On the Ascent of Hollow Glass Bulbs in Liquids

This content has been downloaded from IOPscience. Please scroll down to see the full text.

1880 Proc. Phys. Soc. London 4 265

(<http://iopscience.iop.org/1478-7814/4/1/330>)

View [the table of contents for this issue](#), or go to the [journal homepage](#) for more

Download details:

IP Address: 142.132.1.147

This content was downloaded on 03/10/2015 at 07:50

Please note that [terms and conditions apply](#).

PROCEEDINGS
OF
THE PHYSICAL SOCIETY
OF LONDON.

JULY 1881.

XXVIII. *On the Ascent of Hollow Glass Bulbs in Liquids.*

By EDMUND J. MILLS, *D.Sc., F.R.S.**

1. WHEN a hollow glass bulb is detained at some depth below the surface of a liquid and then released from its position, it rapidly acquires a sensibly uniform velocity; and the motion continues to be characterized by such velocity until the surface is reached or nearly reached, the velocity at that time being much accelerated. The bulb next rises somewhat out of the liquid and then falls; oscillating thus, until it finally comes to rest under the usual conditions of a floating body. In the present paper I propose to give an account of an experimental investigation which has reference to the stage of uniform velocity.

2. The bulbs I have generally employed consist of Fig. 1.
lead glass, and have, as will be seen in the accompanying figure, a somewhat pyriform shape; the stalk terminates in a hook, which carries an adjusted glass weight. A few small projections are sealed on to the body of the bulb in order to prevent too close accidental contact with a wetted boundary. In working with these bulbs, I have always effected the depression with a piece of glass tubing, and find that

Scale $\frac{1}{2}$.

* Read May 14, 1881.

after some practice, it is seldom an experiment is lost by lateral divagations of the bulb. It is necessary that all the surfaces be clean.

I. *Change of the Diameter of the Reservoir.*

3. A series of glass cylinders having been selected, their mean diameters between two fixed marks 220 centimetres apart were determined. These marks were ruled at places sufficiently distant from the surface and bottom of the liquid to ensure the uniformity of the motion observed between them. The liquids were first heated a little above the temperature desired for the experiments, then poured into the cylinders; and these were immersed in a much larger glass vessel containing water of very nearly the same temperature. The thermometers used could be read directly to tenths, and to hundredths by estimation. The times were taken with a metronome beating thirds of seconds.

4. The following experiments were made at 16° with a mixture of alcohol and water of sp. gr. $\cdot 9120$ at that temperature; they are compared in the table with numbers calculated from the equation

$$\left. \begin{aligned} (t-\tau)d^2 &= c, \\ (t-6\cdot10)d^2 &= 23\cdot59. \end{aligned} \right\}$$

TABLE I.

<i>d.</i>	<i>t</i> obs.	<i>t</i> calc.
5·66	6·56	6·84
4·76	6·83	7·18
3·37	8·17	8·18
2·79	8·62	9·13
2·20	12·08	10·97

Probable error of a single experiment, 0·44.

The experiments were actually made on a height of 11 centim.; and the values obtained for *t* were half those given in the table. Each result is a mean of seven determinations.

From the above comparison, it appears that the product of the number of seconds *t* (less a constant τ) into the square of the diameter *d* of the cylinder is a constant quantity *c*. The time of ascent through a cylinder of infinite diameter would have been $\tau = 6\cdot10$ seconds. The law, however, shows indications of failure when the diameter is narrowed to 2·2 centim.

5. Table II. contains the results of some experiments with recently-boiled water, at 15° , and another bulb. The time is calculated to seconds. Each result is a mean of these determinations.

TABLE II.

<i>d.</i>	<i>t</i> obs.	<i>t</i> calc.
17.16	26.2	26.17
9.24	26.1	26.71
5.66	26.3	27.97
4.76	27.7	28.80
3.37	29.9	31.63
2.79	37.6	34.24
2.20	41.0	39.20

Equation, $(t - 25.95)d^2 = 64.56$.

