



XXIV. A comparison of Rowland's mercury thermometers with a Griffiths platinum thermometer

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To cite this article: C. W. Waidner & F. Mallory (1897) XXIV. A comparison of Rowland's mercury thermometers with a Griffiths platinum thermometer , Philosophical Magazine Series 5, 44:267, 165-169, DOI: [10.1080/14786449708621048](https://doi.org/10.1080/14786449708621048)

To link to this article: <http://dx.doi.org/10.1080/14786449708621048>



Published online: 08 May 2009.



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Again

$$\begin{aligned} s^2 + \mu^2 &= 1; \\ \therefore sds &= -\mu d\mu, \\ \mu^2 &= 1 - s^2 = 1 \text{ ultimately,} \\ s &= \frac{\rho}{a}; \therefore ds = \frac{d\rho}{a}; \\ \therefore d\mu &= -s \frac{d\rho}{a} = -\frac{\rho d\rho}{a^2}; \\ \therefore P'_n &= \frac{dP_n}{d\mu} = -\frac{a^2}{\rho} \frac{dJ_0(k\rho)}{d\rho} \\ &= \frac{ka^2}{\rho} J_1(k\rho). \end{aligned}$$

XXIV. *A Comparison of Rowland's Mercury Thermometers with a Griffiths Platinum Thermometer.* By C. W. WAIDNER and F. MALLORY*.

THE determinations of the mechanical equivalent of heat by electrical and mechanical methods show a close agreement between the values obtained by different experimenters using the same method of experiment. There appears, however, a very appreciable difference between the values as determined by the two methods, a difference greater than can be accounted for by errors of experiment. This difference can only be explained on the assumption that the results of the different experimenters are based on different thermometric standards or of a still undiscovered error in the system of electric units employed. The recent comparison by Professor Schuster of Joule's thermometers has indirectly furnished a connexion between Professor Rowland's air thermometer and the nitrogen standard of the Bureau International.

This comparison pointed to differences in these two standards as great as $\cdot 05^\circ \text{C.}$, but as the details of Joule's comparison of Rowland's thermometer (No. 6166) with his own are not known, this correction is uncertain. It was therefore thought advisable to make another comparison of Professor Rowland's mercurial thermometers *under conditions* as nearly

* From the Johns Hopkins University Circulars, June 1897.

as possible *similar* to those under which they *were used* by him in his mechanical equivalent determinations. On account of the many advantages offered by a Griffiths platinum thermometer for the standardization of calorimetric thermometers, this instrument was selected for the comparison. In the comparison the platinum and the mercurial thermometers were placed side by side in a calorimeter and the two read simultaneously while the temperature was slowly rising. Readings on mercurial thermometers were taken by means of a micrometer eyepiece.

The stem corrections of the mercurial thermometers were made, as in Rowland's experiment, by surrounding the thermometer stem for a short distance above the calorimeter with a water jacket, the remaining portion of the exposed stem being assumed to be at the temperature of the surrounding air. The mercury thermometers were placed in ice and distilled water for several hours and the zero determined before each comparison. The corrected stem readings obtained in our comparison were then reduced to Rowland's zero and the corresponding temperatures of his air thermometer taken from his tables of comparison of this thermometer with his Baudin thermometers (Nos. 6163, 6166). The platinum thermometer used in this experiment was one constructed by Mr. E. H. Griffiths. It was provided with compensating leads so that the temperature was independent of stem immersion, provided this was great enough to prevent conduction down the leads to the platinum coil.

The resistance measurements were made with a Griffiths resistance box (No. 7) especially designed for the measurement of platinum temperature. We are under great obligations to the University of Chicago for the use of this box, which was kindly loaned us for this work. The construction and calibration of a resistance box similar to the one used by us has been described by Mr. E. H. Griffiths in 'Nature,' November 14th, 1895. The method there described was employed by us. Two independent calibrations of the coils and bridge wire gave practically identical results.

Temperature on the platinum scale is defined by the equation

$$pt = \frac{R - R_0}{R_1 - R_0} \times 100,$$

where *pt* denotes platinum temperature, R_0 the resistance of the thermometer at 0°C. , R_1 the resistance at 100°C. , and R the resistance at the temperature *pt*. Platinum temperature is therefore independent of the unit of resistance employed,

and all of our measurements are given in terms of the mean box unit of Box No. 7 (approximately one mean box unit equals .01 ohm). Griffiths gives as the values of R_1 and R_0 the following:— $R_1=358.078$, $R_0=258.362$ (in mean box units, Box No. 6). From which the fundamental interval

$$R_1 - R_0 = 99.716, \text{ and } \frac{R_1}{R_0} = 1.38596.$$

To reduce these values to true Board of Trade ohms the factor for this box (No. 6) at 20°C. , as given by Griffiths, is 0.010003. We are uncertain as to the absolute value of the mean box unit of our box (No. 7), and hence cannot yet compare our values in the standardization of our thermometer directly with those of Griffiths.

