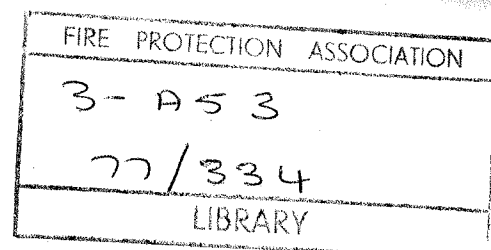




Fire Research Note No 1059



THE FIRE RESEARCH STATION FOAM VISCOMETER -
ITS CONSTRUCTION AND USE

by

J G Corrie

April 1977

FIRE RESEARCH STATION

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SUMMARY

Instructions for the construction of a standard foam viscometer, for measuring the shear stress of fire-fighting foam are provided. The important points in the design are described. Standard procedures for its calibration and use are recommended.

Note Fire Research Note No 1055 describes the studies leading to the design and use of this instrument.

KEY WORDS - FOAM, VISCOMETER, SHEAR STRESS

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Building Research Establishment

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INTRODUCTION

In a previous note⁽¹⁾ studies are described which identify the significant dimensions and operational procedures for the measurement of the shear stress of fire-fighting foam, using a torsional vane viscometer. This note provides constructional details of a suitable viscometer. It describes the important points of the design, and standard procedures for its calibration and use.

The studies referred to showed that the shear stress determined by an instrument of this kind is not a fundamental property of the foam, but depends upon the instrument dimensions, and the method of operation, as well as upon the characteristics of the foam. Therefore to ensure uniformity between laboratories it is necessary that the significant dimensions of the instrument are standardized, and also its method of use. Viscometers designed to this standard can be described as 'Fire Research Station Foam Viscometers', to distinguish them from other instruments.

CONSTRUCTION OF THE VISCOMETER

General points

Figs 1-6 illustrate details of one version of a suitable instrument. Some constructional details may be varied, as for instance the details of the stand and motor cover, but others must not be changed and these are indicated below.

The principle of rotating the sample on a turn-table must be adhered to, and the alternative design of rotating the top of the wire, should not be adopted. The turn table arrangement has the advantages of reading a stationary pointer against a stationary scale at the front of the instrument and simplifies construction of the wire assembly.

Materials of construction

Foam solutions may be slightly acid or slightly alkaline, and may contain salts such as sodium chloride and ferrous sulphate. Sometimes foam solutions have to be prepared using sea water. When working with foam it is inevitable that the apparatus is splashed with foam and materials with a suitable corrosion resistance must be chosen. In the instrument constructed, brass was used and this has proved satisfactory. It does get stained however and a stove enamel or similar finish could be considered for the base plate and motor cover. Mild steel, aluminium, or hard wood, would not be suitable.

The sample pot and the vane must be made of brass. The scale must be made of brass or a material which will not substantially change its moment of inertia.

Electrical Safety

Foam will be splashed upon, and cling to, the instrument, and it will regularly be operated with wet hands. The motor and gears must be raised slightly off the base plate and be effectively covered with a protective guard. The vertical shaft driving the turn-table must have a collar to deflect drainings coming from the turn-table, away from the shaft, and onto the motor guard from which they can drain to the base plate.

The switch should be positioned away from the turn-table and must be of water-proof construction. The electrical supply should preferably be via an earth leakage circuit breaker and the lead be of robust water-proof quality.

The motor

Constant speed of operation is essential, and the speed must not vary with the load, which changes with the stiffness of the foam. The desired speed is 8.75 RPM. Variations of ± 0.25 RPM are unlikely to make a difference in the reading exceeding 1 per cent and would therefore be permissible. In the instrument constructed the motor used was a synchronous type, 0.2 amps/240 volts, 13 kgcm (15 lb in) output torque. One source of a suitable motor is given in the Appendix.

The turntable

The turntable must be carefully aligned with the driving shaft and there should be minimum play in the coupling. The sample pot will frequently be wet on the base and side, and liquid will drain onto the turntable. Drainage channels and drainage holes must be provided in the turntable to allow any liquid to escape - otherwise the pot can float on a layer of liquid and not turn with the table. The pot should fit neatly into the rim of the table so that it is always centred - but the clearance should not be so small as to make positioning of the pot difficult.

The support stand

The stand and guide rod must be vertical and of robust construction so that the wire and vane assembly is positioned accurately in the centre of the sample pot. It has not been found necessary to arrange for the vane assembly to swing away from over the turntable, nor to hold it in the raised position. The vane assembly is only raised while the sample is placed on the turntable and then is immediately lowered. The stop on the vane assembly slide rod should be readily adjustable by a large thumb-screw so that the depth to which the vane descends into the pot can be adjusted to ensure that the vane is at the midpoint of the sample.

A plumb-bob must be provided on the stand, and adjustable feet on the base plate, so that the instrument can be levelled.

The vane

The vane must be made of brass to the dimensions shown - ie 30 mm x 30 mm x 2 mm, with a 3.2 mm diam stem.

