*Citation:*

Clay, J. & H. Kamerlingh Onnes, On the measurement of very low temperatures. XV. Calibration of some platinum-resistance thermometers, in:
KNAW, Proceedings, 10 I, 1907, Amsterdam, 1907, pp. 200-203

**Physics.** — "*On the measurement of very low temperatures. XV. Calibration of some platinum-resistance thermometers.*" By Prof. H. KAMERLINGH ONNES and J. CLAY. Communication N°. 99*b* from the Physical Laboratory at Leiden.

(Communicated in the meeting of June 29, 1907).

§ 1. *Introduction.* The investigation on the variation of the resistance of metals (pure ones and those with known admixtures) set on foot many years ago (see Comm. N°. 77 § 1 These Proc. Febr. 1902) at Leiden, comprises besides the determination of the galvanic resistance of conductors made of the different metals, also the determination of the expansion for each of these metals. We have only little advanced as yet with the latter part of this investigation, the expansion has only been investigated for platinum, which was chosen as standard metal, and then only down to — 182°. [1]) We hope shortly to publish a Communication on the expansion down to — 252° C. For the present, however, the knowledge of this expansion is not yet of much importance for the investigation of the variation of the specific resistance with the temperature. When in this investigation we descend to very low temperatures, the correction for the expansion becomes so small compared with the disturbance in consequence of other influences which are still further to be investigated, that we may disregard it for the moment.[2])

The investigation consists then in the calibration of different resistance thermometers. The wires treated in this Communication being chiefly of importance to us as resistance thermometers, we have inserted their calibration in this series.

1) In Comm. N°. 85 (These Proc. April 1905) it was observed for the first time that in order to represent the expansion of glass from — 180° to 0° a formula of the second degree with other constants was required than for the range from 0° to + 100°. We found this confirmed in Comm. N°. 95*b* (These Proc. Sept. '06), and also applicable to platinum, for which a formula of the third degree, as we gave one for glass, proved necessary between — 180° and + 100°. Afterwards (Dec. '07) SCHEEL, who was at first (Zeitschr. f. Instr.k. April '06) of opinion that a formula of the second degree could be found for platinum between — 190° and + 100°, come to the same opinion as we, and gave the three constants for platinum Our formula of the second degree for platinum between 0° and —180° quoted by SCHEEL was used by us to prove, that for platinum between —180° and +100° a formula of the second degree is *not sufficient*, but that a formula of the third degree is required. In order to show this with given values at + 100°, 0° and — 190° observations at a temperature about halfway between 0° and — 190°, as our — 87°, are more suitable than observations at a temperature between 0° and + 100°, as those by SCHEEL at + 56°.

2) Here it is left entirely undecided whether the variation of the resistance with the temperature is not in close connection with the expansion.

§ 2. *Particulars on the comparison and on the investigated wires.* In these calibrations we have taken the platinum wire which was compared with the hydrogen thermometer in Comm. N° $95^c$ (These Proc. Sept. '06) and which we shall call $Pt_I$, as standard. We determined the variation of the resistance of the other wires by bringing them together with $Pt_I$ at the desired temperature, and by then comparing their resistance with that of $Pt_I$. The two platinum wires $Pt_{III}$ and $Pt_V$ were brought in the same cryostat (see § 4 Comm. $95^c$) together with $Pt_I$, and whereas the temperature was kept constant with one resistance according to the indication of the WHEATSTONE-bridge, the ratio of the resistance of the other to $Pt_I$ was determined by means of the differential galvanometer. $Pt_V$ was also measured separately with the WHEATSTONE-bridge. The difference of the results by the two methods amounted only to 0,02 °/₀ at the lowest temperatures.

Just as $Pt_I$, $Pt_{III}$ and $Pt_V$ were supplied by HERAEUS; they were delivered at the same time, but later than $Pt_I$. The diameter of all three was 0.1 m.m. After having been treated and wound round the glass (see Comm. N°. $95^c$ § 3) in the same way, they were heated for a long time in an annealing furnace for glass. $Pt_{III}$ and $Pt_V$ differed only in this respect that after being heated $Pt_V$ was partly unwound, and then wound again, and was not heated in the annealing furnace again.

To obtain also a resistance thermometer of very small dimensions a platinum wire of 0,05 m.m. diameter was wound round a tube of 1 c.m. diameter and about 8 c.m. long. The thin platinum wire was welded to thick platinum wires which were fused in the glass. Consequently the thermometer could be cleaned by means of acids if necessary. The thin wire $Pt_d$ used for this thermometer, was also furnished by HERAEUS.

A fourth wire was investigated to get an idea of the

§ 3. *Invariability of the resistance thermometers for low temperatures with the time,* viz. the resistance thermometer with which the observations were made by MEILINK in 1902, and which we shall call $Pt_M$. The zero point appeared to have remained unchanged to one 300000$^{th}$[1]). This was also the case with $Pt_I$, after measurements had been made at very low temperatures with the resistance thermometer for two years.

