A CAPILLARY MERCURY–ALKALINE PICK-UP WITH AIR DAMPING FOR RECORDING ACCELERATION BALLISTOCARDIOGRAMS

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Ballistocardiography is one of the methods of recording the propulsive function of the heart [1, 2]. Existing pick-ups are of several types, but nearly all are based on the electromagnetic or photoelectric principle. In recording the acceleration ballistocardiogram, pick-ups of this type require differentiation of the output signal. If this condition is observed, however, they record the mean values between velocity and acceleration [3]. There are reports in the literature of the use of a pick-up based on the so-called "U effect" for recording the ballistocardiogram. This system consists of a capillary tube, filled with alternate drops of mercury and 0.1 N sulfuric acid. According to Watanabe, Elliot and Packard, and Bodrogi, this pick-up enables a ballistocardiogram of pure acceleration to be recorded (cited by Bodrogi [3]). Trials of pick-ups constructed by this method have shown that, on a scale suitable for clinical purposes, they possess an essential drawback – the low value of the output signal demands high amplification.

In our experiments we introduced a series of new and essential additions into the construction of a pick-up of this type, which serve to overcome this drawback, and thereby made it more suitable for clinical and experimental work.

The capillary tube was filled with alternate columns of mercury and alkali (0.75 N NaOH solution). This greatly increased the sensitivity of the pick-up by comparison with an Elliot-Packard-Bodgori pick-up of the same size. Observations showed that the magnitude of the electromotive force created by mechanical displacement of the pick-up was greater, the more freely the drops of mercury moved. This led us to the idea of creating an air damper between each pair of drops (mercury–alkali). A system of this type increased the output signal in general eight to tenfold, and enabled the ballistocardiogram to be recorded with only slight modifications of the pick-up on the ÉKP-4 electrocardiograph, providing a sensitivity of the apparatus of 0.2 mv.

We developed two variants of the pick-up. The first variant was a capillary tube 1 mm in diameter (from a Panchenkov apparatus) and 15 cm long, filled with alternate columns of mercury and alkali and air bubbles. The length of each column of mercury was 6 mm, of alkali 2 mm, and the space occupied by the air bubbles was 1 mm. The number of columns of mercury was 7-15. The end portions of the capillary tube were filled with mercury, into which dipped copper wire electrodes 0.5-1.0 mm in diameter, after which the ends of the capillary tube were sealed with Mendeleev's putty. The outline of the first variant of the pick-up, which was quite convenient to work with, is illustrated in Fig. 1. The curves obtained with its aid were completely indistinguishable from the curves reproduced in the literature. A defect of this type of construction is the instability of the pick-up to sudden mechanical influences in a longitudinal direction. Accordingly, we developed a second variant: in its construction we introduced an additional device which made the pick-up stable to sudden mechanical influ-

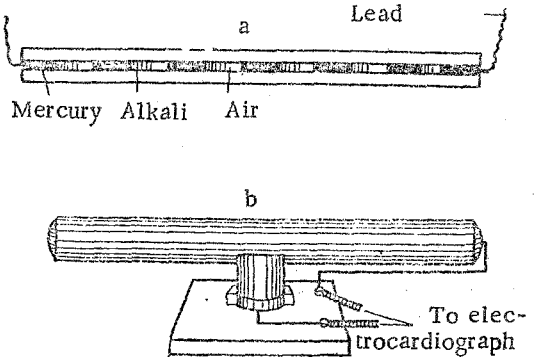

Fig. 1. Scheme of the mercury-alkaline pick-up for recording the acceleration ballistocardiogram (first variant). a) Diagram of the filled capillary tube; b) general view of the assembled pick-up.

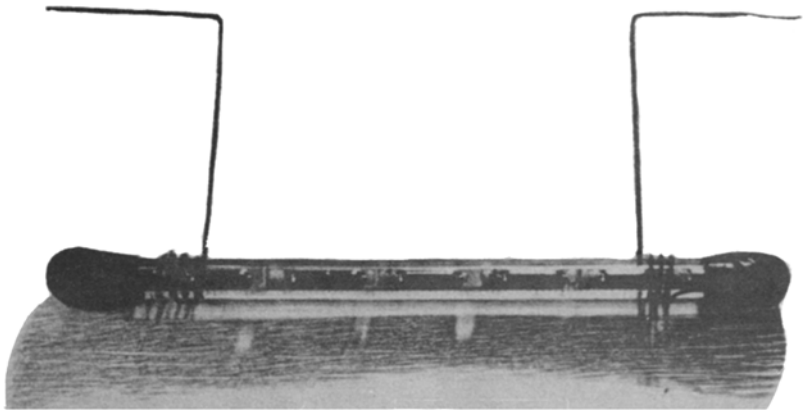

Fig. 2. Mercury-alkaline pick-up for recording the acceleration ballistocardiogram (second variant).

