

count of its weight—20 kilos, on an average—and of the rubbing of the gear, and the formation in soft ground of three ruts instead of a single one, as in the preceding models. In addition, if the cyclist is obliged to follow a column, and to traverse on one of the inclined sides of the road, he is obliged to lean in an inverse direction to his machine in an uncomfortable position for preserving his equilibrium.

An ample vareuse, giving the greatest liberty to every movement, trousers buttoning at the ankle, and laced boots, seem to be the most suitable clothes. Leggings are too hot, and laced brodequins impede the movement of the foot. It is good to add to this an India rubber tippet with a hood, to protect from the rain, and a leather bag to carry dispatches without their being crumpled. The revolver suffices as an arm for a man not intended for fighting, but only to defend himself against a chance attack. The bag can be adapted to any machine easily, but especially to the tricycle.—*La Nature*.

#### ELIAS LOOMIS THE PHYSICIST.

By H. C. HOVEY.

IN an inland town, a place of summer resort, an aged man, who had long dwelt apart from exciting scenes, sought new strength in order to finish his allotted work in life. But the warning came, and he bravely returned to the city where his home had been for the last thirty years, and amid the sheltering elms of New Haven he died, and amid the historic stones of Grove Street Cemetery he was buried, his bearers being Professors Dana, Newton, Brewer, Van Name, Marsh, and Wright, and his eulogist being President Dwight. The man thus honored and lamented was Prof. Elias Loomis, LL.D., who was born August 7, 1811, and who died August 15, 1889, aged 78 years. A brief sketch of his life and eminent services may be acceptable.

He fitted for college under his father, at Willington, Conn., and was graduated from Yale College in 1830. He served as tutor in that institution for three years, during which time he began the long list of brilliant scientific achievements that made his name famous on both continents. In order to qualify himself for the career before him, he spent a year or more in Paris, attending the lectures of Arago, Biot, Dulong, Poisson, etc. On his return he accepted the chair of mathematics and natural philosophy in the Western Reserve College, Ohio, which he held till the year 1844, when he was called to a similar position in the University of the City of New York. He succeeded Prof. Olmstead, in 1860, as professor of natural philosophy and astronomy in Yale University, a place which he held during the remainder of his life.

Prof. Loomis, together with Prof. A. C. Twining, of West Point, made the first concerted observations ever taken in this country of the altitudes of shooting stars, in Nov., 1834. And for fourteen months, in 1834-35, he made hourly observations every day, beginning at 5 A.M. and on till 10 P. M., to mark the declination of the magnetic needle. At a later period he took observations of the dip of the needle at over seventy stations spread over thirteen States from the Atlantic to the Mississippi. While connected with the Western Reserve College, Prof. Loomis observed 200 moon culminations for longitude, 69 culminations of Polaris for latitude, 16 occultations of stars, and determined the orbits of five comets. It should have been mentioned that he was the first person in this country to discover Halley's comet on its return to perihelion in 1835. While in the University of New York, he was interested with others in making telegraphic comparisons for longitude, determining the differences between Washington, New York, Cambridge, Philadelphia, and other localities.

Under the simple title of "Contributions to Meteorology" Prof. Loomis gave to the world through the *American Journal of Science* the results of his patient and long-continued researches in that direction. Subsequently he gave much time to the revision and systematizing of these papers, with the intention of welding them into a complete work on dynamic meteorology. It was stated some time ago that the whole number of his scientific papers would exceed two hundred. These appeared mostly as contributions to the Proceedings of the American Philosophical Society, the American Association for the Advancement of Science, *Gould's Astronomical Journal*, the *American Journal of Science*, and *Smithsonian Reports*.

But after all it may be safely said that the name of Prof. Loomis was made most widely known through his text books, which covered the whole range of mathematics as taught in college and school, and also included astronomy and natural philosophy, all of which had an aggregate circulation of more than half a million copies. Loomis' astronomy became a favorite text book in England; his calculus was translated into Chinese; and his meteorology was rendered into Arabic.

As a matter of course, Prof. Loomis was elected to membership in numerous scientific societies in this country and abroad. The University of New York conferred on him the title of Doctor of Laws. But after all his best monument remains in the hearts of the tens of thousands to whom his text books were as the gates of light, and who had a patriotic pride in the fact that he made it possible for them to master the mathematics and physics without going to any other than an American author.

A heavy affliction befell Professor Loomis a quarter of a century ago, in the loss of his cherished wife, and shortly afterward his two sons, in the natural course of affairs, went forth to their own paths of usefulness, and it followed that the great mathematician, astronomer, and meteorologist dwelt alone with his favorite sciences, and those who knew him least judged him to be a reserved and frigid man. But those who approached him on any errand worthy of consideration found him affable, attentive, helpful, and even ready to spice the graver themes of conversation with sallies of wit and humor. Professor Loomis was a man of many and varied resources. President Dwight thus summed up his character: "He was remarkably gifted by nature for the work which opened before him. His mind was penetrating and capable to hold carefully before it the relations of things, so essential to mathematical thought. He was what we conceive a fine mathematician ought to be, if the ideal is to be realized. As a lecturer he had the power of stating concisely what he had to say, and in a few well chosen words. His works bear witness to his power.

He was a warm hearted and generous friend, and though he was much alone in his work and in his life, yet the element of the hermit was foreign to his character."

#### THERMOMETERS.\*

By FRANK BROWNE.