The following values of R_0 were obtained:—

258.471
258.472
258.469
258.471

—————
258.471 mean box units, 20°C.

Each of these values is the mean of five or six measurements with different combinations of coils and bridge wire. It is interesting to note that the last two determinations suggest the possibility that the effect of radiation is appreciable in a room whose temperature is 20° above the thermometer coil; the first of these was made in a double-wall vessel with ice in both compartments, the second immediately after in the same mixture of ice and water with the inner polished vessel removed.

The determination of R_1 gave the following values:—

358.228
358.229
358.235

—————
358.231 mean box units, 20°C.

These determinations were made in a hypsometer in which the thermometer was screened on all sides from radiation effects. Each of the above measurements was made on a different day with great differences of barometric height, and is the mean of five or six readings all in close agreement.

This gives for the value of $\frac{R_1}{R_0}$ 1.38597.

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The conversion from the platinum to the air scale is made by the following formula :—

$$t-pt=\delta\left\{\left(\frac{t}{100}\right)^2-\frac{t}{100}\right\}$$

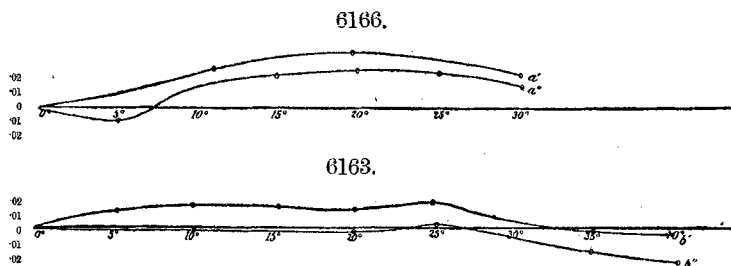
where t is the temperature on the air scale, pt the platinum temperature as defined above, and δ a constant. (For the experimental evidence in favour of this formula, see the elaborate comparison of the air and platinum thermometers by Callendar and Griffiths, *Phil. Trans. Roy. Soc.* vol. clxxxii. (1891), A). This relation being a parabolic one, only three temperatures are necessary for the complete standardization of a platinum thermometer, *i. e.* for the determination of δ .

The identity of our value of $\frac{R_1}{R_0}$ with that obtained by Griffiths in his standardization of our thermometer, made it unnecessary for us to determine the resistance of the thermometer in boiling sulphur (the third point usually employed), and we therefore accepted the value of δ , 1.491, given by Griffiths, as correct.

All auxiliary thermometers used for resistance box, measurement of air temperatures, &c., were compared and reduced to air scale.

Each of the mercury thermometers was separately compared with the platinum thermometer in two independent series of observations.

The results of the comparisons are best shown by the accompanying curves, in which abscissæ represent temperatures on Rowland's air scale and ordinates the corresponding corrections which must be added to Rowland's scale to



reduce to the air scale obtained through the platinum thermometer.

The differences in the above comparisons are far greater than can be accounted for by experimental errors, and must

be partly due to the nature of the glass used in these thermometers, which seem more dependent upon their previous use than the hard glass thermometers. The depression of the zero in these thermometers is large. Thus in one experiment with 6163 the zero at the beginning, after the thermometer had been at about 20° C. for several weeks, was 60.11 millim.; after heating to 40° C. the zero was 59.77, a depression corresponding to $.038^{\circ}$ C.

A similar experiment with Baudin (No. 6165), which was exactly similar to these two thermometers, gave a depression of $.021^{\circ}$ C. after being raised to 30° C.

It will be observed that from 14° to 25° the range on the two air scales does not differ by more than a few thousandths of a degree. We must therefore conclude that the difference between the mechanical and electrical determinations of the mechanical equivalent of heat cannot be accounted for by differences in standards of thermometry, but must be sought in the energy determinations.

XXV. *A Recalculation of Rowland's Value of the Mechanical Equivalent of Heat, in terms of the Paris Hydrogen-Thermometer.* By W. S. DAY*.

THE measurement of the mechanical equivalent of heat made by Rowland in 1877-79 (Proc. Am. Acad. xv. p. 75, 1879) is probably the best one in which the heat was produced by the expenditure of mechanical energy. Later determinations made with great care, in which the heat was produced by the expenditure of electrical energy, give results higher by about one part in four hundred. Rowland's measurement of temperature was based on comparisons made between an air-thermometer and three Baudin mercurial thermometers, by which he reduced his measurements to the absolute thermodynamic scale. It was the object of the present investigation to compare his thermometers with the hydrogen scale of the International Bureau of Weights and Measures, at Sèvres, near Paris, and make a recalculation of his value of the mechanical equivalent accordingly.

For this purpose, three Tonnelot thermometers which had been carefully studied at the International Bureau, and compared with their standards at several points of the scale, were obtained and compared with the three principal thermometers used by Rowland in his experiment. These comparisons were made in a horizontal comparison tank, designed and

* From the Johns Hopkins University Circulars, June 1897.

Phil. Mag. S. 5. Vol. 44. No. 267. August 1897. N