XXVII. Notes on the calibration and standardizing of mercurial thermometers

Spencer Umfreville Pickering M.A.

To cite this article: Spencer Umfreville Pickering M.A. (1886) XXVII. Notes on the calibration and standardizing of mercurial thermometers , Philosophical Magazine Series 5, 21:130, 180-185, DOI: [10.1080/14786448608627833](https://doi.org/10.1080/14786448608627833)

To link to this article: <http://dx.doi.org/10.1080/14786448608627833>

Published online: 29 Apr 2009.

Submit your article to this journal [↗](#)

Article views: 2

View related articles [↗](#)

XXVII. *Notes on the Calibration and Standardizing of Mercurial Thermometers.* By SPENCER UMFREVILLE PICKERING, M.A., Professor of Chemistry at Bedford College*.

HAVING had occasion to calibrate a considerable number of delicate mercurial thermometers, a short notice of the general results, in their bearing on the accuracy attainable in calibration, may not be without interest to those who may have occasion to study this question.

Although several slightly more accurate methods of calibration exist, Gay-Lussac's *step-by-step* method will no doubt be the one generally employed, owing to its simplicity and the comparative shortness of the calculations involved by it. It is the method which is recommended in a Report made to the British Association (1882) by a Committee, consisting of Professors Balfour Stewart, Rücker, and Thorpe, appointed for the purpose of investigating the several methods existing. This method, which is the one which the author has invariably adopted, will alone be referred to in the present communication.

The instruments calibrated were all made by Casella, and were etched with arbitrary scales, each division in the first six instruments mentioned being 1·2 millim., and in the remaining two, 1 millim. The other details respecting their construction are as follows :—

Instrument.	Range.	Weight of mercury in bulb.	Length of scale.
	° C.	grams.	centim.
55080	10 – 25	13·6	47
55081	10 – 25	13·5	47
55083	1 – 16	14·3	46
55084	0 – 27	14·3	45
56117	–5–102		52
56916	5 – 21	15·4	50
62839	$x-(x+3·3)$	36·2	57
63616	$x-(x+3·8)$	30·5	60

The average length of the scales, being thus about 51 centim., is somewhat greater than that of the instrument studied by the above-mentioned Committee, the length of which was 49 centim.

On these thermometers twenty-seven calibrations were performed, sixteen with the aid of the calibrating instrument devised by F. D. Brown (Phil. Mag. [5] xiv. p. 59), and the remaining eleven with a lens only. In every case Gay-

* Communicated by the Author.

Lussac's method was used purely as a *step-by-step* method, and not as a *principal-point* one (see the Report referred to above).

The following table contains the maximum difference observed at any point when a pair of calibration-curves are compared :—

Instrument.	With lens.	With Brown's instr.	Variation of the two mean curves.
55080	millim.	millim. A and B=0.18	millim.
55081	<div style="display: inline-block; vertical-align: middle;"> A and B=0.24 A and C=0.40 A and D=0.29 B and C=0.35 B and D=0.18 C and D=0.21 </div>	A and B=0.096	0.126
55083	<div style="display: inline-block; vertical-align: middle;"> A and B=0.18 A and C=0.27 B and C=0.12 </div>	A and B=0.19	0.114
55084		A and B=0.17	
56117	A and B=0.19	A and B=0.096	0.156
56916	<div style="display: inline-block; vertical-align: middle;"> A and B=0.40 A and C=0.23 A and D=0.20 B and C=0.44 B and D=0.51 C and D=0.42 </div>	A and B=0.19	0.108
62839		A and B=0.09	
63616		A and B=0.11	
	0.29	0.14	0.126

It will be seen that when a lens only is employed the average maximum divergence is 0.29 millim.*; while the substitution of Brown's instrument for the lens reduces the error to one half of this amount, 0.14 millim. This average maximum difference corresponds very nearly indeed to that observed by the Committee in the two Gay-Lussac's curves which they obtained, the quantity there being 0.157 millim.†

* Omitting calibration B of thermometer 56916, this average is reduced to 0.252 millim.

† This number is taken from the curves given in the Report (plate i. fig. 1), and is somewhat higher than that given in the text (p. 16), where it is stated that the "two curves nowhere differ by more than 0.12 millim., except at the point 135°;" whereas it would appear, from a study of the curves themselves, that there is a difference of 0.145 millim. at and near 123°, the difference at 135° amounting to 0.157 millim., as given above. I have taken this maximum difference, inasmuch as the differences quoted in the above table were measured in the same manner.

