district in which the station is placed; on the position in that district which the station occupies; on the general character of the *premises* of the observer, including the form and dimensions of buildings, and other objects in and

* By the term "Observation Hour" is understood the point of time (not necessarily a full hour) about which the several observations forming a group are taken; thus, 7h. 25m. a.m. (Toronto time) is the observation hour for the morning synchronous observations on the North American Continent.

† The result will be more accurate if the reading of the anemometer be corrected for the motion of the wind between the time of reading and the observation hour, so as to be reduced to what it would have been if taken *at* the hour.

about the premises; and on the quality and mode of exposure of the instruments with which the observations were taken.

As it is of great importance that information of the kind above indicated be recorded at the Central Office, observers are invited to lend their aid in procuring, each for his own station, such details as shall be presently specified.

It is likely that it may not be in the power of every observer to furnish all the information that it is desirable to collect, and that it may be necessary sometimes to obtain it through other channels; but it is essential that all particulars relating to the *instruments* and their *exposures* be forwarded from time to time to the Central Office by the observer himself.

The nature of the information that it is desired to procure is further particularized in the following articles:

(381) Facts Descriptive of the District.—For describing a district, no rules that are applicable to every case can be laid down. The following particulars, however, being of special moment, should if possible be procured:

(1) The latitude and longitude of some known point, with the authorities.

(2) The elevation of some permanent mark (called a bench mark)* above mean sea level, above the level of some lake, and also above a specified point in some railway, with the names of the persons from whom the levels were procured, and the dates and other circumstances connected with the operation of levelling.

(3) The names, position, direction, and places of discharge of the streams or rivers which drain the district.

(4) The position of the lines of water-sched,† or the ridges which separate contiguous systems of drainage.

(5) The names, position, extent, and elevation of any high land in the neighbourhood.

(6) The names, position, and extent of any lakes or sheets of water, and if possible their elevation above mean sea level.

(7) The general character of the country, whether cleared or uncleared, and if possible the relative proportions of each.

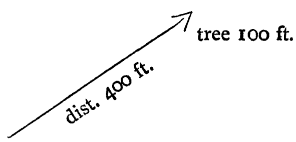
* If there be no recognized bench mark in the neighbourhood, some point in a railway may be used for that purpose.

† Often spelt water-shed.

It is desirable that a map of the district, and a map or plan of the town or village, or, if they cannot be obtained, rough plans constructed by the observer, should be furnished to the Central Office.

The position of the premises where the observations are taken should be marked on the map of the town; and on the same map should be also shown the positions of the "*bench mark*," and of the point whose latitude and longitude are stated in the description of the district.

(382) Facts Descriptive of the Premises.—The observer should construct a ground plan of his premises and of buildings* within 100 yards from the thermometer shed; and if there be any lofty buildings or trees within 200 yards of the thermometer shed, he should shew their positions by lines drawn in the directions pointing to them, and their approximate distances and heights in *feet* by figures, thus:



The heights in feet of the roof over different parts of the building, and the heights of trees, should be written in figures on the ground plan.

Views or elevations of the various buildings on the premises would also be useful.

It is requisite that a well defined horizontal mark† be made on some solid part of the building, and that its vertical height *above* or *below* the bench mark be ascertained by careful levelling. The direction and horizontal distance of this mark, both from the bench mark and from the point whose latitude and longitude are known, should also be recorded.

Letters or other marks of reference should be placed on the plan and elevations to indicate the positions of the instruments.

(383) Changes in the Descriptions of the District and Premises.—As regards the *district*, it is likely that any change to be made in the description will be of the nature of an addition or a correction;‡ but alterations in the description of the *premises* may become necessary by the progressive growth of trees or by their removal, or by the erection or demolition of buildings.

* The utility of the plan would be much increased if it were drawn to scale.

† The sill of a window or door would serve the purpose indicated.

‡ In some districts an alteration in the statement regarding the relative extent of cleared and uncleared land will be required from time to time.

(384) Record of Information relative to Instruments.—The information to be recorded relative to instruments is of three kinds.

(*a*) A list of apparatus and other articles connected with the observations at the station, with notices of the arrival or return of instruments, and other particulars relating to them.

(*b*) A statement of the positions and mode of exposing the several instruments.

(*c*) A statement of the instruments in actual use for each purpose at different times.

(385) Form for Recording the Apparatus in Charge of the Observer.—The list of apparatus, &c., referred to in the paragraph marked (*a*) in the preceding article, is to be entered on a form, the columns of which are headed as follows:

(1) Designation of instrument.

(2) Description.

(3) Number or other mark.

(4) Name of maker.

(5) Proprietor.

(6) Date when received.

(7) From whence received, and by what mode of transit.

(8) If instrument arrived at the station in a damaged condition, state particulars.

(9) If damaged while at the station, state particulars.

(10) If repaired, state by whom, and give dates.

(11) If sent away for repair, state to whom sent, and date when sent, and also date of return.

(12) If lost, stolen, or condemned, give dates and particulars.

(13) If returned to Central Office, or transferred to some other station, give dates and particulars.

Remarks on the Mode of Filling the Several Columns.

Column (1).—The *general* name, without specifying the class, such as "Barometer," "Thermometer," &c.

Column (2).—If an instrument has been supplied directly from the Central Office, it will be sufficient to give its *special* designation. Thus a barometer might be described in such terms as "Marine," "Small, with adjustable cistern;" and a thermometer by "Ordinary Mercurial," "Maximum," and so on for other instruments.

If an instrument be procured otherwise than from the Central Office, a more detailed description will be necessary, in addition to the *special* designation.

For a barometer, state internal diameters of tube and cistern (if known) with the authority, the range of graduation, and whether graduated to .01 or .002.

For a thermometer, state whether it is furnished with an attached scale, and if it is graduated on the *stem* as well as on the attached scale, and also if the divisions represent full degrees or some other measures. State also the range of the graduations, and whether the bulb is or is not partly surrounded by wood or metal.

If a barometer or thermometer be obtained otherwise than through the Meteorological Office, a copy of the index corrections should be furnished by the observer to the Central Office, with the name of the authority from which they were obtained, and the date of the comparisons.

If the rain gauge be not supplied by the Dominion Meteorological Office, give the diameter of the mouth, and also state whether the measuring glass be graduated to cubic inches and tenths, or if the divisions *correspond* to linear inches and decimals when used exclusively with that particular gauge. Arts. 229, 230.

In describing anemometers not supplied directly from the Central Office, state the range of the system of dials.

If the station be furnished with Gibbon's anemograph, state whether the direction is indicated on the paper by dots or by letters, and whether the direction is marked at the end of every mile or at every fifth minute.

Column (6).—State whether the article was conveyed to the station by *hand*, by express, or by other means.

The other columns need no explanation.

When from any cause the space in a column is insufficient to contain all that it may be desired to enter in it, the bulk of the matter must be transferred to another page, a reference to it being inserted in the column, together with any prominent fact for which room can be found.

(386) Record of the Exposure of Instruments.

Barometer.—The most important facts to be given relative to the barometer are the height in feet of the level of the mercury in the cistern above the fixed horizontal mark (Art. 382), and the height in feet above mean sea level. It is desirable also to state the height above the ground outside the house, and the height in inches above the floor, and whether the barometer is suspended in a case.

Thermometers.—It should be stated which of the localities named in Arts. 193 to 195 is employed, and the distances of the shed from various buildings. In any case the height of the bulb of the principal thermometer above the soil should be given in feet and inches.

Rain Gauge.—The distances of the gauge from various trees and buildings should be given in feet, and the height of the mouth above the soil in inches.

Vane and Anemometer.—The description of the mode of exposure should be given in the terms of Arts. 300 to 313, with the heights above the roof and ground.

(387) Statement of the Instruments used for each purpose at any given time.—Art. 384 (*c*). It may sometimes occur that spare instruments are kept at a station, either for special observations or as a provision against accident, or that for other reasons there are at the station more instruments than one of a kind. As instruments of the same kind may differ considerably in their instrumental errors, it is essential that it be known with certainty what instruments were employed in every case for the various observations recorded in the register book ; and hence, in addition to the list of apparatus described in Art. 385, it is very useful to keep a separate statement of the instruments in actual use from time to time. The form supplied for this list will explain the mode of making the several entries in it.

(388) Books in which above named Records are to be Entered.—It has been seen that the records relative to the station and apparatus, which it is desirable to keep, are of the following kinds:

Facts descriptive of the district and town. Art. 381.

Facts descriptive of the premises. Art. 382.

List of apparatus in charge of the observer. Art. 385.

Exposure of instruments. Art. 386.

Statement of instruments in actual use. Art. 387.

As soon as the various particulars named in the four first lines of the preceding have been collected by the observer, he should enter them in a book separate from that in which the observations are recorded, and should forward an exact copy of the same to the Central Office, together with such maps, plans, or drawings, as he may have procured or constructed.

When any alterations are made in these records, a report to that effect should be made at the time of occurrence. For the convenience of reference, it is desired that such reports be never sent as part of a *letter*, but on a separate paper.

The statement of the instruments in actual use (Art. 387) is to be entered at the beginning of every *register* book, together with the following particulars extracted from the description of the exposure of instruments.

The height of the barometer cistern above the ground, also its height above the fixed mark in the building, above the bench mark, and above mean sea level.

The height of the bulb of the principal thermometer above the soil.

The height of the anemometer cups and vane upon the roof and above the ground.

At the conclusion of each year or other period for which the register book is adapted, an exact copy of the statement entered at the beginning of that book is to be forwarded to the Central Office; besides which, whenever any change is made either as regards the instruments used or their positions, a notice is to be sent at the time, on a separate paper, to the Central Office.

(389) **Record of Index Corrections.**—As it is convenient that the tables of index corrections be on separate cards, and as there is a danger that those cards may be mislaid, it is desirable that copies of the index corrections of all instruments received at the station be written in the book which contains the description of the station and apparatus. When, in consequence of age, an alteration has occurred in a thermometer such as to necessitate a new table of corrections, the old table in the book should be *scored through* (not erased), and a reference made to the place where the new table is written.

SECTION II.

ON FORMS FOR REGISTERING OBSERVATIONS.

(390) For recording the primary meteorological elements and phenomena obtained by observation at a station, and for arranging the numbers which express their intensity or frequency in such a manner as to admit of the convenient intercomparison of like quantities or numbers (or averages derived from them) in different hours, different days, different months, and different years, four kinds of form are required.

(1) The *daily register*, in which all the elements or other numbers obtained from observation at the *same* hour, are placed side by side in the same horizontal line, while *like* numbers obtained by observation at *different* hours are written in vertical columns.

(2) The *monthly abstract*, in which the numbers recorded in the daily register are re-arranged in such a way that like numbers, obtained at different hours in the same day, are placed in horizontal lines, and those at the same hours in different days in vertical columns, so as to facilitate the computation of monthly averages.