**History.**—The discovery of thermometers is attributed to several philosophers of the sixteenth century. Galileo's instrument, invented before 1597, was probably the first accurate one known. This consisted of a long glass tube, one end of which was blown into a bulb, the other dipping into colored water. It was an air thermoscope and was the kind first used. Its scale was arbitrary and the readings incorrect, for the variations of atmospheric pressure had not yet been discovered. About 1611 Galileo substituted alcohol for air, and such thermometers were like those of the present day. They had large, usually spherical, bulbs, and the degrees,† intended to represent thousandths of the volume of the bulb, were marked with beads of enamel fused on to the stem. As in the previous instrument, the scale was arbitrary. Down to about 1650, the freezing of water was believed to take place at variable temperatures, and this supposition was held also with regard to the boiling point. In 1665 Hooke wrote of spirit thermometers, describing their manufacture and graduation, saying also that zero on their scales was the freezing point of water. Halley in 1693 stated that water boiled at a constant temperature. In 1702, this statement was confirmed by Amontons. In 1694, Renaldeni, of Padua, proposed to graduate thermometers by taking as standards of temperature mixtures of definite volumes of boiling and ice-cold water. In 1701, Newton proposed, anonymously, a thermometric scale in which the temperature of freezing water was zero, and that of the blood of a healthy man 12°; he found that water boiled at 34°, as indicated by a linseed oil thermometer when graduated upon this scale. In 1714, Fahrenheit substituted mercury for linseed oil, and proved the dependence of the boiling point on pressure.

Three scales have survived. The Fahrenheit is the oldest, and dates from 1724. It is used popularly in Great Britain, the British colonies, and the United States. This scale was primarily divided into 180°; zero was placed at temperate, a point corresponding with 9° C.; the point to which the alcohol rose when placed under the arm of a healthy man was marked 90°; and the temperature of a mixture of ice and salt, then believed to be the greatest possible cold, was marked -90°. In 1714 Fahrenheit again altered his scale; 0° was placed as an absolute zero, and the space between this point and that representing the warmth of the human body was divided into twenty-four degrees.

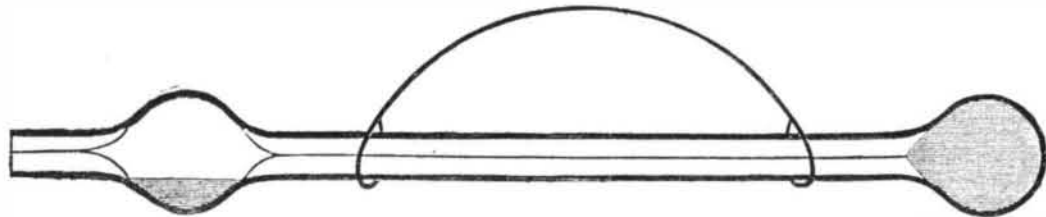


FIG. 1.—FILLING THE TUBE.

The freezing point of water was now 8°. But these long degrees being inconvenient, each was divided into four, and thus, instead of 8°, the freezing point of water became 32°, and blood heat 96°. A mercurial thermometer thus graduated registered 212° as the boiling point of water.

De Lisle in 1724 introduced a scale in which the boiling point of water was placed at 0°, and the temperature of the cellars of the Paris Observatory at 100°. The freezing point of water became afterward the upper point, as 150°. This scale was used for many years in Russia, but is now obsolete.

In 1730 Reaumur made alcohol thermometers with their zero at the freezing point of water. On some of these the boiling point of water was 80°. Deluc introduced mercurial thermometers graduated from 0° in melting ice to 80° in boiling water; these, with Reaumur's name attached, are in use in Germany, Holland, and other parts of the Continent.

A centesimal scale in 1742 was adopted by Celsius; the boiling point was marked 0°, and the freezing point of water 100°. Linnæus reversed these points, and the scale is now known as the Centigrade. This is no doubt destined to supersede all others; at present it is used universally in laboratories, and generally in all except English-speaking countries for scientific purposes.

**Uses.**—Thermometers are instruments for measuring the degree of temperature. The measurement depends upon the law which enunciates that perfect gases expand equally for equal quantities of heat. With regard to this law some liquids behave almost as well as perfect gases, and for many reasons are used in preference to them. For thermometric purposes it is essential that the liquid employed should have a low freezing point, a high boiling point, a good heat-conducting power, and a low specific heat; it should also be readily obtainable in the pure state. One possessing all these properties is found in mercury; it freezes at -40°, boils at 357°, has high conducting power, and its specific heat is such that the same quantity of heat which would raise water from 0° to 1° would raise this element from 0° to 30°.

The mercurial is not, however, so accurate as the air thermometer. 100,000,000 cubic millimeters of mercury measured at 0° become 100,017,915 cubic millimeters at 1°; and 100,000,000 cubic mm. at 300° become 100,019,413 cubic mm. at 301°; these facts show that as the temperature increases, the expansion of mercury is not uniform. Air, on the other hand, expands twenty times as much as mercury, and equally for all temperatures. For low temperatures alcohol is most suitable, as it does not become solid till -130.5° is reached.† Ether is also much used. The expansions of these two

liquids are 6 and 8½ times respectively that of mercury.

**Manufacture.**—To make an ordinary mercurial thermometer, a piece of hard glass tubing is first selected. The bore must be narrow and uniform. Its uniformity is ascertained by measuring a short column of mercury at different points of the tube. A bulb must now be blown. This varies in shape, size, and thickness according to the purpose for which the thermometer is intended. It is sometimes spherical, pear-shaped, oval, cylindrical, or tubular. Very often it is made apart from the stem; this is preferable, as one can then be chosen possessing the right capacity. When made by blowing out one end of the tube, a small elastic bottle is fixed to the open end and compressed by the fingers. For sensitiveness the elongated form is to be preferred, as in proportion to its capacity there is a much larger surface for the conduction of heat. For this reason the gridiron, spiral and bottle-shaped bulbs deserve notice. The thickness of the glass is also a matter of considerable attention, for if too thin the bulb will yield to atmospheric pressure and raise the zero point; if too thick, the instrument will be insensitive.

