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A SPECIFIC GRAVITY BALANCE

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ABSTRACT. The paper describes the details of a balance designed to indicate directly up to the 4th place of decimal the specific gravity of liquids and solutions The balance is as quick in operation as a common hydrometer used in industrial practice

INTRODUCTION

It is well known that the common hydrometer in different forms is universally used in industrial practice for the determination of specific gravity of liquids and solutions because of its simple construction and quick operation. It is, however, limited in its accuracy and in most cases it indicates the specific gravity correctly up to only the second place of decimal. If higher accuracy is desired, the stem of the hydrometer has to be made sufficiently long even for a narrow range of specific gravity commonly occurring. The object of the present investigation was therefore to design a specific gravity balance which would admit of greater accuracy in such determinations without sacrificing the advantages of a common hydrometer.

CONSTRUCTIONAL FEATURES AND WORKING

The specific gravity balance which has been designed is based on the principle of variation of weight of a sinker of constant volume when immersed in different liquids and solutions. The main features of the balance, shown in the accompanying figure, are the following : The longer arm of the balance, which is of uniform cross-section, is marked off in ten equal divisions from the fulcrum with the help of a travelling microscope. It has at its end a plated steel knife edge on which rests the stirrup carrying the hook. From the hook a glass sinker is suspended by means of a fine platinum wire to minimise the error due to surface tension. The sinker is weighted by the introduction of mercury into it. The shorter arm of the balance is provided with three adjustable screws for obtaining the equilibrium of the balance during adjustment when a sinker of a given weight is suspended from the other. At the end of this arm a pointer is attached which in its turn is placed against a mirror with an index mark over it. The fulcrum of the balance rests upon a beam which can be raised or lowered by means of an

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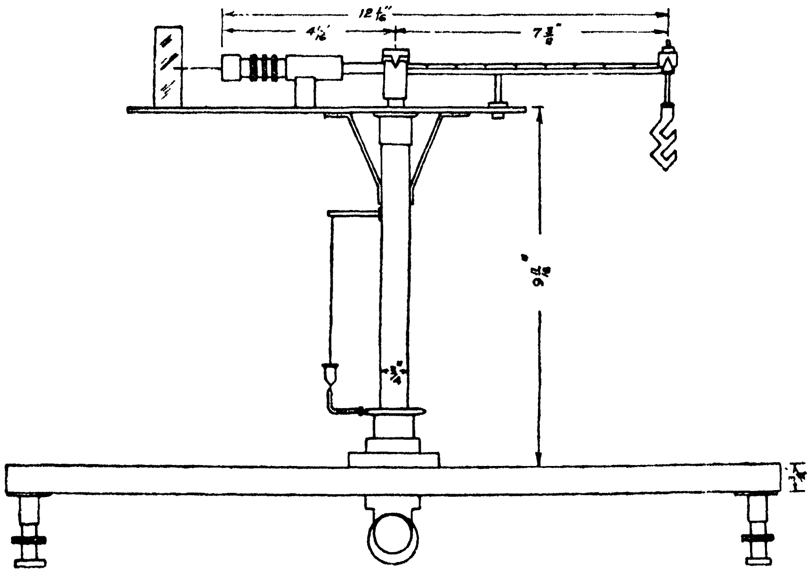
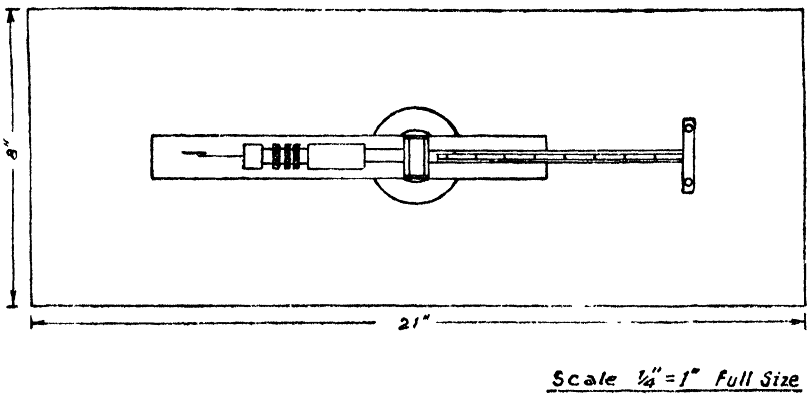
eccentric wheel, attached to the bottom side of the base, which is also fitted with three levelling screws. The balance is enclosed in a suitable case in the usual way.



(a)



(b)

FIG. 1

Specific gravity balance (a) Elevation (b) Plan

The balance is provided with a set of four riders, namely R_1, R_2, R_3 and R_4 of German silver wire. Their weights are so chosen that R_2/R_1, R_3/R_1 and R_4/R_1 have values of 0.1, 0.01 and 0.001 respectively. With the help of these riders and with the given weight of the sinker, the specific gravity up to a value of unity can be measured by the balance. A duplicate of the heaviest rider (R_1) is, however, necessary if the value of specific gravity lies between 1 and 2. It may be noted here that if it is necessary to measure specific gravity of still higher values, the above sinker is to be replaced by another having the same volume but different weight.