(3) *Annual abstracts*, in which like elements or averages derived from them in *different months* are placed consecutively in juxtaposition, either in horizontal rows or in vertical columns, to facilitate their intercomparison, and the computation of yearly averages.

(4) *Secular abstracts*, wherein like elements or averages derived from them corresponding to different *years*, and which are similar to each other as regards the time of day, season, &c., are arranged so as to admit of the convenient intercomparison in different years.

(391) The Daily Register.—The annexed form marked (A) is a sample of *part* of a form for a daily register, adapted for the registration of observations of the several elements and phenomena made at each of the twenty-four hours in one day. It is seen that provision is made for the actual readings of the barometer, and also for the readings as modified by the successive application of the two classes of instrumental corrections, and the reduction to sea level. Throughout the form, moreover, columns are prepared for the uncorrected as well as for the corrected readings of each instrument. Of the two rows of compartments at the foot of the form, the first is designed to contain the *sums*, *i.e.*, the results obtained by the addition of the several corrected observations in the columns below which the compartments respectively stand; while in the second row are to be written the *means* or averages, *i.e.*, the results obtained by dividing each sum by the number of observations of which it is composed, a number which in the present case, as the observations are supposed to be taken at every hour, is 24.

DAILY FORM (A).

Daily Register of Meteorological Observations at ————, taken at every hour, local time.

HOURS.	BAROMETER.					TEMPERATURE OF THE AIR.		&c.
	Observed.	Att'd Ther.	Corrected for Index Error.	Reduced to Temp. 32°.	Reduced to Sea Level.	Observed.	Corrected.	&c.
			January	1st, 1843.				
1 a.m.	29.766	21.0	29.773	29.793	30.223	25.3	25.5	
2 "	29.818	24.0	29.825	29.837	30.259	25.7	25.9	
3 "	29.750	24.0	29.757	29.769	30.188	26.2	26.4	
.						.	.	
.						.	.	
Noon	29.628	24.0	29.635	29.647	30.057	33.2	33.3	
1 p.m.	29.580	28.0	29.587	29.588	29.996	34.0	34.1	
.						.	.	
.						.	.	
11 "	29.658	28.0	29.665	29.666	30.077	29.7	29.8	
Midt.	29.664	28.0	29.671	29.672	30.078	28.5	28.6	
Sums				712.872	722.280		755.8	
Means				29.7030	30.0950		31.49	

(392) The Monthly Abstract.—The form marked (B) is a sample of part of a form for a monthly abstract adapted for the observations of *one* element only, (such as temperature, for example,) made at each hour of every day in one month.

It is seen that the horizontal row of numbers opposite to Jan. 1st is identical with the column in the daily register under the heading "Temperature of the air corrected," and that the "sum" and "mean" from the daily register are placed in the two columns on the right, respectively headed "sums" and "means." The remaining horizontal rows opposite to Jan. 2 to Jan. 31 inclusive, are similarly transcribed from the columns of temperature proper to the corresponding days of the month in the daily register.

The "sums" at the foot of the form, corresponding to the several hours, are obtained in every case from the addition of the numbers in the columns under which they respectively stand; while the "means" at the foot of the form are obtained by dividing those sums by the number of days in the month.

It is easily seen that the sum of the twenty-four sums that correspond to the several hours of the day must be identical with the sum of the daily sums in the last column but one on the right. Thus the result of adding together 824.6, 830.8, 824.6, &c., to 889.7, 827.7 *should* be 21412.3, which was in the first instance obtained by the addition of 755.8, 720.0, 846.0, &c., to 957.6, 1002.0. If the results of the two additions are not exactly the same, it is certain that there has been an error in the calculation.

Again, 892.18, the sum of the column of daily means on the right, may also be obtained by dividing 21412.3 by 24.*

Finally, 28.78 the *general* monthly mean (as distinct from the monthly means proper to *the separate hours*), although properly found by dividing 892.18 by 31, may also be obtained by dividing 690.72 by 24.†

Twelve similar monthly forms are required for temperature, and as many for barometric pressure, and for each of certain selected quantities recorded in the "daily register."

MONTHLY FORM (B).

Monthly Abstract of the Temperature of the Air observed at every hour, local time, in Jauuary, 1843.

DAYS.	1 A.M.	2 A.M.	3 A.M.	....	11 P.M.	MID.	SUMS.	MEANS.
1	25.5	25.9	26.4		29.8	28.6	755.8	31.49
2	26.9	27.2	27.4		30.3	31.0	720.0	30.00
3	32.5	30.4	30.0		33.5	36.0	846.0	35.25
.								
.								
.								
30	38.2	37.6	34.0		36.7	37.2	957.6	39.90
31	37.0	36.8	36.6		40.2	41.3	1002.0	41.75
Sums	824.6	830.8	824.6		889.7	827.7	21412.3	892.18
Means	26.6	26.8	26.6		28.7	26.7	690.72	28.78

* † If in every case, including the computation of daily and hourly means, the divisions be *complete*, the quotients, when the division does not terminate, being expressed in part by a circulating decimal, there should be an *exact* agreement between the sum of the daily means and the mean of the hourly sums, and also between the mean of the daily means and the mean of the hourly means. If, however, the divisions are carried on, say to the second decimal place and are there stopped, a small discrepancy in the two results does not necessarily show that the calculation has been in error.

(393) Annual Abstracts.—C_1 is a sample of a form suited for exhibiting in one view the daily mean temperature of the air on every day throughout the year, together with the general monthly means of temperature for each month.

The numbers in the upper row are transcribed from the right hand column of the monthly abstract (B) for January, the second decimal place being omitted here for brevity, and the numbers in the other rows are taken from the monthly abstracts corresponding to the other eleven months.

C_2 is a sample of a form for shewing in one view, for every month in the year, the monthly means of temperature for every hour of the day, as well as the general monthly means.

The numbers in the upper row are obtained from the row of monthly means at the foot of the monthly abstract (B) for January, and the succeeding rows are obtained from similar monthly abstracts corresponding to the remaining months.

Forms similar to C_1 and C_2 would be employed for each of the separate kinds of observation for which it might be desired to draw up an annual abstract.

ANNUAL FORM (C_1).

Annual Abstract of Mean Daily Temperature, shewing the Mean Daily Temperature in every day of 1843.

Months.	Days of the Month.							Means.
	1	2	3	....	29	30	31	
January	31.5	30.0	35.2		40.2	39.9	41.7	28.78
February	11.7	15.6	23.6		..	..	..	15.92
.								
.								
.								
November	36.2	35.1	31.2		30.2	27.2	..	33.25
December	38.8	31.7	32.4		27.3	26.9	27.2	30.83

ANNUAL FORM (C_2).

Annual Abstract, shewing, for 1843, the Monthly Mean Temperatures for each of the 24 hours.

Months.	1 A.M.	2 A.M.	3 A.M.	....	10 P.M.	11 P.M.	Mid.	Means.
January	26.6	26.8	26.6		29.0	28.7	26.7	28.78
February	13.3	13.1	13.1		14.5	13.9	13.6	15.92
.								
.								
.								
November	31.2	31.0	30.9		32.7	32.3	31.6	33.25
December	29.7	29.8	29.7		30.0	29.6	30.1	30.83

(394) Secular Abstracts.—D_1 is a sample of a form adapted for a shewing in one view the daily mean temperature of the air on every day in the month of January in a succession of years. The numbers in the upper row corresponding to 1843 are transcribed from the right hand column of the monthly abstract (B) for January, 1843, and the numbers in the succeeding rows are taken from the monthly abstracts corresponding to January in 1844, and succeeding years.

The form D_2 is designed for exhibiting, for one month and for a series of years, the monthly means of temperature for every hour of the day, and the general monthly mean. The numbers in the upper row are obtained from the row of monthly means at the foot of the monthly abstract (B) for January, 1843, and the succeeding rows are taken from similar monthly abstracts corresponding to January of 1844, and succeeding years.

Forms similar to D_1 and D_2 would be employed for each of the separate kinds of observation or average for which it might be desired to construct a secular abstract.

If for the *days* of the month in the column headings of D_1 the *names* of the twelve months and four quarters be substituted, and a column headed "year" be added, the form will serve for comparing in different years the monthly, quarterly, and yearly means and extremes and averages of daily extremes of temperature, and of other elements. The modified form may also be employed for comparing in different years the amount of rain or snow that falls in each month, each quarter, and the year; the frequency of rain or snow, and of other phenomena, or the number of days in which they respectively occur.

It may be noticed that rows of compartments are not provided at the foot of the form for the insertion of the sums and means of the columns. Where it is desired to combine several years, it is better to write the sums in a separate book or paper, so that as time advances additional years may be incorporated with the sums before obtained.

SECULAR FORM (D_1).

Abstract of Mean Daily Temperatures for January in a series of years.

YEARS.	DAYS OF THE MONTH.							SUMS.	MEANS.
	1	2	3	....	29	30	31		
1843	31.5	30.0	35.2		40.2	39.9	41.7	892.2	28.78
1844	25.6	33.4	32.7		4.8	10.0	6.6	640.8	20.67
1845	35.2	30.8	37.6		25.2	16.8	7.4	827.1	26.68
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SECULAR FORM (D_2).

Abstract of Monthly Mean Temperatures for every hour in January for a series of years.

YEARS.	1 A.M.	2 A.M.	3 A.M.	....	10 P.M.	11 P.M.	MID.	SUMS.	MEANS.
1843	26.6	26.8	26.6		29.0	28.7	26.7	690.7	28.78
1844	18.8	18.6	18.5		20.8	20.3	20.0	496.1	20.67
1845	24.7	24.8	24.6		25.4	25.1	24.8	640.3	26.68
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.									
.									

(395) Modifications of Forms A, B, C, D.—Although the forms described are designed in the first instance for *hourly* observations, they can be adapted, with slight modifications, to suit the cases when the observations are taken at every second or third hour, or less frequently.

Daily Register, Form A.—There are certain particulars—such, for example, as the highest and lowest temperatures shewn by the self-registering thermometers—the range of temperature, &c., for which, from the nature of the case, only one entry can be made in each day. To provide for these, and to reduce the number of columns in form A, it is convenient (when the regular observations are taken very frequently) to employ a supplementary form suited to contain in each of its columns one month's observations of the same kind. The supplementary form is similar to form (B), except that the columns are headed by the *name* of the observation instead of by the hour of the day. The form for the daily register is not affected by reducing the number of hours at which observations are taken, except as regards the length of the columns adapted for a day; thus, while twenty-four daily observations require the whole depth of a page, the observations of two days or of three days can be entered in the same space when twelve or eight observations only are taken in each day.