The tube having now a bulb at one end, a second is blown a short distance from the other end. When this latter is half cooled, the open end is dipped into pure, recently distilled mercury, which gradually rises into the tube. By judicious cooling and heating the lower bulb is gradually filled. Held by a wire handle (Fig. 1), the tube is heated over a furnace until all air has been expelled by the boiling mercury. This being done, and while the mercury is still boiling, the open end of the tube, which must not be too hot, is placed against a piece of sealing wax, some of which drawn in effectually prevents the ingress of air. When quite cool the mercury perfectly fills the lower bulb and tube. The tube is now inclined and the lower bulb raised to a temperature higher than the thermometer is intended to indicate. Some of the mercury is thus expelled. As the column begins to retreat on cooling, the tube is hermetically sealed just below the upper bulb, which is drawn off. The instrument is now stored for some time, or heated for several days to 50° or 100° above the temperature it is intended to indicate. The reason for this will shortly be seen.

Two fixed points must now be taken. The lower is usually taken first. The thermometer is placed vertically in finely pounded melting ice, or preferably snow if it can be obtained, contained in a vessel which will allow the water to drain away. When ice is used, it should be washed with water, for when it has the appearance of salt, it may be considerably lower than 0°. F. D. Brown finds that ice and water is better than ice only; also that the water used should be distilled, as when such is not the case, a temperature lower than 0° results.\* The whole of the mercurial column should be immersed in the mixture. After from twenty min-

utes to half an hour the thermometer may be raised until the top of the mercury is seen just sufficiently for its position to be noted.

Some thermometers intended for use in very cold countries have a still lower point determined on their scales; it is the freezing point of mercury. The process is as follows: From 17 to 20 pounds of mercury are operated upon; it is first cooled down to about -10°, together with the vessels, thermometers, and ether used during the operation. The valve of a tube containing liquid carbon dioxide is unscrewed and gas allowed to escape for about a minute, during which time about 550 grains of solid carbon dioxide will be deposited in the form of snow. This is laid on the surface of the mercury, together with some ether. Having stirred up the mixture, the liberated gas and ether vapor, escaping through the mercury, rapidly cool it down and cause it to solidify on the surface, which is then stirred in. About 6 charges of acid snow and 6 oz. of ether are required to convert the mercury into a pasty consistence. When in this semi-solidified condition, the thermometers and standard are plunged in, and when the mercuric column begins to rise above the lowest point reached, comparison is made.†

The temperature of water boiling under a pressure of 760 mm. is the higher fixed point. To determine this the apparatus of Regnault is recommended, although in its absence a long-necked flask will be found serviceable, if proper precautions are taken. The former consists of a cylindrical copper vessel with double sides, between which the vapor of water circulates. In this kind of boiler there is no possibility of the exterior air reaching the thermometer.‡ In order to insure the regular escape of steam, a small manometer communicates with the interior of the boiler, to indicate the least pressure within. The whole of the mercurial column must be exposed to the vapor of the rapidly boiling water, but after a few minutes it may be raised just above the cork and its position noted. As the boiling point depends upon the pressure of the atmosphere, the height of the barometer must now be taken. If it stands at 760 millimeters, the temperature is 100°. If not, a calculation will be necessary; 1° C. or 1.71° F. must be added or subtracted for every 26.7 mm. above or below 760 mm. The interval between the two fixed points is then divided into 100 parts or degrees for a Centigrade, or 212 parts for a Fahrenheit thermometer. To graduate the scale above 100°, a column of mercury is measured below that point, then made to pass above step by step; the portions of the tube filled by the column are then divided into the number of degrees which it represents. Craft recommends that graduation above 100° be effected by means of pure liquids, as naphthalene or benzophenone,

\* Read before the Chemists' Assistants' Association.—*Pharm. Jour.*

† Except where the meaning is otherwise obvious, degrees Centigrade are intended.

‡ *Phil. Mag.*, 1883, 75.

\* *Phil. Mag.*, vol. xiv., p. 57.

† *Phil. Mag.*, 1886, p. 27.

‡ A figure of this apparatus will be found in the manuals of Ganot and Deschanel.

whose boiling points, 218° and 306° respectively, under a pressure of 760 mm., he considers should be taken as fixed points. When these compounds are used, an apparatus similar to Regnault's should be employed.\*

**Errors.**—There are several causes of error to which thermometers are liable; the greatest is due to the rise of the zero point. A thermometer tube having been filled with mercury, without further preparation the zero point is taken; if it be now put aside for several months, and this point be then again taken, it is seen to be considerably higher. This fact will be noticed sometimes even after intervals of many years, although the rise usually attains its maximum after one year; its extent varies from 0.5 to 3°. This phenomenon has its fundamental cause in the imperfect elasticity of the glass. A perfect solid when heated expands, and in cooling returns to its original form, its contraction being equal to its expansion. Glass when heated expands, but does not return to its former dimensions for a considerable time after it has cooled. In the course of a few months after the thermometer has been filled the bulb generally shrinks by an amount of from  $\frac{1}{1000}$  to  $\frac{1}{500}$  of its bulk. It must be remembered also that there is a vacuum inside the thermometer tube, so that the amount of shrinkage is increased by atmospheric pressure. Dr. Lowenberg supposes that after having been heated, the particles of glass are in a state of tension produced by the slight conductivity of glass, which occasions a cooling or setting in successive layers, and he thinks that this abnormal tension may disappear in consequence of off-repeated molecular movements. Legend holds the same view.

