Cl^-, —0.2692 volt; S. E., flowing junction, —0.2454 volt; D. E. | KCl(sat.), flowing junction, —0.3373 volt; D. E. (without liquid-junction potential), —0.3353 volt.

CAMBRIDGE 39, MASSACHUSETTS

[CONTRIBUTION FROM THE CHEMICAL LABORATORIES, TRINITY COLLEGE, DURHAM, NORTH CAROLINA]

A LABORATORY VACUUM GAGE[1]

BY MARSTON LOVELL HAMLIN

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The introduction into common laboratory use of moderately priced vacuum pumps producing vacua of 3 to 0.005 mm. of mercury has made desirable the design of a vacuum gage covering approximately this range.

The open or closed type of U-tube manometer cannot be read with sufficient precision at pressures in this range, and the McLeod gage and its modifications, while satisfactory in precision at high vacua, lack range

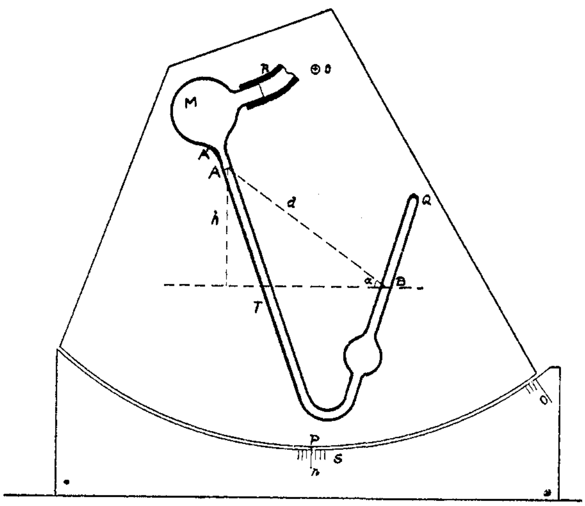

Fig. 1.

and convenience in manipulation, are somewhat difficult to construct and calibrate, and require considerable mercury.

A gage is described below that is simple to construct and calibrate and requires little mercury; it has a useful range of 10–0.05 mm., and may be constructed with a second range covering pressures one-fifth to one-tenth that covered by the first range; it is rapid in operation, only eight to ten seconds being required for a reading.

[1] Presented at the annual meeting of the North Carolina Academy of Sciences, Greensboro, N. C., May 5, 1923.

A diagram of the gage is shown in Fig. 1. It consists essentially of a glass tube of approximately 3mm. inside diameter, having a glass bulb M, connected by rubber pressure tubing with the system to be measured, mounted so as to rotate about a pivot O, and having on its mounting a pointer P, indicating on the scale S the rotation. S is calibrated to read the pressure directly in millimeters of mercury. For a single range the gage carries a single calibration mark at B.

Principle of Operation.—Enough clean mercury is put into the gage to fill the tube completely from B to an arbitrary point A. (The weight of mercury used should be noted for reference in calibrating or refilling, since for a given calibration it is essential always to use the same amount.) In making a reading the gage is rotated counterclockwise until under the vacuum all the mercury runs into the bulb M. The gage is then rotated clockwise until the mercury fills the tube exactly to B, which entraps the volume of air A′Q. The pressure in BQ equals the pressure in M plus the difference in head between A and B. The latter is a function of the angular rotation.

If the volume ratio A′Q:BQ is known, the ratio of the pressure of air in the system measured to that in BQ can be determined; hence, the corresponding head, A—B, and the rotation of the gage can be related to the pressure to be measured. The gage can therefore be made to read directly.

Calibration of the Gage Tube.—After making the tube, the point A′, at which the mercury cuts off the air in the tube, is determined by trial; the volume A′Q is then determined as usual by weighing the mercury required to fill the tube completely to this point. One-eleventh (or some other convenient fraction) of this weight of mercury is now introduced into the empty tube and worked to the end Q with the gage inverted; its meniscus determines the point B.

If a definite amount of mercury is now introduced—enough to fill the tube from B to the arbitrary point A— and the gage operated as described, the following equations hold.[2]

Let the volume A′Q = V, the volume BQ = v, the pressure of the system to be measured = P, the pressure in BQ after operating the gage = p, and the head of mercury in mm. (that is, the vertical height between A and B when gage is read) = h.

Then, since $PV = pv$

$$P = \frac{pv}{V} \tag{1}$$

But $p = P + h$, and $V = 11v$ (or other multiple); so, substituting in Equation 1, $P = (P + h)\,\frac{v}{11v} = \frac{P + h}{11}$.

[2] The volume-pressure relationships here are the same in principle as those used by Gross and Wright [*J. Ind. Eng. Chem.*, **13**, 701 (1921)] in their gage; these authors are responsible for the introduction of this simplification into gages of this type.