Monthly Abstract, Form B.—A reduction in the number of columns is the only direct effect of diminishing the number of daily observations; but if there be only *three* observations in the day, monthly abstracts for more than one element, or monthly abstracts for more months than one of the same element, can be entered on one page.

Annual Abstract.—Form C_1 is not affected by reducing the number of daily observations. C_2 is affected in the same manner as Form B; and if there be only three observation hours in each day, abstracts for more elements than one can be entered on the same page.

Secular Abstracts.—Form D_1 is not affected by reducing the number of observations taken each day, and D_2 is affected in the same manner as B; but different months of the same element should be placed on one page rather than different elements for the same month.

(396) Combination of Daily Register and Monthly Abstract. —When the number of observation hours in the day does not exceed three, and observations of only *a few different kinds* are taken at each observation hour, it is often the practice to employ for a daily register a *combination* of forms similar in principle to (A) and (B).

In the combined form the days of the month are written on the side of the page, and the names of the different kinds of observation along the top. The observations corresponding to the three hours are placed in parallel columns, the three corrected readings being together in one group, on the right of the group containing the three uncorrected readings, as shewn in the annexed sample (F).

(F).—*Sample of part of a Form for a Daily Register, in which the Daily Register and Monthly Abstract are Combined.*

Day of Month.	Temperature of the Air.							Self-Registering Thermometers.					Direction of Wind.			&c.
	Observed.			Corrected.			Mean.	Maximum.		Minimum.		Range.				
	7 a.m.	2 p.m.	9 p.m.	7 a.m.	2 p.m.	9 p.m.		Observed.	Corrected.	Observed.	Corrected.		7 a.m.	2 p.m.	9 p.m.	&c.
1																
2																
3																
.																
.																
.																
30																
31																
Sums																
Means																

This form of daily register is open to the objection that it does not allow the condition of the several elements at the same hour to be seen at one view so conveniently as in Form (A), where the observations made at different hours are written in separate lines. On the other hand, it possesses the very great advantage that by using it the labour of transferring the corrected readings to a monthly abstract is avoided.

On the whole, when observations of the barometer and wet bulb thermometer are not taken, it is better to employ the combined form.

If *all* the ordinary observations be taken three times daily, the very great length of the horizontal lines that would then be necessary in order to place the uncorrected as well as the corrected readings of the three observations in parallel columns, (the barometric pressure and temperature alone requiring twenty-five columns,) would render the combined form extremely cumbersome. On this account it is better, when observations of the barometer are to be provided for, to employ a daily register resembling Form (A) in its general character.

It is a frequent practice, both in Europe and on this continent, to employ for the registration of a full set of observations, including three daily readings of all the ordinary instruments, a form of daily register so arranged that the observations at the three hours may be placed, as in F, in parallel columns; and in past times many stations in Canada have been furnished by the Central Office with forms of the same kind.

Although this form possesses, in common with those of the sample (F), the merit of rendering unnecessary a separate monthly abstract, it is subject to the serious objection that it is not provided with columns for the *uncorrected* readings of the instruments; and in fact the form is constructed on the understanding that the index corrections are to be applied *mentally* as the readings are taken, the corrected readings only being entered on the register. Now experience shews that the risk of error is greatly increased by adopting this practice, and on this account it is desired that it should be universally abandoned by Canadian observers.*

(397) Daily Register Forms in use at Canadian Stations.— The forms of daily register at *present* used at Canadian stations, samples of which are furnished with this volume, are as follows:

Weekly Form I.—This form is adapted for *three* observations daily,

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* The precaution of entering the actual readings of the instruments is not a superfluous one, even in the case of experienced observers; in fact, the best observers are usually most keenly alive to the importance of guarding against the intrusion of error, and the last to object to these safeguards.

and is divided by horizontal lines into seven compartments corresponding to the days of the week, the whole occupying four pages.

Forms A and A_1.—These are similar,* as regards their headings, to the Weekly Form I., and only differ with respect to the *number* of observation hours for which they provide, Form A being divided into three compartments, each intended for eight or for nine daily observations, and Form A_1 not being divided into compartments, so that it may be used either for two days, containing twelve observation hours on a page, or for one day, containing twenty-four observation hours.

Form 20.—This is a weekly form adapted for only *one* observation daily. It is employed for the synchronous observations made at 0h. 42m. p.m. Greenwich time (7h. 25m. a.m. Toronto time nearly), which are used in the compilation of the International Bulletin, a work undertaken by the Washington Signal Office at the request of the Vienna Congress. The readings of the columns are the same as those of the Weekly Form I.†

Form 17.—This form is adapted for three observations daily of temperature and a few other elements. The readings for the three hours are entered in parallel columns, so that all the observations made in one day occupy a horizontal line, extending across the four pages. The observations for one month require one sheet of four pages.

Rain Form.—This is intended for service at stations for which no instruments but rain gauges are provided. It is adapted for recording, for one month, the depth of rain and snow which was measured on each day within the month, and the times on each day when it begun and ended, together with the general state of the weather, and such phenomena as admit of being observed without the aid of instruments.

(398) Monthly Abstracts used at Canadian Stations.—There are three forms of monthly abstracts in use, namely, the following:

Form 11, for the abstraction of the corrected readings of an ordinary full set of observations taken three times daily, and recorded in the daily register of the Weekly Form I.

Form B, which is suited to contain the monthly abstract of one element only on a page, the observations being taken eight times or twelve times daily, and is used for abstracting the observations recorded in the daily registers, Forms A and A_1.

Form C, which is supplementary to Form B, and is designed for such observations as require but one entry only on each day. See Art. 395.

*† The headings are not absolutely identical in all cases, slight variations being introduced in different editions even of the same form.

(399) Daily, Monthly, Yearly, and Secular Summaries.—A summary with respect to any period of time, such as a day, a month, a year, &c., is a statement giving the mean or average condition of the several elements during the period concerned, and certain selected exceptional examples of them, instead of their values in detail. Summaries may vary considerably as regards the number of particulars which they include. It is requisite that the observation hours from which the means are derived should be stated in the summary.

The following are samples shewing the general character of summaries for different periods.

Daily Summary.—

Part of a Daily Summary of Meteorological Observations at ——, for January 1, 187 , (Means from Observations at 7 a.m., 2 p.m., and 9 p.m.).

Mean barometric pressure reduced to temp. 32°	29.476
" " sea-level	29.642
Mean temperature of the air	30°
Highest temperature in 24 hours	34°
Lowest " "	27°
Depth of snow	2.5 inches
Began at	6 a.m.
Ended at	noon

&c., &c., &c.,

Monthly Summary.—The more condensed form of monthly summary resembles in its general character the daily summary shewn above; but in addition to the several particulars there given, it should properly include some others. Thus the monthly summary should shew not only the highest and lowest temperatures in the month, but also the monthly *averages* of the highest and lowest temperatures of every day, and the warmest and coldest days, or the extremes of the daily means of temperature. There are also other details which may be properly included, such as the number of days in which rain fell, the number of days of snow, and of days in which neither rain nor snow fell, the number of days when certain other phenomena were observed, such as lightning, hail, auroras, &c., &c.

Sometimes the monthly summary is further extended, so as to include the monthly means at the separate hours of observation, as well as the *general* monthly means derived from all hours. When these separate means are shewn, another form is required in addition to that described above. A convenient mode of arrangement is to place the different hours of observation along the top of the paper, with the names of the various elements and observations on the left side.

Annual Summary.—A common and convenient arrangement for an annual summary consists of the twelve monthly summaries in parallel columns, headed by the names of their respective months, and with the names of the several elements on the left side of the paper. To these may be added five columns containing analogous results for the four quarters and year.

If condensation be desired, the twelve monthly and four quarterly columns may be removed, the column for the year only being left; in which case the annual summary is reduced to a form similar in the main to that for a single day; or the four quarterly columns, as well as the column for the year, may be retained.

Secular Summaries.—A secular summary may be drawn up in a form nearly precisely similar to that just described; but between it and an annual summary there is this distinction, that whereas an annual summary shews certain results derived from the observations of one year only, a secular summary shews analogous results derived from the observation of several years combined.

If it were desired to shew, with respect to one element, (such as temperature, for example,) the relation between the monthly means of different hours based on the observations of several years, the means or averages of each of the columns in the secular abstracts on Form D_2 (See Art. 394) should be taken with respect to every month, and the results combined in a form similar to the annual abstract on Form C_2. See Art. 393.

In a certain sense,* a table compiled in the manner indicated above would constitute a secular summary with respect to the particular element in question.

(400) This section is designed for giving to observers, and to meteorological students generally, a few slight hints relative to the nature of the processes by which meteorological observations are combined, and in other ways prepared for subsequent investigations; so that, if any one be disposed to work out the successive steps for himself, he may have an opportunity of judging as to the practicability of his doing so consistently with other demands on his time. As the persons having leisure and inclination for such labour must of necessity be very few, observers generally are not invited, and still less are they required, to do more in the way of returns than to furnish an exact transcript of their daily

* In the ordinary sense of the term, a summary should contain a synopsis of all or most of the meteorological elements.

registers, as stated in Art. 432, and also, at some stations, to draw up monthly abstracts of the observations, and forward copies of the same to the Central Office. More detailed information relative to the mode of compiling the various abstracts and summaries will be furnished on application to those observers who may be desirous of engaging in such work.

SECTION III.

CLASSIFICATION OF STATIONS, TIMES FOR OBSERVING, AND MODE OF ENTERING THE OBSERVATIONS IN THE REGISTERS.

Classification of Stations.

(401) Classification proposed by the Vienna Congress.—The Vienna Congress recognizes three classes of observing stations.

Stations of the First Order, at which observations are conducted on a large scale, *i. e.*, either by hourly readings, or by self-recording instruments.

Stations of the Second Order, where complete and regular observations of the usual meteorological elements, such as pressure, temperature and humidity of the air, wind, cloud, rain, &c., are taken, but with less frequency than at stations of the first order.

Stations of the Third Order, where only some of these elements are observed.

(402) Classification of Canadian Stations.—The classification which has obtained in the meteorological service of the Dominion of Canada is as follows:

Chief Stations, where all the ordinary observations are taken, day and night, at equal intervals of time not exceeding three hours.

Telegraph Reporting Stations, where all the ordinary observations are taken three times daily at the same *absolute* times,* namely at 7 25 a.m., 4 25 p.m., and 10 50 p.m., Toronto time, and are reported by telegraph, as soon as taken, to the Central Office at Toronto.

Ordinary Stations of the First Class, where all the ordinary observations are taken three times daily at certain *local* times to be presently specified.

* These hours were selected, in the first instance, by the Signal Office at Washington, and are employed in Canada in order that the observations at all telegraph reporting stations throughout the continent may be synchronous, *i.e.*, be made at the same *absolute time*. The *local* times at different places vary of course very considerably.