Repetition of the calibration at low temperatures of 1902 did not give an equally good harmony. We found:

1) The thermometer had got defect in consequence of the bursting of the glass cylindres. However carefully it was repaired, yet this gave rise to a diminution of length of the wire of 3 mm. or 0,039 °/₀, for which a correction was applied.

| TABLE IV. | | | | |
|---|---|---|---|---|
| Hydrogen th. | 1902 | 1907 | Deviation in $\Omega$ | Deviation in ° C. |
| 0° | 110.045 | 110.048 | — 0.003 | |
| —182.63 | 28.692 | 28.605 | + 0.087 | + 0°.25 |
| —197.08 | 21 877 | 21.999 | — 0.022 | — 0.05 |
| —209.93 | 16.025 | 15.934 | + 0.089 | + 0.25 |

We think that we cannot draw another conclusion from it than that the reliability of the measurements with the hydrogen thermometer in 1902 was not yet so great as it has become now as appears from Comm. N°. 95[d].

§ 4. *Results.* The measurements have yielded for the resistance of each of the wires expressed in that at 0° as unity:

| TABLE V. Comparison of different platinum resistance thermometers | | | | | |
|---|---|---|---|---|---|
| Temperature | $Pt_I$ | $Pt_{III}$ | $Pt_V$ | $Pt_M$ | $Pt_d$ |
| 0° | 1. | 1. | 1. | 1. | 1. |
| — 30.53 | 0.87892 | 0.87846 | 0.87799 | | |
| — 58.58 | 0.76685 | 0.76632 | 0.76643 | | |
| — 87.55 | 0.64991 | 0.64918 | 0.65039 | | |
| —103.83 | 0.58345 | | | 0.58720 | |
| —109.09 | 0.56204 | 0.56025 | 0.56126 | | |
| —140.19 | 0.43311 | 0.43195 | 0.43182 | | |
| —159.11 | 0.35368 | 0.35240 | 0.35214 | 0.35979 | |
| —182.75 | 0.25283 | 0.25141 | 0 25099 | 0.26022 | 0.27374 |
| —195.10 | 0.20045 | 0.19894 | 0.19858 | 0.20812 | 0.22298 |
| —204.68 | 0.15974 | 0.15816 | 0.15880 | | 0.18355 |
| —212.20 | 0.12816 | 0.12653 | 0.12625 | 0.13622 | 0.15285 |
| —216.63 | 0.11024 | 0.10853 | 0.10824 | | |
| —252.82 | 0.01421 | | | | 0.040637 |
| —255.18 | 0.01244 | | | | 0.03766 |
| —259.10 | 0.01053 | | | | 0.03645 |

It appears that wires delivered at the same time show the same course with only small deviations. A considerable difference in deformation of the wire has had only a slight influence for $Pt_V$. The great difference with wires delivered at different times points to the fact that the originally used material and the treatment in drawing the wires out decide on the change of the resistance. How great the influence of the treatment in drawing is appears from the comparison of $P_{III}$ and $Pt_d$. They were supplied by HERAEUS about the same time and are therefore probably made of platinum of the same degree of purity. Yet the thinner wire $Pt_d$ decreases much less in resistance than the thicker one. At the temperature of liquid hydrogen the differences become very large. In view of the results obtained for gold, which have been inserted in the following Communication (N°. $99^c$), the most plausible explanation is this that the admixtures in the platinum of the wires sent by HERAEUS, either due to their being less pure by nature or to the way of drawing, were less with the platinum sent later than with that sent earlier. We come back to this in Comm. N°. $99^c$. Here we may still mention that DEWAR's wire gave 0,30521 to ours 0,25344 at —182°, and that only the thickest (0,2 m.M.) of HOLBORN's wires gave a smaller value than ours, viz. 0,21253 to ours 0,21786 at —191°.

§ 5. *Calibration formulae for the new wires.* Just as for $Pt_I$ we have also calculated the constants for each of the wires $Pt_{III}$ and $Pt_V$ in a calibration formula which is adjusted down to —217° and does not give to great deviations at the hydrogen temperatures. To be adjusted to the hydrogen temperatures too formulae of another form are required. The above mentioned formulae of the form $(A)$:

$$\frac{Wt}{W_0} = 1 + a.t.10^{-2} + b.t.10^{-4} + c.t.10^{-6} + d\left(\frac{10^2}{T} - \frac{10^2}{(273.09)^2}\right)$$

give for the adjustment which we distinguish by $A_I$:

| $A_I$ | $a$ | $b$ | $c$ | $d$ |
|---|---|---|---|---|
| $Pt_V$ | +0.401819 | +0.0007403 | +0.0052641 | +0.020666 |
| $Pt_{III}$ | +0.398291 | —0.0026645 | +0.0039442 | +0.016843 |

The mean error proved to be greater, for $Pt_V$ even considerably greater than in the calibration in Comm. $95^c$, which can be ascribed only partly to the indirect method of the determination of the resistance.