Magnetic Field Measurement in Beta-Spectroscopy

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To measure precisely the instantaneous value of a magnetic field, a device consisting of a drum-armature wound on a Lucite form and rotated by a synchronous motor is described. The direct voltage output is taken off by commutator and brushes, both of silver, to a potentiometer. Changes of 0.01 gauss can be observed. A simple self-regulating circuit is described.

IN the operation of beta-spectrometers of the magnetic semicircular focusing type it is desirable to be able to evaluate the magnetic field quickly and precisely. This has usually been done by the operation of a flip coil with a ballistic galvanometer and a calibrated mutual inductance. Such a method has many undesirable features. It requires an initial and final reading at each position. The inability to observe the deflection accurately together with the uncertainty in the geometry and the general awkwardness of its use, makes any improvement welcome.

APPARATUS

A device, shown in Fig. 1, has been constructed and is being used successfully to give the precise, instantaneous value of a magnetic field. This is essentially the rotor of a multiple coil direct voltage generator. Forty-eight conductors are arranged in twenty-four "lap-wound" coils in a conventional manner with the terminals connected to twenty-four silver commutator segments. The armature core and drive shaft are shaped from Lucite. Figure 2 shows schematically the arrangement of the windings on a reduced scale so as to be less confusing; that is, only twelve segments are shown instead of the actual twenty-four. Each of the forty-eight conductors is 3 cm long and the cylindrical diameter is about 2 cms.

The rotor is driven by a small Bodine synchronous motor which is kept well out of the magnetic field, by the use of a long shaft. The output of the rotor is received by silver brushes bearing lightly against the commutator. Being made of silver no thermal electromotive forces arise, and under the extremely light tension the mechanical wearing is negligible. Each brush is slit into three fingers so that continuous contact is assured. The generated e.m.f. is measured by a Leeds and Northrup K-2 potentiometer.

OPERATION

To calibrate the complete apparatus it is operated in a magnetic field of known value. In order to keep the geometry as simple as possible and calculable with accuracy, the field produced midway between two long parallel conductors comprising a current loop and carrying a known current, was chosen for the calibration. The sensitivity of the first device constructed was 10 gauss per millivolt. Since with the potentiometer it is possible to measure e.m.f. to a tenth microvolt, field changes of 0.001 gauss could be observed. In practice this high sensitivity is not needed, and it is sufficient to observe the output to the closest microvolt or in some cases 10 microvolts.

No current is drawn from the rotor so the

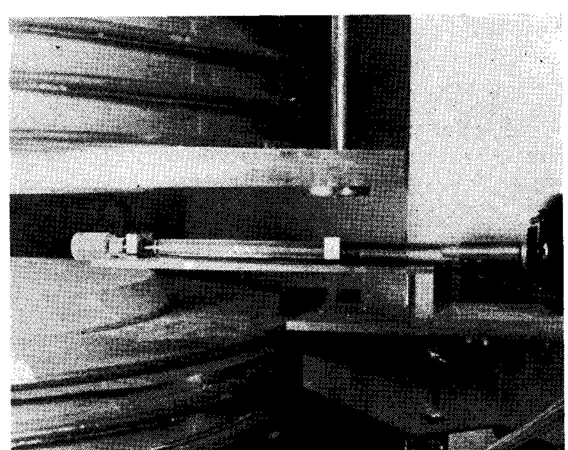

FIG. 1. View of rotor in the magnetic field.

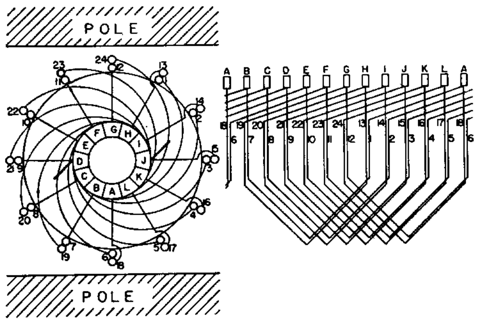

FIG. 2. Arrangement of winding on motor.

torque is very low. The output does depend for accuracy on a constant rotational speed, which in many localities may be had from the synchronous motor operated by the regular power supply. Since the magnetic induction in the gap is not necessarily proportional to the exciting current because of hysteresis in the iron, no special regard is given to the magnet current. The potentiometer is set at the desired value and the exciting current adjusted to and maintained at such a value that the galvanometer in the potentiometer circuit gives a null deflection.

FIELD CONTROL

By the use of "automaton" controls it is readily possible to maintain a constant current through a circuit. It is equally possible to adapt these circuits using a photoelectric cell to the present arrangement by maintaining zero deflection of the galvanometer. In actual practice it may be pointed out that very often these complicated control circuits are entirely unnecessary. If the supply voltage is somewhat greater than the potential fall across the magnet then the simple circuit shown in Fig. 3 gives remarkably good regulation. This consists of a good, low-resistance storage battery connected in parallel with the magnet and a satisfactory resistance R_1. This parallel combination is connected through a resistance R_2 to the voltage source.

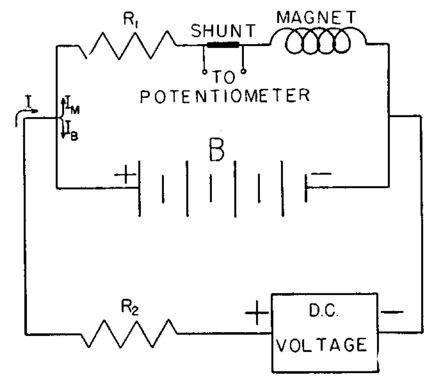

FIG. 3. Simple self-regulating circuit.

By writing expressions for Kirchhoff's laws for the divided circuit, calling the currents through R_2, B, and R_1, respectively, I, I_B, I_m, for the case of charging the battery,

$$I = I_B + I_m \tag{1}$$

and

$$R_1 I_m = E_B - r I_B, \tag{2}$$

where r is the internal resistance of the battery and R_1 includes the resistance of the magnet coils.

Combining Eqs. 1 and 2 gives

$$I_m(r - R_1) = rI - E_B, \tag{3}$$

and for good regulation

$$\frac{dI_m}{dI} = \frac{r}{r - R_1} = 0. \tag{4}$$

That is, if r is zero than the battery will serve as an ideal regulator taking completely any variations in line current. In practice the circuit works extremely well so that input voltage fluctuations of several percent produce scarcely a noticeable change in current in the magnet.