Probable error of a single experiment 1.29.

Sum of the errors (t obs. $- t$ calc.), $+ 0.08$.

The last two numbers suggest the same remark as in (4).

6. A sample of hydrocarbon-oil was next tried, a different weight and bulb being used. Each result is a mean of six determinations. The sp. gr. of the oil was .9120 at 16° , *i. e.* the same as that of the mixture of alcohol and water referred to in (4).

TABLE III.

<i>d.</i>	<i>t</i> obs.	<i>t</i> calc.
5.66	31.5	31.41
4.76	35.3	34.91
3.37	46.0	46.80
2.79	57.4	57.73
[2.20	90.8	78.88]

Equation $(t - 22.96)d^2 = 270.65$.

Probable error of a single (1-4) experiment, 0.37.

II. *Change of the Unbalanced Pressure.*

7. The unbalanced pressure, to which the ascent of the bulb is due, can be conveniently changed by increasing or diminishing the weight attached to the bulb. If we take a centimetre as the unit of volume, and understand by δ the mean density of (bulb + contents + weight) referred to that of the

liquid as unity, then $(1-\delta)=p$ may be termed the "unbalanced unit pressure."

The following experiments were performed with a bulb of the usual size, recently-boiled water at $11^{\circ}5$ being the liquid. The diameter of the cylinder was 5.66 centim.; the times are stated in half-seconds; and each result is the mean of seven determinations.

TABLE IV.

<i>t.</i>	<i>p.</i>	<i>tp</i> ² .
20	·01139	·0025946
40	·00810	·0026244
81	·00569	·0026225

Equation, $tp^2=c=·0026138$.

Probable error of *c*, 0.25 per cent.

8. Another set of experiments was carried out in the same cylinder, under nearly the same conditions, with five variations of weight. Each result is the mean of five observations of ascent through a height of 16.5 centim. The times are stated in thirds of seconds.

TABLE V.

<i>t.</i>	<i>p.</i>	<i>tp</i> ² .
15.5	·00438	·00029735
31.0	·00310	·00029791
60.0	·00223	·00029844
97.0	·00177	·00029705
146.2	·00143	·00029806

Equation, $tp^2=c=·00029776$.

Probable error of *c*=·000000169=0.06 per cent.

The product of the square of the unbalanced unit pressure into the time is therefore a practically constant quantity.

III. *Change of Content.*

9. In all the experiments above recorded the bulb contained air, probably at a pressure slightly below that of the atmosphere. The mean density of (bulb + contents + weight) is of course affected by the contents of the bulb, and then also the rate of ascent.

If we regard as correct the mathematical relation last

arrived at (8), it is easy to deduce from it an equation which involves the specific gravity of the contained gas. Assuming other conditions to remain unchanged, the density of the gas is

$$\gamma = A + B\sqrt{\frac{t-\theta}{t}}.$$

In this expression t is the time of ascent through the constant height for any particular gas, θ the time of ascent corresponding to a gas of density A , and B the density of a gaseous content which just fails to let the bulb sink. It is convenient to put $A=0$, which corresponds to the bulb being vacuous; B and θ are then deduced, as the "constants of the bulb," from two independent determinations.

10. In order to change at pleasure the contents of the bulb its form was slightly altered, as shown in fig. 2, and its volume enlarged. The two stoppers with which it was furnished were coated, on their ground surfaces, with a scarcely perceptible film of grease; the operator's hands were encased in gloves; and every experiment was carried out as speedily as possible. The gases were employed in the dry state, at an average barometric pressure of about 75·7 centim.; in the following table their densities are referred to hydrogen. Each result is a mean of several determinations; and the times are given in thirds of seconds.

Fig. 2.

Scale $\frac{1}{4}$.

TABLE VI.

