

Essays on the construction and graduation of thermometers, and on the heating and cooling of bodies / by George Martine ...

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E S S A Y S

ON THE

CONSTRUCTION AND GRADUATION

OF

T H E R M O M E T E R S,

AND ON THE

HEATING AND COOLING

OF

B O D I E S.

BY GEORGE MARTINE, M. D.

A NEW EDITION,
WITH NOTES AND CONSIDERABLE ADDITIONS,
ESPECIALLY THE
TABLES of the Different SCALES OF HEAT,
exhibited by DR. BLACK, in his Annual
Course of Chemistry.

EDINBURGH:
PRINTED FOR AND SOLD BY WILLIAM CREECH.

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As this book is recommended by DR BLACK, to the Students attending his class, the Editor has endeavoured to render this edition more useful to them by inserting some notes, and by adding, in the appendix, some tables of the scales of heat, which the Doctor usually exhibits and explains in his course.

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ESSAY

ON THE
CONSTRUCTION AND GRADUATION

OF
THERMOMETERS.

Qui vel caloris vires, & calorem ipsum veluti in gradu partiri, vel materiae cui inditus est copiam quantitatemque distincte percipere, &c.— Utinam id alii & perspicaciori praediti ingenio, & quibus in summa tranquillitate rerum naturam perscrutari licuerit assequantur; ut homines non omnium modo scientes, sed omnium fere potentes fiant.

BERNARDINUS TELESIVS.

St. Andrews, Aug. 1738.

SOME
OBSERVATIONS
AND
REFLECTIONS
CONCERNING THE
CONSTRUCTION AND GRADUATION
OF
THERMOMETERS.

WE cannot enough commend and admire that excellent invention of *Thermometers*, whereby we are enabled to make some judgement of the various degrees of heat in bodies. It is not our business at present to determine to whom we owe that noble and useful discovery; whether to Sanctorio, to Galileo, to Father Paul, or to Drebbel: for I find it ascribed to

all these by their respective favourers and admirers*. At first, as is the fate of all other inventions, Thermometers were but rude and imperfect machines, and not easily to be applied to so many purposes as came afterwards to be in use. They were very clumsy; and, as the various degrees of heat were pointed by the different contraction or expansion of air, they came afterwards to be found uncertain, and sometimes deceiving measures of heat; as

* The invention is given to Drebbel by his countrymen Boerhaave (*Chem. I. 152, 156.*) and Muschenbroek (*Tent. Exp. Acad. Cim. Add. p. 8. Eff. de Phys. § 946.*) Fulgenzio (*Life of Father Paul, p. m. 158.*) ascribes it to his master Father Paul Sarpi, that great oracle of the republic of Venice. But there was an humour prevailed, in those days of fathering almost all the curious discoveries of the age on that great statesman and virtuoso. Vincenzo Viviani (*Vit. Galil. p. 67.* See too *Oper. di Galil. Pref. p. 47*) speaks of Galileo as the inventor of Thermometers. But we know how much and how fondly he adored the memory of his great master. (See *Hist. Acad. des Scien. 1703, p. 169, 175, 176, 180.*) Still all these are posthumous claims, and they too imputed by others. But Sanctorio himself (*Com. in Galen. Art. Med. p. 736, 842. Com. in Avicen. Can. Fen. I. p. 22, 78, 219.*) expressly assumes the invention in question. And Borelli (*de Mot. Animal. II. Prop. 175.*) and Malpighi (*Oper. Posth. p. 30*) ascribe it to him without reserve. And these Florentine academicians are not to be suspected of partiality in favour of one of the Patavinian school.

as the bulk of air was affected not only by the difference of the heat, but likewise by the difference of the weight of the atmosphere*.

2. † Ferdinand II. great duke of Tuscany, or the gentlemen of the *Accademia de l' Cimento* under his protection, made a very great improvement on those curious and useful machines. They made them with spirits inclosed in glass tubes, and these hermetically sealed. So that they could suffer nothing by the evaporation of liquor, or the various gravity of the incumbent atmosphere. And it was Thermometers made in this way which were first introduced into England by Mr. Boyle‡, and came immediately to be of universal use among the virtuosi in all the several countries, wherever polite learning and philosophy were cultivated.

3. But there was not so much use made of those instruments as they were capable of. We have plenty of observations made with particular Thermometers at different times and places. But then these were not constructed by any fixed scale or standard. Even the Florentine Weather-glasses themselves, whose highest term was adjusted to the great sun-shine heats of that country, were too vague and indetermined: and in other places every workman made them according to his own way and fancy, without adjusting his numbers to any

A 3

known

* Boyle Exp. on Cold, Abr. I. p. 577, &c.

† Vivian. Vit. Galil. p. 67.

‡ Exp. on Cold, Abr. I. p. 582.

known or determined degrees of heat. And so they could not be compared one with another; nor could the observations made by different persons, and in different parts of the world, be collated with any degree of certainty or justness. By which means, notwithstanding all the very numerous registers of the weather that have been kept and published by different authors, we are still at a loss to determine the comparative differences of heat and cold in different countries and climates, and the result of many other observations.

4. Had all the Weather-glasses in the world been made according to one determined scale, these inconveniencies and uncertainties would have been prevented; which are now unavoidable, and must still continue so, until every body agree to graduate their Thermometers in the same way, or at least determine some fixed or unalterable points of heat, to which all the different scales of those instruments may be reduced.

5. The great and truly honourable Mr. Boyle * found himself very much at a loss for a standard, whereby to measure heat and cold: the common instruments shewing him no more than the relative coldness or heat of things, but leaving him in the dark as to their positive degrees. Whence he could not communicate the idea of any such degree to
another

* Exp. on Cold, Abr. I. p. 579.

another person. Thermometers were then such indefinite and variable things, that it seemed morally impossible from them to settle such a measure of heat and cold, as we have of time, distance, weight, &c. there having been then no method thought upon to compare together any two different Thermometers; or the observations made by them. Now as bodies are variously affected by various heats, regularly undergoing such and such changes, at such and such degrees of it, so the fairest way to fix a standard method of adjusting Thermometers would seem to be from some remarkable change a body underwent by the application of a certain degree of heat to it. In consequence of which, Mr. Boyle proposed the freezing of the essential oil of aniseeds as a term of heat and cold that might be of use in making and judging of Thermometers; and so to graduate them from this point according to the proportional dilatations or contractions of the included spirits. He mentioned, too, the coldness requisite to begin the congelation of distilled water as another fixed term that might be proposed; for he was persuaded that among the ordinary waters some were apt to freeze more easily than others. But the objections which he apprehended might be made to this method scared him so much, that he prosecuted no farther this consideration of fixing a standard for making and graduating Thermometers all in the same way:—which it is pity one of his genius and industry, and assisted with such opportunities, did not carry farther; as it is

of

of such importance on a thousand occasions in the history and philosophy of Nature.

