Determination of the Density of Fluid Bismuth by means of the Oncosimeter

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of somewhat different thickness produced a very appreciable current.

In the experiments given above the E.M.F. produced is about equal to that of a copper and platinum couple in which the difference of temperature is between 2° and 3°.

I was assisted in making the experiments by Mr. E. B. Sargant, Scholar of Trinity College.

XX. *Determination of the Density of Fluid Bismuth by means of the Oncosimeter.* *By* Professor W. CHANDLER ROBERTS, *F.R.S., and* THOMAS WRIGHTSON, *Memb. Inst. C.E.**

SOME time since, one of us described the results of experiments made to determine the density of metallic silver and of certain alloys of silver and copper when in a molten state†. The method adopted was that devised by Mr. R. Mallet‡; and the details were as follows :—A conical vessel of best thin Low-Moor plate (1 millim. thick), about 16 centims. in height, and having an internal volume of about 540 cubic centims., was weighed, first empty, and subsequently when filled with distilled water at a known temperature. The necessary data were thus afforded for accurately determining its capacity at the temperature of the air. Molten silver was then poured into it, the temperature at the time of pouring being ascertained by the calorimetric method. The precautions, as regards filling, pointed out by Mr. Mallet, were adopted; and as soon as the metal was quite cold, the cone with its contents was again weighed.

Experiments were also made on the density of fluid bismuth; and two distinct determinations gave the following results:—

$$\left.\begin{matrix}10{\cdot}005\\10{\cdot}072\end{matrix}\right\}\text{ Mean }10{\cdot}039.$$

The invention of the oncosimeter§ appeared to afford an opportunity for resuming the investigation on a new basis, more especially as the delicacy of the instrument had already

* Read February 12, 1881.

† Roberts, Proc. Roy. Soc. vol. xxiii. p. 493.

‡ Proc. Roy. Soc. vol. xxii. p. 366, and vol. xxiii. p. 209.

§ Wrightson, Journ. Iron and Steel Inst. No. II. 1879, p. 418.

been proved by experiments on a considerable scale for determining the density of fluid cast iron. The following is the principle on which this instrument acts.

If a spherical ball of any metal be plunged below the surface of a molten bath of the same or another metal, the cold ball will displace its own volume of molten metal. If the densities of the cold and molten metal be the same, there will be equilibrium, and no floating or sinking effect will be exhibited. If the density of the cold be greater than of the molten metal, there will be a sinking effect, and if less a floating effect, when first immersed. As the temperature of the submerged ball rises, the volume of the displaced liquid will increase or decrease according as the ball expands or contracts. In order to register these changes the ball is hung on a spiral spring, and the slightest change in buoyancy causes an elongation or contraction of this spring which can be read off on a scale of ounces, and is recorded by a pencil on a revolving drum. A diagram is thus traced out the ordinates of which represent increments of volume, or, in other words, of weight of fluid displaced—the zero-line, or line corresponding to a ball in a liquid of equal density, being previously traced out by revolving the drum without attaching the ball of metal itself to the spring, but with all other auxiliary attachments. By a simple adjustment the ball is kept constantly depressed to the same extent below the surface of the liquid; and the ordinate of this pencil-line, measuring from the line of equilibrium, thus gives an exact measure of the floating or sinking effect at every stage of temperature, from the cold solid to the state when the ball begins to melt.

If the weight and specific gravity of the ball be taken when cold, we have, with the ordinate on the diagram at the moment of immersion, sufficient data for determining the density of the fluid metal; for

$$\frac{W}{W'}=\frac{D}{D'},$$

the volumes being equal. And, remembering that

$$W \text{ (weight of liquid)} = W' \text{ (weight of ball)} + x$$

(where x is always measured as a $+$ve or $-$ve floating effect), we have

$$D=\frac{D' \times (W'+x)}{W'}.$$

The following table shows the results of six experiments to determine the density of fluid bismuth made by the authors in the laboratory of the Royal Mint. The bismuth was kept just above its melting-point; and this was ensured by placing pieces of metal in the molten mass, which were observed just to melt.

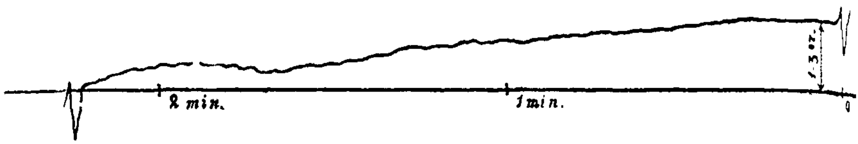
No. of exp.	Diameter of ball, in inches.	Weight, in troy ounces, including the stem for attachment.	Specific gravity of cold ball, including this stem.	Floating effect on first immersion, in troy ounces.	Deduced specific gravity of fluid metal.	Remarks.
1.	2	23·33	9·72	1·0	10·13	Bismuth ball in fluid bismuth.
2.	2·25	33·46	9·755	1·3	10 11	do.
3.	do.	33·37	9·757	0·6	9·94	do.
4.	do.	33·53	9·774	0·7	9·98	do.
5.	do.	22·184	6·99 (iron)	9·3	9·92	Iron ball in fluid bismuth.
6.	do.	22·184	7·02 (do.)	10·2	10·25	do.
				Mean	10·055	
		Specific gravity of solid bismuth			9·82	

It will be seen that, considering the difficulties of manipulation, the results are remarkably concordant, and their mean agrees very closely with that obtained by Mallet's method. We venture to think, therefore, that the density of bismuth in the solid and the fluid state may now be considered to be definitely settled.