Therefore

$$P = 10^{-1}h \tag{2}$$

Construction of the Scale S.—At the time of reading, the two ends of the mercury column always occupy the same positions, A and B, for a given calibration of the gage. This distance between these points, d in Fig. 1, is therefore constant; h is the head of mercury and, of course, variable.

When the reading of the gage is zero, $h = 0$, and AB is horizontal; α, the angle at B, is then zero. In any position of the gage, $\alpha = \sin^{-1}(h/d)$.

To lay out the scale S, draw a quarter circle on the cardboard of which the scale is to be made, with radius d as in Fig. 2. The vertical radius may then be divided in millimeters and these divisions projected horizontally on the circumference. The divisions on the vertical radius represent various values of h, and since $\alpha = \sin^{-1}(h/d)$, their projections on the circumference give the corresponding values of α. And since the angle α, made by d with the horizontal, is the same as the angular rotation of the gage about O from the zero position, the divisions on the circumference indicate rotations of the gage corresponding with various values of h.

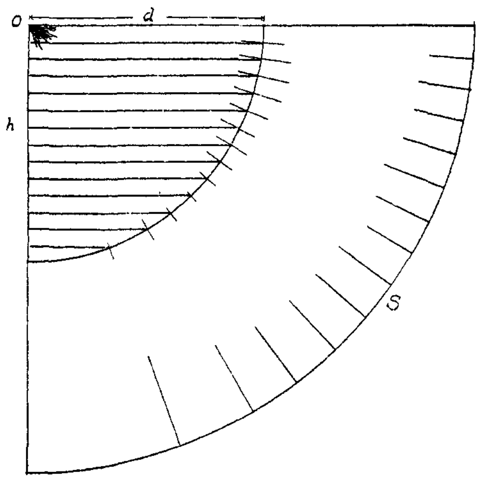

Fig. 2.

These divisions may be projected radially on a scale arc of any radius convenient for reading and operation, and numbered to read P directly, which in the case described was one-tenth h.

Setting the Scale.—The position of the scale was located as follows. The instrument was set up and the rotating part clamped so that AB was horizontal; this was done with the aid of a reading telescope and a U-tube water level. The scale was then fastened in place with its center at O and its zero point opposite the pointer P.

The precision of the scale was checked directly by comparing a number of scale readings with h as measured on a good millimeter scale through a reading telescope with a true horizontal motion.

Direct reading, h, mm.	100.1	80.2	60.0	40.4	20.0	0.9
Direct reading, $10^{-1}h$	10.01	8.02	6.00	4.04	2.00	0.09
Reading of scale S	10.0	8.0	6.0	4.0	2.0	.0

A slight error is present in the gage as described and constructed, due to lack of parallelism of the two arms of the tube containing mercury; it is probably less than the errors of calibration and construction. For the most accurate work this could be eliminated by making the gage in the somewhat more inconvenient form of a U-tube with parallel limbs.

It is obvious that the longer the radius of the scale is, and the shorter AB, the greater will be the reading accuracy, and the less will be the range of the scale of the instrument. The maximum range of the gage is from $h = 0$ to $h = d$, and of the scale S, 90°.

When designed with a volume ratio $V:v$ suitable for vacua too high to permit the use of rubber tubing, an oil-sealed metal union or a mercury-sealed, ground-glass joint can be used as the pivot.

Thanks are due Professor R. S. Tour for suggestions as to the graphical calibration of the scale.

Summary

The construction and calibration of a new type of vacuum gage has been described. The gage is designed for laboratory use and is simple to construct and operate. In accuracy and range it stands between the simple U-tube manometer and the McLeod gage.

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[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE JOHNS HOPKINS UNIVERSITY]

THE VAPOR-PRESSURE LOWERING OF AQUEOUS SULFURIC ACID SOLUTIONS AT 25°

BY ARTHUR GROLLMAN AND J. C. W. FRAZER

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Introduction

The object of this investigation was to determine very accurately the vapor pressures of aqueous sulfuric acid solutions in order to have means of calculating the various functions derivable from such data. Sulfuric acid entering into so many chemical reactions merits considerable attention because of the practical use to which quantitative studies of its properties and behavior may be applied. A study of the vapor pressure of its aqueous solutions is especially desirable inasmuch as the only measurements of this kind heretofore recorded deal with concentrated solutions and lack the accuracy prerequisite for a study of more dilute solutions. Moreover, such studies furnish an excellent confirmation of relationships correlating vapor-pressure measurements with those of freezing points and electromotive force as will be seen in the latter part of this paper. This substance would also serve admirably for isotenoscopic determinations of vapor pressures, being easily analyzed and serving as a rapid dehydration agent.