6. The ingenious and acute Dr. Halley * was likewise very sensible of the bad effects of that indefinite way of constructing Thermometers; and wished to have them adjusted to some determined points. He, with Mr. Boyle, lays aside the freezing of liquors, as being, in his opinion, points of heat not so justly determinable but with a considerable latitude. And what he shews the greatest fondness for, is the degree of *temperature*; such as in places deep under ground, where the heat in the summer, or cold in winter have been found to have no manner of influence. Thus in a cave cut strait into the bottom of a clift fronting the sea to the depth of 130 feet, with 80 feet of earth above it, Mr. Boyle † found the spirit in the Thermometer to be raised to the same height both in summer and winter. And Messrs. Mariotte, De la Hire, and Maraldi assure us, that in the cave under the royal observatory at Paris, the heat continues always the same, scarcely altered by the most sultry summer heats, or bitterest colds of that country.

But, with Dr. Halley's leave, this degree of *temperature* I do not think a very convenient term for an universal construction of Thermometers. Every body cannot go to Mr. Boyle's grotto: and it is
but

* Phil. Transf. Abr. II. p. 36.

† Mem. Hist. of the Air, Abr. III. p. 54.

but few who can have an opportunity of making observations, and adjusting Thermometers in the cave of the Parisian observatory. And we are not sure that other deep pits would coincide precisely with the temperature of these places. The difference of soils and different depths might occasion a considerable variation.

7. Another term of heat Dr. Halley * thought might be of use in a general graduation of Thermometers, is that of *boiling spirit of wine*. “ Only
“ it must be observed, that the spirit of wine used
“ to this purpose, be highly rectified; for otherwise
“ the differing goodness of the spirit will occasion
“ it to boil sooner or later, and thereby pervert the
“ designed exactness.” He objects, too, its great aptness to evaporate, and that in length of time it becomes, as it were, effete, and loses gradually a part of its expansive power. But truly this last mentioned difficulty, though repeated after Dr. Halley by several others, and commonly pretty much insisted on, would seem to be of no great weight. Well rectified spirit of wine, if sealed up in a glass, is pretty unalterable. It cannot evaporate: and by many years experience its force of expansion has continued the same; as, beside other observations, we know especially from the annual registers of Mr. De la Hire’s spirit Thermometer, that

* Phil. Transf. Abr. II. p. 35.

that has been kept in the observatory above these threescore years by-past.

8. But a much more convenient term of heat, though less insisted on by Dr. Halley, is that of *boiling water*. This he found* to be a very fixed and settled degree of heat; and which, when once water has acquired it, cannot be increased by any longer continuance or length of time. And this point of heat Sir Isaac Newton and Mr. Amontons were justly very fond of in settling the limits of their respective Thermometers: wherein too they have been imitated by all those that came after them.

9. Though I could scarcely find any sensible difference in various waters, differing considerably in weight, saltness, cleanness, &c. so as that Mr. Taglini's objections† against the fixedness of this point are of no force; yet truly this heat of *boiling water* is not at all times and places so absolutely fixed and invariable, as most people are ready to conclude from Dr. Halley's and Mr. Amontons's observations. The fixedness or volatility of water depends very much not only on the cohesion of its particles, but also on the pressure of the incumbent atmosphere:

* Phil. Transf. Abr. II. p. 34. See, too, Amontons in Mem. Acad. Sc. 1699, p. 156. 1702, p. 210.

† See Mem. Acad. Sc. 1730, p. 714.

atmosphere: * for, in a vessel much exhausted of air, water and other liquors, being freed of most of the ordinary pressure they undergo, boil in a very moderate degree of warmth, much below what in the open air is usually requisite to set them a boiling. And, agreeable hereto, Fahrenheit actually found †, that water was capable of a greater or less degree of heat in boiling, according to the greater or less weight of the atmosphere, or the greater or less height of the mercury in the barometer. But in ordinary changes of the weather, the difference is not very great ‡. And farther, we may avoid all errors that might arise from any thing of that sort, if we make our observations on the heat of boiling water, and adjust this term of heat at a middle state

* See Boyle Physico. Mech. Exp. Abr. II. p. 473, 474. Newton. Opt. p. 318.

† Phil. Trans. Abr. VI. 2. p. 18. Boerh. Chem. I. p. 171.

‡ It is not so great as Dr. Boerhaave, (Chem. I. p. 171.) in giving an account of Fahrenheit's observations, reckoned. In an alteration of 3 inches in the height of the mercury in the barometer, he says, the boiling heat is found to differ 8 or 9 degrees. I did not find it so very much by the different weights of the atmosphere. From the experiments I have made I judge that, by the rise or fall of the quicksilver an inch in the barometer, the boiling heat of water varieth somewhat less than 2 degrees.

state of the atmosphere in places near the level of the sea, when the mercury in the barometer stands at about 30 inches, or a very little under it. And the same caution will be necessary in judging of the heat of *boiling spirit of wine*, or of the *boiling heat* of any other liquor.

10. It was on this principle chiefly of the determined fixedness of the heat of *boiling water*, that Mr. Amontons * contrived his universal Thermometer. It was indeed a pretty contrivance: but it never was, nor never could be, of universal use; nor could it answer the design of its ingenious author. Its construction is too difficult and complex; the machine itself is too bulky and incumbered to be easily managed, or carried from place to place. And then it is supposed to be fitted at a due temperature of the air, as in the spring and autumn at Paris: which, beside that it is in itself something too indefinite, at other times and places we cannot well be sure of. And the air of that temperature he reckoned to be dilated just one third by the heat of boiling water. But the dilatation of the air is not so regularly proportional to its heat; nor is its dilatation by a given heat near so uniform as he all along supposed. This depends much on its moisture:† for dry air does not expand near so much

* Mem. Acad. Sc. 1702, p. 204, &c.

† See Hist. Acad. Sc. 1708, p. 15. Mem. p. 370. Musschenbr. Tent. Exp. Acad. Cim. Add. p. 40. Eff. de Phys. § 1402.

much by a given heat, as air stored with watry particles; which, by being turned into steam, increase vastly the seeming volume of the air. So then as Mr. Amonton's Thermometer is affected by all these and other inconveniences*, it is no wonder it was imitated by very few, and never came to be of general use in the world.

11. From this one determined point of the heat of *boiling water* there may, however, be laid down a general method of constructing Thermometers all in the same way, so as that they shall correspond with one another in all the various degrees of heat. It is, as Mr. Boyle † proposed long ago, by marking the degree of expansion or contraction of the fluid of the Thermometers, as the heat applied is either greater or less than that of *boiling water*. Supposing, for example, the whole volume of this fluid to consist of 10,000 parts, it is to mark on the tube, where that volume is expanded by heat, or contracted by cold, 1, 2, 3, 4, &c. of these parts. All which may be done at any time by different persons and in different places, so as that they shall answer precisely to one another.

12. This is a very plausible method, and has been actually tried by some, as we shall afterwards have
B occasion

* See Mr. de Reamur in Mem. Acad. Sc. 1730.
p. 654.

† Exp. on Cold, Abr. I. p. 579.

occasion to see: and yet in practice it will not be found very easy to determine exactly all the divisions from the alteration of the bulk of the fluid; beside other unavoidable inconveniences and uncertainties we shall by and by have occasion to take notice of. It is sufficient, and will be much easier and more convenient, in settling an universal method of constructing Thermometers, to determine at least two fixed points of heat at a considerable distance the one from the other, and to divide on the tube or scale the intermediate space into any convenient number of equal parts or degrees. *Boiling water*, in the circumstances we proposed, we just now found to be a pretty uniform and fixed degree of heat. And *water just freezing*, if that come out always the same, will answer the purpose most readily of any degree we could think of.