Ordinary Stations of the Second Class, where regular observations of temperature, the direction and velocity of the wind, and the state of the weather, are taken three times daily at regular *local* times, the rainfall being also measured.

Ordinary Stations of the Third Class, where records are kept of the fall of rain and snow, and the general state of the weather.

(403) The Classification of Canadian Stations compared with that proposed by the Vienna Congress.—There is but *one station in Canada*, namely, the Magnetic Observatory at Toronto, at which continuous records of barometric pressure, and of the temperature of the air and of evaporation, as well as of the direction and velocity of the wind, are kept by self-registering apparatus; and this station is properly the only one which fulfils the conditions necessary to entitle it to be ranked as a "station of the first order," according to the Vienna programme.

The chief stations, as regards the frequency of their observations, and also on account of the fact that nearly all of them are furnished with self-recording anemographs, should take a rank superior to those of stations of the "second order;" but they cannot properly be regarded, excepting in a partial sense, as stations of the "first order."

It is to be hoped that this reproach will be wiped away, and that before long there will be established in every Province of the Dominion at least one Meteorological Observatory, fully equipped and with an adequate staff.

Telegraph stations and ordinary stations of the first class correspond to stations of the "second order" in the Vienna classification, while ordinary stations of the second and third classes in the Canadian classification are to be reckoned as stations of the "third order."

(404) The Meteorological Day.—In every case the meteorological day begins and ends at midnight, and is therefore identical with the ordinary civil day.

ON THE HOURS OF OBSERVATION.

(405) Hours for Reading Barometer, Thermometer, &c.—The hours at which the regular observations are to be taken depend on the class in which the station is included. In stating the combinations of hours proper to the three primary divisions—"Chief," "Telegraph" and "Ordinary"—it will be convenient to consider them in a reverse order:

Ordinary Stations.—The regular observations are to be taken, when practicable, at 7 a.m., 2 p.m., and 9 p.m. If the circumstances of the station render these hours either impracticable or very inconvenient, one of the following combinations may be employed, those which stand higher in the list being taken in preference to those below it:

6 a.m.	2 p.m.	10 p.m.
7 a.m.	1 p.m.	9 p.m.
8 a.m.	3 p.m.	10 p.m.

It is undesirable to change the hours of observation, unless it be by adopting a combination that stands higher in the preceding list, with a fair probability that the new combination will be permanently used; and a change should never be made except at the termination of the month.*

Telegraph Reporting Stations.—The hours for observation are 7 25 a.m., 4 25 p.m., 10 50 p.m., Toronto time. The local times corresponding to the above are to be found by applying to them the difference of longitude between the station and Toronto, expressed in hours and minutes, the difference being added or subtracted according as the place is to the east or to the west of Toronto.

Chief Stations.—When the chief station is not also a telegraph station, or one at which the telegraph hours are used, the hours should be such that the *last* observation hour may be at the end of the meteorological day, or *midnight;* so that if the observations be at every *third* hour, the hours will be—

3 a.m.	6 a.m.	9 a.m.	noon;
3 p.m.	6 p.m.	9 p.m.	midnight;

and if the observations are taken twelve times in the day, the even hours should be taken, the *first* hour being at 2 a.m.

If a chief station be also a telegraph reporting station, or if the telegraph hours are used, and the observations proper to the station as a *chief station* be taken at intervals of three hours, the times can be chosen so as to include the telegraph hours of 7 25 a.m. and 4 25 p.m., the interval between these times being a multiple of 3 hours. At such chief stations nine observations in all will be taken—of which two will be common to the two systems, and one (that at 10 50 p.m., Toronto time,) belonging to the telegraph system only.

* It would be very desirable, when a change of hours is made, to take the observations for *both* systems of hours on the last three days of the old, and on the first three days of the new month.

If the chief station be one at which observations are reported by telegraph at the three telegraph hours, and the observations of the chief station, *as such*, be at alternate hours, they must be taken at the even hours local time, without reference to the telegraph hours.

(406) Hours for Reading Maximum and Minimum Thermometers.—When practicable, these instruments should be read and set at midnight, so that their readings may indicate the highest and lowest temperatures that occur within each meteorological day. When midnight is not included among the regular observation hours, the maximum and minimum thermometers should be read at that regular observation hour which is nearest to midnight. At telegraph stations, or stations using telegraph hours, the *local* times for reading these instruments will vary at different places. At ordinary stations they will be read and set at 9 p.m., or at 10 p.m., if 10 p.m. is used instead of 9 p.m. as one of the regular observing hours.*

(407) Hours for Measuring Rain or Snow.—If observations of rain and snow 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 or at midnight, so that the rain then measured would be the rain which had actually fallen on the day then terminated. At those chief stations, therefore, which include midnight as one of the regular observing hours, a measurement of the rain should be made at midnight, in addition to that made at some hour common to stations of all classes. As regards the hour for general use: as midnight is obviously unattainable in most cases—and even 9 p.m., although suitable for ordinary stations of the first and second class, is much less convenient than a morning hour for the great majority of persons, who might be willing to undertake to measure the rainfall if an hour at which they could conveniently engage to be at home were chosen for the observation—it is best, on the whole, to adopt as the time for measuring rain or snow 7 a.m., or the regular observing hour nearest to 7 a.m., when, as in some cases, 7 a.m. is not one of the regular observation hours.

Wherever the circumstances of the station make it convenient, there should be at least one measurement of rain late in the day, in addition to that made in the morning. At telegraph reporting stations such

* There are certain stations at which, for special reasons, the self-registering thermometers are to be read at some other hour in addition to the hour named above. In such cases a separate communication will be made to the station concerned.

additional observations are provided for, as at these stations the rain and snow that may have fallen since the preceding observation hour is systematically recorded at each of the three hours, namely, 7 25 a.m., 4 25 p.m. and 10 50 p.m., Toronto time.

The following scheme shews, for different stations, the hours at which *additional* measurements of rain and snow are desirable.* In each case the hours are placed in the order of their comparative importance.

Chief Stations at which no telegraph hours are used, the morning observation of rainfall being 6 a.m.

Additional observations: (1) Midnight; (2) noon; (3) 6 p.m.

Chief Stations which are not also telegraph stations, but at which the eight hours of observation include the morning and afternoon telegraph hours; the morning observation of rain being at 7 25 a.m., Toronto time.

Additional observations: (1) The observation hour nearest to midnight; (2) 4 25 p.m., Toronto time.

Ordinary Stations of First Class.

Additional observations: (1) 9 p.m.; (2) 2 p.m.†

MODE OF FILLING UP THE COLUMNS OF THE DAILY REGISTERS.

(408) General Rules.—It is desired that all observers should conform to the following rules:

(1) The actual reading of each instrument, without any modification or correction, should be entered in the Daily Register.

(2) The three steps by which the original reading of the barometer is successively altered by (*a*) the joint correction for index error, capillarity, &c., (*b*) the reduction to temperature 32°, and (*c*) the reduction to sea level, should be shewn *separately;* or if, from any cause, part of this process should be omitted, (*c*) should be omitted rather than (*b*), and (*b*) rather than (*a*); in short, no one result is to be given without all the partial results that precede it.

(3) The corrections to the barometer or to the thermometers, and the reduction of the barometric reading to temperature 32° and to sea level, should in every case be written under the numbers to which they are to be applied, the corrections and the reduction to 32° being marked with their proper signs (+) or (—). As the reduction to sea level is additive in every case, the sign (+) before it may be suppressed.

* At chief stations, and at all stations where the observers receive salaries for their services, the first *additional* observation on the list is essential.

† If the hours of observation are not 2 p.m. and 9 p.m., the times nearest to those hours are to be used.

In the "Instructions to Observers" from the Magnetic Observatory, issued in 1871, the above rules were not enjoined, the common practice of applying index corrections mentally before entering the readings having been adopted. Subsequent experience, however, has made manifest that it is expedient for the following reasons to depart from the common practice:

(1) The risk of error on the part of the observer is thereby much diminished in the first instance, and when the details are written down, it is possible for him to examine and check his work.

(2) The examiners of the reports at the Central Office can discover with greater facility both the fact that an error has been made, and the source from which it arose, and are therefore in a position to look out for the special mistakes into which any individual observer has been betrayed, and to instruct such observer accordingly.

(3) The saving of labour at the Central Office, and the promotion of accuracy in the final results.

DETAILED INSTRUCTIONS RELATIVE TO WEEKLY FORM I.*

(409) Column "Local Time."—Enter the hour and minute with a *space* only, and without any dot or mark between, and with the letters A or P to denote A.M. or P.M. Thus, 7 10 A; *not* 7.10 A.

If the time be between 12 o'clock and 1, the hour is to be written (0) thus, 0 25 P, or 0 50 A; not 12 25 P, 12 50 A.

(410) Columns "Barometer."—In columns headed "*Observed*" and "*Attached thermometer*," write down the entries of these instruments taken from the pocket book.

Under the entry of the observed barometric reading, write in small figures, with its proper sign, the combined correction for index error, capillarity, &c.

Add or subtract according as the joint correction has the sign (+) or (—), and write the result in the column headed "*Corrected for index error, &c.*"

Under this latter result write in small figures, with its proper sign, the "Reduction to temperature 32°," taken from the tables as explained in Arts. 128, 135, 136, 137. Apply the correction, and write the result in column headed "*Reduced to temperature 32°.*"

* The *order* in which the columns stand is determined in part by considerations of the economy of space, and also to meet the requirements of the telegraph synchronous reports, for which this Form I. was originally designed, and for which the details are all on the first two pages. As additional columns are introduced from time to time, a change in the order of some of the columns will probably become necessary.

Under the entry just made, which indicates the true pressure at the place of observation, write the "Reduction to sea level." Add the reduction in every case, and write the result in the column headed "*Reduced to sea level.*"

The following is an example of making the successive entries for an observation with a barometer :* †

OBSERVED.	ATTACHED THERMOMETER.	CORRECTED FOR INDEX ERROR, &C.	REDUCED TO TEMPERATURE 32°.	REDUCED TO SEA LEVEL.
30.098	52°.0	30.105	30.042	30.438
+.007		−.063	.396	

(411) Columns "Temperature of the Air" and "Temperature of Wet Bulb."—In the columns headed "Observed," enter to tenths the readings taken from the pocket book (Arts. 349, 356), prefixing the sign (—) if the reading be below zero.

Under these readings write the index corrections with their proper signs (+) or (—); apply them according to the rules explained in Arts. 178, 179, and enter the corrected readings in the columns headed "corrected."‡

Example:

TEMPERATURE OF THE AIR.		WET BULB.	
Observed.	Corrected.	Observed.	Corrected.
35°.2	34°.8	32°.4	32°.6
−.4		+.2	

* If the joint correction for index error, &c., of a barometer be 0 *throughout* the scale, the column headed "*Corrected for index error, &c,*" may be left blank, except that the words "*no correction*" are to be written lengthwise along the column. If, however, the correction be 0 at a *particular part of the scale only*, and not *throughout* the scale, the column is to be filled in the ordinary way.