The spindle and wire clamp

Details of the bearing assembly at the lower end of the wire support are important. A bearing is necessary to give stability to the wire assembly. Two bearing points 30 mm apart and 4.25 mm diam., with a 3.2 mm spindle are required. When the vane is lowered into the foam sample slight lateral displacement of the vane occurs. If the clearances on the bearings are too small the spindle will 'hang diagonally' across the bearing points and cause erratic operation. The weight of the vane and the connecting block between vane and spindle assists the wire to hang vertically and minimize this problem. Therefore the weight of the vane and the connecting block should not be reduced. If the instrument is not levelled this problem will arise also. Note that the thumb screw holding the vane must have a matching screw to maintain the balance.

The clamp for anchoring the vane when the instrument is being transported or moved about the laboratory is used regularly. Ensure that when in the free position the clamping disc can be screwed-up tightly against the lower wire chuck to avoid riding down while the instrument is being used. The spindle must be screwed into the lower wire chuck very firmly to ensure it does not unscrew while the instrument is being used.

The scale and pointer

The scale should be engraved. The 360° is divided into 100 divisions, with the 10's numbered and the 5's clearly recognisable by larger division marks. The pointer is attached to the lower support by a spring band so that the pointer can be adjusted to zero reading or in height. The pointer must therefore be of robust construction so that it does not bend when being pushed against the resistance of the spring band, but its tip must be a fine point which permits reading its position to $\pm \frac{1}{2}$ scale division.

The upper wire support

The grub screws which hold the wire in the holding rod must not be proud so as not to hinder the vertical adjustment of the rod. The holding rod should be easily fixed in any position by a liberally sized thumb-screw. When the vane is hanging free the holding rod at the top of the wire must be adjustable so that the scale hangs just clear of the pointer and does not foul the lower support.

The wires

A selection of torsion wires should be supplied. 26, 28 and 32 SWG wires will accommodate most fire-fighting foams. The wires are to be provided with end mountings which can be secured in the top and bottom holders with grub screws. The wire should be soldered in its end mountings, taking care not to destroy the wire tempering by overheating. Supports to house the 2 wires not in use should be provided inside the main support tube.

Wires 36.5 cm long can be purchased from laboratory suppliers already fitted with end mountings, or piano wire may be used. (See Appendix for suppliers)

36.5 cm length of wire is suitable but this could be varied considerably without affecting the results obtained.

The sample pot

The sample pot must be made of brass and fit neatly into the recessed turntable. Its base should be stippled and its weight be not less than 0.3 kg to ensure that it grips the turntable and does not slip. Its internal dimensions must be close to those recommended ie 75 mm dia x 75 mm high. An increase in diameter of 10 mm will increase the reading obtained by $2\frac{1}{2}$ per cent with some foams, and reducing the diameter will have a larger effect. Limits of ± 3 mm on the pot dimensions are appropriate.

The calibration cylinder

Provide a solid brass, or stainless steel, cylinder, 70 mm dia x 20 mm high, with a 3.2 mm dia stem, 85 mm long. Provide a socket on the instrument base plate to hold the calibration cylinder.

Provide a holder on the motor cover to take a card on which the wire constants can be noted. Site the holder away from the turntable and arrange for the card to slide in sideways and to be protected from drips.

Calibrating the viscometer

Remove the wire from the instrument, attach the calibration cylinder, using adhesive tape, and suspend from a suitable stand. Twist the cylinder to oscillate approximately 180° , with a minimum of lateral movement. Using a stop watch determine the period for one complete oscillation by noting the time for 10 oscillations. Proceed according to the following example.

Dimensions of calibration cylinder

$$\text{Radius} = 0.035 \text{ m.}$$

$$\text{Mass} = 0.658 \text{ kg.}$$

$$\text{Moment of inertia} = I = \frac{\text{mass} \times \text{radius}^2}{2}$$

$$= \frac{0.658 \times .035^2}{2}$$

$$= 0.000403 \text{ kg m}^2$$

$$\text{Period of oscillation} = 5.19 \text{ s} = t$$

$$\text{Torsional constant for wire} = \frac{4\pi^2 I}{t^2 \times 57.3}$$

$$= \frac{4\pi^2 \times 0.000403}{5.19^2 \times 57.3}$$

$$= 0.0000103 \text{ Nm /degree}$$

Area of vertical cylinder sheared by the vane

$$\begin{aligned} &= \pi d h \\ &= \pi \times 0.03 \times 0.03 = 0.00283 \text{ m}^2 \end{aligned}$$

Instrument constant

$$\begin{aligned} &= \frac{\text{torsional constant for wire}}{\text{sheared area} \times \text{radius}} \times \frac{360}{100} \text{ N/m}^2 \text{ per division.} \\ &= \frac{0.0000103 \times 360}{0.00283 \times 0.015 \times 100} \\ &= 0.87 \text{ N/m}^2 \text{ per division} \end{aligned}$$

Typical instrument constants are

24	SWG wire	=	1.5	N/m ²	per division
26	" "	=	0.7	" "	"
28	" "	=	0.3	" "	"
32	" "	=	0.1	" "	"
34	" "	=	0.05	" "	"

Calibrating the wire in-situ

By using a calibrated wire and determining the period of oscillation of the assembled instrument with the calibration weight in place of the vane, a constant for the weight + scale assembly can be obtained. Wire constants can then rapidly be checked without removing the wire, just replacing the vane by the calibration weight. When using this method the number of oscillations which are timed may be reduced to 5 or 3, with the thinner wires, because of the deceleration effect of the bearing, which does not however affect the resulting value for the constant. Special care is necessary to ensure that the instrument is level and the weight hangs free in the bearings.