13. It is true, Dr Halley * thought this to be a point admitting a considerable latitude. And some have suspected that water freezes at different degrees of heat in different seasons, countries and climates. And Dr Cyrilli's observations † would seem to confirm it. At Naples he found water to freeze when his Thermometer was 10 degrees above the freezing point, as it had been constructed in
England

* Phil. Transf. Abr. II. p. 36.

† Phil. Transf. No. 424, p. 336. No. 430, p. 189. No. 434, p. 407, 408. No. 435, p. 464.

England by the directions of the Royal Society; and Father Martini * talks of the frosts in the province of Pekin in China as greater than its latitude of 42 degrees would induce one to expect, the rivers being often frozen for two months together, &c. And adds, that it is surprising the Europeans should remain unaffected by this cold, and slight it as unable to produce ice in their quarter of the world. From all which one might be ready to conclude, with Dr Derham †, Prof. Musschenbroek ‡, and others, that the farther north we go, it takes the greater degree of cold to freeze water. And what might strengthen such a suspicion is, that I found some of the Dutch mercurial Thermometers made at Amsterdam, in which the *freezing point* was marked at *gr.* 32, to be a degree or two lower here when immersed in thawing snow or beaten ice beginning to melt.

14. But I am convinced all this seeming difference flows from the carelessness of observers, or errors of the workmen. Or what if Dr Cyrilli kept his weather-glass shut up and sheltered in a house while it freezed abroad? As I know it is but too ordinary with those who pretend to keep registers of the weather. To satisfy myself in this article, I took a very

B 2

fair

* Atlas Sinenf. p. 27. See too, Boyle's Exp. on Cold, Abr. I. p. 577. Reaumur in Mem. Ac. Sc. 1734, p. 233.

† Phil. Transf. ibid.

‡ Ess. de Phys. § 913.

fair method of inquiring if there was really any such difference in the cold of *freezing water* in different climates. I marked two mercurial Thermometers here in the latitude of 56 deg. 20 min. and got a correspondent of mine to mark some others at London in the latitude of 51 deg. 32 min. all at the freezing point in snow or powdered ice melting: and, upon exchanging these Thermometers, we found them, when again immersed in thawing snow on ice, still to point at the very same marks precisely, without the least observable difference. Were there any odds occasioned by the difference of climates, would not near 5 degrees of latitude have shewn it very sensibly *? And at this same very mark does the quicksilver stand in such thawing ice or snow at all seasons of the year, in summer or winter, in cold weather or warm weather, under a light or a heavy atmosphere, &c. From whence I conclude the *freezing point* to be a very constant and settled degree of heat, more fixed and determined than even that of *boiling water*, and consequently

* The universality and fixedness of the term of congelation I can now affirm with still greater confidence and certainty after the trials I lately made, not only at London, but at Paris in the latitude of 48 deg. 50 min. and Dijon in the latitude 47 deg. 20 min. by which I found that precisely the same degree of cold was requisite to freeze water in Burgundy and in the isle of France, as in our northern climates.

consequently very fit to be one of the fixed limits in adjusting our Thermometers.

15. The fixedness then of the freezing point, I think we may take for granted, and sufficiently established by these observations, notwithstanding what Professor Taglini may have said to the contrary; and the unnecessary concessions Mr. De Reaumur thought fit to make on that head*; and the observations adduced by Dr. Mussichenbroek†, by which he would prove the *freezing of water* to begin in various degrees of cold, depending on some saline additional mixture from the air. All which may be allowed to shew, that in some places and circumstances water freezes more or less easily, though the degree of cold in this act of *natural freezing* be, for any thing we can perceive, in all pretty nearly the same.

16. The cold of *water beginning to freeze*, or which is the same thing of *ice beginning to melt*, is such a convenient fixed point, such a remarkable period of heat and cold, and withal so easily determined by emerging the bulb of the Thermometer in thawing snow or ice, that it is surprising so few have taken it into the scale of their Thermometers, that theirs might be the better compared

B 3

with

* Mem. Acad. Sc. 1730, p. 712.

† Tent. Acad. Cim. Add. p. 184, 185. Ess. de Phys. § 913, &c.

with other peoples observations. We are not absolutely sure even of this part of the scale of the Florentine weather-glasses. And the French have not yet precisely determined the *freezing point* in Mr. De la Hire's standard Thermometer of the Observatory, by which the register of the weather has been so very long kept, and with which they sometimes compare other observations: and most of the other observations of the weather, both in the Memoirs of the Academy of Sciences and in the Transactions of the Royal Society, are done with Thermometers so negligently constructed, that we are left altogether uncertain of their degrees of heat: most of those that have the *freezing point* marked on them having it very erroneously graduated, and also having no other determined or known period of heat; and so coming to be as indefinite and uncertain as the other.

17. The great Sir Isaac Newton thought the settling the degrees of heat and cold well worth his notice; and, as he carried every thing he meddled with beyond what any body had done before him, and generally with a greater than ordinary exactness and precision, so he * laid down a method of adjusting Thermometers in a more definite way than had been done hitherto. We have already † found it

* Phil. Transf. Abr. IV. 2. p. 1, &c.

† § 12.

it necessary, at least convenient, to fix on two determined periods of heat to make up an intelligible scale of its various degrees. We have likewise * found *water freezing* and *water boiling* to be in twopoints of heat very convenient to such a purpose. And these are the very degrees of heat he pitched upon. The liquor he used was Lintseed Oil, a homogeneous fluid enough, and capable of a considerable rarefaction, and not having been observed to freeze even in very great colds, and able to bear a great heat without boiling. Supposing the bulb when immersed in *thawing snow* to contain 10,000 parts, he found the oil expanded by the heat of the *human body* so as to take up $\frac{1}{32}$ more space, or 10,256 such parts: and by the heat of *water boiling* strongly 10,725; and by the heat of *melting tin* 11, 516, beyond which he did not carry his oil Thermometer. So that, reckoning the *freezing point* as a common limit between heat and cold, he began his scale there, marking it *gr. 0*; and the heat of the *human body* he made *gr. 12*; and consequently the heat of *boiling water* was expressed by *gr. 34* $= \frac{725 \times 12}{256}$; and *melting tin* by *gr. 71*.

28. I wish the world would have received this or any other determined scale for adjusting their Thermometers. But I suppose they might be apprehensive

* § 8, 14.

five of some inconveniences in this scheme. Besides some inconsiderable arithmetical errors in Sir Isaac's paper, and some few not accurately enough made observations of no great moment, they would allege * that he had expressed himself as if he had thought the point of *freezing water* to be the lowest degree of heat. And indeed he has not mentioned any winter cold beyond that : though, as we shall take notice on another occasion, we sometimes experience vastly intenser colds : in consequence of which, it would be easy to protract Sir Isaac's scale downward below *gr. 0*, or the freezing point, and so to make it as serviceable in common use, even for great degrees of cold, as other Thermometers.

But there is another difficulty which will hold in all oil Thermometers, or any made with a viscid liquor, that it adheres too much to the sides of the tube. In a sudden cold or fall of the oil, a good deal sticks by the way, and only sinks gradually after, so that at first the surface appears really lower than the present temperature requires. And beside, as at all times some must continue to stick and moisten the inside of the tube, in different degrees of heat and cold, the oil becoming alternately more or less viscid, will adhere sometimes more and sometimes less ; and therefore will inevitably disturb the regulatity and uniformity of the Thermometer.