† In writing down a correction, noughts or cyphers between the decimal point and the first significant figure counting from the left, as well as the decimal point, *may* be omitted; but noughts to the right of the last significant figure, as far as the third decimal place (or the second, if the barometer is only read to hundredths), must always be retained, in order that there may be no doubt as to the local value of each figure in the correction. Thus in the above example, +.007 and −.063 might have been written without risk of mistake as + 7 and − 63; but if a correction written in full were .010, or .100, it must *not* be written 1, as a slight displacement in the figure might cause an uncertainty as to the local value of the figure 1.

‡ If the index correction of a thermometer be a constant (0), *i.e.* be nought *throughout* the scale, the column headed "corrected" may be left blank, the words "no correction" being written along the column; but if the correction be (0) at one or more points only, and not throughout the scale, no departure is to be made from the rule in the text.

(412) Columns for Hygrometric Reductions.—Subtract the corrected reading of the wet bulb from that of the dry bulb, *i.e.* the number in the column "Temperature of the air corrected," and enter the difference in the column headed "Difference."

Employ the hygrometric tables, as explained in Art. 357, to find the "Pressure of vapour" to three decimal places, the "Relative Humidity" to whole numbers, and the "Temperature of the Dew Point" to tenths, (when a column for the Dew Point is provided,) and enter these several quantities in their proper columns.

(413) Notation for Expressing Weather and Phenomena.—The modifications of the aqueous condition of the atmosphere, which for the most part constitute what is commonly termed 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 be regarded to a great extent as arbitrary. Some of the terms used as descriptive of 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 certain 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. It has, however, been found necessary to suppress some of the letters, and replace them by symbols, and also to introduce new symbols for other purposes.

Letters and Symbols to Denote the State of the Weather.

Letter.	Symbol.	
b		Blue sky; whether with clear or hazy atmosphere.
c		Cloudy, but detached opening clouds.
	⊕	Overcast, the whole sky being covered with impervious cloud.
	◎	Clearing weather.
d		Drizzling rain.
f	≋	Foggy.
	∿	Misty, caused by condensed vapour.
	∞	Dust haze.
g		Gloomy, dark weather.

Letters and Symbols to Denote the State of the Weather.—(Continued.)

Letter.	Symbol.	
h	▲	Hail.
	△	Soft hail.
l		Lightning.
p		Passing temporary showers.
q		Squally.
r	●	Rain, continued rain.
s	✱	Snow.
	↕	Flurries of snow.
	→	Ice crystals.
		Snow drift.
t		Thunder.
		Thunderstorm.
u		"Ugly," threatening appearance of the weather.
	Ⓥ	"Visibility" of distant objects, whether the sky be cloudy or not.
w		Dew.
	⊔	Hoar frost.
	V	Silver thaw.
	~	Glazed frost.
		Strong wind.

In the above list, some of Beaufort's letters are suppressed on account of their liability to be mistaken for symbols employed for other purposes; and additional symbols have been also introduced:

Beaufort's Letters Suppressed.		New Symbols.	
o	Overcast.	⊕	Overcast.
m	Misty.	◎	Clearing.
v	Visibility.	ʌʌʌ	Misty from condensed vapour.
		↕	Flurries of snow.
		Ⓥ	Visibility.

Symbols to Denote Phenomena.

⊕	Solar Corona.
○	Solar Halo.
	Lunar Corona.
	Lunar Halo.
⌒	Rainbow.
	Aurora.

Intensity is to be indicated by the exponents 0 or 2 attached to the symbols or letters, thus :

$*^0$ means light snow ; $*^2$ heavy snow.

Remarks on the preceding Letters and Symbols.

Fog, denoted by *f* or ≋. This is to be used when the observer is completely surrounded by fog. In other cases the symbols ⩪ or ∞ should be used.

Hail, denoted by *h* or ▲, which are to be used whether the stones be large or small, provided that they are *hard*.

Soft Hail, denoted by △. The stones are small and soft, like snow pellets without any crystalline structure.

The German term is "Graupel" and the French Grésil.

Lightning without thunder, whether sheet lightning or of other kinds, is denoted by *l* or by the symbol ⚡.

Snow.—The symbol is a six-pointed star, a common form of snow crystals.

Ice Crystals.—These sometimes fall in winter. They are distinguished from hail by their shape and size.

Snow Drift.—This is introduced partly because reports relative to snow drift, transmitted by telegraph, are very valuable in relation to travelling.

(414) Columns for Weather and Phenomena at the Time of Observation.—When the form has two distinct columns for weather and for phenomena, the weather column should be used for the letters or symbols contained in the first of the two foregoing lists, and the phenomena column for those of the second list. The observer can make use either of the symbol or of the letter, where a symbol and a letter are both provided.

(415) Columns for Weather and Phenomena since Previous Observation.—In this column the observer should enter the combination of letters or symbols which describe the weather during different periods or portions of the whole time since the previous observation, or which denote any phenomenon that may have occurred in the same periods, separating by commas the several combinations. If the beginning and ending of each period, and the time when any phenomenon occurred, be also given, the value of the record will be much increased.

(416) Columns for Direction and Velocity of the Wind.—To the column headed "*Direction*" transfer from the pocket book that one of the eight principal points which is nearest to the point *from* which the wind was blowing at the observation hour. When a special column is provided for the purpose, enter also the nearest of the *sixteen* principal points.

If there be a calm, or if the motion of the wind be so slight that its *velocity* is entered as "calm," the *direction* must also be entered "calm." The point towards which the arrow happens to be pointing at the time of observation must not be entered for the direction.

Column "Velocity."—Transfer to this column from the pocket book the velocity derived from the anemometer at the hour of observation. If the station be not provided with an anemometer, the velocity must be expressed by one of the numbers in the following scale, ranging from (0) a calm to 10 a hurricane. In order that the scale numbers may not be mistaken for *miles*, they should be written in Roman numerals.

			Approximate Velocity in Miles per Hour.
0	denotes	a calm or very light air	not exceeding 2 miles.
I.	"	light air	above 2 and not exceeding 4 "
II.	"	light breeze	" 4 " " 8 "
III.	"	moderate breeze	" 8 " " 16 "
IV.	"	fresh breeze	" 16 " " 25 "
V.	"	strong breeze	" 25 " " 34 "
VI.	"	moderate gale	" 34 " " 44 "
VII.	"	fresh gale	" 44 " " 55 "
VIII.	"	strong gale	" 55 " " 67 "
IX.	"	heavy or whole gale	" 67 " " 80 "
X.	"	hurricane	" 80 miles.

Column "Steady or in Gusts" (S. or in G.).—This column has reference to the *velocity*. The entry in it is to be (S.) if the wind has a fairly uniform velocity near the time of observation; but if it varies rapidly in velocity, and is fitful and gusty, the entry should be (G.).

(417) Columns for Clouds.—*Column "Upper Clouds."*—The clouds designated as *upper* clouds are as follows:

Cirrus	to be expressed by	....	c;*
Cumulus	" "	....	k;
Cirro-cumulus	" "	....	ck;
Cirro-stratus	" "	....	cs.

* The letters employed to designate the different forms of clouds are the same as those recommended in the "Manual of Scientific Enquiry," published under the authority of the Royal Society in 1840. Clouds are designated by small letters, and directions of the wind by capitals.

The entries in the column for upper clouds should shew approximately what portion of the sky is covered by each of the above named clouds, by means of a number on the left of each cloud letter, which number should express the surface covered by that particular kind of cloud, the whole sky being denoted by 10. Thus, if 2 tenths of the sky be covered by cirrus, the entry would be 2c.

When upper clouds of different kinds are present, separate entries should be made for each; thus 2c, 3ck, 2k.

Column "Upper Clouds, Direction from."—This column should contain, to the nearest of the eight principal points, the direction *from* which the upper clouds appear to move.

Columns "Lower Clouds."—The clouds designated as lower clouds are as follows:*

Stratus	to be expressed by..................	s;
Cumulo-stratus	" "	ks;
Nimbus	" "	n.

The two columns are to be filled up in a manner similar to that explained for upper clouds.

Scud.—When scud is seen, the word "scud" is to be entered in full, with the direction from which it is moving in the columns for "Remarks."

Column "Clouds to Tenths."—The entry in this column should shew, without reference to the particular kind of cloud, how much of the sky is clouded, the whole sky being expressed by 10.†

If *less* than 1 tenth be covered	the entry should be..	0;
less than 2 tenths, and not less than 1 tenth,	" " ..	1;
less than 3 tenths, and not less than 2 tenths,	" " ..	2;
. .		.
. .		.
less than 9 tenths, and not less than 8 tenths,	" " ..	8;
not less than 9 tenths,	" " ..	9;
entirely overcast,	" " ..	10.

The numbers prefixed to the cloud letters express the *extent of surface* of the sky covered with that form of cloud without any reference to the

* The letters employed to designate the different forms of clouds are the same as those recommended in the "Manual of Scientific Enquiry," published under the authority of the Royal Society in 1840. Clouds are designated by small letters, and directions of the wind by capitals.

† Although the number in this column can never *exceed* the sum of the numbers expressing the extent of sky covered by upper and lower clouds, it may often be *less* than that sum; for although the lower clouds may intercept the view of part of the upper clouds, there are portions of the latter of which, though they are hidden, the extent can be estimated with a high degree of probability.

thickness of the cloud. If the observer desires to express the fact that the cloud is very thin, he may do so by placing (0) as an exponent to the right hand and a little above the cloud letter; thus $4s^0$ would indicate a very thin sheet of stratus. Also, if the thickness be unusually great, the number (2) should be written on the right and above the cloud letter; thus $3n^2$.

(418) Columns for Rain.—*Columns headed "Began," "Ended," or "Times of Beginning" and "Ending of Rain."*—In these columns write the hour 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 meteorological or 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 A," or "thr. 0 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 the first rain began between midnight and 5 A.M., the entry should be $\frac{\text{0 A.}}{\text{5 A.}}$

Similar remarks apply to the time of ending.

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

Column "Depth in Inches."—The rain measured at any hour is to be entered for the day and hour *when it was measured*,* without reference to the *times* between which it may have fallen. Thus, supposing it be measured once only in the day, namely at 7 a.m., the rain measured at 7 a.m. on the 10th is to be entered in a line with the other observations made at 7 a.m. of the 10th. If a second measurement of the rain be made, which at ordinary stations would usually be at 9 p.m., the rain

* It has been a common practice, in Canada and elsewhere, to enter the rain measured in the morning of one day as having fallen in the *previous* day. If these entries are designed to shew not only *how much* rain fell, but also *when* it probably fell, and if a uniform rule is to be adopted in crediting the rain to one day or to the other, it would be nearer the truth to credit it always to the previous day, because that day includes 17 hours of the whole period in which the rain might have fallen. But as there is at least an apparent objection to entering rain as having fallen on the previous day in those cases when it is known to have fallen on the current day, it is better to evade such difficulties by adopting the rule in the text, which involves no contradictions.

then measured should be entered in a line with the 9 p.m. observations of the same day.*

If no appreciable rain was found in the gauge at the proper time for measuring it, and the observer was aware that some light rain had fallen since the time for the previous rain observation, he should enter the letter *r* for the depth fallen. See Art. 413.