ences directed along its axis. We used a capillary tube 3 mm in diameter; into this tube, between each pair of dissimilar drops (mercury–alkali) and air bubble, we inserted a penoplast plug, which restricted the displacement of the drops of mercury within the confines of the space thus created (Fig. 2). This type of construction, without altering the physical parameters of the pick-up, ensures complete stability to sudden mechanical jolts.

In order to fill the capillary tube more accurately and quickly, we used a specially constructed apparatus,

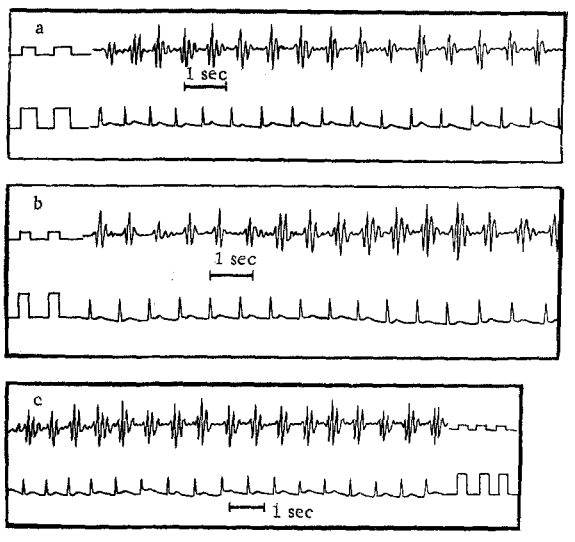

Fig. 3. Acceleration ballistocardiograms recorded simultaneously with electrocardiograms from the leg of a healthy human subject by means of the mercury–alkaline pick-up. Velocity of movement of the tape 2 cm/sec. a, b) Curves recorded with the use of a 0.03 mf filtrate; c) curves recorded without a filtrate.

the main part of which was a 2 ml syringe. The capillary tube, however, may also be filled by means of an ordinary syringe, fixed in a stand. In doing so, it is essential that the entire system, including the syringe, connecting the rubber tube and the capillary tube itself, should first be filled with the alkaline solution. The capillary tube is filled from a test tube (into which mercury and alkali are poured in two layers), by placing its end first in the mercury and then in the alkaline solution, and afterward in the air. In the second variant of the construction a thick capillary tube was selected and filled by means of an ordinary pipette. It is advisable to mount the complete pick-up in a copper or brass tube, and to fix it on a plate of organic glass. The tube protects the apparatus against outside forces, and at the same time acts as a screen.

Investigation of many pick-ups showed that their intrinsic frequency depends on the mass of mercury and the number of its columns. The greater the mass of the mercury, the lower the frequency of oscillation. This enables each researcher to produce a pick-up with a frequency most suited to his needs – from 65 to 300 cps. The apparatus described is compact and convenient in use and enables the ballistocardiogram to be recorded with the subject in any position and from any point on the body. The pick-up is simple in construction and may quickly be made in any medical institution. The weight of the filled capillary tube is 13-20 g, and that of the assembled pick-up is 130-150 g. The recording of ballistocardiograms taken with the capillary mercury–alkaline pick-up in healthy human subjects and patients showed the high sensitivity of the apparatus to changes in the mechanical working of the heart. The character of the curves, the amplitude of the waves, and the time relationships of the wave segments were identical to those reported in the literature.

In Fig. 3 are shown ballistocardiograms, recorded with the capillary mercury—alkaline pick-up (second variant) from the leg of a healthy human subject.

SUMMARY

The paper gives a description of the design, and presents physical characteristics, of a capillary mercury-alkaline pick-up with air damping, as well as the procedure used in its operation. It is based upon the principle known as the "U effect," and consists of a capillary tube filled with alternating columns of mercury, alkali, and air. Between each pair of adjoining drops (mercury, alkali) there are provided stops in the shape of penoplast plugs to raise the mechanical stability of the pick-up. The natural frequency of the pick-up may be within the range of 65-300 cycles per sec. The pick-up supplied with mechanical stops is stable and gives curves identical to those described in the literature.

LITERATURE CITED

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