It is convenient to engrave the calibration weight with the constant for use in this way eg

$$C = \frac{29.5}{t^2} \text{ N/m}^2 \text{ per division}$$

USING THE VISCOMETER

Preparing the instrument

1. Select a wire which gives a reading of not less than 25 and not more than 100 divisions with the foam sample to be tested. Fit the wire in the instrument and place a card showing its calibration constant in the holder on the motor cover.
2. Adjust the feet on the base plate so that the viscometer is level, by observing the plumb bob, and ensure that all four feet sit on the bench.
3. Release the vane locking nut and screw it up firmly against the lower wire connector.
4. Using the top wire support adjust the height of the wire so that the scale zeros against the pointer at the front of the instrument. Lock the wire in position with the thumb screw on the top wire support. Any small final adjustment of the zero reading can be made by moving the pointer.
5. Adjust the height of the vane assembly by releasing the stop clamp on the main support rod, so that the vane is close to the centre of the sample pot and then secure the clamp.
6. Connect the electrical supply lead to a plug via an earth leakage circuit breaker.

Making a measurement

1. Wet the vane and sample pot using a sample of the foam to be tested.
2. Fill the sample pot with foam, scrape the surface level. Start a stop-watch the moment the foam is produced:- eg when commencing to fill the pot from a continuous generator, or when commencing to fill a collecting bin from which the pot is to be filled.
3. Raise the wire assembly and place the pot on the turntable, making sure it seats properly, and lower the vane into the foam. If necessary rotate the pot slightly by hand so that the pointer reads zero.

4. When the foam is 30 seconds of age, start the motor and observe the scale and pointer. Note the deflection after the motor has run for 30 seconds and the foam is 1 minute of age.

In field tests where samples have to be carried some distance it may not be possible to position the sample in the 30 seconds allowed and a longer period may be required - say 45 or 60 seconds; but the reading should still be made 30 seconds after starting the motor. Significant errors are unlikely to result from reasonable extensions with normal fire-fighting foams.

5. Stop the motor and measure the temperature of the foam by stirring with a thermometer until a constant reading is obtained. Record the temperature with the shear stress reading.

Reproducibility of results, and wire life

Unless subject to accidental maltreatment, torsion wires retain their characteristics for a number of years.

It is not feasible to determine the variability of the instrument alone, because consecutive tests must also be influenced by true variations between consecutive foam samples. Using the best laboratory technique for producing foam of constant quality the following measures of variability were obtained. Operator A controlled the foam generator, while operator B collected the foam sample and made the shear stress measurement. Between 10 & 20 tests were made with each foam.

Foam	Torsional constant for wire N/m^2 per division	Shear stress	95% Confidence limits of mean of duplicate determinations	
			N/m^2	%
Fluorochemical	0.11	6.2	± 0.13	± 2.1
Synthetic	0.46	14.0	± 0.4	± 2.9
Protein	0.88	51.0	± 1.4	± 2.7

REFERENCES

1. CORRIE J G. Measuring the shear stress of fire fighting foam.
Fire Research Note 1055. (1976).

APPENDIX

Suppliers of suitable components

Motor: Fractional Horse Power Motors Ltd., Hastings, England.
FRACMO Synchronous type 230/250 volts, 50 Hz, single
phase, 0.2 amps, 8.75 RPM, 15 lb - in torque.

Made-up
Torsion wires: A. Gallenkamp & Co. Ltd., PO Box 290,
Technico House, Christopher Street, London,
EC2P 2ER. - Catalogue 18th edition
Item VS.020.

Piano wire: Fletcher, Coppock & Newman. 39-41 Shelton Street,
London, WC2.