Phil. Mag. S. 5. Vol. 21. No. 130. March 1886. O

It would seem, therefore, that this must represent very nearly the limits of accuracy of which the method is capable—a limit which gives, for the maximum probable error of any point in the mean curve deduced from two such calibrations, a quantity corresponding to about 0.08 millim. of the mercurial column. It would, however, seem difficult to reduce this error much further by increasing the number of calibrations performed; for the numbers given in the third column of the table show that the mean curve deduced from those obtained with a lens still differs from the mean deduced from those with Brown's instrument by as much as 0.126 millim.

A possible error of 0.08 millim. represents in the first three and the fifth thermometers $0^{\circ}.0029$ C., while in the last two it represents only $0^{\circ}.0005$ C.

In their Report the Committee recommend a means of separating for calibration-purposes a thread of mercury of any required length, consisting in applying a very small flame to the point at which the separation of the column is desired. I find, however, that it is most undesirable to apply such heat to a portion of the divided scale itself. Some alteration in the bore and in the nature of the glass appears to be effected at the point heated; in five or six cases it was found that the thread of mercury when travelling in one direction would not pass the point which had been thus heated, whereas when travelling in the opposite direction it rushed past it at an ungovernable rate. In one case a very noticeable alteration in the size of the bore was observed to have occurred at the heated part. One of Mr. Casella's assistants, a man on whose powers of observation I can rely, assures me that he can at once tell the point at which a fine thermometer-tube has been heated in this manner, by means of the peculiar jerky motion of the mercurial column when passing it. All the tubes to which the present remarks apply were very flat and fine in the bore, probably much more so than in the instrument examined by the Committee, and this no doubt accounts for their not having observed any injurious effects produced by heating. Separation of a thread by means of the so-called *vacuum bubble* is not possible in these very fine tubes, so the flame method must be adopted, taking care, however, that it be applied to a point either above or below the graduated portion of the stem. Another, but less convenient, method consists in passing some of the mercury into the top chamber of the instrument, and distilling a certain quantity of it back into the tube.

Great difficulty is sometimes experienced in passing a short thread of mercury past certain points in a very fine tube, even

where no sudden alteration in the bore sufficient to affect the calibration-curve can be detected. It will often, though not always, be found that the obstacle may be passed by wrapping round the tube a rag soaked in ether which is evaporating rapidly. This same method of cooling is of great service in helping the mercury to become detached from the bulb, when it is required to run it into the upper chamber of the instrument.

The thermometers here mentioned were intended for calorimetric purposes, and therefore an accurate knowledge of the exact temperatures which they registered was not of so much importance as a knowledge of the value of any given interval on them, and that they should all be strictly concordant among themselves. Instead, therefore, of being standardized by a direct comparison with the natural standard 56117, they were all compared with 55084, which embraced the ranges of all of them, and which had previously been standardized by means of the natural standard itself. Inasmuch as the scale of 55084 was three and a half times as open as that of the natural standard, a proportionate gain in concordance of the instruments compared with it was in this manner obtained.

The comparison was effected by suspending the two instruments in a large bath of water which had been brought to the required temperature, the surrounding atmosphere being likewise heated as nearly as possible (within $0^{\circ}\cdot 2$ C.) to this same temperature. After thorough agitation of the water, the upper ends of the thermometers were tapped, and the height of the columns in each read by means of a lens; immediately afterwards they were read again, reversing the order in which they were taken. After tapping them again, they were again read twice over as before: the water was then stirred, and a second series of four readings of each instrument obtained in the same way. The operation was repeated a second time; and thus the readings at the points of comparison consisted in reality of twelve separate readings of each instrument. The points of comparison were the highest and lowest available ones in the thermometer being standardized. During every comparison the temperature of the bath was falling appreciably, though very slightly.

In the case of the two most delicate instruments, 62839 and 63616, three and two such comparisons were made respectively, using different portions of the standard 55084 for each, *i. e.* at different temperatures; this being effected by removing by heat some of the mercury in the thermometers to be standardized into the upper chamber. In the three comparisons of 62839, the lowest point in the scale was thus made to

register about $7^{\circ}\cdot7$, $12^{\circ}\cdot5$, and $17^{\circ}\cdot7$ C. respectively; and in the two comparisons of 63616, $5^{\circ}\cdot5$ and $17^{\circ}\cdot3$ C. These repeated standardizations give the means of ascertaining the experimental error involved in the process.

