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Graphical Registration of the Heart Sounds.

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I. Introduction.

A correct and exact graphical representation of the heart sounds is indispensable for the analytical study of the acoustic phenomena of the heart. It has been for a long time an object of investigation and research to find an ideal method by which such graphical representation may be obtained. Unfortunately, however, the efforts of the earlier investigators were not fruitful. In fact, the advancement along this line of work has been so slight as to be scarcely worth mentioning until recent years, when the rapid progress and development in radio telephony has induced the revival of research through this channel.

The graphical registration of the heart sounds by means of electrical instruments had been thought of and numerous experiments had been carried out in the past, but they had to be discontinued owing to the excessive distortions involved.

However, the rapid progress and development in the science and the art of radio telephony in recent years, has paved the way to the perfecting of a method by which a correct and exact graphical record of the heart sounds can be obtained conveniently and successfully.

For the reason just stated above, the writer has adopted this method of attack for the investigation of the subject under consideration. He has been fortunate enough to obtain the results which have long been sought for, by the application of the principles and the apparatus of radio telephony. It is the purpose of this paper to present the practical working-out of this principle and the general set-up of the apparatus which was designed by the writer for this particular work. The records and their practical utility will be briefly discussed.

II. Construction of the Apparatus.

A. Transmitter.

The transmitter is one of the essential parts of this apparatus and is in effect, the key to success or failure in obtaining the desired result. For instance, a carbon microphone, which was used first by the earlier investigators, is too sensitive, so that it is easily affected by even the

Fig. 1.

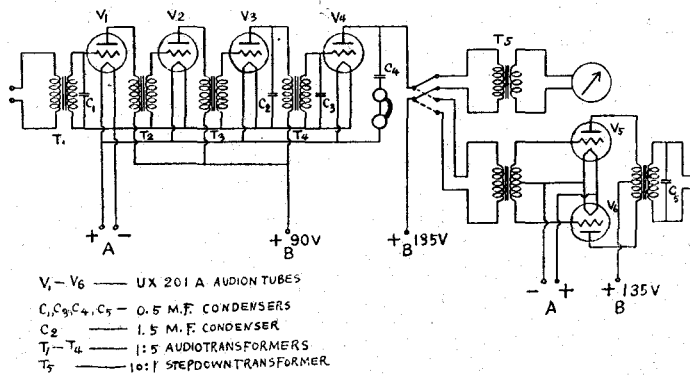
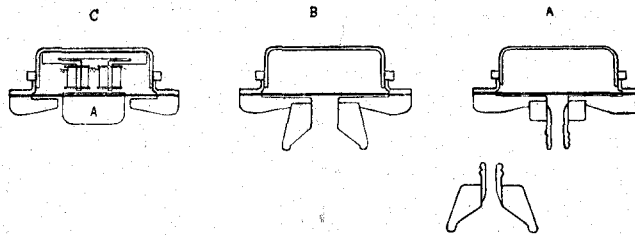


Fig. 2.



slightest mechanical vibrations. Therefore, it could not be justly expected that such a microphone could transmit the heart sounds without interference by the disturbances caused by the heart beating unless a special provision is made to eliminate the latter influences. In the more recent experiments, microphone of the condenser type or the electromagnetic type have been used, since they were found to be almost free from the defect encountered in the carbon microphone.

The writer has used an electromagnetic type transmitter for the reason stated above and also because it can be handled and operated with much ease and simplicity.

The transmitter used by the writer was one reconstructed from an ordinary "Telefunken E H 333 head receiver", as shown in figure 2. C. The contactor A was made of ebonite, 2.1 cms. in diameter and 0.9 cm. high. It was glued on to the vibrating diaphragm of the transmitter at the center and on the opposite side was put an iron disc of the same diameter and 0.5 cm. in thickness. The latter was placed there to increase the rigidity of the diaphragm so that the diaphragm could not be strained by a slight compression and in the same time to increase the proper frequency of the diaphragm while keeping the sensitivity of it within the desired limits.

The transmitter was applied directly to the chest and it was fixed by elastic rubber tape. Thus, the transmitter free from any influence of interference, can respond only to the acoustic vibrations of the chest.

For the purpose of comparison, several other types of transmitter were examined, which will be discussed in a subsequent article. Figure 2. A and B, show two examples of such transmitters, in which the chest piece of an ordinary stethoscope, with and without a rubber tube, was attached to the transmitter instead of the ebonite contactor.

B. Amplifier.

Since the fundamental vibrations of the heart sounds lie in the lowest range of acoustic vibrations, the apparatus must be so arranged as to obtain the amplification with the least distortion possible in each frequency of this range. Special attention has been paid to this point by the writer and his amplifier was so designed that frequencies within the range of about 32-512 could be amplified to the desired magnitude without distortion.

The circuit diagram of the set-up is as shown in figure 1. Sounds corresponding to heart sounds can be heard by the receiver phone from the output of the fourth stage of the amplification. At this stage of amplification, the intensity of the sounds is much increased without change in the quality of the tone. However, by the addition of one more stage of power amplification the sound can be reproduced through a loud-speaker with sufficient intensity and without any noticeable change in the quality of the tone i. e. without distortion of the sound waves.

C. Device for recording.

For the writer's experiments, an oscillograph manufactured by the *Yokokawa Electric Works* was used (the vibrator of the galvanometer, type A, has a natural frequency of about 6000, a sensibility of 1×10^{-3} amp. D. C. per 1 mm. deflection and a resistance of 1 ohm). This oscillograph was coupled to the plate circuit of the fourth stage with a step down transformer as shown in the figure.