If in consequence of some accident to the gauge, or from any other cause, a measurement of the rain was prevented, and the observer was satisfied that appreciable rain had actually fallen during the period terminating with the proper time of observation, he should enter the letter *r*, with a reference mark to the "Remarks" column, where he should enter the *estimated* depth, and state the fact that it is estimated.

(419) Columns for Snow.—The entries in the columns for snow are to be made in a manner precisely similar to that described in the preceding article for the corresponding headings for rain.

If, in consequence of a thaw, no snow be on the ground at the proper time for measuring it, and the observer is satisfied that snow more or less heavy had fallen during the period then terminated, he should enter, for the depth of snow, the snow symbol (Art. 413), and a sign of reference to the column of "Remarks," wherein he should insert the depth of snow which, according to his estimation, would have been on the ground if it had not melted.

Column "Water Equivalent."—If the form is provided with a column with this heading, and the observer uses a Snow Gauge, he should enter in this column the depth of water which is obtained by melting the snow, in the manner explained in Arts. 242, 243; but if he is not furnished with a snow gauge, the column is to be left blank.

(420) Column "Rain and Melted Snow," sometimes written "Total Precipitation."—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) should be added to the depth of rain as an approximate water equivalent.

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.

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* The observer may take the second measurement at any time in the afternoon, instead of at 9 p.m., if the weather has unmistakably cleared up; but in such a case, a note to that effect should be made in the "Remarks," stating the time when the second measurement was made.

(421) Columns for Anemometer.—*Column "Reading of Dial."*—In this column enter the reading of the anemometer dial at the time of observation, in its own proper units as taken from the pocket book. See Art. 379 and note.

Column "Miles since Last Observation."—Enter in this column the difference obtained by subtracting the reading of the anemometer dial at the preceding observation from the reading of the dial at the present observation, and reduced to miles. Arts. 284, 285, 288.

Column "Miles in Twenty-four Hours."—Subtract the reading of the dial at the last observation of the preceding day from the reading at the last observation of the present day; reduce the difference thus obtained to miles, and enter the result in the column in a line with the last observation hour.

If the observer desires to know the miles passed over by the wind in the period of 24 hours ending with any other observation hour, he should proceed in a precisely similar manner with reference to the dial readings at that hour; but the miles run in the 24 hours terminating with the last observation hour should not be omitted.

(422) Columns "Maximum and Minimum Thermometers."—From the pocket book transfer to the column* in the register headed "observed" the readings of these instruments (with their proper signs) made at the last observation hour in the day, which for ordinary stations is 9 p.m. Under the observed readings write the index corrections with their proper signs, from the card which accompanies the Register Book; apply the corrections according to rules in Arts. 178, 179, 180, and write the corrected readings in their proper columns.

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.

(423) Columns "Aurora and Time of Occurrence."—When the form contains this column, the entry to be made in it is the class to which the Aurora belonged, expressed in Roman numerals (Art. 338), together with the hours between which it occurred. Any descriptive details which the observer is prepared to give, may be entered in the column of "Remarks." The symbol for Aurora should also be entered in the column for Phenomena.

* The words "read at," which, in some editions of this form, appear in the headings of these columns, may be expunged, as the times at which the readings are taken are shewn in the column "Local time," and are also entered at the beginning of the Register Book.

(**424**) **Column "Sleighing."**—This column is to contain one of the figures 0, 1, 2, to denote the general state of the roads in the immediate neighbourhood of the station. If there is an interruption in the sleighing during its proper season, the entry in the column should be (0); but when sleighing is at an end, the column is to be left blank. It will be sufficient if one entry of the state of sleighing be made in the day.

A knowledge of the total depth of snow actually remaining on the ground at any time, as distinct from that which fell in a given time, has an important connection with agricultural prospects; and is useful also for other reasons. Observers are therefore requested to insert in the sleighing column, if there be such a column, and otherwise in the "Remarks" column (Art. 426), twice a week or oftener, an approximate measure in inches of the total depth of snow in the open field, and also on the high road. The entries should be made thus: "field 20," "road 8."

(**425**) **Spare Columns.**—In some forms a few columns are given without printed headings. These are designed for any special observations which it may be desired to take at certain stations, such as readings of spare instruments in different positions, the temperature of wells, or of the sea, or of lakes, or of the earth at different depths, &c.

(**426**) **Compartment for "Remarks."**—The following details should be entered in this compartment:

(1) Notices regarding the instruments and the regular observations. If an instrument be broken, or changed, or if its position be changed, a notice of the fact should be briefly stated in the "Remarks," while particulars regarding the cause should be given in the proper place at the beginning of the current register book. If a change, designed to continue, be made in any of the times of observation, such change should be noticed in the "Remarks," and also at the beginning of the book. If an observation be accidentally taken before or after the proper time, the time at which it was actually taken should be entered in the "Remarks," and a reference mark should be made in the column "Local time."

(2) Notices of any phenomenon for which no column is provided elsewhere, and remarks, if necessary, relative to any phenomenon of which the presence is noticed in the column referred to in Arts. 414, 415, with a reference to the page of the extra Register Book in which the observer may have given a detailed account of the phenomenon, supposing that he is in the habit of keeping such extra register.

(3) Events.

(*a*) Periodical events relative to the seasons, such as the first snow or frost, or first sleighing, ice formed or broken up, opening or closing of navigation, mill work began or ended, Indian summer, &c.

(*b*) Events relative to the animal kingdom, such as the appearance or departure of migratory birds, &c.

(*c*) Events relative to the vegetable kingdom, such as the budding and flowering of plants, maturity of fruits, &c.

(*d*) Events not specified.

(427) Column for "Initials of Observer."—The initials of the person who takes the observations are to be entered in this column, unless they are taken by the Superintendent, in which case the column may be left blank.

(428) Remarks on Daily Registers, Forms A and A_1.—The directions for making the various entries in the columns of the Weekly Forms, are applicable also to the corresponding columns in Forms A and A_1.

Sums and Means.

The columns of which the sums and means should be taken, are those with the following headings: "Barometer Reduced to 32°;" "Barometer Reduced to Sea Level;" "Temperature of the Air Corrected," and "Temperature of the Wet Bulb Corrected;" "Pressure of Vapour;" "Relative Humidity;" "Velocity of the Wind;"* "Clouds to Tenths," and "Miles in Twenty-four Hours."

When the morning and afternoon telegraph hours are included in the eight equidistant observations, the observations made at the night telegraph hour must be excluded from the sum. In dividing by 8 or by 12 for finding the daily means, the division is to be carried on to one decimal place further than in the individual entries: thus, the barometer being read to three places, the mean is to be entered to four places. If the first figure omitted be 5, or more than 5, the last figure retained is to be increased by 1; but if the first figure omitted be less than 5, the last figure retained should remain unaltered: thus, if the mean temperature be 37°.235, or 37°.237, or 37°.232, the entry to two places should

* The mode of computing the resultant direction and resultant velocity of the wind, will be furnished to any observers who use Forms A or A_1, and who may desire to make these computations.

be 37°.24, or 37°.24, or 37°.23. The mean velocity per hour will be found by dividing the sum of the entries in the column "Miles in Twenty-four Hours" by 24.*

(**429**) **Remarks on Form 20.**—This form is used for recording observations which are taken for insertion in the "International Bulletin," a daily publication compiled by desire of the Vienna Conference, and undertaken by the Chief Signal Officer at Washington. The observations are made in various parts of the world at the same *absolute* time, which corresponds to 7 25 a.m., Toronto time.

Form 20 is issued to persons not ordinarily observing at the telegraph hours, who are willing to take the observations of the synchronous system, in *addition* to their three ordinary observations.

(**430**) **Remarks on Form 17.**—The directions for filling the several columns of Weekly Form I., contained in Arts. 409 to 427, may, with slight modifications, be adapted to Form 17.

When the observations of temperature are taken at 7 a.m., 2 p.m. and 9 p.m., a near approach to the daily mean is found by taking the fourth part of the sum of the temperatures at 7 a.m., 2 p.m., and *twice* that at 9 p.m.

Where other combinations of hours are used, special instructions will be given on application.†

Column "Kind of Clouds," &c.—When a separate column is not provided for the direction, the letters denoting the direction should be written to the right of the cloud letters with "fr" (from) between them, thus k s fr S W, denotes cumulo-stratus from south-west. Without this precaution, there might be a chance of mistaking the letters n and s for the directions North and South.‡

Column "Anemometer," "Sum and Mean for Twenty-four Hours."—The sum is obtained by adding together the "miles since last observation" in the three adjoining columns, and the mean is then found by dividing this sum by 24.

In computing the means of temperature, sky clouded, or velocity of the wind, the division should be carried on to one decimal place further than in the individual entries. See latter portion of Art. 428.

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* Observers are at liberty to omit the computation of the means, and leave the corresponding space blank.

† Observers are at liberty to leave blank the columns for means.

‡ The clouds should always be expressed by small letters, and the wind's direction by capitals.

Column "Aurora."—If Aurora is visible at the night observation hour, the class in which it is included is to be entered in Roman numerals in this column. If Aurora be observed at other hours, the class and time of occurrence should be entered in the column, "Aurora and Time of Occurrence," if the form includes this column; but if not, the Aurora symbol with its class, and the times between which it was seen, should be entered in the column, "Miscellaneous Phenomena, &c."

Column "Total Snow on the Ground."—When the form includes this column, an entry should be made twice a week, or oftener, shewing the total depth of snow in inches on the ground (as distinct from the depth that fell within any given time). Two entries should be made on each occasion—one to shew how much remains untrodden in the open fields, and the other to shew the snow packed on the high road. The first should be entered thus: "field 20;" and the other, "road 7."

Column "Remarks."—The directions for filling the column "Remarks" in the Weekly Form I., are applicable also to Form 17.

(431) Remarks on the Rain and Snow Register.—This form is used only by observers who confine their attention to recording the depth of rain and of snow which falls within 24 hours, and to giving brief notices regarding the weather and miscellaneous phenomena. The rain or snow is to be measured each morning at 7 a.m., and entered in a line with the day of the month in which it was measured, and without any reference to the time when it was supposed to have fallen.

For filling the various columns relative to rain and snow, consult the articles herewith indicated:

For *Rain*, Art. 418.

