A Couette Viscosimeter

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Ogston & Stanier (1950, 1951, 1952) have referred to measurements made with a Couette viscosimeter. Since this viscosimeter can be constructed almost wholly in an ordinary laboratory workshop, and since it has proved to be convenient and accurate in use, a description of its details is given here. With some modification, the same instrument has been used for measuring streaming birefringence. The basic design is that of Lawrence, Needham & Shen (1944), the main features and dimensions being copied from their design.

* With assistance in the design and construction from J. T. Cox.

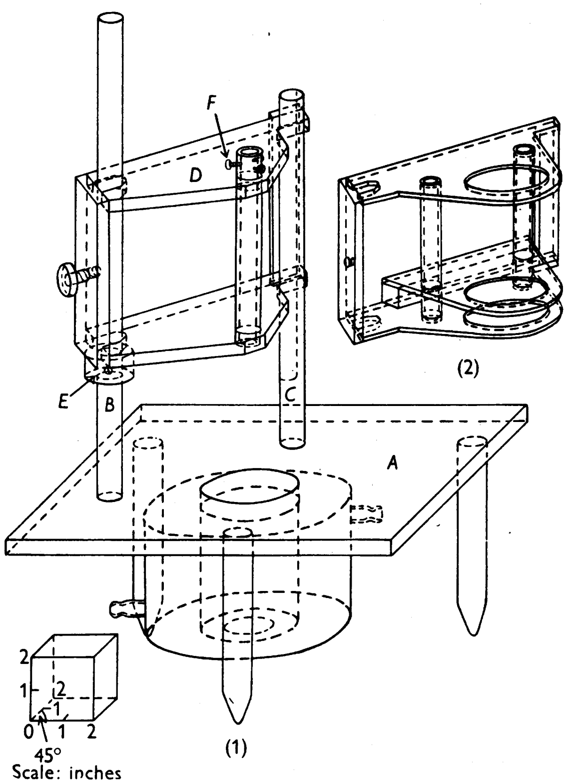

Fig. 1. Isometric (45°) sketches of (1) framework and viscosimeter head; (2) birefringence head. Certain constructional details have been omitted, including two vertical tubes on the viscosimeter head, the graduated rings on the birefringence head, and the screw feet on the framework.

Construction

Drive. A type RQ synchronous motor, 73 rev./min. (Drayton Regulator and Instrument Co. Ltd.) is coupled by a stirrup coupling to the plate of a ball-type variable gear (Variable drive Mk III Bombing trainer Mk III). The cylinder shaft of the gear carries a triple pulley, diameters 2·75, 2 and 1·25 in. This pulley drives a corresponding pulley on the viscosimeter by a loop of soft cotton string, long-spliced, and run moderately tight. Speeds of revolution of the viscosimeter pot between 0 and 150 rev./min. can thus be obtained.

Viscosimeter framework (Fig. 1 (1)). This consists of a 0·5 in. brass base-plate *A*, 12 in. square, supported on three steel legs, $\frac{7}{8}$ in. diam. and 6 in. long, two of which are fitted with screw feet for levelling. The plate carries a 0·75 in. steel rod *B*, 15 in. long, and a similar rod *C* milled flat on one side; these carry and locate the head *D*.

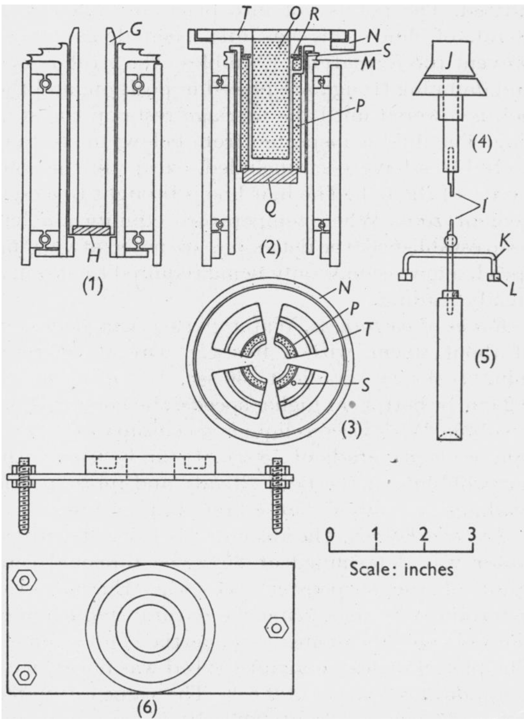

Fig. 2. (1) Section of viscosimeter bearing assembly and pot. (2) Section of birefringence bearing assembly, pot and inner cylinder, with Perspex annulus in place. (3) Plan view of (2). (4) Viscosimeter torsion head. (5) Viscosimeter bob, with damping arms and mirror. (6) Elevation and plan of viscosimeter damping trough. Transparent parts are hatched, ebonite stippled.

