SYNCHRONOUS HEART SOUND RECORDING BY APPLICATION OF A SECOND CHANNEL TO THE COSSOR-ROBERTSON CARDIOGRAPH

BY

G. D. DAWSON AND A. MORGAN JONES

From the David Lewis Colony, Cheshire, and the Cardiographic Dept., Manchester Royal Infirmary

Received February 1, 1944

By using a microphone to provide the input, the standard Cossor-Robertson cardiograph can be used to record heart sounds instead of the electrocardiogram, but such a record is of little value unless it is recorded synchronously with an electrocardiogram. For this purpose two separate recording channels are necessary. The double-beam cathode ray tube with two amplifying channels has been developed by Donovan (1943). With the addition of stationary spots and a moving-film camera to avoid loss of focus and definition due to curvature of the tube face, this is the method of choice. The possibility of replacing the standard single-beam tube of the Cossor-Robertson cardiograph with a double-beam tube was therefore investigated, but unfortunately it was found that the necessary alterations involved almost complete rebuilding of the instrument.

It is possible, however, to record simultaneously two different wave forms with a single-beam tube by using two valve amplifiers and an automatic switch which connects their outputs alternately to the single deflecting plate of the tube. The effect which this gives is illustrated in Fig. 1. If the switching rate is sufficiently high the gaps in the traces become small com-

\[\text{Fig. 1.—Action of Switch. (A) slow, and (B) more rapid switching rate. As the switching rate is increased the wave form becomes more accurately outlined.}\]

pared with the spot size and each trace appears to be continuous. The passage of the spot from one trace to the other is so rapid that it is not visible. Such switching may be carried out either mechanically or by a thermionic valve device—the electronic switch. Mechanical methods cannot easily provide a switching rate that is sufficiently rapid to record the frequencies of heart sounds and murmurs, but a very efficient type of electronic switch was designed by Clothier (1939). The Clothier circuit is capable of switching between the two
SYNCHRONOUS HEART SOUND RECORDING

recording channels 2500 times a second, and this very rapid switching rate can be used because the cathode-ray tube provides a recorder free from inertia and with an instantaneous response. The highest frequency that can be adequately recorded depends upon the switching rate (Fig. 1); with a rate of 2500 a second it is possible to record satisfactorily the wave form of frequencies up to 200 cycles a second, which is more than adequate for electrocardiography and quite sufficient for cardiophonography. Much higher frequencies can, of course, be recorded, but their wave form will not be completely outlined. With reasonable precautions in design there is no coupling between the two recording channels, so that a potential fed into one amplifier has no influence upon the other trace (Fig. 3).

The Clothier switch can be applied to the Cossor-Robertson cardiograph by connecting the output of its amplifier and the output of an external heart sound amplifier to the switch input. The switch output is connected to the cathode-ray tube. The entire recording system of the cardiograph is used without modification.

Modification of the Cossor-Robertson Cardiograph Recorder Unit

The required alteration is simple, and Messrs. Cossor kindly undertook to carry it out to meet our requirements. It is only necessary to divide the lead from the cardiograph amplifier to the cathode-ray tube, and to bring both ends to terminals on the case; it is then possible to connect the output of the cardiograph amplifier to the Clothier switch by one terminal (A2),

**Fig. 2.** Connections of Clothier Switch with Recording Unit. The lead A2 to Y1 in the recorder unit is broken and the two ends brought to the central terminals of a double-pole double-throw switch (S). The switch then permits them to be connected together, restoring the circuit to its original form, or allows Y1 to be connected to the switch output, and A2 to one switch input, as used in the double-channel recorder.
and the switch output can be taken to the cathode-ray tube by the other terminal (Y1). These terminals were fixed on the back of the recorder unit. When Y1 and A2 are connected together the instrument is restored to its original condition and can be used in the ordinary way as a portable cardiograph. It is convenient to incorporate a double-throw double-pole switch so that a single movement converts the simple cardiograph to the double-channel recorder. The connections are shown in Fig. 2. One point of importance must be noted. The introduction of an extra valve in the amplifying system produces a phase shift of 180 degrees in all the potentials amplified. Thus if the deflections of the electrocardiogram are to appear in the same sense as that in which they are normally recorded the patient leads must be reversed.

The Clothier Electronic Switch

It is unnecessary to describe this here for full details have been published by Clothier (1939) and its application to medical purposes has been described elsewhere by one of us (Dawson, 1941).