The results obtained were as follows :—

	deg.		deg.
With 62839,			
A. An interval of 53·2811*	=	an interval of 4·5362	of 55084,
B. " " 51·9524	=	" " 4·4260	" "
C. " " 53·7366	=	" " 4·5819	" "

From which was deduced, that the average value of 1 degree (*i. e.* 10 millim.) of 62839 is

A. . . .	$0^{\circ}\cdot0601967$ C.
B. . . .	$0^{\circ}\cdot0602480$ C.
C. . . .	$0^{\circ}\cdot0603066$ C.

	deg.		deg.
With 63616,			
A. An interval of 55·1059	=	an interval of 5·0039	of 55084,
B. " " 53·1093	=	" " 4·8184	" "

From which, 1 degree of this thermometer represents

A. . . .	$0^{\circ}\cdot0641605$ C.
B. . . .	$0^{\circ}\cdot0641059$ C.

Now the extreme difference in these numbers in the case of the first instrument is $0^{\circ}\cdot0001099$ C., while the average difference between any pair of observations is $0^{\circ}\cdot0000733$ C.; in the case of the second instrument this difference is somewhat less, namely $0^{\circ}\cdot0000546$ C. This latter number I take to represent more nearly the error which would be likely to be obtained with any ordinary thermometer; for, owing to the large size of the bulb of No. 62839, the readings were subject to a source of error which was not thoroughly understood and guarded against at the time when the comparisons were made.

This difference of $0^{\circ}\cdot0000546$ C. in the results would be caused by a total error in the readings of 55084 of $0^{\circ}\cdot0043$ deg., or in those of 63616 of $0^{\circ}\cdot056$ deg., or by an error in those of both thermometers of $0^{\circ}\cdot004$ deg. each. As any such pair of comparisons involves four readings of each instrument, it follows that any temperature can be read with an error of $0^{\circ}\cdot001$ deg., or $0\cdot01$ millim. (remembering that each such reading is really the mean of twelve observations).

* One of these arbitrary degrees, with thermometers 62839 and 63616 measures 10 millim., with 55084 12 millim. All the numbers given here are fully corrected.

With delicate thermometers, such as those described, this quantity is negligible (amounting to $0^{\circ}00006$ C.*); it is of importance in the standard instrument only. The natural standard No. 56117 is nearly as long as such a thermometer can be made with due regard to convenience; and the distance between the freezing- and boiling-points of water on it being 480 millim., this error of 0.01 millim.† at each point of comparison represents $0^{\circ}002$ C. The value of the total scale of any very delicate thermometer can thus be determined in a single comparison with an error of $\pm 0^{\circ}004$ C. If the thermometer is not very much more delicate than the standard itself, the error in reading it will become appreciable, and the probable error in the determination of the value of the distance between its extreme points will be $\left(0.004 + \frac{0.004}{x}\right)^{\circ}$ C., where x represents the ratio between the ranges of the standard and the instrument compared with it.

XXVIII. On the Flow of Gases.

By Professor OSBORNE REYNOLDS, LL.D., F.R.S.‡

1. **A**MONGST the results of Mr. Wilde's experiments on the flow of gas, one, to which attention is particularly called, is that when gas is flowing from a discharging vessel through an orifice into a receiving vessel, the rate at which the pressure falls in the discharging vessel is independent of the pressure in the receiving vessel until this becomes greater than about five tenths the pressure in the discharging vessel. This fact is shown in tables iv. and v. in Mr. Wilde's paper: thus, the fall of pressure from 135 lbs. (9 atmospheres) in the discharging vessel is 5 lbs. in 7.5 seconds for pressures in the receiving vessel, ranging from one half-pound to nearly 5 or 6 atmospheres.

* With the majority of the instruments mentioned in the previous tables this 0.001 deg., or 0.01 millim., would correspond to $0^{\circ}0004$ C. These differences include all errors due to imperfections in the calibration-corrections applied.

† I shall show elsewhere that the average error of reading, as deduced from a large number of calorimetric determinations, is ± 0.011 millim. It will also be shown that the error at any point due to imperfections in calibration and standardization amount to ± 0.014 millim.; but this had been deduced from simultaneous observations on two different instruments, and by far the greater portion of this error I believe to be due to an imperfection, hitherto uninvestigated, which renders concordance between two such instruments throughout their scales impossible, unless, perhaps, the height of the column of mercury is the same in each.

‡ Communicated by the Author, having been read before the Manchester Literary and Philosophical Society, November 17, 1885.