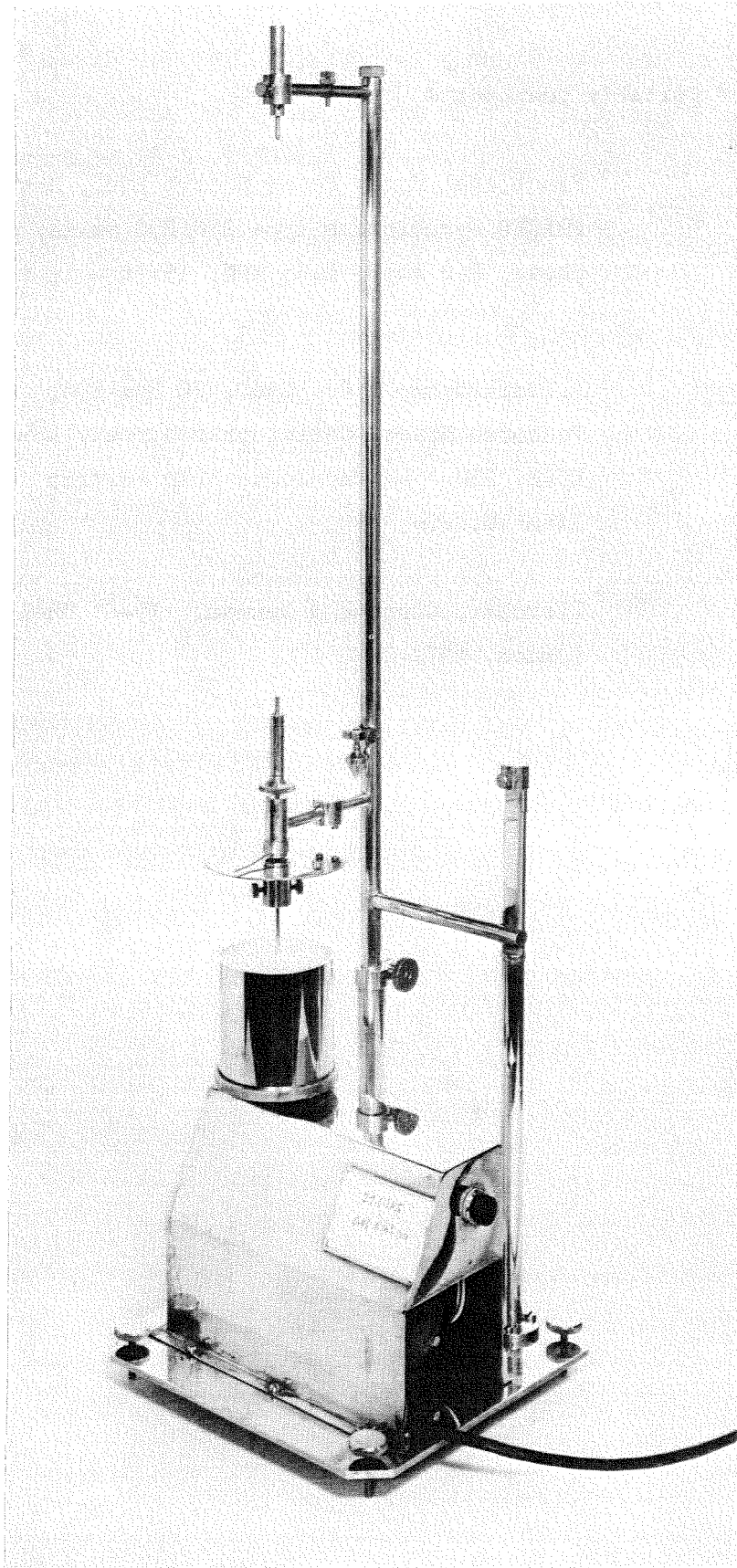


FIG 1 FRONT VIEW OF VISCOMETER WITH VANE IMMERSSED IN FOAM SAMPLE
READY TO MAKE A MEASUREMENT

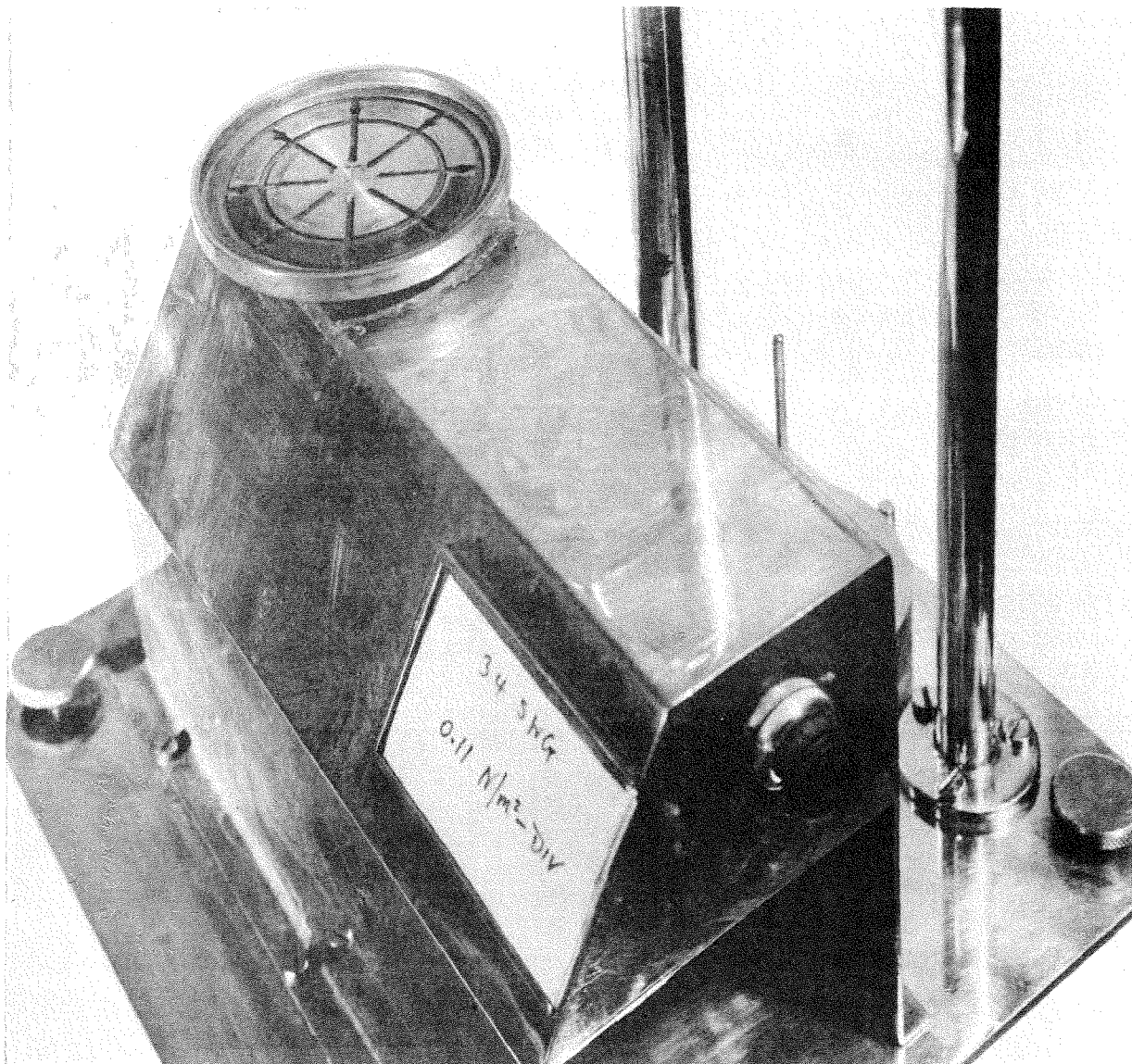


FIG 2 FRONT VIEW OF BASE OF INSTRUMENT, SHOWING GROOVES AND HOLES IN
TURN TABLE, LEVELLING SCREWS, MOTOR COVER WITH CALIBRATION CARD
AND STOP/START SWITCH ON COVER END