Below the centre of the plate is brazed a brass cylinder $2\frac{7}{8}$ in. internal diam. and 4·25 in. deep: this is open at the top and closed at the bottom, except for a central hole 1·5 in. diam. Round this cylinder is brazed a cylindrical water jacket, 6 in. diam. and 4·25 in. deep, closed except for two tubes through which to circulate water.

Bearing assembly for the rotating cylinder (Fig. 2 (1)). An outer brass cylinder $2\frac{7}{8}$ in. diam. is an easy push fit into the cylinder of the framework. Two ball-races separate this from the inner brass cylinder. This is open at both ends, of 1 in. internal diam. and 4 in. long. It carries a narrow annular flange at its lower end to support the steel viscosimeter pot *G*: its upper end carries the triple pulley mentioned above, this standing just clear of the framework base-plate.

Outer viscosimeter cylinder ('*pot*') (Fig. 2 (1) *G*). This is of stainless steel, $4\frac{5}{8}$ in. long, external diam. 1 in., internal diam. $\frac{5}{8}$ in. (1·570 cm.). It is a push fit into the bearing assembly. Difficulty was experienced in machining the bore, within the limits required (0·0005 in.), by the normal boring technique on a Smart and Brown Model '*A*' lathe, as it was found that the boring tool wandered. The pot was eventually made for us by the Pressed Steel Co., Oxford, by grinding, the inner bore being polished, uniform and coaxial within the limits stated. The open lower end is recessed to take a glass or Perspex bottom (Fig. 2 (1) *H*).

Inner viscosimeter cylinder ('*bob*') (Fig. 2 (5)). This was made on the laboratory lathe, of stainless steel, length $3\frac{1}{8}$ in., diam. 0·5 in. (1·258 cm.). Its lower end is made concave to trap an air bubble, as recommended by Lawrence *et al.* (1944) to reduce end effects: its upper end is drilled centrally $\frac{3}{32}$ in. diam., fitted with a small grub-screw, to secure the suspension. Both the steel pot and bob must be demagnetized after machining.

Viscosimeter head. (Fig. 1*D*). This was so constructed that the suspended bob could be raised and swung out of the way and could be returned to exactly its former position. The carriage consists of two parallel horizontal plates of duralumin, $\frac{3}{8}$ in. thick and 4·5 in. apart. They are fastened together by three vertical duralumin tubes, 0·75 in. external diam., 0·5 in. internal diam., cemented with Araldite (Aircraft Accessories Ltd.). A vee, with steel inserts at one corner of each plate, slides on the circular rod *B* carried by the framework, and a cross-piece carries a locking screw. The opposite side of the carriage carries a magnet on a cross-piece, which locates against the flat-sided rod, *C*, of the framework. The vertical position of the carriage is fixed by a stop-ring, *E*, which is located on the circular rod, *B*, of the framework by a set-screw.

One of the three duralumin tubes is approximately vertically over the centre of the bearing assembly, when the carriage is located on the two rods. The suspension wire for the bob runs in this tube and is secured, by a grub-screw, into the torsion head (Fig. 2 (4)). This last is located within the top of the duralumin tube by three set-screws, *F*, set at 120°, which allow the inner cylinder to be exactly centred.

Suspension of the bob (Fig. 2 (4) and (5)). Eureka wire of 40–45 s.w.g. has been found satisfactory for this purpose, showing no fatigue or hysteresis over the range of torsions used. The length of wire used is about 7·5 in. It is soldered at each end to brass rods of $\frac{3}{32}$ in. diam.; these are filed so that the wire is central with the rods (*I*). The lower rod is 2 in. long and fits 0·5 in. into the bob, being secured by a grub-screw. The upper rod, 1 in. long, is similarly secured to the torsion head (J). The lower rod has a galvanometer mirror of 1 m. radius cemented to its upper end and also carries the torsional damping device.