That the bulb is elastic and yields to pressure has been shown by Mills and Egen.† They find that the expansion of the mercury produced by a pressure of two atmospheres is twice as much as that caused by one; or, expressed as a law, the expansion experienced is inversely as the pressure. They observe also that a cylindrical is twice as rigid as a spherical bulb. The effect of the elasticity of the bulb may readily be comprehended from the results of some of Pickering's investigations. He shows that the bulb of every thermometer has two different shapes, one when the column is rising, the other when it is falling. He takes this view from some experiments in which he found that there was a considerable difference in the rate of heating and cooling, up to and down from certain temperatures. He further strengthens his supposition by calling into notice the fact that when the column of mercury rises to any temperature, it will go on rising regularly afterward; but when it falls to that temperature, a certain time elapses before it will begin to rise again, and although the mercury is expanding, the column is stationary, and therefore the bulb must be expanding and assuming a new form.‡

(1) **Rising of the Zero Point.**—If a thermometer be graduated soon after manufacture, the zero point after a short time rises and is incorrect. The graduation must, therefore, be deferred for a considerable time until no further rise takes place. As it may not be convenient to store the tubes, another method is fortunately at hand by which the period is greatly shortened. The thermometer is made and heated to a high temperature; at the end of a few days the zero rises to its utmost extent. The freezing point now taken remains afterward nearly constant. At the Kew Observatory of the Royal Society new thermometers are always subjected to an annealing process, by heating the bulbs in a sand bath for three or four days. Hicks exposes the thermometer tubes for sixteen days to a temperature of 50° or 100° above the highest point which the thermometers are intended to indicate. They are placed in linseed oil; this is gradually heated to the required temperature, and having remained at that point for the proper time, it is very slowly allowed to cool.

Mercury or any liquid which does not act upon the glass may be used. By either of these methods a rise of 2° to 2.5° has been effected in sixteen days, which would have taken months, and probably years, to effect if the annealing process had not been used. It may be said that this error, caused by the rise of the zero point, is very nearly in the inverse proportion of the expansion of the liquid contained in the bulb.§ Mercury in this particular is not the best liquid for thermometers; alcohol has been said to expand six times as much, and ether eight and a half times; therefore the uncertainty of error in the case of alcohol is  $\frac{1}{6}$ , and of ether  $\frac{1}{8}$ , when the possible error in a mercurial thermometer is represented by  $\frac{1}{5}$ .

(2) **Depression of the Zero Point.**—If a thermometer in which the bulb has contracted to its maximum extent be suddenly exposed to boiling water for a short time, the freezing point is found to be lowered by 0.1° or 0.2°; this is known as the "depressed freezing point." A satisfactory explanation of this phenomenon does not appear yet to have been given by any observer. On account of this depression it is customary to ascertain the freezing before the boiling point; the reverse should be done if the instrument is intended for high temperatures, otherwise the readings taken will be 0.1° or 0.2° below.

(3) **Error of Parallax.**—An apparent change in the situation of the end of the mercurial column, owing to the eye not being in the same horizontal plane as the mercury. If the eye is too high, too high a temperature is taken; if too low, the temperature recorded is too low. When looking obliquely at the top of the mercurial column, the graduation mark at that point is reflected from the outside of the mercury. This cannot be seen when the eye is level with it, consequently this fact may be applied for overcoming the difficulty. Another method is to take the reading through a narrow slit in a sheet of note paper or by using a cathetometer.

Minor sources of error are, expansion of the glass, unequal expansion of the mercury, reading the thermometer placed in a vertical position (this is an error only under certain conditions), volatilization of the thermometric liquid, and inertia of the bulb. Although the expansion of the glass gives rise to an error above 204.5°, it does not do so below that temperature, for in the latter case it almost exactly compensates for the unequal expansion of the mercury. Comparing the air thermometer with the mercurial, the following figures show the compensation:

Temperature indicated by air thermometer.

By mercurial.\*

200° 200°  
300° 300°  
350° 354°

When a thermometer that has been graduated in a horizontal position, which is seldom the case, is read in a vertical position, an error of from — 0.1° to — 0.2° is occasioned, owing to the column of mercury pressing upon and dilating the bulb.

Volatilization of the mercury takes place at all temperatures; but at about 150° an error is very liable to be caused, particularly if the upper portion of the tube is comparatively cool. In Geissler's instruments a small volume of hydrogen is contained in the tube, which considerably retards the volatilization.

The inertia of the bulb causes the mercury to rise by a series of small oscillations; in instruments of fine bore about a dozen taps should be given before reading, while less delicate ones require tapping for two or three minutes.†

It is sometimes noticed that the mercury refuses to pass certain points of the tube; this Pickering attributes to a difference in the nature of the glass. Instruments intended for delicate work should be examined for any such imperfections.

When taking exact readings, the whole of the mercury column should be immersed in the liquid. When this is not done, an error arises, owing to a portion of the column not being exposed to the same temperature as the bulb. An approximate correction of this error may, however, be made as follows:

Ascertain the mean temperature ( $t$ ) of the air or other medium to which the upper portion of the stem is exposed, by means of a second thermometer, the bulb of which is placed in contact with the stem of the thermometer used in the determination. Then if ( $a$ ) represents the number of degrees of mercury not immersed in the liquid, and ( $T$ ) the thermometer reading, to this latter must be added 0.00016 :  $a(T-t)$ . 0.00016 is the difference between the coefficients of cubical expansion of mercury and glass, or the apparent coefficient of expansion of mercury in glass. In long and massive thermometers 0.00012 may be written for 0.00016, and the air temperature may be taken for ( $t$ ).‡

**Verification and Calibration.**—It has been shown that many errors may occur in thermometers; in accurate work it is essential to ascertain to what extent these exist, in order that the proper corrections may be made. This is effected by several methods; the most frequently employed are:

1. Verification by comparing with a standard.
2. Bessel's method, simplified by Professor Forbes.§

been purchased of well known apparatus makers, been regarded as correct, serious errors might have arisen.