19. The

* See Amontons in Mem. Acad. Sc. 1703, p. 233.

19. The Florentin Thermometers made with spirit of wine were by no means so liable to errors of this kind. The spirit indeed must moisten the inside of the tube: but as this is so very thin a liquor, it is probable that moistening is always pretty uniform, and extremely thin: so as that it can have no other effect but to render the tube a very little narrower. And so truly rectified spirit of wine has been more used in Thermometers than any other liquor. It is very ticklish, is easily and very much affected by heat and cold; nor does it soon gather air bubbles, as watry fluids are ready to do even in no very great heats. But, as we said before*, these spirit Thermometers did not use to be reduced to a fixed standard. At length Mr. De Reaumur † has in a very ingenious way attempted to establish a general construction of such Thermometers, which might be copied at all times, and in all countries: and so to settle, as it were, a general correspondence of observations that should be made by such instruments. He adjusted his Thermometer to the *freezing point* by an artificial mixture: and then, immersing it in *boiling water*, found how much it was dilated by that heat, in the way Sir Isaac Newton had managed his oil Thermometers. The quantity of spirits in his glass he supposed to be 1000 parts; and he found to how many of these parts

* § 3, 4, 19.

† Mem. Acad. Sc. 1730, p. 645, &c.

parts the bulk of the liquor was dilated by that boiling heat. The stronger the spirits, this dilatation is found always the greater. The best spirit of wine commonly sold, from this *artificial freezing of water*, to that *boiling heat*, was dilated $87\frac{1}{2}$ of those parts*: and a mixture of such a strong spirit and water in equal portions (which would be about the state of common brandy) was expanded only $62\frac{1}{2}$ such parts †. He speaks too of a spirit so strong as to have the dilatation of 90 in its *boiling heat* ‡. But what he judged most convenient for his ordinary Thermometers was a spirit of such a degree of strength, as in the above period of heat, to be dilated just 80 of these 1000 parts**.

20. This imitation of Sir Isaac Newton with spirit of wine instead of oil is a promising enough method of making a settled standard scale for Thermometers; and accordingly one of them constructed by Mr De Reaumur himself is now placed in the Royal Observatory at Paris; and a journal kept of the weather by it. And others constructed in the same way have been sent to different quarters of the world, to compare the degrees of heat and different climates: a project long ago of the great Colbert's †, but never till now satisfactorily executed.

* Mem. Acad. Sc. 1730. p. 690. † Ibid. p. 692.

‡ Ibid. 1734, p. 261.

** Ibid. 1730. p. 697, 698. and fig. 8.

† See Mem. Acad. Sc. 1702. p. 209.

executed. Observations have been made with them in the Torrid Zone. And the French Academicians had them in their philosophical embassy to the north, for determining the figure of the earth. And yet I am afraid these Thermometers are constructed on principles, that will by no means be found so accurate as were to be wished and expected in such a case: Mr De Reaumur determines his freezing point, not from *thawing snow* or *ice*, * but from an *artificial congelation of water* in warm weather. And as he † uses very large bulbs for his glasses, it may be 3 or 4 inches in diameter, I am apt to think that, before the due temperature of the surrounding ice can be thoroughly propagated to the whole contained spirits, it will be quite melted down again; and so the *freezing point* marked much higher than what it should be ‡. He indeed †† speaks of a quarter of an hour as sufficient to bring the contained spirit to the temperature of the ambient *medium*. But as far as I can judge from my observations (and many I have made on

* Mem. Acad. Sc. 1730, p. 655, 656, 680, 681, 712.

† Ibid. p. 660, 710.

‡ From collating some observations together, I reckon Mr De Reaumur's mark of freezing water, instead of coinciding with Fahrenheit's *gr.* 32, as it should do, to correspond with *gr.* 34. or a little above it.

†† Ibid. p. 711.

on this subject), it would rather take some hours to penetrate thoroughly such a great bulk of any liquor, and reduce it fully to its own degree of heat. And so Thermometers of great bulbs can never be used with success, or trusted to in common experiments of the heat of bodies, or observations of the weather: as we may be satisfied by collating the several observations in the Royal Observatory made with De la Hire's and De Reaumur's Thermometers, which at different times I find to quadrate very ill together, just I suppose from that cause of the different sizes of their bulbs*. For large bulbs can never be so quickly influenced by great and sudden variations of heat and cold, as to make these changes, if they last but a short while, sufficiently remarkable, or to shew their real and full quantities. Small bulbs and small tubes are (notwithstanding the imaginary faults and difficulties started against them by Mr De Reaumur †) vastly more convenient, and may be constructed sufficiently accurate. I have them made with capillary bores that correspond almost entirely to one another in all degrees of heat; and consequently must be allowed to have all the exactness that can be imagined or desired in such instruments.

21. But

* The diameter of the bulb of Mr De Reaumur's I found to be about $3\frac{1}{2}$ inches; while the other was less than 2 inches.

† Mem. Acad. Sc. 1730. p. 650, 656, 659.

21. But if we cannot trust to Mr De Reaumur's *point of congelation*, what shall we say to his other fixed term, to wit, the heat of *boiling water*? This, I humbly think, is, under his management, still more vague and uncertain. As water, were it surrounded by melted tin, though it would boil and foam and suffer very great agitation, is yet incapable of being warmed beyond its ordinary great boiling heat, and continues always much colder than melted tin; just so, as I experienced upon trial, spirit of wine, though immersed in boiling water, can never acquire near such a great heat, but keeps always a good deal under it, though bubbling and foaming, and tossed to a very great degree. The spirit then in the Thermometer is absolutely incapable of such a great heat as Mr De Reaumur ascribed to it; and that not by a small or trifling difference. I find highly rectified spirit of wine cannot be heated beyond *gr.* 175, or so, in Farenheit's Thermometer, while boiling water raiseth the quicksilver 37 degrees higher: and common brandy was able to conceive a heat no greater than about *gr.* 190. So far was Mr De Reaumur in the wrong when he thought that all spirits, weak and strong, immersed in *boiling water* received a given degree of heat, and that equal to the heat of the surrounding water. I suppose his standard spirit could take on a heat of about *gr.* 180; less by 32 degrees than what he reckoned.

C

22. Beside

22. Beside all this, I truly think spirit of wine, though good enough for ordinary weather-glasses in temperate climates, is yet not so fit a fluid whereof to make standard Thermometers. It is incapable of bearing very great heats, or very great colds. It boils sooner than any other liquor. And though it keeps fluid in pretty strong colds, yet it would seem, from some experiments, that it does not condense very regularly in them: and at Torneao near the polar circle, the winter cold was so violent, that the spirits were frozen in all their Thermometers *. So that the latitude of heat spirit of wine is capable of expressing, is by much too limited to be of very great or universal use.