Torsional damping (Fig. 2 (5) and (6)). This was found greatly to increase the steadiness of the readings of deflexion. It consists of a crossbeam of aluminium wire (K), 2 in. long, cemented to the lower brass rod. The ends are bent downward 0·5 in. and each carries a cross-shaped paddle, L, of aluminium foil, 0·25 in. across and $\frac{1}{8}$ in. deep. These paddles rotate freely in an annular trough 0·5 in. broad and 0·25 in. deep, containing propylene glycol. This trough (Fig. 2 (6)) is made of Perspex and it stands on levelling screws on the framework baseplate, straddling the stroboscope. Care is required that the damping fluid does not contain dust.

Measurement of speed. At speeds less than $16\frac{2}{3}$ rev./min., revolutions are counted against a stop-watch. For higher speeds, a stroboscope disk was made by marking degrees from a circular protractor and making segments alternately black with Indian ink. A hole in the centre fits over the top of the pot. The stroboscope is observed with a neon lamp and gives speeds of $16\frac{2}{3}$, $33\frac{1}{3}$, 50, $66\frac{2}{3}$, $83\frac{1}{3}$, 100, $133\frac{1}{3}$, and 150 rev./min.

Measurement of deflexion. The galvanometer mirror is arranged to project an image of a vertical hair line on to a circular scale, at its focal distance (50 cm.). The scale is made from $\frac{1}{8} \times 1$ in. brass strip, bent into a circle of 50 cm. radius, with millimetre graph paper stuck on to it. Its useful length is 100 cm.

Control of temperature. This is effected by circulating water from a cylindrical thermostat tank. Circulation is by a Stewart Turner 120 G.P.H. centrifugal pump, which also stirs the thermostat. A Sunvic thermostat type TS 3, with a 100 W. bulb controls the temperature to better than 0·1°. The contents of the viscosimeter come to within 0·1° of the temperature of the circulating water after 15–20 min. It was, therefore, found to be unnecessary to fill the bearing space with paraffin, as Lawrence *et al.* (1944) recommend.

Adjustment and use

Levelling. It is important that the axis of rotation should be vertical. This is best achieved by levelling the pot directly, by means of a sensitive clinometer, placed on top of the pot. The framework is levelled, by means of its levelling screws, until the clinometer shows a constant reading when the pot is rotated through 360°.

Centring. It is estimated that the bob can be centred to within 0·1 mm. by eye alone, and no variations ascribable to imperfect centring have been observed. The pot is filled with water (10 ml.) and the bob is lowered until its lower end is about 1·5 cm. above the bottom of the pot; the water level is then about 1 cm. above the top of the bob. The stop ring (Fig. 1 E) is locked in position. The position of the bob is observed from below, by means of a mirror, and the set-screws (Fig. 1 F) are adjusted until the bob is central in the pot.

Assembly for use. The thermostat circulation is started. The pot is put into place and filled with 10 ml. of fluid: this has first been de-gassed to prevent the formation of bubbles. The stroboscope and damping trough are placed in position, and the bob is lowered until the carriage rests on the stop ring. The fluid is inspected from below, to see that no bubbles have been included, except in the concavity of the bob. The hair line is brought to a convenient zero. When temperature equilibrium has been established, the deflexions are noted at varying speed, a few seconds only being required to obtain a steady reading.

Range of usefulness. Water gives a scale deflexion of about 10 cm. with a 40 s.w.g. wire at 100 rev./min. (velocity gradient 50 sec.$^{-1}$), accurate to 0·2 cm. or better; at higher speeds, the bob develops a wobble. With viscous liquids speeds up to 150 rev./min. (velocity gradient 75 sec.$^{-1}$) can be used without wobbling of the bob. Steady and reproducible readings are obtained at 0·3 rev./min. or less.

Test of accuracy. The absolute viscosity of distilled water was determined at 25°. The torsional constant of the suspension (44 s.w.g. Eureka) was determined by measuring the natural frequency of the bob and its moment of inertia (14·3 g. cm.^{2}). The plot of deflexion against speed was linear, with a standard deviation of 0·6 %. The value estimated for η (25°) was $0{\cdot}90 \pm 0{\cdot}006 \times 10^{-2}$ poise, agreeing with the value $0{\cdot}8941 \times 10^{-2}$ (Landolt-Börnstein, 1927) within the standard deviation of the estimate.

Streaming birefringence

For measurement of streaming birefringence the apparatus was modified in the following ways.

