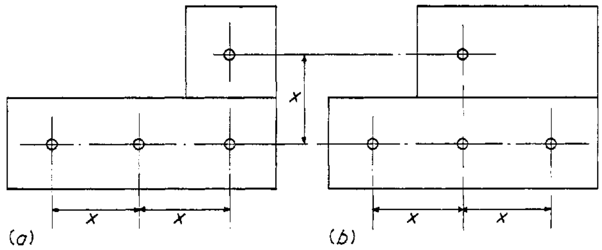

Figure 4 Exit beam arrangements for three-dimensional studies; both systems may be focused using a single lens. (*a*) Unsymmetrical beams; (*b*) symmetrical beams

studies. In this case the beam splitter could be as shown in figure 4: (*a*) shows an unsymmetrical system whilst (*b*) shows a symmetrical system. Both of these systems may be focused using a single lens; the need to polarize the beams would depend upon the flow under study and if interference was a problem it would be possible to polarize only the two outer beams of the in-plane two-dimensional system, leaving the beam for the third dimension unaltered. A two-colour system would enable any interference in the third dimension to be eliminated and here again the same beam splitter could be employed. In both cases difficulty would again be experienced where curved boundaries are encountered. All the beam splitters discussed require accurate manufacturing but are otherwise simple, cheap and robust. A three-dimensional laser Doppler system is at present under development and an unsymmetrical beam splitter, type (*a*), has been manufactured using much wider beam spacings to improve optical resolution.

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A sensitive oil manometer

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Abstract A simple, sensitive and accurate oil manometer for measuring pressures in the range 10–10^{-2} Torr is described. The principle of deaeration of oil in vacuum is used for removing soluble vapour and gases from the oil. The readings on the manometer are compared with those of a McLeod gauge.

The normal range of the simple U-tube mercury manometer is 760–1 Torr with an accuracy of $\pm 0{\cdot}5$ Torr. From time to time, attempts have been made to increase the sensitivity of the mercury manometer, for example by using micrometer screwheads (Carr 1964, Gerard 1966), an interferometric method (Terrien 1959) or a capacitance method (Stimson 1955). The simplest way of increasing the sensitivity of the manometer is to replace mercury by low vapour pressure and low density oils such as butyl phthalate or apiezon (A and B) oils. This allows pressure differences of the order of 10^{-2} Torr to be measured by the oil manometer without the use of cumbersome procedures. The main difficulty with these oils is that they absorb air and other gases. As the solubility of air in oil is directly proportional to the absolute pressure, at lower pressures the imbalance caused by the difference in the densities of the oil in the two columns of the manometer may cause serious errors in observations. If this error can be eliminated, the oil manometer could be used as a reliable absolute manometer. The easiest way of degassing the low viscosity oils is by deaeration under vacuum (Hayward 1963). In this paper, an oil manometer with increased sensitivity and using the principle of deaeration under vacuum is described.

The manometer is shown in figure 1. It is made of Pyrex glass and is filled with apiezon A oil having a density of

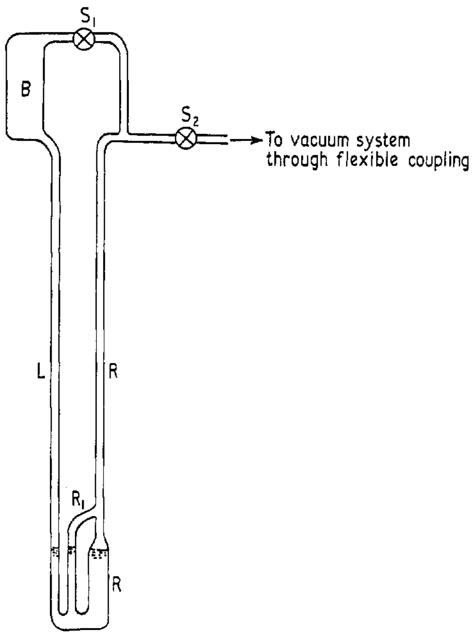

Figure 1 Schematic diagram of an oil manometer

$0{\cdot}86$ g cm^{-3} at 30°C. The sensitivity of the manometer is increased by making the diameter of the right column, R, two or three times that of the left column, L, at the lower end (as shown in the figure), which causes the liquid level to rise or fall in L at a rate 4–9 times that at which it falls or rises in R. In order to eliminate error due to difference in surface tension, a side tube R_1 of the same diameter as that of the left column L is provided with the right column R as shown in the figure. A bulb B with a volume roughly three times that of the oil used in the manometer is provided at the upper end of L. It is connected to R through stopcock S_1. Typical dimensions of the manometer are: total length, 60 cm; length of the bulb, 10 cm; diameter of the column tubes (R, L and R_1), 6 mm; diameter of the lower end of the right column, 18 mm. The manometer is connected to the vacuum system through stopcock S_2 and flexible tubing (not shown in the figure) and mounted on a light metal frame which can be tilted.