23. What fluid then shall we take for our Thermometers? We have found inconveniences in air, oil, and spirits; and water is more exceptionable than any of them. We have, it seems, nothing left but quicksilver. This is a very moveable and ticklish fluid; it both heats and cools faster than any liquor we know, or have had occasion to try; faster I am sure than water, oil, or even spirit of wine; it never freezes by any degree of cold hitherto observed, and bears a great deal of heat before it arrives at a boiling expansion, and, if well purified, does not wet or stick to the inside of the

* See de Maupert. Fig. de la Terre, p. 58.

the tube. Dr Halley *, though apprised but of some of these remarkable properties, thought it a fluid very fit for Thermometers, were but its expansion more considerable. However, as any inconvenience arising from this consideration may be avoided by making the bulb have a great proportion to the tube, so it is now very deservedly come to be in the greatest use in the Thermometers that people would most trust to. It is said †, that they were first contrived by that curious mathematician Olaus Roemer. Mr Fahrenheit in Amsterdam, and other workmen in that country, manufactured very many of them, and that in a portable and mighty convenient form for many purposes, making them very small, and inclosing the tube in another glass hermetically sealed. From Holland they were distributed into different quarters of the world, and have been imitated in some other places. And now they are made no where in greater perfection, or with greater exactness, than by our countryman Wilfon at London.

24. As Roemer's or Fahrenheit's scale is convenient enough, I wish it were universally kept and used, to preserve an uniformity in our observations; and so that every body, when they speak of experiments wherein the heat of bodies was adjusted,

C 2

or

* Phil. Trans. Abr. II. p. 34.

† See Boerh. Chem I. p 720.

or pretended to be observed by Thermometers, were to have the same language; and so be universally understood.

In this Thermometer the bulb is supposed to contain, as Dr Boerhaave * and Dr Musschenbroek † tell us, 11124 parts of quicksilver, which stands at the lowest mark, or *gr.* 0, in a very intense intolerable cold, being surrounded with a mixture of snow or beaten ice and sal ammoniac or sea-salt ‡.

If the same bulb be immersed in *snow* or *ice thawing* naturally, or in *water beginning to freeze*, the quicksilver is dilated, and so rises in the tube 32 of these 11124 parts; and therefore the space of the tube from *gr.* 0 to the *freezing point gr.* 32, is divided into these 32 equal parts ||.

When the Thermometer is placed in water brought to strong *boiling*, (the atmosphere being in the condition formerly mentioned **,) the quicksilver is dilated 212 of these parts beyond its original bulk of 11124, so as now to possess in the bulb and tube together a space equal to 11336 such parts: and the space from *gr.* 32 to *gr.* 212, is divided into 180 equal parts or degrees of the Thermometer ††; which, if the tube be long enough, may

* Chem. I. p. 174.

† Eff. de Phys. § 948.

‡ Fahrenh. in Phil. Trans. Abr. VI. 2. p. 52.
Musschenbr. Diff. Phys. p. 680. Eff. de Phys. § 948.

|| Fahrenh. in Phil. Trans. Abr. VI. 2. p. 52.

** § 9.

†† Fahrenh. in Phil. Trans. Abr. VI. 2. p. 18. 52.

may be protracted as far as is convenient. It may go well enough to *gr.* 600, and not much farther; for, with a heat but little greater than that, the mercury begins to boil.

25. Dr Boerhaave is not always quite consistent with himself in his account of the number of parts into which the mercury in the bulb is supposed to be divided. In another place *, instead of 11124, he reckons only 10782, and afterwards † he raises it to 11520, (which I take to be nearer the truth), and yet still speaks of a given heat as expanding the quicksilver the same number of parts as in the other supputation. Which of his suppositions is right I am not absolutely sure of before making trial, nor need we much to care; for, without all that *apparatus*, I humbly think the easiest and surest way too, and what in practice I have followed, is not to be solicitous about the bulk of the quicksilver, but to fill the bulb and tube so, as that in freezing water, or melting ice, the mercury shall stand at a convenient height, which must be very nicely marked *gr.* 32. and then as accurately to observe where it stands when dilated by the heat of boiling water to *gr.* 212. The intermediate space is then divided into 180 degrees; which scale may be protracted upwards and downwards as far as we shall judge convenient. In the construction of

C 3. these

* Chem. L. p. 265.

† Ibid. Expl. Tab V. fig 3.

these Thermometers the two great limiting or fixed points being *freezing water* and *boiling water*; which we found to be the most convenient periods of heat for adjusting these instruments.

26. Indeed in all this we have supposed the bore of the tube to be perfectly cylindrical; which cannot always be obtained. But though it be tapering, or somewhat unequal, it is easy to manage that matter, by making a small portion of the quicksilver, as much for example, as fills up a half, or, if you please, a whole inch, slide backward and forward in the tube: and by this means to find the proportions of all its inequalities, and from thence to adjust your divisions to a scale of the most perfect equality.

27. The conceiving the bulk of the contained mercury at the beginning of the scale to be either 10782, or 11124, or 11520, or, as I guess it should be near 11790 parts, and its expansion from thence by the heat of boiling water to be 212 of these parts, was, to be sure, a division originally quite arbitrary. And I confess there might have been a more convenient one fixed upon at first, and adopted, yet, if this were not now so universally known and used; and Thermometers constructed in that form every where scattered up and down, and in the hands of most of the Virtuosi in Europe. I shall readily allow that Mr De l' Isle's at
Peterburgh,

Petersburgh, might have had a greater look of simplicity. * In his the whole bulk of quicksilver, when immersed in *boiling water*, is conceived to be divided into 10000, or rather 100000 parts; and from this one fixed point the various degrees of heat either above or below it are marked in these parts on the tube or scale, by the various expansion or contraction of the quicksilver in all the imaginable variety of heat. “As pure mercury,” says he, “is of the same nature every where, nor is liable to any alteration from being inclosed in a tube; and as it is probable that, taking it equally purified, it will in different countries be subject to the same expansion, if exposed to the same degree of heat; for this reason he is persuaded these Thermometers may very well serve to compare the temperature of different countries.” And indeed such a construction bids fair for being a very good standard method for graduating Thermometers all in the same way; and is much less liable to uncertainties than that similar one of Mr De Reaumur, whereof we have already given an account †. However, if Mr De l’Isle had pleased, I cannot but think it would have been rather something better to have made the integer of 100000 parts, or fixed point, at *freezing water*; and from thence to compute the dilatations or condensations

* Phil. Trans. N. 441. p. 222.

† § 19, 20, 21.

denfations of the quicksilver in those parts. All the common observations of the weather, &c. would have been expressed by numbers increasing as the heat increased; which surely is the more natural way. Nor would there have been great incongruity or inconvenience in expressing, after the manner of Mr De Reaumur, the few observations we have below simple freezing by numbers of contraction below *gr. 0*, or 100000.

28. But, as I said before *, however promising in theory such a scheme may appear, it will not in practice be found very easy to determine exactly all the divisions from the alteration of the bulk of the contained fluid. And beside, as glass itself is dilated by heat, though in a less proportion than quicksilver, so that it is only the excess of the dilatation of the contained fluid above that of the glass that is observable; if different kinds of glass be differently affected by a given degree of heat, this will make a seeming difference in the dilatations of the quicksilver in the Thermometers constructed in the Newtonian method, either by Mr De Reaumur's, or Mr De l'Isle's rules. Now Dr Boerhaave †, from Fahrenheit's observations, speaks of different kinds of glass as very differently affected by heat. And upon inquiry I was informed that Dr Musschenbroek found by his Pyrometer, that
tubes

* § 12.

