162. *A Sensitive Balance with an Auxiliary Electromagnetic Weighing.*

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In an accurate weighing with a balance, if the last two digits (say cgrm and mgrm) of the figures indicating the measured mass be determined without arresting the beam, as is necessary in an ordinary balance every time the weight or rider is changed, the time required for measurement would be markedly reduced. For realising this object an electromagnetic method was introduced in the following manner.

Two small bar magnets made of K.S. steel, well known for its large coercive force, are fixed vertically to the beam of a balance at equal distances (m.m Fig. 1) from the central knife edge. Underneath

each magnet and free from them, two coils (c,c) are fixed to the projections (p,p), which are attached to the main support of the balance. The coil is wound on a small bobbin of ivory, which is bored at the centre, and the magnet moves up and down in it when the beam swings.

The two magnets are made equal to each other in dimension and magnetic strength, and are arranged astatically. Two coils are so connected that when one of the magnets is pulled downwards the other is pushed upwards. The current is measured by a milliammeter with a scale divided into 120 divisions and adjusted to give directly the last two digits of the figures representing the measured mass, and to three digits by estimation of the tenth of each division. The calibration shows that the strength of the current is practically proportional to the weight added or taken from the pan. Besides the main winding, there is an auxiliary coil of few turns, which serves for zero adjustment. The current for this purpose does not pass through the milliammeter, and is independent of the measurement. This is the first form, but the second form to be next described is more convenient and accurate.

After several shapes and arrangements for the magnet and the coil had been tried, the final arrangement is shown in Fig. 2. The magnet is ring-shaped with a narrow air gap to leave little space for magnetic leakage, which is to be feared in the first form, and is fixed to the beam in such a way that the air gap is in the plane of the swing of the beam. The coils for these ring magnets are shown in Fig. 2; each of them is wound in a deep groove made in the periphery of a brass disc. To make the air gap as narrow as possible, a sector of the side of the groove is cut off, and as in the previous coil, there is additional winding for zero adjustment.

By a short circuiting key connected to the terminals of the main coils, the current can be cut off momentarily, giving an impulsive couple to the beam at the desired moment; this can be given in the same or in the opposite direction with the oscillation of the beam, so that the amplitude is controlled at will, much desirable for accurate working.

Fig. 3 shows a general view of the arrangement; the maximum weight carried by the balance is 100 grm and the minimum 1 mgrm; the distance between the central and the end knife edge on each arm is nearly 97 mm; the magnets are fixed at the distance of 30 mm from the centre of the beam. The external diameter of the magnet is 16 mm,

the inner 11 mm and its section 2.7×2.5 mm, the air gap 1.8 mm; the sharp corners are slightly rounded. The mass of the magnet is about 2 grm; that of the beam being over 100 grm, the extraneous weight due to the magnets is only 4 per cent of it. Each of the coils has 500 turns of No. 40 S.W.G. enamelled copper wire and the auxiliary coil has 50 turns of the same wire, both being wound in the same groove, whose section is 1.2 mm wide and 5 mm deep.

To balance 100 mgrm on the pan, 2.75 mA is required and the shunt of the milliammeter is so adjusted that with this current the pointer of the instrument deflects just 100 divisions for a standard decigram each division corresponding to one mgrm on the pan.

For more delicate weighing, the deflection of the pointer of the balance can be magnified ten times, by means of a simple microscope with ocular scale thus raising the sensitivity to tenth of a mgrm. In this case the shunt of the milliammeter is so adjusted that each division represents $1/10$ mgrm by means of a standard cgrm; the mean deviation of zero in the ocular micrometer is about $3/10$ of a division, corresponding to $1/100$ mgrm on the pan.

Fig. 4 indicates the connections of the circuit.

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Thus all features of the equal armed balance are retained, and the permanency of the calibration of the balance is of the same degree as an ordinary D.C. moving coil instrument. It is needless to state how much time is saved by the present arrangement and process in accurate weighing by dispensing with the riders and the small weights. This is but a preliminary design for attaining still greater accuracy in delicate weighing, for which the ordinary construction becomes much complicated and the process is rendered extremely tedious.