XI. On the value of some mercury resistance standards

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it was suggested by Mr. Swinburne that the most useful function of such an indicator would be to continually show the diagram on a screen in an engine-room, so that at every instant the engineer would not only know the pressure of steam in his boiler, but also the pressure at every instant in the cylinder.

I quite forgot to put this in my paper, although its importance was not unknown to me. I am now attaching an indicator to each end of the cylinder of my driving-engine at Finsbury. These will receive their miniature piston-motion from one rod. One gas-jet will throw from the two mirrors two diagrams upon a screen some seven feet away from the mirrors, and these diagrams will be visible from nearly every part of the engine-room at all times. In the room at present there are not only very visible pressure- and vacuum-gauges and a speed-indicator (not a counter), but also a dynamometer coupling, which shows at a glance the actual horse-power which is being transmitted along a shaft. If, instead of tracing the diagram with a pencil, I were to trace it with the point of a planimeter, the reading might represent the horse-power.

It is unnecessary to describe here how the indicator might be fixed to the valve-chest or receivers, or to other parts of an engine, such as the air- and force-pumps; or to pumping-machinery generally; or to engines driven by fluids. In fact it may be said that I have made the discovery that the beautiful method of observation of vibration of M. Lissajous has hitherto been neglected in its applicability to all sorts of practical purposes. Quite a number of other applications of the reflected beam of light principle suggest themselves.

XI. *On the Value of some Mercury Resistance Standards.*

By R. T. GLAZEBROOK, M.A., F.R.S., *Fellow of Trinity College, Cambridge* *.

IN a paper read before the Physical Society * on May 23, 1885, I described the results of a comparison between the original standards of the British Association and some copies of the mercury unit representing Legal Ohms made by M. Benoit in Paris and sent to me by him. Two of these copies have remained in my possession since that time; the third, at M. Benoit's request, was handed to Mr. Preece.

* Communicated by the Physical Society: read May 9, 1891.

† Glazebrook, Phil. Mag. October 1885; Proc. Physical Society, vol. vii.

The mercury with which the tubes were filled in 1885 has remained in them since that date. Now recent observations had seemed to indicate that a small change had taken place in some of the platinum-silver standards, and it became desirable to compare them again with M. Benoit's tubes. The method was the same as that of my former paper. The tubes immersed in melting ice were compared with the B.A. standards. The temperature of the room was kept very low, from $0^{\circ}5$ to 3° C., and thus the errors caused by the conduction of heat into the tubes through the copper connecting rods were avoided. The connecting pieces used to connect the tubes to the bridge differed from those employed in 1885, being a modification of the platinum cups described in my paper* on the specific resistance of mercury. A hollow platinum cup, about 3.5 cm. long and rather more than 1 cm. in diameter, is secured firmly into an ebonite tube; the outside of the tubes are turned to fit the ground portion of the glass vessels which form the ends of the mercury tubes, thus taking the place of the stoppers which usually close the tube; the platinum cups dip into the mercury, the surface of contact being about 12 sq. cm. The cups had previously been platinized; on the present occasion they were merely cleaned with nitric acid and distilled water. Stout copper rods, well amalgamated, fit tightly into the inside of the cups; the other ends of these rods are in contact with the bridge. Thus the connexion with the bridge is made through the rods and across the platinum of the cups, avoiding contact between the mercury and copper.

The resistance of the connexions was determined, and it was shown that the resistance of the platinum was negligible. This was done by making the rod and cup part of a circuit, the resistance of which was measured. The rod was then removed from the cup, and the latter was removed, so that the part of the copper which had been in the cup was now in direct contact with the mercury into which previously the cup had dipped. No change in the resistance of the circuit was produced by this. To secure this result it was necessary that a considerable area of the platinum should dip into the mercury; and this condition was in the experiments always carefully attended to. The resistance of these connecting-pieces was thus found to be .00291 B.A. unit.

The tubes were compared both with the B.A. units and also with the Legal-Ohm standards. In the comparison with the B.A. units, a large amount—about 300 divisions, or .015 B.A. unit—of the bridge-wire was used. Since the resistance of the

* Phil. Trans. 1888.

bridge-wire is known at 15° , this required, when the temperature of the room was as low as 1° or 2° , correcting for temperature; but as the whole correction amounted to less than 2 per cent. of the bridge-wire used, while this again was only 1.5 per cent. of the resistance measured, no very accurate knowledge of the temperature of the wire was needed. In some cases a coil of 100 B.A. units was put in multiple arc with the mercury tube; and the resistance of the combination, which amounted to a little over 1 B.A. unit, was compared with the wire standard.

