

X. *Account of an improved Thermometer.* By Mr. James Six ;
communicated by the Rev. Mr. Wollaston, F. R. S.

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ATTEMPTING some time ago to ascertain the greatest degree of heat and cold that happened in the atmosphere each day and night, or during the course of twenty-four hours, I experienced the inconvenience which attends thermometers commonly made use of for that purpose ; the necessity I mean of the observer's eye being on the instrument the very instant the mercury stands at the highest or lowest degree : for, since the time when that may happen is utterly uncertain, if it be not immediately noticed, it can never after be known. The sultry heat of the summer's days, and freezing cold of the winter's nights, which is commonly most severe at a late unseasonable hour, render it very unpleasant to be abroad in the open air, although it is absolutely necessary for the thermometer to be placed in such a situation. Ingenious men of our own country, as well as foreigners, have, it seems, long ago endeavoured to remedy this inconvenience ; and several thermometers of different constructions have been invented for that purpose. VAN SWINDEN describes one which he says was the first of the kind, made on a plan communicated by Mr. BERNOULLI to Mr. LEIBNITZ. Mr. KRAFT, he also tells us, made one nearly like it*. A description of those by Lord

* Diff. sur la Comparaison du Therm. par VAN SWINDEN, p. 253—255.

CHARLES

CHARLES CAVENDISH and Mr. FITZGERALD may be seen in the Philosophical Transactions *. Though much ingenuity appears in the invention of those curious instruments, I could not forbear thinking, that a thermometer might be constructed more conveniently to answer the purpose, and shew accurately the greatest degree of heat and cold which happened in the observer's absence. I therefore attempted to make one: with what success I submit to your better judgement, and proceed to give a description of the instrument. Fig. 1. *ab* is a tube of thin glass, about sixteen inches long, and five sixteenths of an inch in diameter; *cdefgb* a smaller tube with the inner diameter, about one fortieth, joined to the larger at the upper end *b*, and bent down, first on the left side, and then, after descending two inches below *ab*, upwards again on the right, in the several directions *cde*, *fgb*, parallel to, and one inch distant from it. On the end of the same tube at *b*, the inner diameter is enlarged to half an inch from *b* to *i*, which is two inches in length. This glass is filled with highly rectified spirits of wine to within half an inch of the end *i*, excepting that part of the small tube from *d* to *g*, which is filled with mercury. From a view of the instrument in this state, it will readily be conceived, that when the spirit in the large tube, which is the bulb of the thermometer, is expanded by heat, the mercury in the small tube on the left side will be pressed down, and consequently cause that on the right side to rise; on the contrary, when the spirit is condensed by cold, the reverse will happen, the mercury on the left side will rise as that on the right side descends. The scale, therefore, which is FAHRENHEIT'S, beginning with 0 at the top of the left side, has the degrees numbered downwards, while that at the right

* Phil. Transf. vol. L. p. 501. and vol. LI. p. 820.

side, beginning with *o* at the bottom, ascends. The divisions are ascertained by placing this thermometer with a good standard mercurial one in water gradually heating or cooling, and marking the divisions of the new scale at every 5° *. Thus far our thermometer resembles in some respects those of Mr. BERNOULLI and Lord CHARLES CAVENDISH; but the method of shewing how high the mercury had risen in the observer's absence, the essential property of an instrument of this kind, is wholly different from theirs, and effected in the following manner. Within the small tube of the thermometer, above the surface of the mercury on either side, immersed in the spirit of wine, is placed a small index, so fitted as to pass up and down as occasion may require: that surface of the mercury which rises carries up the index with it, which index does not return with the mercury when it descends; but, by remaining fixed, shews distinctly, and very accurately, how high the mercury had risen, and consequently what degree of heat or cold had happened. Fig. 2. represents one of these indexes drawn larger than the real ones, to render it more distinct. *a* is a small glass tube, three quarters of an inch long, hermetically sealed at each end, inclosing a piece of steel wire, nearly of the same length; at each end *cd* is fixed a short piece of a tube of black glass, of such a diameter as to pass freely up and down within the small tube of the thermometer. The lower end, floating on the surface of the mercury, is carried up with it when it rises, while the piece at the upper end, being of the same diameter, keeps the body of the index parallel to the sides of the thermometrical tube. From the upper end of the body of the index at *c* is drawn a spring of glass to

* The divisions below the freezing point are taken by means of a mixture of sea salt and ice, as described by NOILLET, DE LUC, and others.