† Chem. I. p. 148

tubes of different kinds of glass were variously affected, some more, some less, by the same degree of heat. From whence Thermometers constructed of such different sorts of glass would necessarily make the seeming dilatation of the contained fluid appear at different degrees in the very same point of heat. And accordingly Mr Campbell, an ingenious and worthy member of the Royal Society, has, by experiments made with all imaginable exactness and scrupulosity, found, in Thermometers constructed in Mr De l'Isle's way, the quicksilver to stand at different degrees of the scale, when immersed in thawing snow. In some it was at *gr.* 154, in others at 156, and in another at 158: and emptying the tubes, and preparing them again, and that sometimes with other mercury, he always, even in a great many trials, found the result come out the very same. So careful and exact had he been that the same tubes gave always the same degrees of dilatation as nearly as could be expected in such nice and subtle experiments. One of Mr De l'Isle's own Thermometers, which I tried very carefully, gave me always the quicksilver at about *gr.* 150. In another of his, where on the one side he has put Fahrenheit's scale, I see *gr.* 32. over against his own *gr.* 148½. In one constructed by Mr De Monier at Paris, on De l'Isle's principles, I saw the *terme de congelation* put down at *gr.* 148. Nay, by Mr De l'Isle's own accounts, I find his weather-glasses disagreeing considerably from one another.

another. So uncertain and precarious would this way of constructing Thermometers seem to be. From all which I humbly think that it is better and more convenient to drop this method altogether, and to fix on two points of heat at a considerable distance the one from the other; and to divide the intermediate space of the tube into a convenient number of equal parts or degrees: as we just now proposed * to be done in our imitations of Roemer's or Fahrenheit's Thermometers.

26. To enlarge our views of heat, and to enable us to compare other Thermometers with these, (which after this I wish were always to be the Standard), it would not be amiss to observe a great many remarkable periods of heat and cold that have been taken notice of by others, and to determine where they fall on Fahrenheit's scale. We should determine about what degrees on it the several sorts of weather are marked: the various degrees of animal heat; what degrees of heat reduce such and such consistent bodies into a fluid state; the quantities of heat required to boil the fluids we have occasion to try, &c. But the comparing the different Thermometers which have been in use in the world, and the determination of the various degrees of heat in bodies, make fruitful enough subjects for other curious and useful inquiries.

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* § 24, 25, 26.

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LONDON, 1740.

A N

E S S A Y

TOWARDS COMPARING

DIFFERENT THERMOMETERS

WITH ONE ANOTHER

WE had occasion formerly to take notice of the great uncertainty of thermometrical observations, by reason of the vague and inconstant way that people had of making their instruments. However, it will be worth while narrowly to inquire, as far as our lights can carry us, into the principles on which they were constructed; and if we can find out these principles so as to compare the old Thermometers with any regular one we are well acquainted with, we shall recover, as it were, the lost observations of our predecessors; lost for want of knowing the meaning of their numbers and graduations. And then observations made at different times and places by any known instruments

ments will be no longer useless memorandums. We shall be able to compare them with one another, and with our own observations, and with the degrees of heat we are acquainted with.

2. As Sanctorio seems to be the first who had a notion of measuring the various degrees of heat by the dilatation of bodies, people will be apt to expect, and many will fondly wish, that he had left us his method of numbering the degrees of his Thermometers. Though, to acknowledge the truth, it would be a matter of more curiosity than use, as they were affected by the difference of weight of the atmosphere, as well as by the difference of heat of the ambient medium. To remedy which inconvenience, the virtuosi of the Cimentin Academy contrived their Thermometers in a better way; carefully sealing up the included spirits from any influence of the gravity of the atmosphere; and marking on the tubes, or on the scales fixed to the tubes, numbers whereby to judge of the various dilatations of those spirits by the various degrees of the heat applied.

I am surprised to find Dr Musschenbroek*, who had been at the pains to give a Latin translation of their whole work, and to enlarge and embellish it with excellent additions, representing these Florentine Thermometers as constructed in a very loose, arbitrary

* Ess. de Phys. § 947.

arbitrary and indefinite way, and without any rule at all. This is an imputation to which they are less liable than many others that came after them. They made them of several sorts, some with greater and some with less accuracy. But in the constructing of those in which they could most confide *, they tell us expressly at what degree the spirit stood in the ordinary cold of simple ice or snow. Which, as their experiments were done within doors in Italy, I take commonly to have been in a thawing state, and consequently to point out to us the degree of freezing water, which we found † to be a very fixed period of heat and cold, coinciding, we know ‡, with our *gr.* 32. Thus, in their 1st sort, this point of heat fell at *gr.* 20 §; and in their 2d to about *gr.* 13½ ||.

So then we have one fixed and intelligible point of heat in their Thermometers, which is more than we have in those of many others. But from one point we cannot judge of the rest of the numbers: and it must be confessed their highest degree of heat is not defined in a way we could have wished. They tell us that in their first or long Thermometer the spirit, when exposed to the great midsummer heats in their country, rose to where they

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marked

* Tent. Exp. Acad. Cim p. 5.

† Eff 1. § 14.

‡ Ibid. § 24.

§ Tent. Exp. Acad. Cim p. 2, 7.

|| Ibid II. p. 129.

marked *gr.* 80 *. And the spirit in the 2d or smaller Thermometer in such a heat stood at *gr.* 40†. This indeed is a very incongruous way of graduating Thermometers, as the great heat of the summer sun is such an indefinite degree of heat in different days, years, climates, &c. And yet, by good chance, there is left us a way to judge of the particular summer heat they happened to pitch upon; and of finding whereabouts it would have fallen in a Thermometer constructed in Fahrenheit's way, which we have taken up as our standard. To affirm this will, I know, be looked on at first sight as pretending to a thing in itself lost, and now impracticable. But Borelli and Malpighi, two curious and careful observers of nature, luckily had occasion to tell us, that the *viscera* of some hot animals, such as of cows, deer, &c. raised the spirit in the small Florentine Thermometer to about *gr.* 40. the very degree of this their summer sun heat. And that animal heat I find to coincide with *gr.* 102, or thereabouts in ours. From which two periods of heat determined in both Thermometers, we can make a pretty good estimate of all observations made by any of the regular and well constructed Florentine glasses; as we may see by looking on the table at No. I, II, III.

3. The Thermometers that came to be used in the world, were all imitations of these of the *Accademia*

* Tent. Exp. Acad. Cim. p. 2, 4. † Ibid. p. 4.

demia de l' Cimento, but not constructed in such a regular way, or upon such determined principles. In France Mr Hubin was employed in making them for the *Academie des Sciences* at Paris. But we find they were not made all perfectly alike. The Indian missionaries * tell us, that they used those that were graduated lowest. However, we may reckon at a medium that which Mr Amontons gives us a view of in the Memoirs †, under the name of the *Ancienne Thermometre*. In it the freezing point was at *gr.* 25, corresponding consequently to Fahrenheit's *gr.* 32. and the heat of the cave of the Observatory was *gr.* 50, which I know to be our *gr.* 53. So that the comparison is easy in the table at No. I. IV.