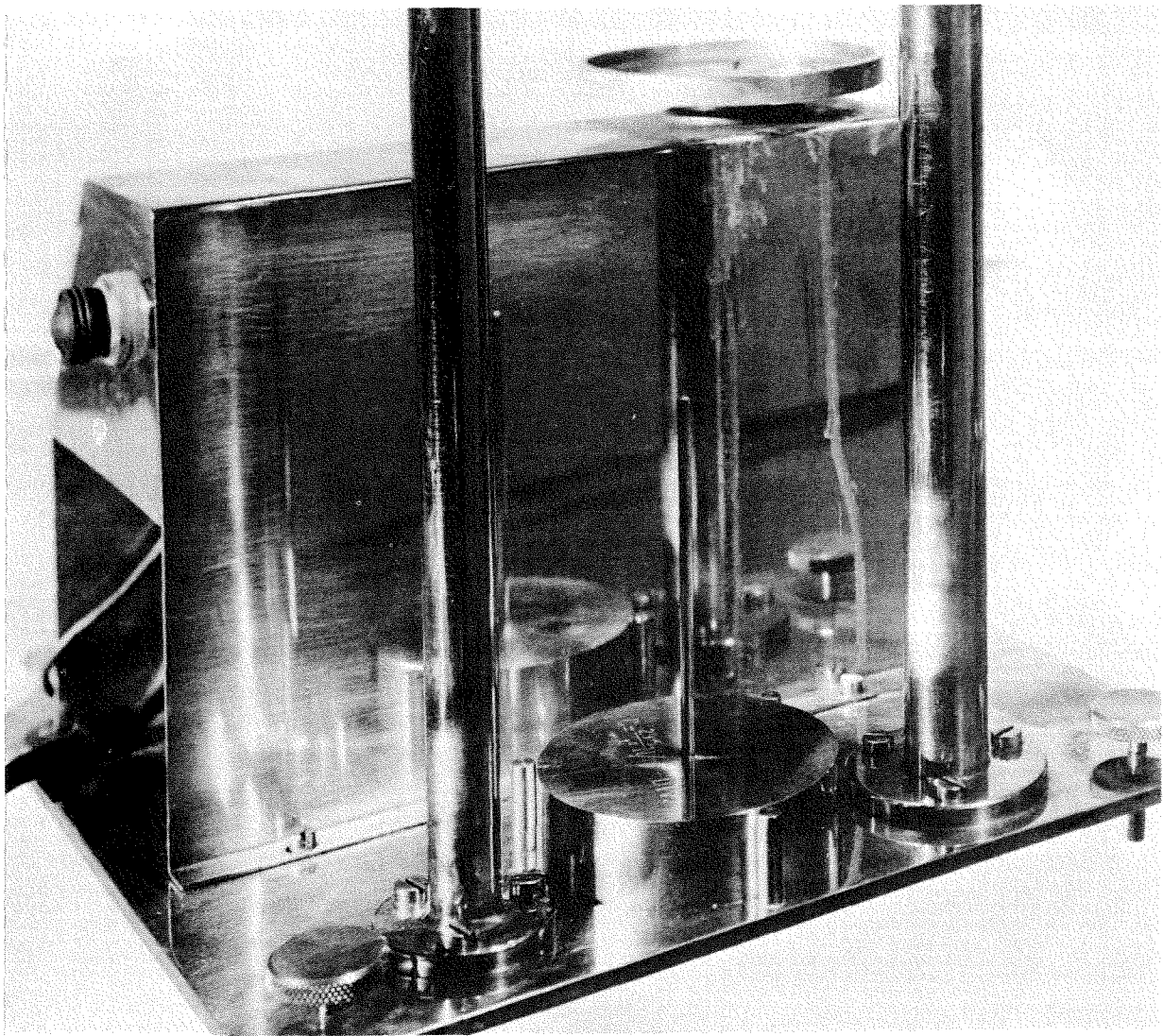


FIG 3 REAR VIEW OF BASE OF INSTRUMENT SHOWING FIXING OF WIRE ASSEMBLY
SUPPORT AND GUIDE ROD, CALIBRATION WEIGHT HOUSED ON BASE PLATE,
AND REAR LEVELLING SCREWS