Gas.	γ found.	γ .	t .
Carbonic dioxide ...	21·81	22·00	72·5
Oxygen	17·17	16·00	38·2
Air	14·13	14·50	30·6
Water-gas	6·44	6·00	23·0

The equation is $\gamma = 26·032\sqrt{\frac{t-21·589}{t}}$.

Probable error of a single comparison, 0·51.

Great accuracy in work of this kind is, of course, out of the question; but for approximate determinations, when only very small volumes of a gas are available, the method will probably be advantageous.

11. The following set of experiments has reference to a medium consisting of two mixed liquids, the rate of ascent of a bulb in each of which separately is known. One of the liquids was castor-oil, the viscosity of which is very considerable; to 100 parts of this, successive quantities z of linseed-oil were added so as to gradually reduce the viscosity. The uniform temperature was $12^{\circ}4$. By separate experiments with the oils it was found that, if t were the rate of ascent of the bulb in seconds per centimetre, λ the rate for linseed, α the unbalanced unit pressure in castor, and β the change in that pressure for every unit of linseed added, then

$$\left. \begin{aligned} (t-\lambda)(\alpha+\beta z)^2 &= c, \\ (t-0.32335)(0.09122+0.00169z)^2 &= 0.034376, \end{aligned} \right\}$$

are equations which fairly represent the experiments.

TABLE VII.

t .	z taken.	z calc.
4.45454	0.0	0.0
3.10027	11.1	11.9
2.21798	25.0	25.7
1.52758	42.9	46.0
1.22140	66.7	61.8
0.32335	∞	∞

Probable error of a single comparison, 1.7.

Sum of the errors, +0.3.

12. Castor-oil presents the remarkable property of recovering its normal viscosity very slowly after heating. A sample of the oil, through which a bulb rose in a known number of seconds per 22 centim., was heated to a temperature not exceeding 80° , and cooled to its previous condition. The bulb now took ten seconds less for its ascent. After a day's repose it rose again in the oil with its original velocity.

13. The fundamental formulæ given in this paper admit of easy extension to other cases. I have, for example, found in the ascent of a hollow glass bulb a good indication of the maximum density of water, and of the amount of dissolved matter in saline solutions; and it could obviously be applied to determine the specific gravity of solid bodies.

The experiments which I have recorded show clearly that

the rate of ascent of a solid through a liquid depends, not only upon the density of the liquid, but upon some other property—probably the viscosity. When the ascending solid approximates in diameter to the diameter of the reservoir, special retardation occurs, and some new law controls the motion. The commencement of this retardation is earlier with oils than with water, earlier with water than with alcohol and water—earlier, in short, when viscosity is greater. In reservoirs of sufficient diameter, the rate is inversely proportional to the square of the altered condition.

My thanks are due to Messrs. Ellis and Smith for their aid in this investigation.

Glasgow, March 1881.

XXIX. *Change of State : Solid-Liquid.* By J. H. POYNTING, *Late Fellow of Trinity College, Cambridge, Professor of Physics, Mason College, Birmingham.*

[Plate XIII.]

Two distinct types of change of state from solid to liquid have usually been recognized. The most familiar of these is the ice-water type, in which, as the temperature rises, the solid remains quite solid up to the melting-point; when this is reached it begins to melt *at the surface*, and the temperature remains constant till the whole is liquid, when the temperature again rises. Corresponding to this change of state there is a definite latent heat. In the second class of bodies, of which sealing-wax and phosphorus are examples, there is a gradual softening as the temperature rises; and this softening takes place *throughout the mass*. There is no definite arrest of the rise of temperature, and no definite latent heat.

It has sometimes been supposed that the ice-water type is merely a limiting case of the sealing-wax type, where the softening takes place, but through a very small range of temperature. Prof. Forbes held this view, and by it attempted to explain regelation; but subsequent experiments have not supported the theory, and I believe it is now generally abandoned.

Since, in the ice-water form of change of state, fusion only