III. *The Records of the Heart Sounds.*

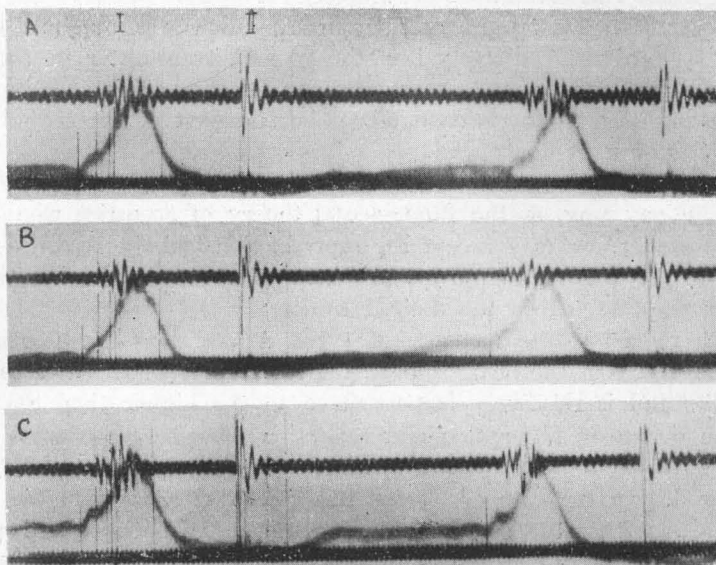
The movements of the vibrator of the galvanometer corresponding to the amplified heart sounds were recorded by the optical equipment and the operation of the apparatus was checked at all times by listening in with the receiver phone. Thus, the proper operation of the apparatus was checked and confirmed by listening to actual sounds reproduced. This check system, which was never satisfactorily realized in any of the early methods, may appear matter of fact and insignificant, but in actuality it is very important and significant.

But the sensitivity of the human ears to such a low range of acoustic vibrations as the heart sounds is not perfect. So, we must be especially careful in speaking of the accuracy of the record when it is checked by such a direct listening method. As a matter of fact, while a slight vari-

ation in the method of application of the transmitter did not show any perceptible change in the quality of the tone, there were considerable variations in the graphic records.

This is illustrated in figure 3.

Fig. 3.



These curves were obtained from the same person at one fixed point on the chest (on the left fourth intercostal space near the sternum) by the transmitters shown in figure 2. The only difference perceived by auscultation was that the last one was most intense.

Curve A was obtained with an attachment consisting of an ordinary stethoscope as shown in figure 2 A. This curve shows the most simple form of oscillations, in both the first and the second heart sounds. The first sound begins with small oscillations, more or less irregular. They are followed by a number of prominent oscillations. The features of these oscillations are quite simple and they disappear finally after the fifth or sixth oscillation, though the amplitude of the beginning one is of considerable magnitude. The fundamental frequency of this latter group of oscillations is found by measurement to be about 55 per sec.; the period of each oscillation of the first group can not be measured exactly, but they are a little more rapid than those of the latter group. The beginning of the second sound is indicated by an abrupt increase in the amplitude of rapid oscillations, the frequency of which is about 90 per sec. The following part of the oscillations shows the same appearance as the end part of the first sound. As a whole, the form of the oscillations of the second sound is more simple. Curve B in the same figure shows the result obtained with the type B transmitter shown

in figure 2. The shorter air passage between the source of the sound and the vibrator of the transmitter caused such a difference as to make the result seem as if it came from quite a different source from that obtained with the type A transmitter. Curve B is characterised by well-distinguished fine oscillations in both the first and the second heart sounds. These fine oscillations are scarcely perceptible in curve A. They are however, still less prominent than in C, which was obtained by applying the transmitter directly i. e. the type C, transmitter in figure 2. The fine oscillations in question are most prominent in this case, especially in the middle part of the first sound. The end part of the second sound alone remains almost unchanged.

A perfect reproduction or a record of sound phenomena can not be obtained in any way, as the fundamental theory of acoustics would indicate. However, we may accept the reproduction and the record as being correct in the practical application when they are obtained with least distortion possible within the desired limits.

With regard to the response of types A and B to each frequency within the range of the heart sounds, the former responds better to lower frequencies and is relatively less sensitive to the higher than the latter. A certain degree of absorption and reflection of some components of the heart sounds can not be avoided when a transmitter such as the type A is employed. In the case of C, the transmitter is applied to the source in such a way that the ebonite attachment comes in direct and perfect contact with the chest. The vibrations of the chest are transmitted perfectly, without beformation and practically without loss of energy.

Since the heart sounds which are auscultated as usual over the chest are nothing but the vibrations of the chest caused by the acoustic phenomenon of the heart, any superfluous conducting medium between the surface of the chest and the transmitter should be avoided. Otherwise no accurate result can be expected, as is seen in the experiment described above.

IV. Conclusion.

Records of the heart sounds were obtained successfully by employing the principle of radio telephony.

An electromagnetic type of transmitter and an audio-frequency amplifier of four stages were designed by the writer especially for his purpose, and as the recording device, an oscillograph manufactured by the *Yokokawa Electric Works* was employed.

Several methods of applying the transmitter were examined and it was found that the features of the records of the heart sounds obtained from one and the same person, varied considerably according to the method of applying the transmitter. But the best results were obtained by direct application.

The recording of the heart sounds was checked at all times during

the operation of the apparatus by listening to the actual sounds reproduced through the telephone receiver, and thus the proper operation of the apparatus, and hence the accuracy of the record, was checked and confirmed.

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