Table showing temperature indicated by the six thermometers and a Standard S. when similarly exposed to heat.

a.	a.	b.	d.	e.	f.	h.
°	°	°	°	°	°	°
0	0.5	1	1	1.5	1	0.75
5	5.5	6	6	6.25	6	5.75
10	10.5	11	11	11.25	10.75	10.75
15	15.25	16	16	16.25	16	16
20	20.35	21.1	21.1	21.35	21.1	20.85
25	25.6	26	26.1	26.35	26.2	26.1
30	30.6	31.1	31	31.35	31.35	30.6
35	35.6	36.1	36.1	36.35	36.35	35.85
40	40.5	41	41	41.25	41.25	40.75
45	45.5	46	46	46.1	46.25	45.75
50	50.5	51	51.1	51	51.5	50.5
55	55.5	56	56.1	56	56.5	55.25
60	60.5	61	61.1	60.75	61.5	60.5
65	65.5	66	66	65.75	66.5	65.25
70	70.5	71	71.1	70.5	71.25	70.5
75	75.5	76.5	76	75.75	76	75.25
80	80	81	81	80.5	81	80.25
85	85.1	86.1	85.85	85.35	85.6	85.35
90	90.1	91.1	90.6	90.35	90.6	90.1
95	95.1	96.1	95.1	95.1	95.1	94.85
100	99.85	101.1	100.35	100.1	100.6	100.1
105	104	105	105	105.25	105	105
110	109.4	110.4	109.65	110.4	109.9	109.9
115	114.35	115.35	114.85	115.1	114.85	114.85
120	118.8	119.8	119.55	120	119.8	119.3
125	123.8	124.8	124	125	124.8	123.8
130	128.8	129.8	129	130	129.8	128.8
135	133.75	134.75	134.25	135	134.75	133.75
140	138.7	139.2	139	140	139.7	138.7
145	143.6	144.1	143.1	144.6	144.35	143.1
150	148	149	148	149.75	148.5	148
155	152.5	154	152.75	154.75	153.25	152.75
160	157.5	158.5	157.5	160	157.75	157.5
165	161.9	163.4	162.4	165.4	162.4	162.15
170	166.8	168.3	167.8	169.3	167.3	166.8
175	171.3	173.3	173.8	174.3	172.3	172.3
180	176.3	178.3	177.8	179	177.3	176.8
185	181.25	183	182.75	183.75	182.5	181.75
190	186.2	188.2	187.2	188.2	187.3	186.8

**II. Calibration.**—In this method a standard is not required. In order that this method may be perfectly intelligible, the calibration of a thermometer is described in detail.

The freezing point was first determined and was

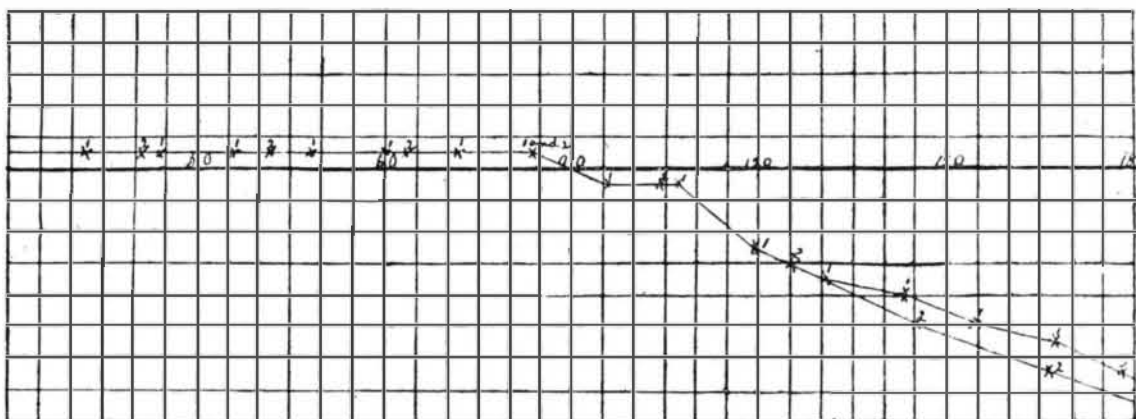


FIG. 2.—CHART SHOWING THE RESULT OF THE CALIBRATION OF A MERCURIAL THERMOMETER.

The numbers 1 and 2 opposite the crosses show where the end of the mercury column rested in the two experiments.

In the course of an investigation conducted in the Research Laboratory of the Pharmaceutical Society it became necessary to regraduate six thermometers; for these the first method was employed. As more than one instrument was verified at a time, only three similar experiments were required. The standard and thermometers were first placed in melting ice and the zero points determined. Melting ice was then exchanged for water, which was slowly heated to 5°, as indicated by the standard. The position of this point was then observed upon the other instruments. This plan of procedure was followed up to 15°, when a different apparatus was required. This consisted of a boiling tube, length about 1 meter, half filled with water. Two thermometers and the standard were fastened together by India rubber bands, and in order to overcome the effects of convection currents they were fixed by means of grooved corks in a long test tube, which was also filled with water. The thermometers were completely immersed in the liquid. Heat was now applied, and when the mercurial column reached the required point, it was kept there for a few seconds while readings were taken. The water was constantly agitated. The comparison of the boiling points having been made, the water was removed and glycerine substituted; the process then proceeded as before. The thermometers marked *a*, *b*, *d*, *e*, *f*, and *h* were verified for every 5° from 0° to 190°. In the curves the abscissæ represent the readings of the scale, and the ordinates the errors. The curve to the right of the letter in every case represents the particular thermometer denoted by that letter. From the table it is seen that the zero point of—

- (a) had risen 0.5°
- (b) " 1.0°
- (d) " 1.0°
- (e) " 1.5°
- (f) " 1.0°
- (h) " 0.75°

The errors are greatest at about 170°. In *f* at 27° there was an inequality in the bore of the tube, it being perceptibly constricted at that point.