For Snow, Art. 419.

Total precipitation, Art. 420.

Column "Miscellaneous Phenomena, &c."—In this column enter the symbols expressing any phenomena which may have been seen, with the times when or between which they were seen. For the symbols to be used for various phenomena, see Art. 413.

(432) On Meteorological Returns.—The returns forwarded to the Central Office are to be exact transcripts from the Daily Register Book. As soon as the week, or other period for which the observations are sufficient to fill one sheet, is completed, the loose sheet, after careful comparison with the original in the book, is to be forwarded by mail, addressed, "The Superintendent, Meteorological Office, Toronto."

Meteorological Reports are transmitted by mail at the same rate as printed matter, *i.e.* at 1 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 *open*, or in a one cent postal wrapper with the ends not inclosed. The envelope or wrapper must not contain any matter of the nature of a letter; and, of course, no communication that does not properly form part of the report must be written on the form.

Each form of Daily Register should be transmitted to the Central Office as soon as possible after the expiration of the period for which the form is adapted; thus, the Weekly Forms I. and 20 should be mailed, if possible, on Monday of the following week; the Monthly Form 17 and the Rain Form on the 2nd or 3rd of the following month; and Forms A and A_1 on every third, or every alternate day.

Observers who are furnished with self-registering anemographs should forward to the Central Office all the register papers taken off the cylinder of the instrument, and also the *written* record of the direction and velocity of the wind at every hour. The papers taken from the cylinder should be inclosed in the wrapper or envelope that contains the regular returns of the other observations; but the written record of the wind should be sent as soon as the form on which it is entered has been filled up, and, if convenient, by a different mail from that which carries the cylinder papers, to provide for the contingency of one or the other being lost.*

Returns of every kind should be carefully compared with the originals by *two persons*, one of whom should read aloud while the other corrects; the latter of the two operations being done by the more experienced person of the two. The practice enjoined in this article is very important, and one to which, it is feared, sufficient attention has not been given by some correspondents.

(433) Rules for Preserving Uniformity of Notation and for Avoiding Ambiguity in the Registers.—For the sake of preserving uniformity of notation and for the prevention of errors, attention is called to the following rules, to be observed alike in the register books and in the returns:

(1) The sign minus (—) should always be on the *left* of the number

* The observer should write up the hourly record of the wind as soon as possible after the paper is taken from the cylinder, as there is then less danger of the marks being indistinct; besides which, when the facts are fresh in his memory, there is less danger of his mistaking the marks or letters. It is for a like reason, and also on account of the danger of partial obliteration in transit, that the written records are required at the Central Office.

to which it is applied, and never in any other position; thus, a temperature 10°.5 below zero, should be written −10°.5.

(2) Vulgar fractions are never to be used, but decimal fractions only; thus, ten and a half should be written 10.5, and *not* 10½.

(3) 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 by (0). Moreover (0) *should* be entered in the units place, if the units be wanting.

Thus, in the *same* column, the numbers,	16.23,	14.50,	16.00,	0.47,	0.60,
should not be written,	16.23,	14.5 ,	16 ,	.47,	.6 ;

for although the latter entries are not wrong, they are liable to lead to error, and should be avoided.

(4) 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.

(5) The inches of barometric readings are to be entered in *full*; thus if 29 be the integral part of the reading at two or more consecutive observations, 29 should be repeated on each occasion.

(6) When two or more observations taken at the same hour on consecutive days, or at consecutive observation hours in the same day, are identical, the corresponding 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.

(7) In filling up the columns, the figures, letters, and words should be written in a plain, distinct manner, *without flourishes*, so that they may be read without danger of mistake.

(434) 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. The best chance of discovering the cause of an anomaly lies in the same being rigidly recorded, and a few blanks in the columns are of less importance than the detection therein of a conjectural emendation, which would vitiate the whole series by destroying its trustworthiness.

CHAPTER III.

MISCELLANEOUS MEMORANDA.

(435) 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 removing it elsewhere.

(436) Damaged Instruments not to be Returned without Instructions.—When an instrument is injured, or is supposed to be injured, either in transit or otherwise, it is not to be returned to the Central Office, or sent elsewhere for repair, without instruction to that effect from the Central Office. It sometimes occurs that an inexperienced observer, in consequence of his imperfect acquaintance with an instrument, imagines a defect where none really exists; or it may be that a defect, though real, is one which admits of being rectified either by the observer himself, or by some mechanic in the neighbourhood of the station. In such cases, to return the instrument not only causes needless expense and stoppage in the observations, but also exposes the instrument to the danger of being broken in the transit. Again, it may be that the defect is such as to render the instrument useless, and not worth the cost of carriage; or the defect, though not incurable, may be such as to necessitate the supply of a new instrument. For such like reasons the rule enjoined in this article should be carefully observed.

When any damage or defect, real or supposed, has taken place or has been discovered, the fact should be reported to the Central Office on one of the forms designed for that purpose, in order that the necessary instructions may be forwarded to the station. This report may be inclosed with the next periodical report of observations, if the latter be due within three days, or with a letter, if the observer should have occasion to write on any business; but otherwise the report may be mailed in a separate *open* envelope with a one cent stamp.

(437) Reports on Instruments to be on Separate Papers.—Any report to the Central Office of the breakage or damage of an instrument, or of any defect that may be discovered in it, or any report on its mode of working or suggestion for its improvement, or notice of change in its position or in the circumstances affecting its exposure, or any communication relative to facts descriptive of the district or premises (Arts. 381–383), should be written on one or more of the forms usually supplied for such purposes; and, if the observer be not provided with the special forms, the paper or letter on which the report is written should contain no other matter whatever. It is desired moreover that facts descriptive of the district or of the premises be not entered on the same paper with those that relate directly to instruments. It must be understood that the term "Instrument" must be taken here to include sheds, screens and other articles not included under the head of stationery. The reports may be forwarded as explained in Art. 436.

(**438**) **Requisitions to be on Special Forms.**—Requisitions made by an observer to the Central Office for instruments, forms, &c., for service at his station, should be written on a requisition postal card, or other requisition form, or on a paper that contains no other matter. Remarks by the observer explaining the special reasons for the requisition, if explanations be necessary, may be made in a letter with or without other matter. Requisitions made otherwise than by postal cards should be forwarded as explained in Art. 436.

(**439**) **Instruments are not to be Sent on Loan from a Station without Authority.**—An observer having on loan, for the use of his own station, an instrument the property of the Dominion of Canada, must not transfer it to another station without definite authority from the Central Office, even though he may not (as he supposes) have need of the instrument himself; as such action defeats the purposes for which the additional instrument was furnished to him; one of which was to guard against the stoppage of the observations by accidents to the instruments in use, and another to enable the observer to take any special and extra observations that might be necessary. The removal of instruments, moreover, from station to station greatly increases the difficulty of keeping a record of the localities of the various instruments, and on that account also should be avoided.

If it should come to the knowledge of any observer that some qualified and trustworthy person, residing in a suitable locality, is desirous of engaging in meteorological work, he should report the circumstances of the case and his opinion thereon to the Central Office at Toronto, that the necessary action may be taken; but he should not furnish the proposed station from the instruments intended for his own use.

(440) Blank Forms to be Carefully Preserved.—Observers are requested to keep their stock of blank loose forms, and other articles of stationery connected with the observations, in a safe place, and apart from other stationery, so as to diminish the risk of loss. Although care is taken to send to every station a timely supply of the forms necessary for each period, requisitions for further supplies not unfrequently reach the Central Office long before the expiration of the period, thus shewing that the forms before furnished must have been either lost or misapplied.

(441) Books of Reference on Meteorology.—Observers 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.

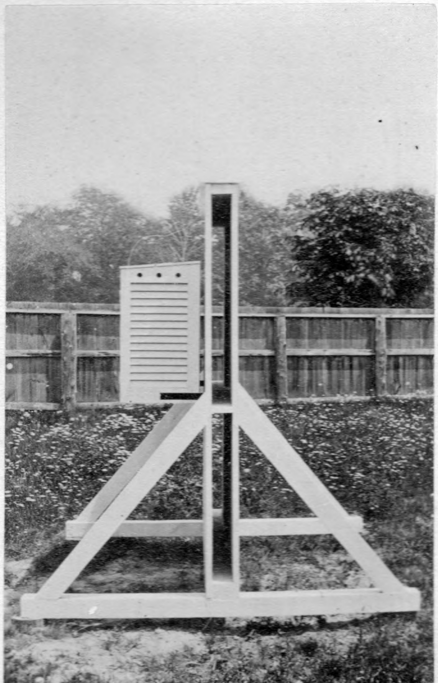


Fig. 1.—Therm. Shed from West.

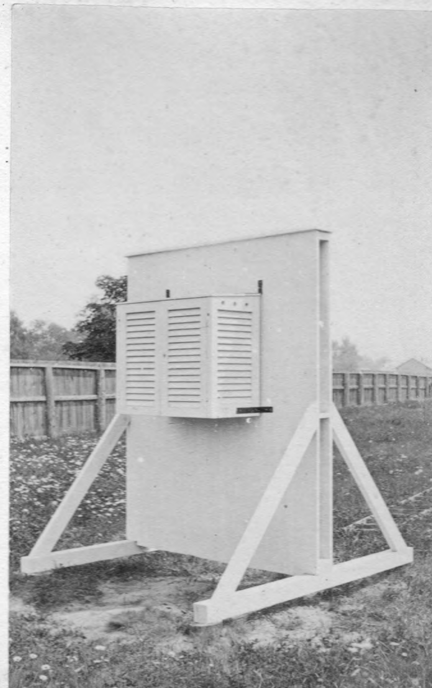


Fig. 2.—Therm. Shed from North-west.

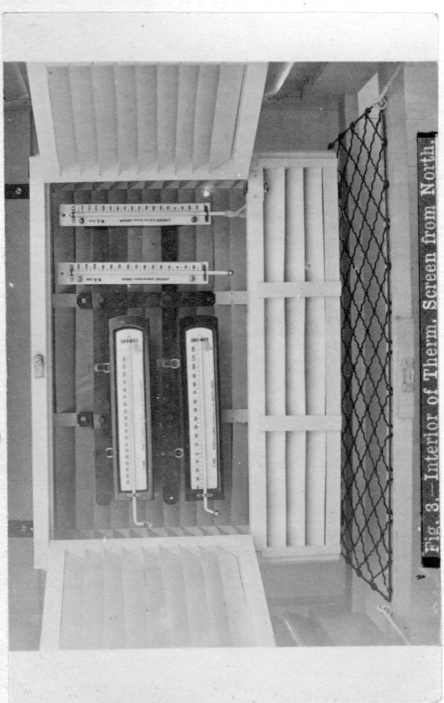


Fig. 3.—Interior of Therm. Screen from North.