The results of the comparisons are given in the following Tables.

TABLE I.—Tube, Benoit No. 37.

Date.	Standard.	Notes.	Value in B.A. units.
Jan. 3.....	Flat.		1.01111
" 5.....	Flat.		1.01103
" 5.....	Flat.	100 B.A. units in multiple arc with tube.	1.01108
" 6.....	Flat.		1.01099
" 6.....	Flat.	Mercury drawn through.	1.01101
" 7.....	Flat.		1.01109
" 7.....	Flat.	Mercury drawn through.	1.01109
" 7.....	Flat.	After interval of 1 hour.	1.01106

Mean for No. 37..... 1.01106 B.A. units.

TABLE II.—Tube, Benoit No. 39.

Date.	Standard.	Notes.	Value in B.A. units.
Jan. 3.....	Flat.		1.01053
" 5.....	Flat.		1.01058
" 5.....	Flat.	100 B.A. units in multiple arc with tube.	1.01060
" 6.....	Flat.		1.01049
" 6.....	Flat.	Mercury drawn through.	1.01037
" 7.....	Flat.		1.01041
" 7.....	Flat.	Mercury drawn through.	1.01034
" 7.....	Flat.	After interval of 1 hour.	1.01029
" 8.....	Flat.		1.01022
" 8.....	Flat.	Mercury drawn through.	1.01027
" 8.....	Flat.	After interval of 1 hour.	1.01033

Mean of last seven for No. 39..... 1.01032.

With regard to the observations on No. 37, it will be seen that they are extremely close, the greatest difference between

any two is $\cdot 00012$ B.A. unit, or rather more than 1 in 10,000 ; and no appreciable change was produced by passing the mercury through the tubes. The observations on No. 39 are not quite so close. On January 6 a distinct change was caused by passing the mercury through ; after that date the results are fairly consistent, and no further alteration was observed ; the mean of the values found after this date may be taken as the resistance of the tube to an accuracy of about 1 in 10,000.

The two results therefore are:—

No. 37.....	1·01106 B.A. units.
No. 39.....	1·01032 B.A. units.

The observations in 1885 were reduced to Legal Ohms, using the value for the resistance of mercury in terms of the B.A. unit adopted by the B.A. Committee in that year, and based on Lord Rayleigh's experiments. According to this 1 Legal Ohm= $1\cdot 0112$ B.A. units.

If we take these values we have as the resistances in Legal Ohms the following:—

	Benoit.	R. T. G. 1885.	R. T. G. 1891.
37	1·00045	·99990	·99986
39	·99954	·99917	·99913

Comparing the last two columns we see that the tubes have apparently fallen in value relative to the standard Flat in the $5\frac{1}{2}$ years by $\cdot 00004$, but this quantity is too small to be really certain of. The results of the experiments therefore prove within this limit that the platinum-silver coil Flat has not altered relative to the mercury-tubes in this interval. The difference between the values found by Benoit and myself depends on the value used for the resistance of mercury in B.A. units. According to Lord Rayleigh *, the resistance of a column of mercury 100 cm. long, 1 sq. mm. in section, at 0° C., is $\cdot 95412$ B.A. unit, and this is the value which has been used in the above. The value found by Mr. Fitzpatrick † and myself for this resistance was $\cdot 95352$. Practically the same number has been obtained by Wuilleumeier ‡, Hutchinson §, and Salvioni ||. If this number be adopted, then

$$\begin{aligned} 1 \text{ Legal Ohm} &= 106 \times \cdot 95352 \text{ B.A. unit.} \\ &= 1\cdot 01073 \text{ B.A. units.} \end{aligned}$$

* Phil. Trans. 1883.

† Phil. Trans. A. 1888.

‡ Wuilleumeier, *Comptes Rendus*, cvi., 1888.

§ Hutchinson, Johns Hopkins University Circulars, 1890.

|| Salvioni, *Rend. della R. Acad. del Lincei*, vol. v. fasc. 7.

