A Cheap and Simple Micro-Balance

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II. *A Cheap and Simple Micro-Balance.* By CAPT. J. H. SHAXBY, B.Sc., University College, Cardiff.

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THE name micro-balance should, perhaps, hardly be applied to the instrument described below, as it is designed for maximum loads varying between 5 milligrams and 5 decigrams. It is a simplified and rough form of a piece of apparatus designed for smaller loads, to be used in a research which the war has postponed.

The present type was put together for bacteriological use, to weigh small drops of fluid absorbed in bits of filter paper, rapidly and with an accuracy of one or two parts in 1,000. The balance was required to be reasonably robust and portable, and above all cheap. It has proved suitable for its purpose, and also in weighing small samples of mixed powders.

The principle is very simple: A light thread has its extremities attached to the lower ends of a pair of nearly vertical rods 2 ft. or so apart, each of which is pivoted at a point very little above its centre of mass. Thus, a very light load suspended at the middle of the thread causes a considerable depression of that point. The depression is not quite proportional to the load; but a series of five weights, one-fifth, two-fifths, &c., of the maximum load, gives means of calibration.

Detail of construction is illustrated in the diagrams, and is as follows: The metal parts are built up of "Meccano" strips of various lengths, fixed together where necessary by the small nuts and bolts supplied with the sets. The fixed framework consists of a long horizontal arm, 2 ft. in length, built up of two 25-hole strips, with three holes overlapping, supported at a height of about 1 ft. by a sort of tripod. This is built up of three 25-hole strips (as shown in the photograph, Fig. 1), two of which are in a vertical plane, while the third, bent slightly about the third to fifth holes from the top, slopes away like the back leg of some easels. The lower end of this leg may be bent so as to lie flat on the table, to which a drawing-pin through the last hole clamps it rigidly and holds the whole frame steady.

To the ends of the horizontal beam are fixed short pieces bent twice at right angles, so that they lie as shown in the plan of the end of the beam (Fig. 2).

Each of the two vertical suspended arms consists of two strips, the lower a 25-hole one and the upper a 6-hole one, bolted together through their end holes. The purpose of this is to allow of ready variation of sensitiveness, as explained later. A short piece ($\frac{1}{4}$ in. long) of glass tubing with rounded-off ends is cemented into the 15th hole from the free (lower) end of the longer strip; this hole is slightly below the centre of

FIG. 2.—PLAN OF END OF FIXED BEAM.

mass of the compound strip. A small nut and bolt a few holes lower brings the centre of mass down sufficiently and permits of adjustment. The middle points of two short bits of copper wire are joined by a thread of ordinary sewing silk, so that the free length of thread is about equal to the distance AB (Fig. 2). One bit of wire is then passed through the end hole at A , through one of the glass tubes, T , and through the end hole at B (bent temporarily toward A), so that the wires now lie flat on the outer sides of A and B , and keep the thread taut.

FIG. 3.—DIAGRAM OF SUSPENSION.

The movable arm is thus suspended (Fig. 3) with very little friction. The other arm is supported similarly at the other end of the fixed horizontal beam. Light aluminium vanes attached to the lower ends of the vertical arms play in water lashpots and keep the whole dead beat.

A thin wire hook is also soldered on near the bottom of each arm (Fig. 4). Thin wire loops are attached to the ends of an unspun silk or other fine fibre of length equal to the distance

between the pivots of the movable arms, the loops are slipped over the hooks and the lower ends of the movable arms thus linked together. The tension in the thread, and thus the sensitiveness of the balance, can be largely and immediately varied by changing the angle between the two strips which make up each compound movable arm. The parts of the

FIG. 4.—LOWER END OF MOVABLE ARM.

balance will not in general be quite symmetrical, so that if one arm has its two parts in a straight line the other will have to be adjusted slightly, in order that the lower portions may rest at the same small angle with the vertical, *i.e.*, so that the middle point of the fibre shall lie directly under the middle point of the fixed horizontal beam. To decrease the sensitiveness, both the upper short strips are to be turned inward. If they are turned outward the fibre is usually no longer kept taut, so

FIG. 5.—CLIP AND FILTER PAPER.

greater sensitiveness cannot be obtained thus ; if it is necessary, the small adjusting nuts are raised nearer to the pivots.

