DESIGN FOR ELECTROMAGNETIC BALLISTOCARDIOGRAPH.*

By M. E. Folan.

Cardiac action and the consequent flow of blood in the vessels impart motion to the body. The resulting minute positional changes are ordinarily inapparent, but by suitable amplification may be recorded as a tracing. Such tracings have a recurrent waveform which can be correlated to the systolic-diastolic phases of the cardiac cycle. The term ballistocardiography defines the process of recording these positional body changes in graphic form. The earlier ballistocardiographic techniques were of the "indirect" variety, in that the body motions due to the cardiac cycle were imparted to a special table on which the subject was positioned. The resulting table movements were recorded electrically or optically. (Starr et al.; Nickerson; Nickerson and Curtis; Hamilton et al.) The special apparatus used was not portable, and therefore not always readily applicable to clinical work. The basic idea of ballistocardiography was first used by Gordon in 1877 (Starr et al.).

Direct methods of recording ballistocardiograms were needed, and the most readily applicable techniques were described by Dock and Taubman. It was decided here that the electromagnetic method was the most likely to be readily applied, and that the material requirements were not difficult to obtain.

Construction and Principles.

An electromotive force proportional to the ballistic movement of the body is applied to a direct writing electrocardiogram to give a wave record which can be correlated with the cardiac cycle.

The instrument depends for its action on the movement of a coil of wire in a magnetic field. The principle is that enunciated by Faraday, viz., an electromotive force being induced in a conductor which is moved in such a manner as to cut the lines of magnetic force. The induced E.M.F. is then proportional to the velocity of the coil movement, its polarity to the direction of motion, and it can be amplified to actuate a recording device. The to-and-fro coil movement is obtained by suitable coupling between the coil and either the vertex or shins, so that movement in the long axis of the body is transmitted to the coil. In this case, it is the velocity of body movement which is measured rather than the positional change. It appears, to date, that such records are as significant as those which record extent of movement.

As is apparent from the line drawing and photograph, the instrument is simple in construction. The base board (a) and vertical supports (b) are constructed of seasoned hardwood. The coil (e) is "pie-wound", of fine wire, and was obtained from a surplus radar intermediate frequency coil assembly. Any coil of fine wire and suitable

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size can be used (preferably pie-wound) with an air core. Iron-cored coils have been tried, but were subsequently discarded because the "magnetic history" of the core was unknown, and the mass was considered too large. The coil is firmly fixed to the lower end of a non-ferrous arm (brass Valance rod in the present case) which is pivoted between two metal cheeks at the upper end. The angle metal cheeks are firmly screwed to the top cross member and carry the bearings for the swinging coil arm. The bearing and pivot are actually the 'scape wheel and recessed screw bearing from a defunct alarm clock. One cheek is bored out to a depth of 1 mm. to a conical finish, which accepts the pointed end of the 'scape wheel pivot. The opposite cheek is bored and tapped to match the adjusting screw and allows the bearing to be "set-up" to the required tension with minimal slack and side play. The 'scape wheel and pivot are firmly fixed to the upper end of the swinging lever, a clearance hole for the pivot being first drilled through and the 'scape wheel then sweated firmly to the flat of the lever. The rear face of the lever is drilled with a shallow conical hole to take the point of the connecting rod from the shin bar. In the present instrument, this hole is one-third way between the suspension and coil. This gives a 2:1 amplification of coil movement, increases the peripheral speed of the coil, and gives a greater E.M.F. for a given body movement than would be the case were the coil to duplicate directly the extent of bodily positional change. Other lever ratios can, of course, be readily obtained, but the present 2:1 ratio has proved very satisfactory, in addition to giving a suitable height match for average adult shin dimensions.

The magnet (f) is clamped in a rigid aluminium sheet metal holder, at an angle to the base. The angle is an arbitrary one, and is not critical. However, the angle mounting was chosen to allow the coil-lever combination being "pre-loaded" in the operating position, and minimising the natural periodicity of the pendulum effect. This pendulum effect is apparent when the coil-lever assembly is vertical, and was discarded in favour of the angled version during development experiments. The actual angle is determined by the dimensions of the apparatus, and should be taken off the working drawing prepared, or from the actual assembly during construction. The "tie strip" at the rear of the magnet holder provides an adjustment which is one that allows the pole-face to parallel the coil axis in the operating position.

The coil is adjusted to work over one magnet pole. Certain advantages accrue from this. The coil can always be positioned to a standard position in reference to the pole chosen, giving reproducible effects. In addition, the number of flux lines cut by the coil will not vary widely, as is the case when the magnet is worked in the space between the poles, with resulting variation in the induced E.M.F. and, consequently, in the amplitude of the recording at any one setting of the recording device. The coil leads are soldered to a length of light flex, which is strapped to the swinging arm, carried in a loose loop to the support and from there to a suitable plug on the base. In this plug are inserted the two arm leads of an electrocardiograph, the receptacles being marked to correspond with the proper leads after initial setting up has shown which is the correct polarity for a properly oriented B.C.G. trace.