It is clear that had these instruments, which had

found to have risen 0.1°. The apparatus used consisted of a cylindrical lamp glass, filled with powdered ice and resting upon some coarser lumps at the bottom of a large beaker; the space between the outside of the glass and the beaker was filled also with powdered ice. After the thermometer had remained in the inner vessel for twenty minutes the reading was taken by removing the ice, so that the zero might be seen without raising the scale.

The boiling point was then determined by exposing the thermometer to the vapor of boiling water contained in a long-necked flask. Steam was allowed to escape through a piece of glass tubing bent at right angles passing through the cork. The top of the mercurial column remained constant for about fifteen minutes at 100.3°; the barometer was then read, and indicated a pressure of 770.5 mm. As water boils at 100° only under a pressure of 760 mm., the true point was calculated; it has been observed that 26.7 mm. above 760 mm. raised the boiling point of water 1°, and the barometric pressure was now 10.5 mm. above 760 mm. The true boiling point is therefore at 100.3° — 0.39° = 99.91°, or 0.09 under the 100° indicated on the scale.

A column of mercury had now to be detached, and the bore of the tube measured from 0° to as near 100° as possible. The length of this short column should be, if possible, an aliquot part of 100°. A little difficulty was at first experienced in obtaining a column sufficiently short. This was overcome by tapping the upper end and allowing a little mercury to run down the tube; a jerk was then given in a downward direction and another away from the operator. When a short column is separated, it may be made shorter by bringing one end of the column contiguous to the remainder of the mercury, then cooling; if it is required longer, heat must be applied. In either case a jerk must be given away from the operator immediately after the heating or cooling. In this way a column of exactly 12° was made to pass step by step from 0° to the point nearest 100°, which was 95.8° after eight columns had been measured. The calibration was then continued to 180°.

0° on the scale has been shown to be 0.1° too high; its correct reading is therefore — 0.1°.

The last reading was 95.8°; assuming the error here to be the same as at 100°, the true reading is 95.8° + 0.09° = 95.89°.

\* *American Chem. Journ.*, vol. v., No. 5.

† *Phil. Mag.*, 1887, 406.

‡ *Phil. Mag.*, 1886, 330.

§ *Encyclop. Britannica*, (Heat.)

\* Fownes' "Chemistry," p. 32.

† *Phil. Trans.*, 1886, 330.

‡ Kohlrausch's "Physical Measurements," p. 79.

§ *Phil. Trans.*, 1836, 578.



The value of the space from starting point to finish is readily seen to be 95.89°—the true reading at 0°, which is  $-0.1^\circ$  (this being a minus quantity has therefore to be added)=95.99°. This space had been traversed by eight columns, therefore the value of a single column or  $I = \frac{95.99}{8} = 12^\circ$ .

The readings taken at the points which the column successively reached can now be corrected. The true temperature in every case is length of the column or  $I$ —error at 0°. Thus at the first point,  $12^\circ$ , at which the column rested the true reading is  $12^\circ - 0.1 = 11.9^\circ$ , at the second  $24^\circ - 0.1$ , or  $23.9^\circ$ , and so on.

A lens was used to take every reading. The exact part of the degree at which the end of the column stood was determined by means of a degree magnified, divided into ten parts, sketched on a piece of paper, which was placed by the side of the degree in which the end fell.

The results are recorded in the tables below; they are projected also into a curve (Fig. 2), from which the error at any point of the scale can easily be seen. The accuracy of the method is seen by comparing the results obtained by using, first, a column of  $12^\circ$ ; secondly, one of  $21^\circ$ . Two columns should always be taken, as they serve to fix the errors at a greater number of points on the scale. The process is not tedious, requiring only three or four hours for its accomplishment. The mean is taken of the two results.

#### First Experiment.

True temperature.	Scale reading.	Error of scale.
$-0.1^\circ$	0°	$+0.1^\circ$
11.9	12	$+0.1$
23.9	24	$+0.1$
35.9	36	$+0.1$
47.9	48	$+0.1$
59.9	60	$+0.1$
71.9	72	$+0.1$
83.9	84	$+0.1$
95.9	95.8	$-0.1$
107.9	107.8	$-0.1$
119.9	119.4	$-0.5$
131.9	131.2	$-0.7$
143.9	143.1	$-0.8$
155.9	154.9	$-1.0$
167.9	166.8	$-1.1$
179.9	178.6	$-1.3$

#### Second Experiment.

True temperature.	Scale reading.	Error of scale.
$-0.1^\circ$	0°	$+0.1^\circ$
20.9	21	$+0.1$
41.9	42	$+0.1$
62.9	63	$+0.1$
83.9	84	$+0.1$
104.9	104.8	$-0.1$

True temperature.	Scale reading.	Error of scale.
125.9	125.3	$-0.6$
146.9	145.9	$-1.0$
167.9	166.6	$-1.3$

#### Table of Corrections.

0°	$-0.1^\circ$	70°	$-0.1$	140°	$+0.85$
10	$-0.1$	80	$-0.1^\circ$	150	$+1.0^\circ$
20	$-0.1$	90	0	160	$+1.1$
30	$-0.1$	100	$+0.1$	170	$+1.25$
40	$-0.1$	110	$+0.15$	180	$+1.4$
50	$-0.1$	120	$+0.5$	—	—
60	$-0.1$	130	$+0.7$	—	—

