A SIMPLE, CALIBRATED, ULTRA-LOW FREQUENCY BALLISTOCARDIOGRAPH*

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Abstract—The physical basis of ballistocardiography has now been thoroughly investigated and there is general agreement that the ultra-low frequency system is the most satisfactory. The physiological basis of ballistocardiography and its clinical application require further study. For this purpose a reliable instrument which can be easily operated and calibrated is needed.

The design of such an instrument and its calibrating system, with an analysis of its performance and an indication of the results obtained by its use is presented.

1. INTRODUCTION

BALLISTOCARDIOGRAPHY is the technique of recording the movements of the whole body in response to the beating of the heart and the circulation of the blood. This is usually achieved by detecting the movements when a subject is recumbent on a horizontal platform. Current research in this field started with the work of STARR and his colleagues (STARR et al., 1938 and 1939). Their original instrument had a heavy platform which was constrained by a stiff spring and was undamped. This type of instrument became known as “high-frequency”, when by contrast NICKERSON and CURTIS (1944) introduced the “low-frequency” instrument, which used a lightly constrained, damped platform. Later, theoretical analysis and experimental studies (VON WITTERN, 1953; TALBOT and HARRISON, 1955; BURGER et al., 1953; BURGER and NOORDERGRAAF, 1956; BURGER et al., 1956 and 1957) established the superiority of systems using lightweight platforms supported so as to have very low natural frequencies of oscillation. These are now generally known as “ultra-low frequency” systems. Recent experiments in a weightless environment have yielded longitudinal (head-foot) records similar to those from u.l.f. systems (HIXSON and BEISCHER, 1964) thereby confirming their validity.

The construction of an u.l.f. instrument poses several practical problems in relation to choice of methods of suspension, transducers, calibrating and testing techniques, etc. We describe here the design and performance of an instrument in which simplicity of construction and operation have been the main considerations so as to make it suitable for routine clinical use. From the outset it was planned that the instrument should be used for longitudinal (head-foot) recording of the acceleration of the platform, over a frequency range of 1–20 c/s, studying adolescent and adult subjects.

2. THE ULTRA-LOW FREQUENCY BED

The apparatus is shown schematically in Fig. 1. The bed, which is made of paper honeycomb sandwiched between sheets of 0.08 cm plywood, weighs (together with supporting wires and girders) 7.5 kg (16.5 lb). It is suspended by four wires of mild steel 2.1 mm dia.

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and 2.75 m long from beams bolted to the ceiling. The natural frequency of oscillation as a simple pendulum is 0.3 c/s. The wires are fixed at the lower end to two cross girders made of Duralumin with provision for adjustment of length to equalise the tensions. The bed is raised by a few millimetres and steadied on a hydraulic jack whilst the subject gets on or off and is released before the recording is made. Not shown in Fig. 1 is the damping system of the bed, consisting of four oil dashpots, mounted one underneath each end of the dural girder supports, into which dip vertical plates orientated in the head-foot direction, so that lateral motion is more than critically damped with the full deadweight loading; but in the head-foot direction the damping is small so that manually applied restraint is required to neutralize motion after a subject has moved, before recording can commence.

The velocity transducer (Perls and Kissinger, 1954) consists of a bar magnet and coil assembly. The magnet is attached to the mid-point of the cross girder at the foot end of the bed and projects longitudinally into the cylindrical coil. The coil assembly is supported on a weighted