The actual value to be assigned to each rider is of importance and forms the special feature of the balance. In order that the positions of the riders on the longer arm of the balance when in the equilibrium condition, may indicate directly the specific gravity of a liquid in which the sinker is immersed, the heaviest rider (R_1) should have its weight in grammes numerically equal to the volume of water in c.c. displaced by the sinker when immersed in distilled water up to a predetermined mark at a given temperature. Thus once the weight of the rider R_1 is ascertained, it is very simple to fix the weight of the other riders. In the present balance we have the following data—

Weight of the sinker	9.2304 gm.
Volume of water displaced by the sinker at a room temperature 32°.4.C	6.0800 c.c.
Hence $R_1 = 6.0800$ gm. ;	$R_2 = 0.6080$ gm.
$R_3 = 0.0608$ gm. ;	$R_4 = 0.00608$ gm.

All weighings were done on a set of accurate balances available in the institute. The sinker and the heavier riders were weighed on an accurate chemical balance having a sensitivity of 0.00001 gm., while the lighter riders on a micro-balance.

The equality of the interval between successive scale marks on the longer arm of the balance and the correctness of the weights of the different riders were checked from the principle of moments. For the first purpose, three additional riders, two of weights $2R_2$ each and one of weight $5R_2$ were prepared. The rider R_1 was placed successively at each scale mark from the fulcrum. For each position of the rider R_1, the equilibrium condition of the balance was first obtained with R_1 in position and then by removing R_1 and placing riders of suitable multiple weights of the rider R_2 at the terminal knife edge Besides ensuring the equality of the divisions, it also proved the correctness of the weight of riders R_1 and R_2. A similar procedure was adopted to check the weight of the other riders.

It is evident that at the above temperature the true specific gravity of a liquid will be indicated correctly by the balance. But when the temperature during observation is different from the above temperature, a correction is necessary to take into account the change in volume of the sinker. If S_t and S_t be respectively the specific gravity indicated by the balance and true specific gravity of a liquid at t°c and if V_t be the volume of the liquid displaced by the sinker at t°c, then

$$S_t = \frac{\text{weight of the volume of liquid displaced by the sinker at t°c}}{\text{weight of the volume of liquid of unit density displaced by the sinker at 32°.4C.}}$$

$$= \frac{V_t \, S_t}{6.08 \times 1}.$$

$$\therefore \quad S_t = \frac{6.08}{V_t} . S_t$$

$$= \frac{6.08}{6.08[1 + \gamma(t - 32.4)]} . S_t$$

$$= [1 - \gamma(t - 32.4)] . S_t$$

where γ is the co-efficient of cubical expansion of glass and may be taken to be 24×10^{-6}.

Thus the true specific gravity of a liquid at any temperature can be calculated from the above equation whenever higher accuracy is desired.

TEST DATA

In order to check the working of the balance and the accuracy obtainable, the specific gravity of a number of pure organic liquids and solutions of a few inorganic salts in water at varying concentrations were measured with its help as well as by means of a specific gravity bottle. In the latter case all weighings were done with the chemical balance which was used previously to measure the weight of the sinker and the heavier riders. During each observation the temperature of the liquid or solution used was noted and their specific gravity as indicated directly by the balance was corrected, if necessary, to obtain their true specific gravity. The value of their specific gravity obtained by the specific gravity bottle method was also corrected for temperature. The two sets of values are included in the following tables for comparison.

TABLE I

Organic Liquids and Oil

Name of Sample	Temp (°C)	True specific gravity by		Error
		Sp gr. bottle	Sp gr. balance	
Aniline	32	1.0230	1.0231	+0.0001
Amyl acetate ..	32	0.8596	0.8597	+0.0002
Transformer Oil ...	32	0.8447	0.8449	+0.0002

TABLE II

Potassium Bromide Solutions of different concentrations

Samples	Temp (°C)	True specific gravity by		Error
		Sp. gr bottle	Sp gr balance	
1	34.0	1.3626	1.3624	−0.0002
2	34.0	1.3050	1.3048	−0.0002
3	34.0	1.2828	1.2826	−0.0002
4	34.0	1.2146	1.2147	+0.0001
5	34.0	1.1950	1.1948	−0.0002
6	34.0	1.1833	1.1835	+0.0002
7	29.6	1.1025	1.1026	+0.0001
8	29.6	1.0978	1.0976	−0.0002
9	29.6	1.0641	1.0639	−0.0002
10	29.6	1.0286	1.0288	+0.0002

TABLE III

Copper Sulphate Solutions of different concentrations

Samples	Temp. (°C)	True specific gravity by		Error
		Sp gr bottle	Sp gr balance	
1	33.6	1.1994	1.1992	−0,0002
2	33.6	1.1713	1.1715	+0,0002
3	33.6	1.1305	1.1303	−0.0002
4	33.6	1.0961	1.0962	+0.0001
5	34.0	1.0230	1.0228	−0.0002

It is easily seen from the above tables that in no case the value of specific gravity found with the help of the present balance differs by more than ± 0.0002 from its value determined by the specific gravity bottle method. On the other hand it does not take more than a few seconds to complete the measurement with this balance, which can be easily constructed and set up in any laboratory.

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