4. But I know not many observations made with this Weather-glass. It is much more to our purpose to know the construction of that very remarkable one of Mr De la Hire, that has stood in the Royal Observatory at Paris above these threescore years, and by which a register of the weather has been constantly kept. And yet we cannot but regret that neither Mr De la Hire himself, nor any of those that succeeded him in that office, have been at the pains exactly to determine any two

D 3 points

* Mem Acad. Sc. 1666.——1698. VII. p. 835.

† Mem. Acad. Sc. 1703. p 53.

points of it, so as that we may be enabled to imitate it; or compare it with other Thermometers; though I hope we shall be able to trace it pretty near the truth. We are expressly told, that the spirit in it always stands at *gr.* 48. in the cave of the Observatory *, corresponding by this to *gr.* 53. in Fahrenheit's. And when it freezes in the fields, they speak of their Thermometers standing in the open tower as pointing at from *gr.* 30. to *gr.* 32 †: something below which the real degree of freezing would be. And from some concurring circumstances and observations, I reckon this would fall to about *gr.* 28. corresponding to our *gr.* 32. as in the table No. I, V. We have an observation of Mr De la Hire himself, whereby we find that his *gr.* 28. corresponded with *dig.* 51. *lin.* 6. in Mr Amontons's Thermometer ‡.

5. Mr Amontons made a fine step to settle an universal Thermometer, had it not been for some inconveniences of which we had occasion to take notice formerly ||. In his the freezing point was at *dig.* 51. *lin.* 6. where our *gr.* 32 is; and the heat of

* Mem. Acad. Sc. 1700, p. 8. 1701, p. 10. 1702, p. 5. 1703, p. 3. 1704, p. 2. 1705, p. 4. 1706, p. 3. 1707, p. 2. 1708, p. 61. 1709, p. 3. 1710, p. 141.

† Ibid. 1702, p. 5. 1704, p. 4. 1705, p. 4. 1706, p. 3. 1707, p. 2. 1708, p. 62. 1709, p. 3. 1710, p. 141. 1711, p. 2.

‡ Mem. Acad. Sc. 1710, p. 142.

|| Ess. I. § 10.

of boiling water at *dig.* 73. where Fahrenheit's is at *gr.* 212; whence they can easily be compared together, as in the table No. I, VI.

6. * The Marquis Poleni gives us the result of a vast number of excellent and well-made meteorological observations, in which the heat and cold are measured with a Thermometer constructed in Mr Amontons's way. But, as his numbers are considerably different, I thought it well worth while to give a scheme too of his Thermometer in the table at No. VII.

7. Mr de Reaumur was very sensible of the difficulties of Mr Amontons's construction, and proposed a new and more certain way, as he thought, of making Thermometers. He determined to begin his scale at freezing water, and at boiling water marking *gr.* 80, dividing the intermediate space of the tube into so many equal parts. I have on another occasion † given my reasons for thinking he was in some mistake with respect to both these two periods of heat. But, as many very curious and useful observations have been made with his Weather-glasses, it will be of singular use to find out the correspondence of his scale with that of Fahrenheit. His boiling-water heat is really only the boiling heat of weakened spirit of wine, coinciding

* Phil. Trans. 421. p. 205.

† Eff. I. § 20. 21.

ciding nearly, as I guefs, with Fahrenheit's *gr.* 180, and as his *gr.* 10 $\frac{1}{4}$ is the constant heat of the cave of the Observatory *, or our *gr.* 53. thence I find his freezing point, instead of answering just to our *gr.* 32, to be something above *gr.* 34, as in the table No. I, VIII †.

8. On

* Mem. Acad. Sc. 1730. p. 503.

† The French at present use a Thermometer, which goes by the name of Reaumur's Thermometer, very different from this which the Author describes. It is filled with mercury, has 0 for the freezing point, and 80 for boiling water. So that 0 of the modern, or mercurial Reaumur's Thermometer, corresponds with 0 of the old Reaumur's Thermometer, and 32 *gr.* of Fahrenheit's; but 80 *gr.* of the mercurial Reaumur's corresponds with 212 *gr.* Fahrenheit's. One degree of Reaumur's mercurial Thermometer is equal to 2 $\frac{1}{4}$ degrees of Fahrenheit's; but to save the reader the trouble of computation the following table is subjoined, shewing the corresponding degrees of Fahrenheit's scale for every one of Reaumur's.

R.	F.	R.	F.	R.	F.
0=32.		9=52.25		18=72.5	
1=34.25		10=54.5		19=74.75	
2=36.5		11=56.75		20=77	
3=38.75		12=59		21=79.25	
4=41		13=61.25		22=81.5	
5=43.25		14=63.5		23=83.75	
6=45.5		15=65.75		24=86	
7=47.75		16=68		25=88.25	
8=50		17=70.25		26=90.5	

8. On principles very like those of Mr De Reaumur, Mr De l'Isle constructed his mercurial Thermometer: but, instead of freezing cold, he began his scale at the heat of boiling water, and, inverting the common order, marked downwards the several degrees according to the condensations of the contained quicksilver, and consequently by numbers increasing as the heat decreased. This, as I observed *, was not in all glasses so uniform as were to be wished. But as in Mr de l'Isle's
own

R.	F.	R.	F.	R.	F.
27=	92.75	45=	133.25	63=	173.75
28=	95	46=	135.5	64=	176
29=	97.25	47=	137.75	65=	178.25
30=	99.5	48=	140	66=	180.5
31=	101.75	49=	142.25	67=	182.75
32=	104	50=	144.5	68=	185
33=	106.25	51=	146.75	69=	187.25
34=	108.5	52=	149	70=	189.5
35=	110.75	53=	151.25	71=	191.75
36=	113	54=	153.5	72=	194
37=	115.25	55=	155.75	73=	196.25
38=	117.5	56=	158	74=	198.5
39=	119.75	57=	160.25	75=	200.75
40=	122	58=	162.5	76=	203
41=	124.25	59=	164.75	77=	205.25
42=	126.5	60=	167	78=	207.5
43=	128.75	61=	169.25	79=	209.75
44=	131	62=	171.5	80=	212

* E. I. § 28.

own standards the freezing point is near to his *gr.* 150, coinciding with our *gr.* 32, it is easy to compare observations by them with the degrees of heat marked in ours by the table at No. I, IX.

9. Mr Crucquius * in Holland has made many curious and accurate meteorological observations with an air Thermometer. In freezing water the whole volume was 1070, in boiling water 1510; so as to render it very easy to collate his Thermometer with Fahrenheit's by the table No. I, X.

10. The most common Thermometers in England are those made (and commonly very carelessly made) after the standard one kept in the Royal Society: and many fashioned on this plan, by order of the Society, have been sent into foreign parts to establish a correspondence of observations concerning the weather in different countries: for which reason it is the more incumbent on us to find out the principles of its construction, so as to enable us to compare it with other Thermometers. The scale begins, or *gr.* 0 is marked at the top, I know not well upon what grounds, and thence the numbers increase downwards as the heat decreases. † In it it is said to be *extreme hot* about the top of the scale, *hot* at *gr.* 25, *temperate* at *gr.* 45, and *gr.* 65 is marked as the *point of freezing*. But, by
 trials

* Phil. Transf. N. 381. p. 4.