In order to obtain complete information as to the methods used for the verification of thermometers, I was enabled to watch at the Kew Observatory of the Royal Society the graduation of an instrument intended for a standard. Instead of dividing the interval between the zero and boiling points into 100 parts, without paying regard to the bore of the tube, the following process was employed:

The thermometer was attached to a dividing engine, furnished with a micrometer eyepiece having a cross wire in its focus. One end of a short detached column of mercury was placed in the focus of the micrometer, a screw was turned until the other end became visible. Thus its length was ascertained in revolutions of the screw. This process was repeated until the column had been measured for every length of itself from below  $0^\circ$  to  $100^\circ$ . The length of tube comprised between these latter two points was then ascertained. This was divided by the number of calibrations included in that portion; this gave the mean length of a calibration. The value of this in degrees was ascertained by dividing  $100^\circ$  by its length; the value in degrees of each calibrated portion was then obtained. The tube was then dipped into melted beeswax, contained in a long cylindrical tin, around which steam passed. Afterward it was again placed on the engine and divided by means of a fine needle point into the requisite number of degrees. These were etched upon the glass by dipping into hydrofluoric acid, and the wax having been melted off, a mixture of lampblack and oil was rubbed in to fill up the graduation marks.

In another room verification was conducted. The freezing point is ascertained by placing the thermometers in a wooden box filled with powdered ice, from which the water is allowed to drain. Above  $0^\circ$  to  $100^\circ$  verification is effected by fixing about forty instruments and a standard to a revolving stand. This is placed in a copper cylinder filled with water; there is a slit about two feet long in one side of this, glazed with a sheet of glass. Loss of heat is obviated by placing this cylinder in a wooden box, the space between the sides of the box and the cylinder being filled with sawdust. An aperture in the side of the box is cut out, opposite to the glass plate of the internal vessel. Heat is applied by a boiler which sends heated water to the top of, and receives the cooled water from the bottom of, the water vessel. A handle turns a number of paddle-wheels, which revolve in the center of the stand; thus the water is thoroughly mixed. When readings are taken the source of heat is removed, and another handle is turned, by which the thermometer frame is turned once round forward and once backward. Each instrument is read twice, and the mean of the two readings is taken.

The verification of clinical thermometers has an entire room devoted to it. The apparatus is much the

same as that used for ordinary instruments, except that a separate heating arrangement is not used; fewer readings are required, usually about four. Each then has K. O. (Kew Observatory) and a number, succeeding that of the thermometer last verified, etched upon it.

**Various Forms of Thermometers.**—A description is given only of such of which the construction has been modified for some scientific or technical requirement.

1. **Minimum Thermometer.**—Many forms are in use. Casella's consists of an ordinary thermometer, of which the bulb is furnished with an overflow chamber; when a rise of temperature occurs, the mercury expands into this chamber, from which it cannot pass when a fall of temperature takes place. The height of the column in the stem now indicates the minimum temperature reached.

2. **Maximum Thermometer.**—A small plug of porcelain is inserted just above the bulb; the expanding mercury passes this, and when once past, can no longer return; the maximum temperature is thus easily read off.

3. **Six's Maximum and Minimum Thermometer.**—One form consists of a U tube having a bulb at each extremity. One arm of the tube is half filled with mercury; one bulb and the remaining portion of the tube above the mercury is filled completely with alcohol; the other bulb is only partially filled with this liquid. A steel index, prevented from falling by a hair tied round it, moves on the surface of the mercury in the side tubes. Should a rise of temperature take place, the spirit in the full bulb expands, causing the mercury to push up the index in the other limb. The reverse of this occurs when a diminution of temperature takes place. The lower ends of the indices nearest the mercury indicate the maximum and minimum temperatures.

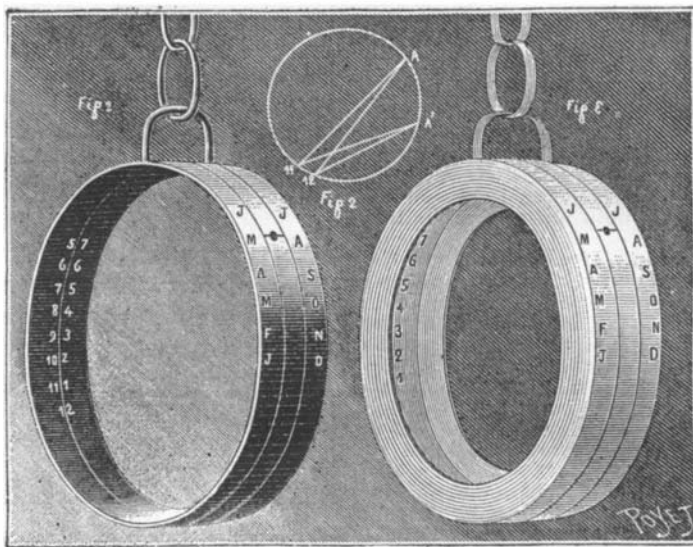
4. **Solar Radiation Thermometer.**—When an electric current is passed through a vacuum, the inductive spark is white, filling the whole tube. Any pressure exceeding one tenth of an inch will not show this effect; if moisture is present, a redness in the light is perceived.

variation of the height of the sun above the horizon during the day. An experiment soon confirmed this. A few rough measurements showed me that this sun dial had been constructed for a latitude that I estimated to be that of London.

