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LeRoy D. Weld
Coe College

TEST OF A U-TUBE CAPILLARY VISCOMETER

LEROY D. WELD

The usual form of Poiseuille's equation for the flow of a viscous liquid through a capillary tube is not difficult to deduce mathematically upon the basis of certain assumptions. These are: (1) that there is no appreciable slip at the inner surface of the capillary, that is, that at this distance from the axis the speed of flow is zero; (2) that the flow is steady, so that inertia plays no part in it; (3) that the capillary is perfectly cylindrical and perfectly straight, and (4) that there are no end effects, such as surface tension and eddies.

Under these circumstances the theoretical rate of flow, expressed as volume V per unit time t, is

$$\frac{V}{t}=\frac{\pi r^4 p}{8 l \eta}.^1 \qquad (1)$$

In this expression, r is the radius and l the length of the capillary; p is the pressure equivalent of the fall in total head from inlet to outlet of the capillary; and η is the coefficient of viscosity of the flowing liquid. It is obvious that if the formula can be relied upon, it furnishes a very convenient method of making either absolute or relative determinations of liquid viscosity. Many viscometers making use of the principle are in common use.

The actual conditions confronting the experimenter are, however, not so simple. The question of slip has been open to discussion, but the assumption above made regarding that point is generally accepted as not giving rise to appreciable inaccuracy.[2] The flow is certainly not steady in the usual form of viscosity determination, for the liquid must be both started and stopped. This might be remedied by cutting into and out of the flow at the ends of a measured interval of time without altering its velocity; a procedure which, however, presents some difficulties. If drops are formed at the outlet, the flow may vary periodically, due to slight changes in the surface tension pressure. End effects would

1 For a detailed discussion of Poiseuille's law, see G. Barr, Journ. Sci. Inst., Vol. 1, p. 81, Dec., 1923, and p. 111, Jan., 1924.

2 Whetham, Phil. Trans. R. S., A, Vol. 181, p. 559. See also *Friction*, by T. E. Stanton, Chapter I.

seem to be inevitable. And in the form of apparatus here described, the capillary, so far from being straight, is bent into a U; and is, furthermore, not known to be of strictly uniform diameter.

There is therefore some uncertainty as to whether the use of equation (1) is justifiable even for relative viscosity measurements. Before presenting the experimental evidence on this point, it is desirable to give a brief description of the apparatus (Fig. 1),

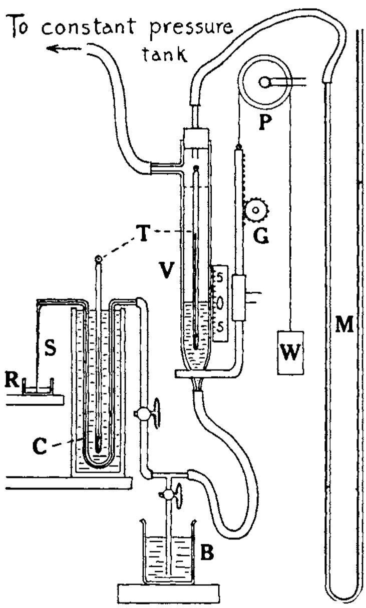

Fig. 1

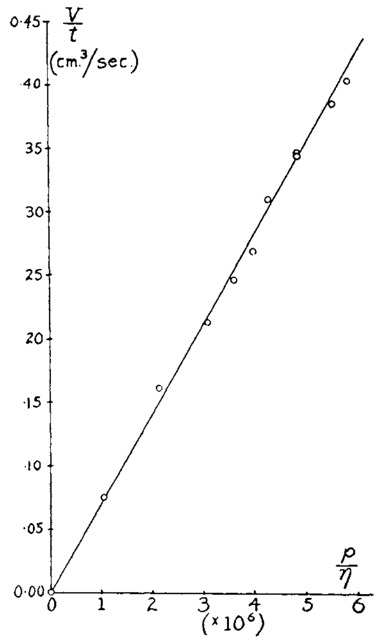

Fig. 2

which was designed for investigating the effects of various physical agencies upon the viscosity of moderately dilute solutions at ordinary temperatures.

The liquid under examination is first drawn into a cylindrical reservoir V, which may be raised or lowered at pleasure. From V it is expelled by constant air pressure through the capillary C, and thence runs down a glass stylus S into the receiver R, in which it can be weighed. The object of the stylus is to prevent the flow from breaking into drops. The liquid in V is at the same level as the outlet of the capillary; or rather, it is started as high above that level as it is to be below that level when the flow ceases. Hence, the hydrostatic pressure of the liquid itself is negligible.

A sensitive manometer M gives the air pressure, which is taken as the value of p.

Equation (1) may be written

$$\frac{V}{t} = k\,\frac{p}{\eta}, \qquad (2)$$

since the factor $\frac{\pi r^4}{8l}$ is constant. The practical question now to be settled is whether (2) is really linear with respect to the quantities $\frac{p}{\eta}$ and $\frac{V}{t}$ under the actual experimental conditions.

The experimental results are best exhibited in the form of a graph (Fig. 2), the scales of which are numbered in absolute C.G.S. units. The liquid used was pure water at different temperatures, flowing at various pressures throughout the range of the manometer. There appears to be no systematic departure from the linear relation expressed by (2). The most probable value of k, deduced by least square adjustment from the results, is 7.018×10^{-8} (in C.G.S. units), and the straight line on the graph is drawn accordingly. Whether this value actually represents the quantity $\frac{\pi r^4}{8l}$, corresponding to the capillary used, is immaterial. The instrument may in any case be used for the determination of moderate viscosities in accordance with equation (2), rewritten, for this purpose, in the form

$$\eta = k\,\frac{pt}{V}. \qquad (3)$$

Coe College,
Cedar Rapids, Iowa.