To begin with stopcock S_1 is opened and the manometer is connected to a high vacuum system through stopcock S_2 and both the limbs are evacuated by opening S_2. Thereafter, the manometer is tilted and the oil is drained into the bulb B. Instantaneously the degassing of oil starts. The bulb B is either shaken while pumping under vacuum, or the oil from B is allowed to fall slowly back into the manometer columns, so that the evolution of the absorbed gas becomes vigorous, the latter method being more effective. This process may be repeated five or six times, but in the authors' experience a maximum of three tiltings is needed for complete degassing of the oil. During winter, holding the bulb in one's palm while shaking provides sufficient heat for accelerating the deaeration of the oil. The entire process of degassing takes much less than five minutes. After the oil is completely freed of dissolved gases, stopcocks S_1 and S_2 are closed and the manometer is ready for use.

The manometer was used to measure pressures in a vacuum system in which pressure was varied over the range 10–10^{-2} Torr. The readings obtained were compared with those obtained from two McLeod gauges; the first one had a sensitivity of $1{\cdot}4\times10^5$ mm per Torr for 1 mm length of mercury while the other was a miniature McLeod gauge made in Germany by E Kammerer (Compression Vacuum Indicator, range 10–10^{-3} Torr). For measuring pressures of the order of a few Torr a mirror scale was attached at the back of the manometer, while for measuring pressures in the range of 10^{-2} Torr a cathetometer was used. The manometer readings remained in close agreement with the two McLeod gauges and the overall % deviation was found to be between 2 and 5%.

The authors have found that the manometer is quite suitable in the range 10–10^{-2} Torr and compares favourably with the McLeod gauge. It is simple in construction and much cheaper than a McLeod gauge of the same range. Further, in this manometer pressure changes can be recorded continuously. The inclusion of stopcocks S_1 and S_2 enables the operator to degas the oil in a high vacuum system and after complete degassing the stopcocks S_1 and S_2 are closed and the manometer is ready for use as described above. Though Hayward has discarded the use of stopcock S_1, the authors are of the opinion that it provides an extra pumping line for the bulb B and also eliminates any possibility of the oil rushing into the vacuum system during initial evacuation. As oil manometers are generally required to measure pressures around and below 10 Torr, the size of the manometer is limited to around 50–60 cm (and should not be unduly increased). The manometer can be evacuated on any vacuum system and once the degassing of oil has taken place it can be connected to any desired vacuum system to measure pressures. By adopting the above design, the sensitivity of the manometer has been increased and the method of deaeration of oil in vacuum has been made more effective than was originally claimed by Hayward (1963).

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Motorized stage controls for the Cambridge S600 scanning electron microscope

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Abstract The three stage micrometers of a Cambridge S600 scanning electron microscope have been equipped with stepping motors, the control of which is effected through a triple-action joystick. This has permitted coordinated orthogonal translations of the specimen in the microscope which is valuable not only in the general use of the instrument but also in the study of dynamic processes occurring in the specimen.

1 Introduction

Most current commercial scanning electron microscopes (SEM) are capable of operating at conventional TV rates of scan (i.e. 625 line, 50 Hz interlaced). This type of instrument is valuable not only for conventional 'static' studies of the surface architecture of specimens but also for dynamic experiments in which processes of deformation can be recorded onto video tape for later detailed scrutiny including frame-by-frame analysis. In the course of examining the combing of human hair in the SEM (Brown and Swift 1975), we have found that the manual movement of the specimen by the micrometer stage controls of our Cambridge S600 SEM is extremely difficult to coordinate with the shifting of the image field resulting from the separate action of pulling the hair through a comb mounted on the specimen stage. This problem was particularly acute at high instrumental magnifications when it was necessary to maintain a feature of interest within the recorded field of view and when normal traverse adjustments tended to yield an unsatisfactory zig-zag movement of the field. In addition, there were further manipulative demands for keeping the image in focus and for periodically adjusting video signal levels.

To alleviate these problems we have modified our SEM so that x, y and z specimen translations are carried out with the aid of electric motors controlled by means of a triple-action joystick. In this way not only could specimen movements be carried out more rapidly and smoothly than by the manual actuation of the stage micrometers, but the fact that the joystick could be operated with one hand meant that the other hand was free for controlling the other microscope functions.

2 Apparatus

2.1 *Design considerations*

Motorized stage traverse attachments for some types of SEM are commercially available (Ernest F Fullam Incorporated, Schnectady, New York). Unfortunately, this type, in which the stage micrometers are rotated through a belt drive, does not give the accuracy of specimen movement we require for our