Bearing assembly (Fig. 2 (2) and (3)). A separate assembly is used, with narrow ball races: inner diam. $1\frac{1}{2}$ in., outer diam. $2\frac{7}{8}$ in. The single driving pulley (M) has diam. $1\frac{7}{8}$ in. The outer housing carries an annular flange (N), to support the inner cylinder (O), and is cut away for the driving string to the pulley.

Outer cylinder ('*pot*') (Fig. 2 (2) and (3) P). This is of brass outside, and ebonite inside to reduce reflexions of light: length $2\frac{5}{8}$ in., external diam. 1·5 in., internal diam. 0·9055 in. (2·30 cm.). Its bottom is recessed to take a glass plate (Q) and its top to take a Perspex annulus (R). A flange supports it in the bearing assembly, and this flange is drilled (S) for filling.

Inner cylinder (Fig. 2 (2) *O* and (3)). This is of ebonite, length 2·5 in., diam. 0·7874 in. (2·00 cm.), secured to the centre of a brass disk (*T*), 0·3 in. thick, diam. 3·25 in., which rests on the flange of the bearing assembly. This disk is partly cut away, to allow viewing of the liquid. Disk and cylinder were machined together, so as to ensure their being concentric and coaxial.

Head (Fig. 1 (2)). This is similar to the viscosimeter head, but consists of three horizontal plates. The lower two are fitted with rotating rings, engraved in degrees, to hold cross-wires, polarizer or quarter-wave plate.

Optical parts. A Pointolite lamp, with a 25 cm. lens, is used to project a vertical parallel beam through a hole in the bench below the apparatus. This beam is made vertical by marking a point on the ceiling vertically above the centre of the pot by plumb-line, and adjusting until the circle of light, projected through the pot, is centred on this point. The polarizer, a 5 cm. Nicol prism, is secured below the bench. The analyser (a similar prism) is placed on the middle deck of the head. For measuring angle of isocline, cross-wires, made of thin Nylon thread, are placed on the lowest deck: for measurement of birefringence, a $\frac{1}{4}$-wave plate is placed on the lowest deck. A field lens, on the top deck, allows the whole annulus of liquid to be viewed at one time. The glass plate (*Q*) and the annulus (*R*) must be free from birefringence. The hole in the annulus is just large enough to allow it to rotate freely round the inner cylinder. It was found that the annulus can be made from Perspex, 1–2 mm. thick, by cutting very lightly with a fretsaw and finishing with sandpaper.

Filling. The pot is set up in the bearing assembly: the Perspex annulus is placed in position: the inner cylinder is inserted through the annulus. The space between pot and inner cylinder is then filled through the filling hole *S* (Fig. 2 (2)) until the liquid surface reaches and wets the under side of the annulus; by filling slowly, formation of bubbles can be avoided.

Range. Velocity gradients up to 100 sec.$^{-1}$ are attainable with the present apparatus. There is no reason why higher speeds should not be used.

SUMMARY

1. A Couette viscosimeter is described, which can be made in a laboratory workshop.

2. The accuracy of measurement is 1–2 %. The range of velocity gradient is 0–75 sec.$^{-1}$.

3. Modification for measuring streaming birefringence is described.

Mr J. T. Cox was responsible for details of design and construction. We are most grateful to Dr H. G. Kuhn, of the Clarendon Laboratory, for the loan of optical parts. This work was supported by a Research grant from the Medical Research Council.

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Studies Involving Enzymic Phosphorylation

2. CHANGES IN THE HEXOKINASE ACTIVITY OF THE SMALL INTESTINE OF RATS CAUSED BY FEEDING DIFFERENT DIETS

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Although there is no universal agreement regarding the biochemical mechanisms of intestinal absorption, many workers at the present time accept the theory of Verzár & McDougall (1936), whereby the absorption of carbohydrate and fats takes place through the formation of phosphorylated intermediates. In a recent study, Lawrie & Yudkin (1949) determined the alkaline phosphatase activities of small intestine from rats fed diets containing different amounts of carbohydrate, fat and protein; they found that phosphatase activity was significantly higher in animals fed a high-protein or high-fat diet than in those fed a high-carbohydrate (balanced or fat-free) diet. This result would not have been expected on the basis of the theory that glucose and certain other monosaccharides pass from the lumen into the mucosal cells by enzymic phosphorylation, and from the cells to the tissue