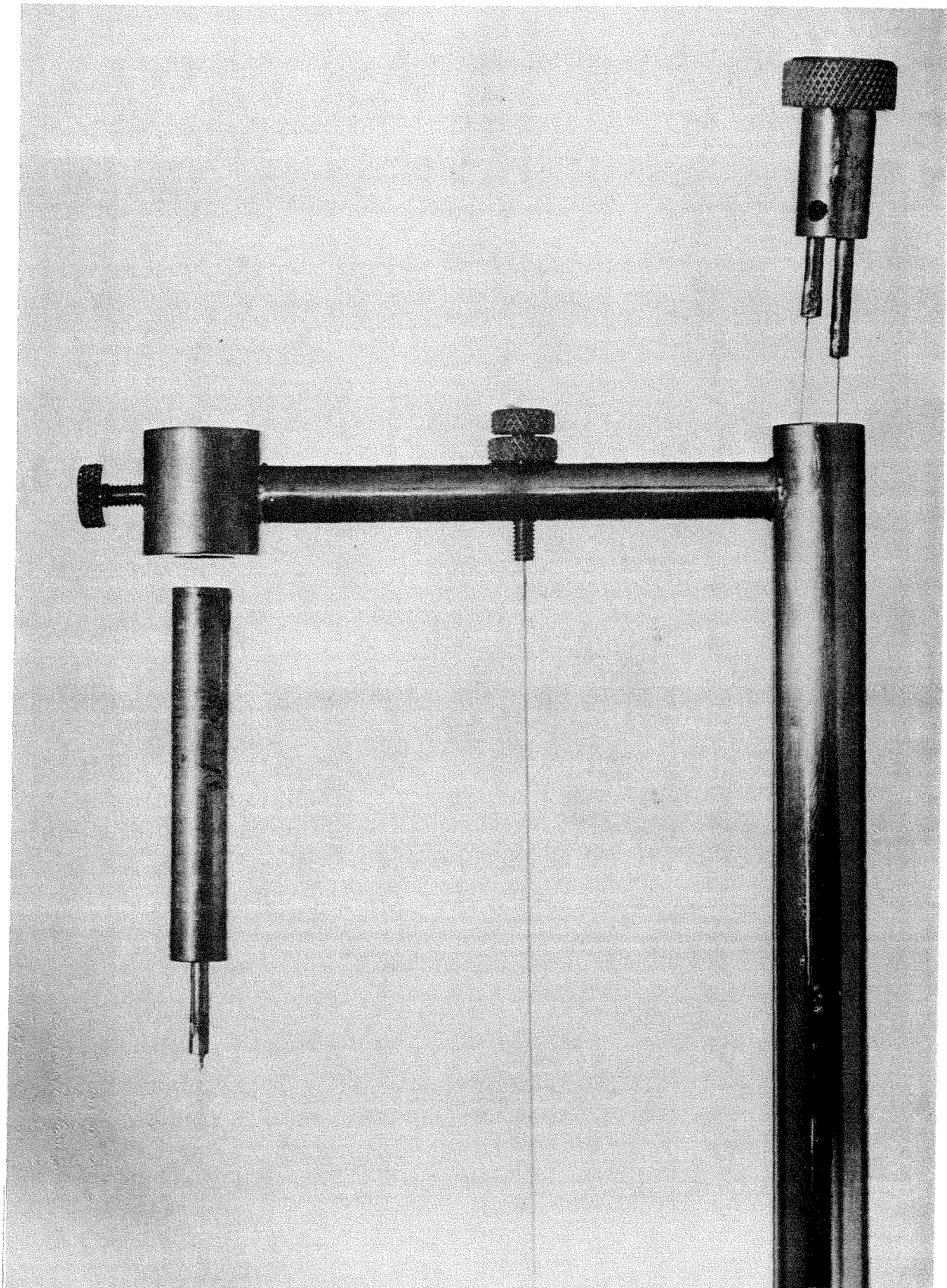


FIG 4 UPPER WIRE SUPPORT WITH WIRE CHUCK WITHDRAWN - SHOWING FIXING SCREW FOR TOP WIRE CHUCK, AMPLE LENGTH OF WIRE CHUCK FOR ADJUSTMENT OF VANE HEIGHT, PLUMB LINE, AND SPARE WIRES LIFTED FROM STOWAGE PLACE IN GUIDE ROD