74 *On the Value of some Mercury Resistance Standards.*

And then we find as the values of the tubes in Legal Ohms:

	Benoit.	R. T. G. 1891.
37	1·00045	1·00033
39	·99954	·99959

and these numbers show an extremely close agreement, thus proving that the resistance of a column of mercury 100 cm. in length, 1 sq. mm. in section, as given in this indirect way by Benoit's experiments, is very close to the value ·9535 B.A. unit.

In my previous paper * are given some values for the change of resistance of mercury with temperature. On January 3 I observed the resistances of the tubes Nos. 37 and 39 at a temperature of 12°·9 C. The results were:—

	Resistance at 12°·9.
37.....	1·02254
39.....	1·02193

From these we get as the values of the coefficients per 1° C., ·000875 and ·000870 respectively. Thus the mean coefficient between 0° and 13° is ·000872. This agrees well with the values found in 1885, the mean value between 0° and 10° being ·000861, and between 0° and 15° ·000879. From these we have as the value between 0° and 13°, ·000872.

Benoit † and Strecker ‡ give higher values than the above, Strecker's value between 0° and 13° being ·000906.

In the paper on the specific resistance of mercury, Phil. Trans. A, 1888, I have called attention to some of the consequences of this difference. The value of the coefficient between 0° and 10° found by Mr. Fitzpatrick and myself in 1888 was ·000876. Kohlrausch § and Strecker || find as the values for the resistance of mercury in B.A. units, ·95338 and ·95334; these are less than the value found by Salvioni, Hutchinson, Wuilleumeier, and myself, and the difference is, I believe, mainly due to the uncertainty in the temperature coefficient. They both worked with their tubes in a bath at about the temperature of the room, and reduced their results to 0° by the use of Strecker's coefficient. The mean temperature adopted by Kohlrausch was 10°, he puts

$$\sigma_0 = \frac{\sigma_{10}}{1·00904},$$

* Phil. Mag. October 1885.

† Benoit, *Journal de Physique*, 1884.

‡ Strecker, Wied. *Annalen*, vol. xxv. p. 475.

§ Kohlrausch, *Abhand. der K. bayer. Akad. der Wiss.* ii. Cl. xvi. Bd. iii. Abt.

|| Strecker, Wied. *Annalen*, vol. xxv. p. 475.

σ_0 and σ_{10} being the resistances at 0° and 10° . According to my own results in 1888 we should have

$$\sigma_0 = \frac{\sigma_{10}}{1.00876};$$

and the value of σ_0 would be increased from .95334 to about .95360, which is rather greater than my value. The value .000876 is given by Benoit for the mean coefficient between 0° and 10° .

XII. On the Mutual Solubility of Salts in Water.

By J. E. TREVOR*.

INTEREST in this problem has been again aroused by a new investigation by Dr. W. W. J. Nicol †, in which is presented a review of the older literature, together with new solubility determinations and a series of interpolation formulæ to express the results. Inasmuch as no mention is made of the recent investigations which have shed so much light upon this hitherto dark subject, I take this opportunity to call attention to the solidly grounded explanations which characterize the more recent progress in the study of the complicated phenomena which are here presented.

That the addition of a salt to the saturated solution of another sometimes increases, sometimes diminishes the solubility of the latter, has been long known. The explanation was first given in 1889 by Nernst ‡, in a simple application of the famous Law of Mass Action § to the conditions of electrolytic dissociation shown by Arrhenius || to exist in aqueous solutions of electrolytes, to which class of bodies the inorganic salts belong. This theory, as is well known, indicates the necessity for assuming the dissociation of a certain portion of the dissolved electrolyte into its ions, and is intimately connected with the van't Hoff theory of osmotic pressure ¶, which shows the entire analogy between the conditions of bodies in gaseous form and in solution. The undissociated dissolved molecules and the dissociated ions produce the same pressure effects as the undissociated and dissociated molecules of a gas. Direct application of the laws of gases explains the

* Communicated by the Author.

† Phil. Mag. 1891, xxxi. p. 369.

‡ Nernst, *Zeitschrift für phys. Chemie*, iv. p. 372.

§ Theory of Guldberg and Waage.

|| Arrhenius, *Zeitschr. für phys. Chem.* i. p. 631.

¶ Van't Hoff, *Zeitschr. für phys. Chem.* i. p. 481.