Fig. 1 is the *oncosimeter* diagram of experiment No. 2 (see table), with a calculation of the fluid specific gravity annexed. When first immersed, the floating effect is 1·3 troy ounce, which (with the weight and density of the ball known) is all we require to determine the fluid-density. Bismuth has a low heat-conducting power; and therefore the mass of the ball is reduced by surface-melting before much heat can penetrate to

Fig. 1.

Oncosimeter Diagram of Bismuth Ball, 2·25 inches diameter, immersed in Fluid Bismuth (see table, Exp. 2).



Weight of ball and immersed part of stalk	33·46 oz.
Specific gravity of do. do.	9·755
First floating effect	1·3 oz.

$$\text{Specific gravity of fluid} = \frac{34{\cdot}76 \times 9{\cdot}755}{33{\cdot}46} = 10{\cdot}11.$$

the centre. Hence the diagram does not accurately show, as in metals of high conducting-power, the change of volume, the effect being compounded with that produced by loss of mass.

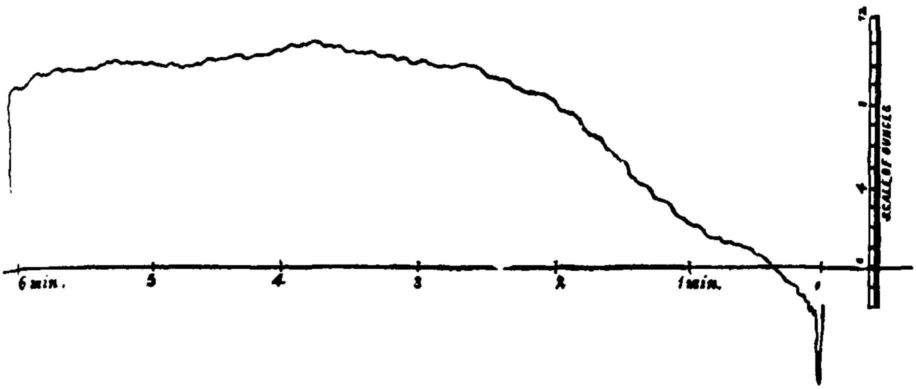
In the case of iron, the conducting-power of which is high, diagrams taken with the oncosimeter show correctly the expansion of the ball until it is in a uniformly plastic state. Fig. 2 is a diagram of a cast-iron ball, 4 inches diameter, immersed in fluid iron of the same quality (No. 4 Cleveland). In this the solid iron is shown to be of less volume than the liquid for about 25 seconds, then to rise gradually in volume until in 4 minutes it becomes plastic (this having been proved by taking balls out in this stage of temperature, when an iron pin could be run through and through the metal as though it were a piece of putty). The slight fall of the line for about 2 minutes towards the left of the diagram probably shows a slight loss of mass owing to surface-melting; and then the whole ball melts with great rapidity, and as it joins the liquid metal of the bath the line of volume shoots rapidly down to the equilibrium-line. This diagram shows, up to the plastic point (where loss of mass commences), the gradual change of volume at progressive intervals of time.

The diagram read from left to right should represent the change from liquid to solid; and this is quite in accordance with other observations on cast iron*.

* Journ. Iron and Steel Inst. No. II. 1879, and No. I. 1880.

Fig. 2.

Experiment No. 23, on Iron.



Weight of ball and immersed part of stalk............	132 oz.
Specific gravity of ball and immersed part of stalk	6·95
Maximum sinking effect..................................	2 oz.
Maximum floating effect	11 oz.

Specific gravity of fluid iron $= \frac{6{\cdot}95 \times 130{\cdot}0}{132} \ldots = 6{\cdot}84$

Specific gravity of plastic metal $= \frac{6{\cdot}95 \times 132}{145{\cdot}00} \ldots = 6{\cdot}33$

4-inch ball of No. 4 foundry iron (Cleveland). Run with very hot metal. Immersed in No. 4 foundry iron.

According to these experiments, iron expands rapidly (as much as 6 per cent.) in cooling from the liquid to the plastic state, and then contracts 7 per cent. to solidity; whereas bismuth appears to expand in cooling from the liquid to the solid state about 2·35 per cent.

XXI. *An Integrating-Machine.*

By C. V. Boys, *Assoc. Royal School of Mines.**

[Plate XI.]

All the integrating-machines hitherto made of which I can find any record may be classed under two heads:—one, of which Amsler's beautiful instrument is the sole representative, depending on the revolution of a disk which partly rolls and partly slides on the paper; the other, comprising

* Read February 26, 1881.