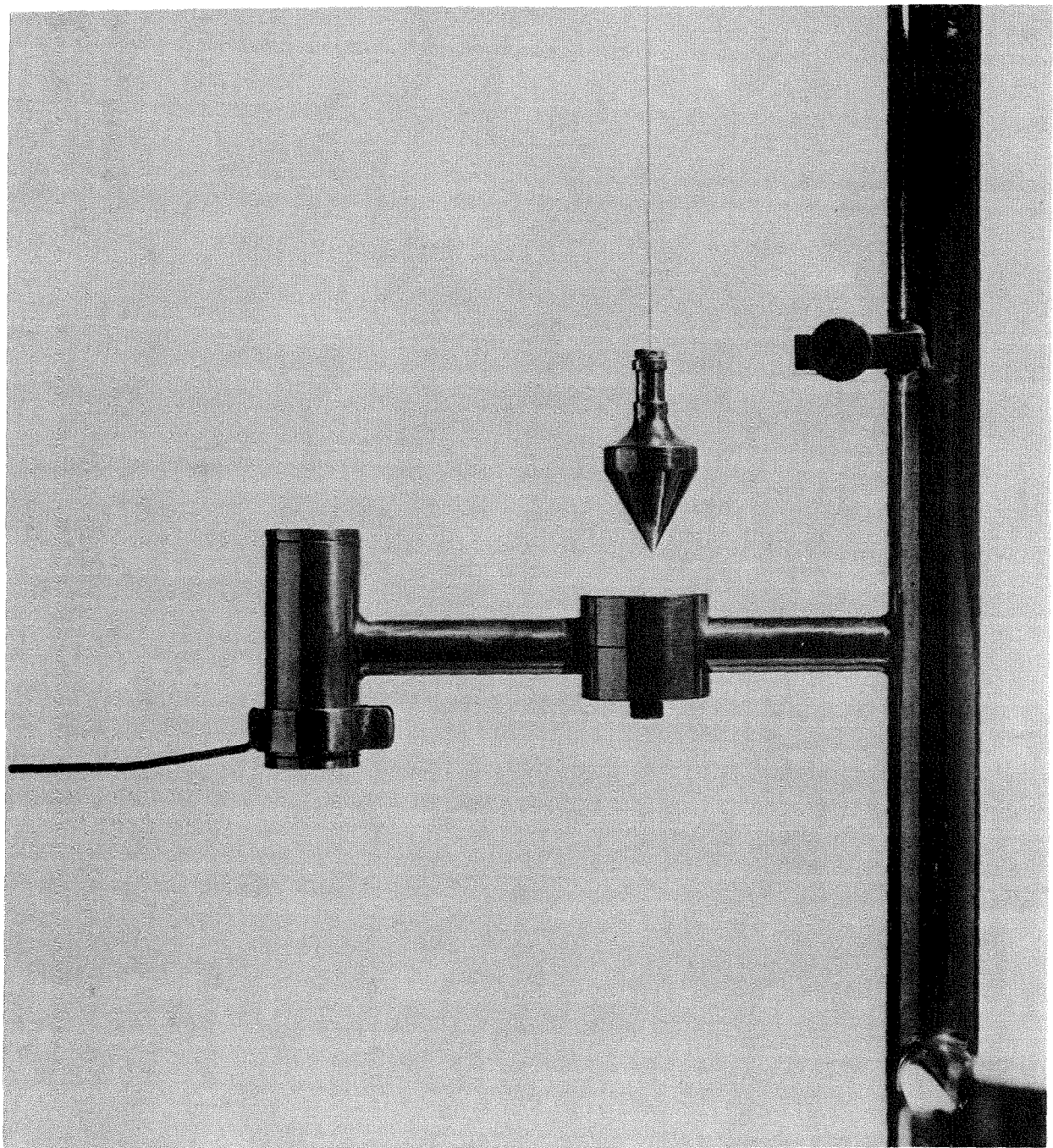


FIG 5 LOWER WIRE SUPPORT SHOWING POINTER ATTACHED WITH SPRING CLIP, DISKS WITH BEARING HOLES AT TOP AND BOTTOM OF SUPPORT, PLUMB BOB AND SCREW ON THE CLAMP TO FIX HEIGHT TO WHICH WIRE ASSEMBLY DESCENDS