The loads are supported by a very light aluminium-foil clip loosely looped over the middle of the fibre ; the scrap of filter paper is inserted in this (Fig. 5). For powders a small thin paper scalepan replaces the clip.

Weighings are made thus. The calibrating weights are inserted in turn, and the resulting depressions noted. In the

case of weighing a drop the filter paper is included in all the observations. The depression due to the object to be weighed is finally observed, and its weight readily found from a calibration curve.

Of course the deflections could easily be measured by a cathetometer microscope, but as has been said above, cheapness was a *sine qua non*. The balance itself costs about eighteen-pence, and an auxiliary microscope costing several pounds was clearly ruled out. The deflections were measured as follows : A cardboard slider carrying a zero mark, and pierced by a circular " peephole " about the size of the pupil of the eye is attached to a millimetre scale, which is set up vertical 2 ft. or 3 ft. in front of the balance. A small cardboard tube closed at one end (the cap of an old rather wide thermometer case) was blackened inside, and across its mouth was stretched a fine fibre, which thus showed up sharp and white against the dark background of the interior of the tube. This was put an inch or two behind and slightly lower than the middle of the long balance fibre. If both fibres are horizontal a position can be found for the slider on the scale, so that one fibre hides the other from an eye looking through the peephole, when the clip is unloaded, and for each successive load. The deflections thus measured on the vertical scale are clearly equal large multiples of the actual deflections of the middle of the balance fibre. In practice it is found that the setting of the slider can be made with the greatest certainty, not with a horizontal fibre or a pair of cross-hairs on the tube, but with a single fibre set at a slight angle with the horizontal. The slider is adjusted so that the horizontal part of the balance fibre appears to bisect the short fibre in the tube. The angle between the two fibres should be small, and the slider can then be set with great precision ; an astonishingly small displacement noticeably upsets the bisection.

ABSTRACT.

The instrument, devised for bacteriological use, had to be cheap and moderately robust. It consists of a long horizontal fibre joining the lower ends of two vertical beams, each pivoted very little above its centre of mass. A small weight acting at the middle of the fibre thus causes a considerable depression. This is read off by arranging a slider on a vertical millimetre scale about 2 ft. in front, so that the middle of the fibre and a second short fibre placed just behind it are in line with a " peephole " on the slider. Adjustment is provided for quickly and largely altering the sensitiveness. The deflections are converted to masses by the use of calibrating weights. The apparatus is built up from a " Meccano " set.

DISCUSSION

Mr. C. C. PATERSON thought the instrument would have many useful applications. Had the author considered the possibility of making it a null method? A simple electromagnetic arrangement could be employed for the purpose.

Prof. BRAGG suggested a simpler null method, which consisted in the addition of weights to attachments to the side pieces. The arrangement could be such that quite considerable weights had to be added to produce a slight disturbance of the balance.

Mr. T. SMITH asked if the author had tried reading the position of the fibre against a thick thread mounted parallel to it, instead of the inclined thread he had described. If the thick thread were brightly illuminated, and the fibre adjusted so that it appeared to bisect the width of the thread a very accurate setting would result.

Dr. D. OWEN asked for the sensibility of the instrument shown at the meeting.

Mr. F. J. HARLOW asked the form of the calibration curve.

Prof. LEES said the instrument reminded him of a well-known text-book method for measuring small horizontal forces, in which the force produced a small horizontal displacement of a weight suspended by a long thread. If two such suspended weights were connected by a horizontal fibre to which small loads could be attached, a micro-balance somewhat similar to Mr. Shaxby's would be obtained.

The AUTHOR, in reply, said Mr. Paterson's suggestion was interesting. He had made some attempts to convert the instrument into a null one with a magnetic control below the load. He had also tried Prof. Bragg's suggestion, by mounting weights on short horizontal arms near the fulcrums of the vertical rods. As regards sensitivity, readings could be repeated to about 1/500th of the maximum load for which the balance was adjusted. The calibration curve was nearly a straight line.

FIG. 1.—COMPLETE BALANCE, FILTER PAPER IN POSITION