the fineness of a hair, about five sevenths of an inch in length, which, being set a little oblique, presses lightly against the inner surface of the tube, and prevents the index from following the mercury when it descends, or being moved by the spirit passing up or down, or by any sudden motion given to the instrument by the hand or otherwise; but at the same time the pressure is so adjusted as to permit this index to be readily carried up by the surface of the rising mercury, and downwards whenever the instrument is be rectified for observation. To prevent the spirit from evaporating, the tube at the end *i* is closely sealed*. Fig. 3. represents the thermometer on its frame; the plates on which the scale is graved on either side are made to slide out, and the frame is open to the back, behind the large tube, which does not touch it, except at each end. The cap *a*, and the base *b*, are made to fix on with screws, and only cover the turning of the small tube. By a screw at the bottom of the frame, it may be made fast to the wall against which it is to hang without doors, to prevent its being shaken by violent winds. Towards evening I usually visit my thermometer, and see at one view, by the index on the left side, the cold of the preceding night; and by that on the right, the heat of the day. These I minute down, and then apply a small magnet to that part of the tube against which the indexes rest, and move each of them down to the surface of the mercury: thus, without heating, cooling, separating, or at all disturbing the mercury, or moving the instrument, may this

* When this tube is closed (not hermetically, but only so as to prevent the spirits evaporating) the thermometer must be brought to the greatest heat it is likely at any time after to sustain; and though no more air is inclosed than what remains at that time above the spirits, yet that will, by its elasticity pressing on the fluid, answer every purpose as well as if the external air was freely admitted.

thermometer, without a touch, be immediately rectified for another observation. When I wish to put the thermometer out of my hand, without hanging it up, I have a stand to place it on; for if the mercury presses against the index, while the instrument lies in an horizontal position, it is in danger of passing by it, which is avoided by keeping the thermometer in a position nearly vertical. To prevent the mercury shifting its place in the spirits within the tube (which I apprehended it might do on account of the superiority of its specific gravity, especially when kept for a considerable time, very high on one side, and low on the other), I made that part of the small tube from *e* to *f* with the inner diameter exceeding small; and found, upon trial, that after the summer's heat had kept the mercury for a long time high on one side, the winter's cold brought it again as accurately to the freezing point on the other as at first*. This thermometer may be made a mercurial one by inverting the glass, and filling with mercury that part which in the first is filled with spirits, and with spirits that part of the small tube from *d* to *g* which in the former is filled with mercury; the indexes in either case may be the same, and will be carried up in the same manner upon the surface of the mercury; but the end of the tube at *i*, instead of being sealed, must then be left open, and stand inverted in a bulb, or small cistern of mercury, into which the external air has free access. The diameter of the tube *ab* should be considerably increased if the degrees on the scale are required to be as wide as those in the spirit thermometers. It is indeed better in this case to have a double rather than a larger single tube; but finding the weight of so great a quantity of mercury in a thin glass tube

* With a thermometer of this sort I observed the greatest heat and cold that happened every day and night throughout the year 1781.

attended with many disadvantages, and the motion of the fluids in the spirit-ones perfectly agreeing with, and being as readily excited by change of heat and cold, as in the mercurial thermometers, I preferred the former as much more commodious. A person cannot approach near to the thermometer first described when the air is very cold (especially with a light which by night is necessary) without causing the spirits presently to expand, and consequently the mercury on the left side immediately to descend. This sensibility is here attended with every advantage, without the inconvenience to which common thermometers in this case are liable *; for the index will accurately shew the greatest height to which the mercury had risen, although, before the exact degree can well be distinguished, it will appear separated from the index, and descending apace. As the scale is sixteen inches long, and divided into 100° only, which are more than sufficient for the temperature of the air, they are large enough to be sub-divided at pleasure. The indexes, though of a tender and delicate nature, when once placed in the tube, are not liable to suffer any alteration by time or accident; and the thermometer may be exposed to rain at all times, without suffering the least injury in any respect.

In constructing the thermometer before mentioned, I at first hit on a plan by which the same end was obtained by a dif-

* The most sensible mercurial thermometers commonly have the column of mercury as well as the degrees very small, and a person assisted with a light can hardly view them near enough, when the weather is very cold, without causing the mercury to rise before the degrees where it stood can be well ascertained.

Freezing fogs also, which with us usually attend the greatest degrees of cold, by covering the glass with frost, render the mercury invisible, and cannot well be mercury removed without causing the to rise, or at least render the observation doubtful, which at such a time is very disagreeable; for, in proportion to the extraordinary degree of cold, so is our curiosity likely to be excited.

ferent method; and though, in some respects, and for some purposes, it may not be so proper as that already described, yet, for some others, it may be found useful, and therefore I shall briefly describe it. The glass of this instrument is in all respects the same as in the former, excepting that the diameters of the tubes are something larger. It is likewise filled with spirits of wine and mercury, in the same manner; but the indexes are different, being only a small tube of black glass, about five-sevenths of an inch in length, hermetically sealed at each end, containing a piece of steel wire. An index of this sort is placed in the thermometer on either side, which, having no spring to support them, sink down in the spirits, and rest upon the mercury. Whenever the mercury descends, the index will follow it; but when it rises, the index will not rise with it, and by remaining at the place to which the mercury had descended, will shew the greatest degree of heat or cold which had happened. In this manner do these indexes answer the same purpose, though they move directly contrary to the others in the other thermometer; but this instrument is not so easily rectified as the former, for the most powerful magnet will not bring the index up again while the mercury above presses against them; and although it is possible to remove the mercury, and by that means set the index at liberty, yet inconveniences will be incurred from which the other is entirely free.