The Heart Sound Amplifier

A simple resistance-capacity coupled amplifier is suitable, provided it has a frequency response up to 1000 cycles a second, and a gain of 50,000 to 100,000 times. To eliminate slow vibrations, such as movements of the chest and the cardiac impulse, low-frequency filtering is necessary, and this can be introduced by using interstage coupling of suitable value. The degree of attenuation of the lower frequencies depends on the product of the sizes of the grid condenser and the grid leak and, when the values are taken in microfarads and megohms, the product is the time-constant of the coupling. An overall time-constant for the amplifier of 0·1 sec. will attenuate a sine wave of 10 cycles a second by less than 5 per cent. This is the best response likely to be needed in cardiophonography, and increased low-frequency attenuation can be obtained, if required, by switching in grid condensers of smaller values in a single interstage coupling.

When a crystal microphone is used a very simple and satisfactory method of filtering is possible. The impedance of such a microphone is almost purely capacitative and, if the resistance of the load into which the microphone works is reduced, selective attenuation of the low frequencies occurs. The parallel connection of a variable resistance of 1 or 2 megohms allows continuous variation of low-frequency response. The inaudible low components of the heart sounds and of chest pulsations can then be reduced to any desired size.

The connections between recorder unit, Clothier switch, and heart sound amplifier are illustrated in Fig. 2.

Arrangement of the Traces

In order to keep the Cossor-Robertson cardiograph as compact as possible the back of the fluorescent screen is photographed through the side wall of the cathode-ray tube. Light from an image on the upper part of the screen passes very obliquely through the side wall of the tube and this leads to slight blurring of the photographic record owing to the formation of a double image. This is an intrinsic disadvantage of side-tube photography, and can only be overcome by direct photography of the front of the screen. In designing a portable cardiograph the slight blurring of the record when using side-tube photography has been justly regarded as of much less importance than the great increase in bulk which is inevitable when the front of the screen is photographed, and in practice the blurring is largely overcome by using only the lower two-thirds of the screen. In heart sound recording, however, a greater degree of sharpness is advisable and this can be obtained by using only the lower third of the screen from which light passes much less obliquely to the camera. The electrocardio-
gram was, therefore, arranged to occupy the middle third of the screen and the cardiophonogram was placed on the lower third. With side-tube photography it is never possible to obtain records comparable in clarity with those obtained by direct photography of the front of the screen, but it will be seen that this method gives images which are sufficiently clear for most purposes.

The separation of the two traces is controlled by the difference in grid bias of the two switching valves. The two traces tend to set themselves equidistant from a line, the position of which is controlled by the spot position control of the recorder unit. They can thus be moved down to the appropriate position without affecting their separation.

Records

Examples of the records obtained are illustrated in Fig. 3. The input was from a crystal microphone similar to the Cossor cardiophone but with a larger diaphragm opening, which we prefer. It will be noticed that the more rapid deflections of the heart sound records are discontinuous. This is due to the flick of the spot from the cardiophonogram to the electrocardiogram. It will be clear from Fig. 1 that exact vertical alignment (i.e. synchrony) of the traces is automatic and accurate provided that the axis of the tube is set so that the displacement of the spot is truly vertical. It is normally set accurately in this position by the makers, and if far from the correct position it will be found that one trace will fail to record owing to the displacement of the spot outside the camera recording slit.

Fig. 3.—Records. (A) Auricular fibrillation. (B) Systolic murmur (S. M.). (C) Diastolic murmur (D. M.). (D) Triple rhythm due to audible third heart sound. (E) Abnormal first heart sound with auricular component (a) which precedes the peak of R. (Time marker : 1/10th sec.).

Downloaded from http://heart.bmj.com/ on 1 January, 1944.
G. D. DAWSON AND A. MORGAN JONES

Summary

A method of synchronous heart sound recording is described in which the standard Cossor-Robertson cardiograph is modified by introducing a second channel using the Clothier electronic switch.

Synchronisation of the tracings is automatic and requires no adjustment.

The alteration to the commercial instrument is simple and does not affect its use as a simple portable cardiograph.

We are indebted to Professor Crighton Bramwell for his interest in this work and to Messrs. A. C. Cossor Ltd., for their co-operation in undertaking the alteration to the Recorder Unit.

The total cost of the conversion, including fitting the terminals to the recorder unit, and the cost of materials for constructing the switch and external amplifier should not, in normal times, exceed £20. In addition a microphone is necessary.

REFERENCES