A CAPACITANCE-OPERATED NULL DETECTOR FOR SURFACE BALANCES*

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The Wilhelmy plate technique has been used frequently in work on monomolecular films either in conjunction with an electromagnetic detecting system (cf. Padday 1957) or, more usually, with a torsion balance. In the latter case the movement of the plate is generally followed optically by means of a small mirror on the balance beam. Another possibility is to utilize the change in capacitance of a small variable condenser having its moving plate attached to the beam (Stewart 1960). The present work describes a simple detector unit based on this principle, which can be used conveniently with a normal laboratory surface trough for routine measurements on monolayers.

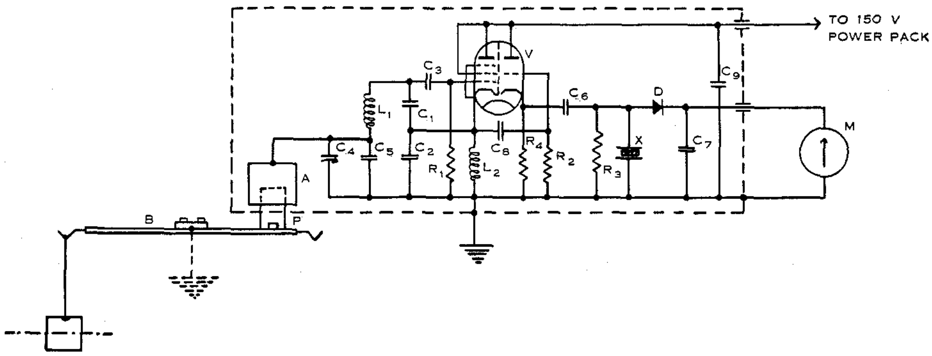

Fig. 1.—A diagrammatic sketch of the capacitance-operated null detector showing the approximate relative positions of the screened unit and the balance beam. Note that the aluminium plate P is earthed by way of the torsion wire and the frame of the balance. The various component values are : C_1, C_2, $0 \cdot 001$ μμF mica ; C_3, C_8, 100 μμF mica ; C_4, 3–30 μμF trimmer ; C_5, 47 μμF mica ; C_6, 22 μμF mica ; C_7, C_9, $0 \cdot 1$ μF paper ; R_1, 100 KΩ ; R_2, $1 \cdot 5$ MΩ ; R_3, 33 KΩ ; R_4, 10 KΩ ; L_1, 330 μH ; L_2, R.F. choke ; D, OA81 ; V, 6BL8 ; X, 1000 Kc/s crystal ; M, voltmeter.

There are numerous methods, of varying complexity and sensitivity, for the measurement and detection of small capacitance changes (Smith 1955). For the present purpose a quartz resonance method was selected, and a diagram of the final single-valve detector unit is shown in Figure 1, which also indicates the relationship of the detector to the torsion balance and Wilhelmy plate. The detector circuit is based on the four-valve dielectric constant apparatus of Buckingham, Harris, and Le Fèvre (1953).

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The transducer condenser consists of a piece of aluminium foil P (2 by 1·2 cm), attached to one end of the beam, and free to move vertically within a thin copper box A (2·5 by 3 by 0·3 cm). This system forms part of the tank capacitance of a Clapp oscillator built around the pentode section of the triode–pentode V. The Clapp circuit was chosen because of its good frequency stability with respect to variations in the internal valve impedances. The triode section of the valve is a cathode follower, which does not load the oscillator appreciably while providing a low impedance output to the germanium diode rectifier D and the D.C. voltmeter.

The operation and adjustment of the detector is straightforward. With the Wilhelmy plate in position in the surface the trimmer C_4 is adjusted until the oscillator frequency approaches the natural resonant frequency of the quartz crystal X. At resonance the latter acts as a very small shunt resistance so that the voltmeter registers a sudden dip in the rectified output voltage over a narrow range of capacitance. At all other frequencies the crystal constitutes a very high impedance. Some convenient reading on one side of this voltage crevice is selected as the zero reference point to which the meter is adjusted during a measurement by means of the torsion head. After the initial adjustment it is generally not necessary to alter the setting of the trimmer C_4 again.

The circuit is assembled in a small metal chassis (represented by the dashed line in Fig. 1), with the copper box A mounted on a Perspex block at one end. The unit is attached to the frame of the surface balance by brackets. It does not interfere with the normal manipulations of the balance, such as the hanging of weights on the beam for calibration, or the removal of equipment for cleaning.

References

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