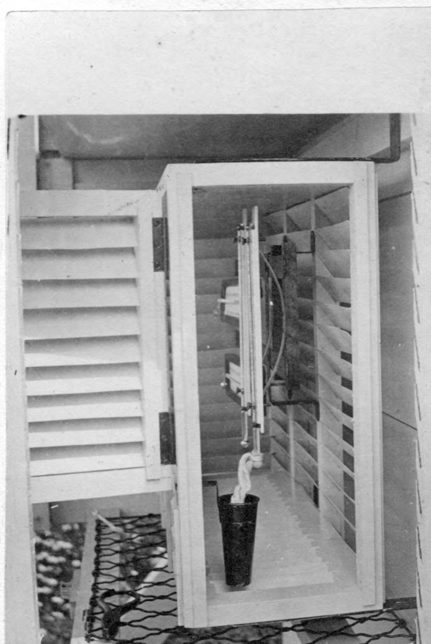


Fig. 4.—Interior of Therm. Screen from West.

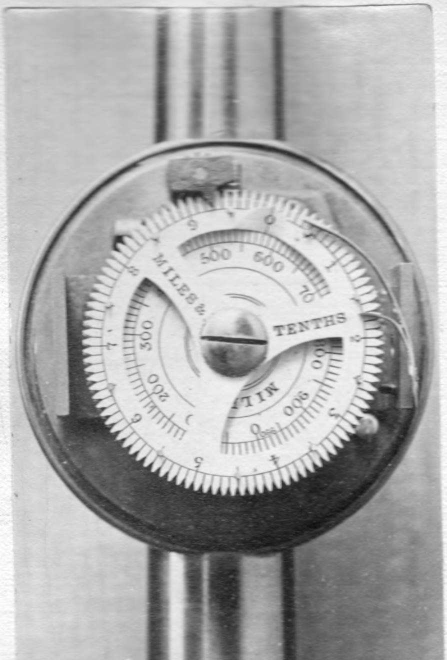


Fig. 5.—Dial of Green's Anemometer.

Fig. 6.—Dial of Foster's Small Anemometer.

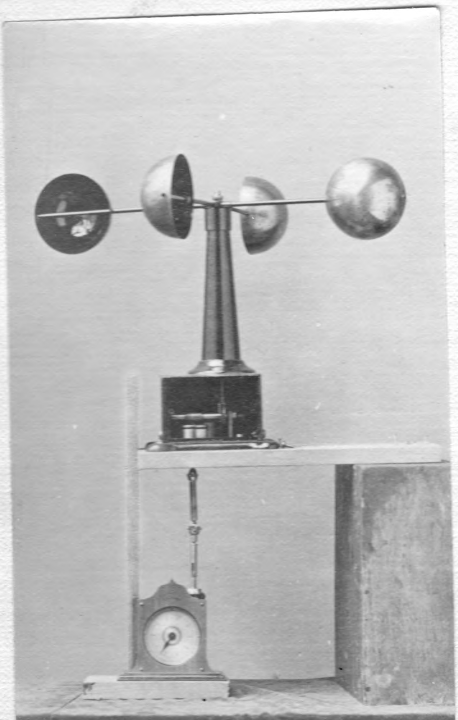


Fig. 7.—Long Shaft Anemometer.

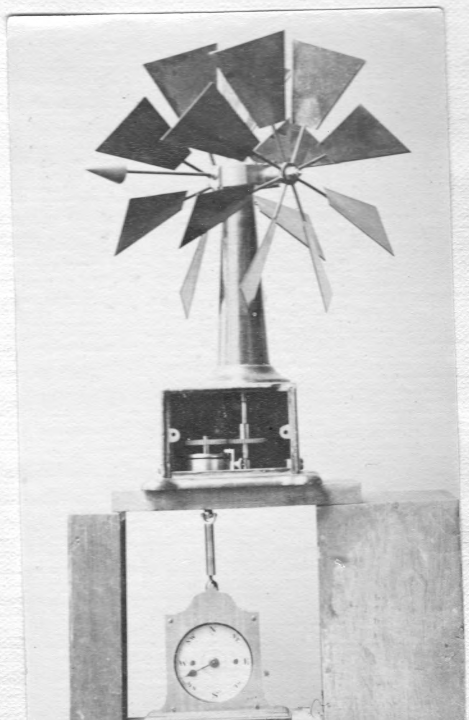


Fig. 8.—Long Shaft Windmill Vane.

Fig. 9.—Electric Windmill Vane.

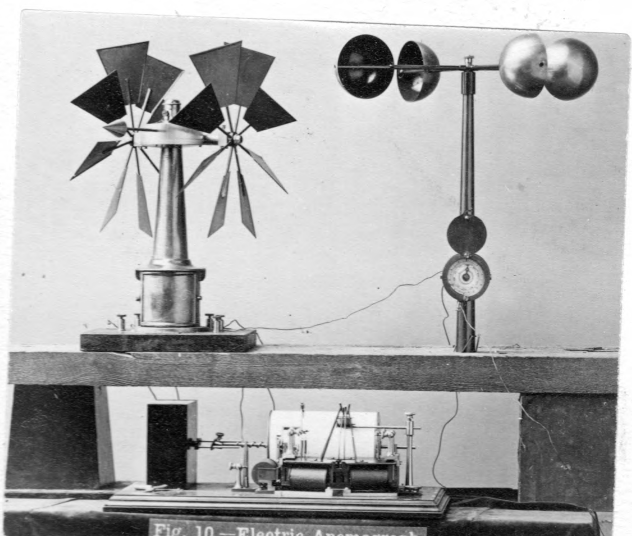


Fig. 10.—Electric Anemograph.

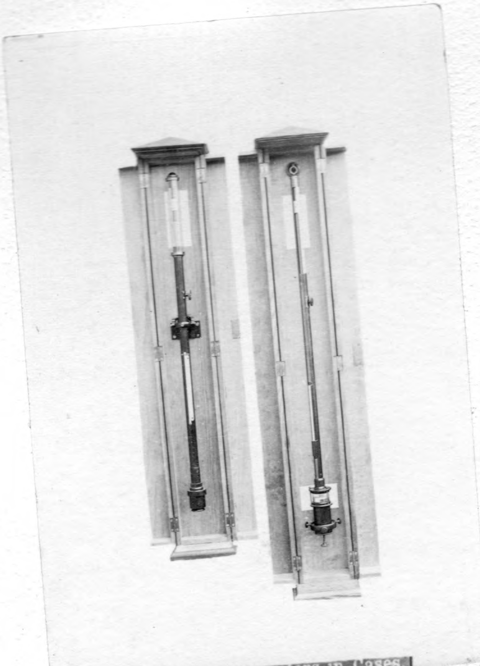


Fig. 11.—Barometers in Cases.

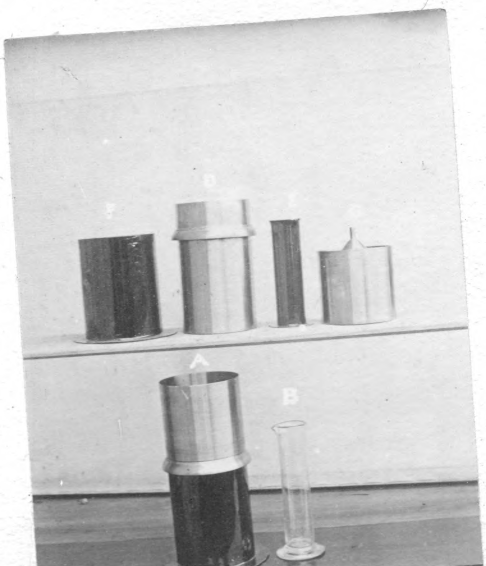


Fig. 12.—Rain Gauge and Measuring Glass.

FORMS OF VARIOUS CLOUDS.

Fig. 1. Cirrus. *(Cir.)*

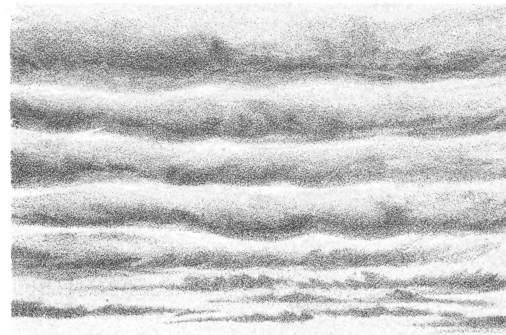
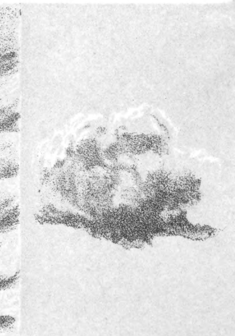


Fig. 5. Roll-Cumulus. *(Roll_c.)*



Small Cumulus.

Fig. 2. Cirro-cumulus. *(Cir_c.)*

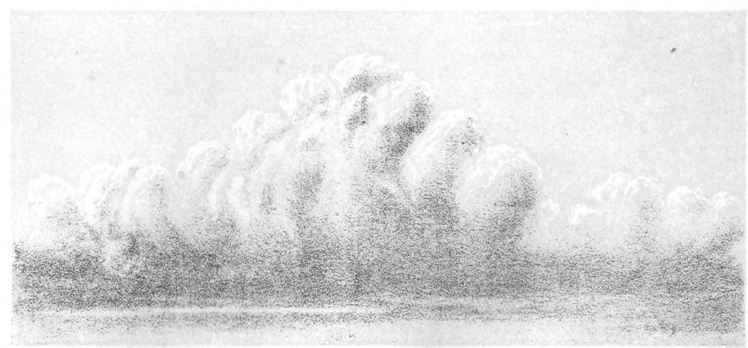


Fig. 6. Cumulus. *(Cum.)*

Fig. 3. Cirro-stratus. *(Cir_s.)*

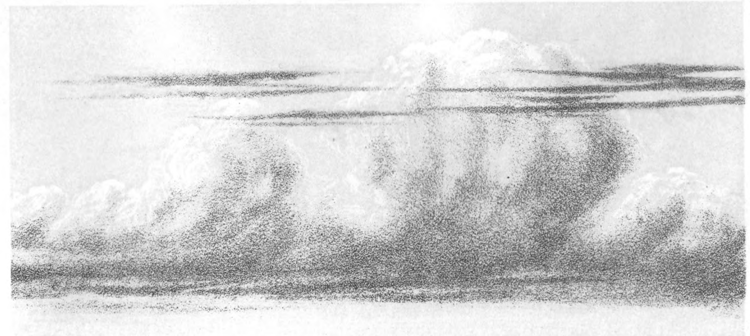


Fig. 7. Cumulo-stratus. *(Cum_s.)*

a

Fig. 4. Stratus. *(Str.)*
a. Detached Stratus.

Fig. 8. Nimbus. *(Nim.)*

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