In some cases it may be found expedient, instead of the double thermometer first described, to make two single ones; one to shew the greatest degree of heat only, and the other the cold, each having its proper index (see fig. 4. and 5.). The first has the small tube bent down on the left side, and the lower end immersed in a bulb or small cistern of mercury, to which the external air has free access; the other has the small
tube

tube turned up on the right side, with some mercury let down to the bottom, and the upper end closely sealed, as in the double instrument. Making a standard mercurial thermometer, by which the scale of the spirit one was to be divided, I endeavoured to obtain as wide degrees as possible, that the motion of the mercury might thereby be rendered more conspicuous, and the height of it ascertained with greater precision. It is true, the larger the degrees, the larger in some measure must be the bulb, and therefore the fluid contained in it not likely to be so soon affected by any change of heat or cold in the atmosphere as in a smaller. But as this thermometer was principally to be used immersed in a large quantity of water, gradually heating or cooling, little or no disadvantage could arise from making the bulb somewhat larger than those commonly made use of in the air. Not being able, however, to procure glass tubes so long as I had occasion for, whose inner diameters were perfectly equal, I took the following method to adjust the divisions on the scale to the inequality of the tubes. Choosing a tube of a length suitable to my purpose, with a proper bulb at the end, I put into it a small quantity of mercury * sufficient to form a column about one inch in length. Drawing then on a board the three lines *aa*, *bb*, *cc*, fig. 6. I placed the glass tube on the line *aa*, and while the mercury remained at rest at the end of the tube, near the bulb, I made two pencil marks on the line *aa*, one at *d*, and the other at *e*, perfectly coin-

* To put in a small quantity of mercury, and measure its length at different parts of the tube, as described by Abbé NOLLET, vol. IV. p. 370. *Lecons Physique*, is a very excellent method to discover the error; but in what manner readily to adjust the scale, so as to avoid any inaccuracy from such inequality (which in tubes of the length I had occasion for seemed to me unavoidable) was a matter concerning which I could meet with no information.

ciding with the two ends of the column of mercury: then causing the mercury to move slowly on farther from the bulb, till that end of the column which was first at *d* coincided with the mark at *e*, and letting it rest again, I made another mark at *f*; after which, causing the mercury to move on as before, and continuing to mark its length at every part of the tube till it reached the end farthest from the bulb; by these means I obtained the several intermediate points on the line *aa*. Through these several points I drew dotted lines parallel to each other, and at right angles with the line *aa* to the line *bb*. Taking now, with a pair of compasses, the widest intervals between any of the dotted parallels, which in this case is from *d* to *e*, I inserted that distance successively between the several parallels, beginning at the lowest pair, as from *d* to *e*, from *e* to *f*, from *f* to *g*, and so on to *b*, as exhibited in the figure; and the aggregate of these lines may be considered as one continued line, without any error of consequence in this matter. Having now the thermometer completely filled with mercury, the air expelled, the point of the scale at 102° , and the freezing point properly taken * and marked upon the tube, which was now hermetically sealed, I again applied the tube to the line *aa*, and marked on that line the point of 102° and the freezing point. Through those points I drew the lines *ii*, *kk*, and divided that part of the compound line *db* included between *ii*

* The freezing point, marked on the tube of this thermometer, is immediately taken by means of grated ice; but the point of 100° by a standard mercurial thermometer, the upper point of the scale of which was properly taken by boiling water, and the lower one by grated ice; but it is more commodious in the first to have the tube no longer than the air scale, especially as the degrees are pretty wide. The method of adjusting the scale to the inequality of the tube remains the same, let the given points be at any distance, or the divisions increased to any number,

and

and *kk* into 14 equal parts, beginning at *o*, the point where *ii* cuts the line *db*, continuing afterward six divisions now on that line below *kk*, making in all 20 equal divisions. If now lines be drawn through each of the dividing points, from *o* to 20 to the line *cc*, at right angles with the same, they will give on the line *cc* the true thermometrical scale to every 5° from 2 to 102, properly adjusted to the inequality of the tube*, which in this case is nearly of the same diameter at each end, but smaller towards the middle. Tubes may indeed be found of some considerable length with less inequality than what this scale exhibits; but the error is here enlarged, to render the method of correcting it more conspicuous.

* Experimentally to prove this method I have made mercurial thermometers, whose scales from the freezing point to that of boiling heat were nearly three feet, and though the inequalities of the tubes were very considerable, varying in contrary directions to each other; yet when they were placed on the same frame, they perfectly agreed in a motion of the mercury in every part of their scales.