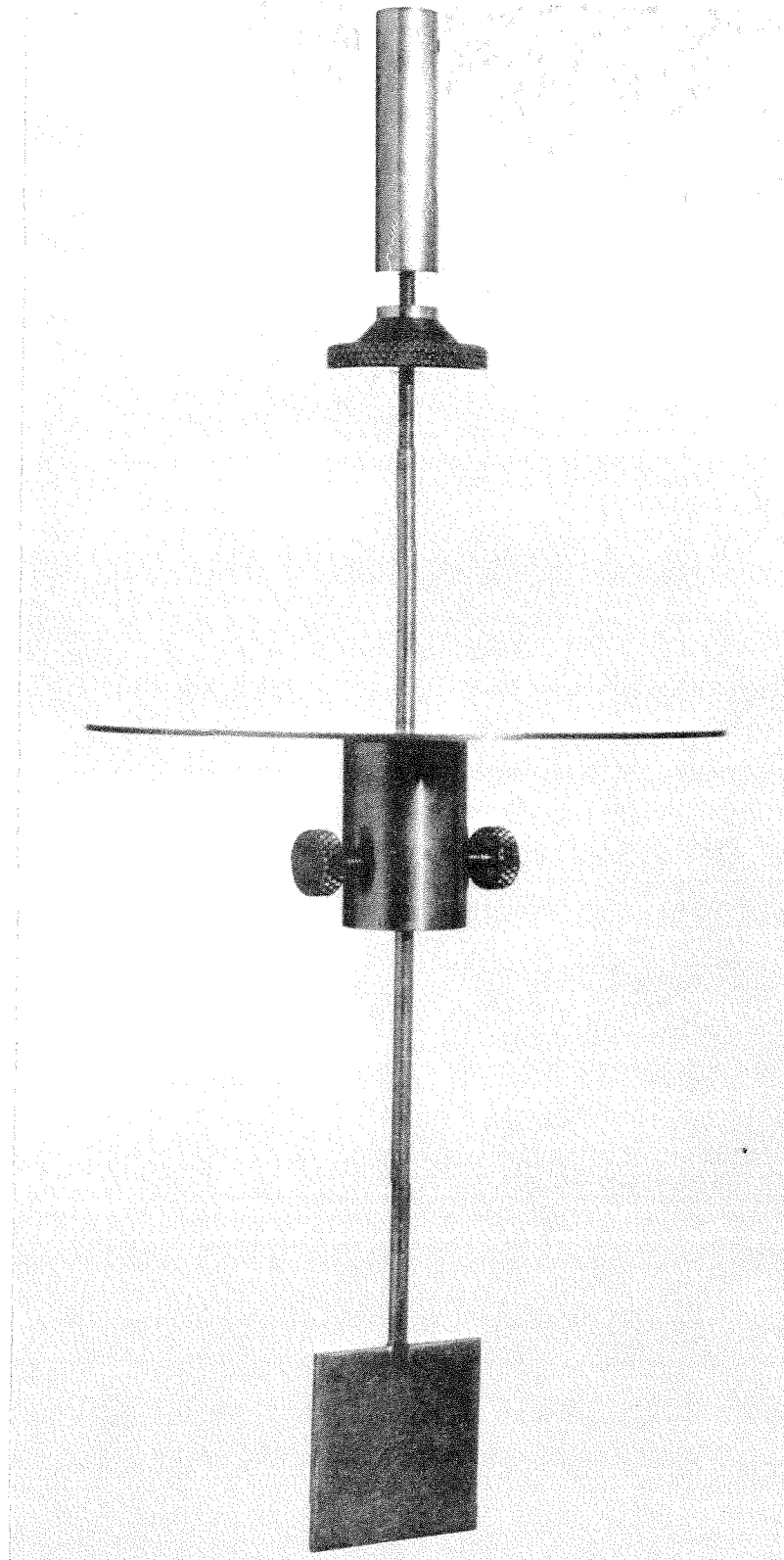


FIG 6 VANE ASSEMBLY SHOWING TWO BALANCING SCREWS SECURING VANE, THE SCALE
FIXED TO THE VANE CHUCK, THE GUIDE ROD WHICH IS PASSED THROUGH THE BEARINGS,
THE CLAMPING SCREW WHICH SEATS TO THE LOWER BEARING SUPPORT, AND THE
LOWER CHUCK BY WHICH THE VANE ASSEMBLY IS HUNG ON THE WIRE