I have, on several occasions, had an opportunity of assuring myself that this form of sun dial is very little known. I have, however, found a trace of it in an English book entitled "Time and Time Tellers," the author of which (J. W. Benson) states that it was one of the first timepieces ever constructed. Rings of this kind were extensively used during the last century. They were manufactured in large numbers at Sheffield, when watches were still too expensive to be generally used. Some of these rings, of superior construction, were made in such a way that they could be employed in various latitudes.

The elementary theory of this instrument is easy to establish. We find that the nearer we approach the summer solstice, the more the aperture, A, is to be lowered. Outside of the equatorial zone, its extreme positions differ by about  $94^\circ$ . But thanks to a well known property of the circle, the angles, such as  $11^\circ$  A 12,  $11^\circ$  A' 12 (Fig. 2), having their apex in the various points that the small aperture can occupy, and the sides of which pass through the same hour figures, are equal. The instrument would therefore be perfectly accurate were the differences between the heights of the sun for two determined instants of the day the same at every season. Such is not the case; but, upon adapting the internal figures to the mean of the variation in the solar height, we succeed in reducing the extreme errors to less than a quarter of an hour for a mean latitude. It is easy to satisfy one's self, without any calculation, that this instrument cannot be employed in high latitudes, since, at the poles, the sun is perceptibly at the same height during the entire day.

It is very easy to construct a portable sun dial of Bristol board. It is well to give it a diameter wider than four inches, and to secure an invariable form by strengthening it with rings cut out as shown in Fig. 3.



PORTABLE SUN DIAL.

These facts are made use of in making solar radiation thermometers. The thermometer is surrounded by a chamber, having a platinum wire near each end. This is made vacuum; the test is then applied and the perfectness of the exhaustion determined.

The instrument is now exposed to the sun's rays, and a true indication of their temperature is given by the height of the mercurial column. Upon the perfect exhaustion of the chamber the accuracy of the thermometer depends.

5. **Immisch's Metallic Thermometer.**—This consists of a minute tube, filled with liquid and fixed at one end; the other end bears on the short arm of a lever, the long arm of which acts by a rack on the pinion forming the axis of the pointer. They are watch shape, one inch in diameter, and very accurate.

6. **Clinical Thermometer.**—Perfection in these seems almost to have been reached. They may be obtained only two inches in length, and are sometimes fitted with lens fronts, so that their scales are magnified many times—a great desideratum considering the small size of the instrument.

7. **Fire Alarm Thermometer.**—A thermometer is balanced on a knife edge, a sliding band having previously been placed at the temperature which has not to be exceeded. So soon as this temperature is reached, the mercury overbalances the thermometer, and causes its upper end to make contact with the wires of a battery; a bell immediately rings loudly and continuously until attention has been called.

I wish to thank Mr. G. W. Whipple, B.Sc., F.R.A.S., superintendent of the Kew Observatory of the Royal Society, for allowing me to watch there the methods employed for the verification and calibration of thermometers; also Mr. Hicks, 9 Hatton Garden, for lending me the thermometers to illustrate this paper.

#### A PORTABLE SUN DIAL.

SOME years ago, an antiquarian made me a present of a small brass ring of a singular form, that he did not know the use of and could not tell where it came from.

Set into a groove on the exterior of this ring (Fig. 1) there was a brass band that could be moved circularly. This band contained an aperture traversed by a straight line at right angles with its sides. Upon examining the ring more closely, I noticed upon the external part, not far from a ring that apparently served to support it vertically, some ill-formed letters, in which I recognized the initials of the names of the months, and, in the interior, a series of figures on each side of a line. The band covered a slit formed in the ring near the letters.

After turning this singular object over and over again, the idea occurred to me that it might have served as a sun dial of a peculiar kind, based upon the

A plumb line placed within serves to control its verticality.

This little device will perhaps tempt some of our readers, who will find in the construction of the instrument a good opportunity to study the apparent motion of the sun.—C. E. Guillaume, in *La Nature*.

#### THE AGEING OF LOGWOOD.

IN some articles on logwood by L. Bruehl in the *Textile Colorist*, a subject of importance to logwood users is touched upon, namely, the necessity for the ageing, or mastering as it is called here, of logwood.

It is well known that logwood, when freshly cut, is of a pale yellowish brown color. On exposure to the air it gradually acquires its characteristic red color, this being due to changes in the coloring principles of the wood, which exist in the wood in three forms, first as a glucoside, secondly as hæmatoxyline, a colorless body, and lastly as the color hæmateine. The glucoside which exists in the wood splits up by some change into a glucose and hæmatoxyline, and this latter body, by oxidation, is transformed into the colored body hæmateine.

This change occurs naturally, but the process is a very slow one. It can be brought about more rapidly by artificial means, and herein constitutes the process carried out by all dyewood grinders of ageing the logwood, which is done because most dyers think that the darker the wood the richer it is in coloring power, and, therefore, they demand dark wood from the dealers, who naturally supply the demand of the dyers. Now Bruehl states that this oxidized or aged logwood does not yield as fast colors as fresh wood does. After testing samples of wood oxidized in several different ways, he found the unoxidized wood to give colors superior in their power of resisting exposure to light as well as to washing and the action of chlorine.

It may then be asked why should logwood be aged if unaged logwood gives better results? Probably the reason is this, that for most of the uses to which logwood is put, it is necessary to have clear decoctions, and it is easier to get a decoction from aged than from fresh logwood, and the decoctions, too, look stronger, even if they are not really so. For some classes of goods, blacks, a decoction is by no means necessary, and the wood may be used direct in the dyebeek with much more satisfactory results than if a decoction were used; the color obtained would be more solid and fast; the wood could easily be brushed off the goods after dyeing, and, from some experience, we are of opinion that a decoction made from fresh wood would be found to give much better results than one prepared from many of the extracts which are nowadays so largely used, and the constitution of which is so very doubtful.