† Ibid. N. 429, p. 103. N. 433, p. 337. 339. N. 434, p. 470.

trials made with some Thermometers that had been adjusted pretty exactly with the standard one in the Society-house, I found that the spirit fell to about *gr.* 78 or 79 in thawing snow; near 14 degrees lower than what had hitherto been reckoned; and this increases the wonder still more, how Dr Cy-rilli * should have found the freezing point at Naples so high as *gr.* 55, if his Thermometer was truly adjusted to the standard.

But, to compare this Thermometer with those of other people, it is necessary to find out where they correspond in some other period of heat. What is marked *hot* or *temperate*, &c. on it, is indeed very equivocal. But, to put an end to the uncertainty, I tried and found by experience, that *gr.* $34\frac{1}{2}$ answered to *gr.* 64 in ours: from whence their agreement is easily determined for all the rest of the scale as in the table, at No. I, XI.

11. Sir Isaac Newton † saw very well how vague and uncertain all the Thermometers in common use were; and therefore he contrived a new one, which I am surprised has gained so little ground in the world, as it is so simple and so easily imitated. You but begin your scale at freezing, and the distance from that to the heat of boiling water you divide into 34 equal parts or degrees, which, as they are large, may be subdivided at pleasure. How such a Thermometer answers to Fahrenheit's is seen at No. I, and XII.

12. There

* Phil Transf. N. 424. p. 336. N. 434. p. 407.

† Ibid. No. 270. p. 824.

12. There is a Thermometer in pretty frequent use in England, wherein they conceive the middle temperature of the air as neither hot nor cold, which therefore they mark *gr. 0*, and number both above and below, denoting by this means, as they conceive, the degrees of heat and cold of the ambient medium. Thermometers graduated in this way they commonly have in stoves and green-houses for adjusting the respective degrees of heat the various tender exotic plants require for maintaining their life and vigour. I do not believe that these Thermometers are made upon any regular or fixed principles. They commonly indeed mark freezing at *gr. 30* under *gr. 0*. But in Mr Fowler's regulator, who furnishes most of the green-houses with them, he, on my desiring him to try it, found that in melting snow the spirit fell to about *gr. 34* under *0*, and I found by some comparisons I made, that his *gr. 16* coincided *q. p.* with our *gr. 64*: so that the whole correspondence of this with Fahrenheit's Thermometer is easily determined, as in No. I, XIII.

13. Dr Hales* thought fit to employ a new construction of a Thermometer in making his curious experiments. He began his scale or lowest degree at freezing, or our *gr. 32*, and carried it up to *gr. 100*, which he marked where the spirit stood when the ball was heated in hot water on which wax swimming first begins to coagulate. In
such

* Veg. Stat. p. 37.

such water I found Fahrenheit's Thermometer point at *gr.* 142; by which the two Thermometers might easily be compared. But by experience his *gr.* 100 falls considerably above our *gr.* 142. The result, from collating the two Thermometers together, is at No. I, and XIV. At a spring-head the Doctor found his to point at *gr.* 13. while ours stood at *gr.* 48*.

14. At

* There is a mercurial Thermometer that is graduated in the same manner as this of Hales, namely having 0 for the freezing point, and 100 *gr.* for the boiling water point. This Thermometer is used by the Swedish chemists and philosophers. One degree of this scale is equal to $1\frac{8}{5}$ of Fahrenheit's. Hence the following table of comparison.

S.	F.	S.	F.	S.	F.
0=32		15=59		30=86	
1=33.8		16=60.8		31=87.8	
2=35.6		17=62.6		32=89.6	
3=37.4		18=64.4		33=91.4	
4=39.2		19=66.2		34=93.2	
5=41		20=68		35=95	
6=42.8		21=69.8		36=96.8	
7=44.6		22=71.6		37=98.6	
8=46.4		23=73.4		38=100.4	
9=48.2		24=75.2		39=102.2	
10=50		25=77		40=104	
11=51.8		26=78.8		41=105.8	
12=53.6		27=80.6		42=107.6	
13=55.4		28=82.4		43=109.4	
14=57.2		29=84.2		44=111.2	

14. At Edinburgh they have for these many years kept a very exact register of the weather, part of which is already published in their Medical Effays : for which it is well worth while to find out its relation to other Thermometers ; which, from what the authors tell us, is easily done : for, * when the bulb was immersed in melting snow, the spirit stood 8.2 inches high, the heat of the human skin raising it to 22.2 inches ; so that the intermediate 14 was divided into inches and tenths of

S.	F.	S.	F.	S.	F.
45=113		64=147.2		83=181.4	
46=114.8		65=149		84=183.2	
47=116.6		66=150.8		85=185	
48=118.4		67=152.6		86=186.8	
49=120.2		68=154.4		87=188.6	
50=122		69=156.2		88=190.4	
51=123.8		70=158		89=192.2	
52=125.6		71=159.8		90=194	
53=127.4		72=161.6		91=195.8	
54=129.2		73=163.4		92=197.6	
55=131		74=165.2		93=199.4	
56=132.8		75=167		94=201.2	
57=134.6		76=168.8		95=203	
58=136.4		77=170.6		96=204.8	
59=138.2		78=172.4		97=206.6	
60=140		79=174.2		98=208.4	
61=141.8		80=176		99=210.2	
62=143.6		81=177.8		100=212.	
63=145.4		82=179.6			

† Edinb. Med. Eff. I. p. 8.

of inches. And the heat of that person who graduated it I found to be *gr.* 97 in mine; from whence the comparison at any intermediate degree of heat is very easy, as in No. I, XV.

15. We have heard of many other Thermometers, and of observations and registers of weather kept by them. But they have been generally so ill limited and described, that they are of no manner of use, and, to whatever purpose they might serve their authors, are to us as if they never had been.

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	I
212	174	81.3	230	199.1	73	62.8	67.1	0	1350	111.1	3.1	250.2	163	47	212
200	170	80	230	190			60	10	1300	110		240	160		200
190	160		220	180			50	20	1250	100	30	230	150		190
180	150	70	210	170	70		40	30	1200	90		220	140	40	180
170	140		200	160			30	40	1150	80		210	130		170
160	130	60	190	150			20	50	1100	70		200	120		160
150	120		180	140			10	60	1050	60	70	190	110		150
140	110	50	170	130	60		0	70	1000	50		180	100	30	140
130	100		160	120			0	80	950	40		170	90		130
120	90	40	150	110			0	90	900	30		160	80	20	120
110	80	30	140	100	60		0	100	850	20	10	150	70		110
100	70		130	90			0	110	800	10		140	60		100
90	60	20	120	80			0	120	750	0		130	50	10	90
80	50		110	70			0	130	700	0		120	40		80
70	40	10	100	60			0	140	650	0		110	30		70
60	30		90	50			0	150	600	0		100	20	10	60
50	20	20	80	40			0	160	550	0		90	10		50
40	10		70	30			0	170	500	0		80	0		40
30	0	10	60	20			0	180	450	0		70	0	10	30
20			50	10			0	190	400	0		60	0		20
10			40	0			0	200	350	0		50	0		10
0			30	0			0	210	300	0		40	0		0
Fahrenheit	Florence	Florence	Paris	De la Hève	Amontons	Poleni	Reaumur	De lisle	Croquiers	R. Society of London	Newton	Fowler	Hales	Edinburgh	

