To terminate the diffusion, the tube is broken as described above, when the lower section falls out of the furnace and the upper half is withdrawn for analysis.

RESULTS

The method has been tested on a 1 . 1 $CdCl_2$. KCl melt, using Cd–115m as tracer.

Time of diffusion (*s*)	$D \times 10^5$ *cm*^{2} *s*$^{-1}$ (469–471° *C*)
2×10^4	1 39
2×10^4	1·38
$4\ 1 \times 10^4$	1 35
$2\ 2 \times 10^4$	1·48

mean value: 1 40
probable error: 2·5%

The present method avoids the crucible rotation and associated end correction difficulties inherent in the capillary method. The main sources of error in the measurement lie in a small but irreproducible dilution of the radioactive column during the filling process, and statistical uncertainties in the radio-analysis. Removal of the dilution effect should reduce the probable error to 1%.

The method is clearly applicable to the investigation of the effect of applied potential differences on the diffusion coefficient, the electrodes being placed beyond the regions where concentration changes due to tracer diffusion take place.

ACKNOWLEDGEMENTS

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An apparatus for visual and acoustical display of electrocardiograms

By A. STROJNIK, Dr.Ing., Electrical Engineering Department, University of Ljubljana, Yugoslavia

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A simple electrocardioscope with a cathode-ray tube and an electrocardiophone are described for use in lectures and during surgical operations. The electrocardiophone can be attached to the cardioscope amplifier and converts the amplified bioelectric potentials into signals of constant audio frequency and of variable intensity.

Amplifiers with cathode-ray tubes have been used extensively in the past for the display and recording of bioelectric potentials of the heart (electrocardiograms). The mechanical construction of such a device can be simplified considerably if it is to be used only for demonstrations in lectures and during surgical operations, no recordings being then necessary. An attempt has been made to simplify also the electronic circuits and the following inexpensive electrocardioscope has been developed.

THE ELECTROCARDIOSCOPE

The electrocardioscope consists (Fig. 1) of the amplifier (valves T_1, T_2, T_3, T_4), sweep generator (T_5, T_6), rectifier (T_7, T_8) and cathode-ray oscilloscope (T_9). It may be noted that all valves are EF 80 (though any similar pentodes may be used without significant changes in the circuit), except two AZ 1 rectifier valves which may also be replaced by any approximately (electrically) equivalent valves

An important feature is the use of a single rectifier for all parts of the cardioscope. Thus a fairly high voltage for the amplifier and the sweep generator is available. The rectifier is of the Greinacher voltage-doubler type with one end of the transformer secondary earthed, giving + and −950 V with respect to earth. The amplifier and the sweep generator are supplied by two separated sets of smoothing circuits in order to prevent a possible interference from the abrupt voltage changes in the sweep generator. Extensive use of electrolytic capacitors has been made. Chokes have not been found necessary. Owing to low current drain the ripple developed at the output of the smoothing circuits is low and, at the point A, is of the order of a few mV. The AZ 1 rectifiers are not supposed to stand up to a peak inverse voltage of almost 2 kV, but no trouble has been experienced, however, by using them in this circuit though a number of them and of various makes were tried. The transformer primary and the heater for the cathode-ray tube are electrostatically shielded.

The amplifier is of the well established cathode-coupled push-pull difference type. In order to obtain the necessary amplification of about 8 cm/mV with only two pairs of valves, working at 900 V, fairly high plate, screen grid and cathode resistances are employed. The connexion of the cathode resistor R_1 to −950 V provides a very high rejection factor. In fact, when the person under observation is artificially earthed (usually at the right leg) *via* a coupling capacitor C_1 at the amplifier input, there is less than 1 mm mains frequency interference under usual working conditions at the highest amplification. In the presence of very strong disturbing fields which may be caused by the high frequency and similar instruments used during surgical work, the potentiometer P_1 compensates for the residual asymmetry at the amplifier input. The variable resistor R_2 controls the overall amplification. Little effort is necessary to match the pair of valves in the first stage. Among the 6 EF 80 valves installed in the electrocardioscope it is easy to find one pair that matches the heater characteristics, the plate transconductance differences being less important. It might be expected that a sparkover might occur inside the amplifier tubes when switching on the electrocardioscope, owing to the delay in the heating up of these tubes. To prevent it a switch was originally inserted at the point *B*. Tests have proved, however, that no harm has been done to the valves when switching on heaters and h.t. simultaneously, probably due to high time constants of the smoothing circuits.

The time base is of the Miller Transitron[1] type (T_5) combined with a simple phase inverter T_6. Both T_5 and T_6 run with low plate currents. With the potentiometer P_6 the trace speed can be varied from 2 to 6 cm/s. The circuit of the 5 in. cathode-ray tube is conventional. The potentiometer P_5 is used for minor vertical shifts of the trace.

THE ELECTROCARDIOPHONE

Experience has shown that still another monitoring device is desirable, particularly for use in surgery. In order not to

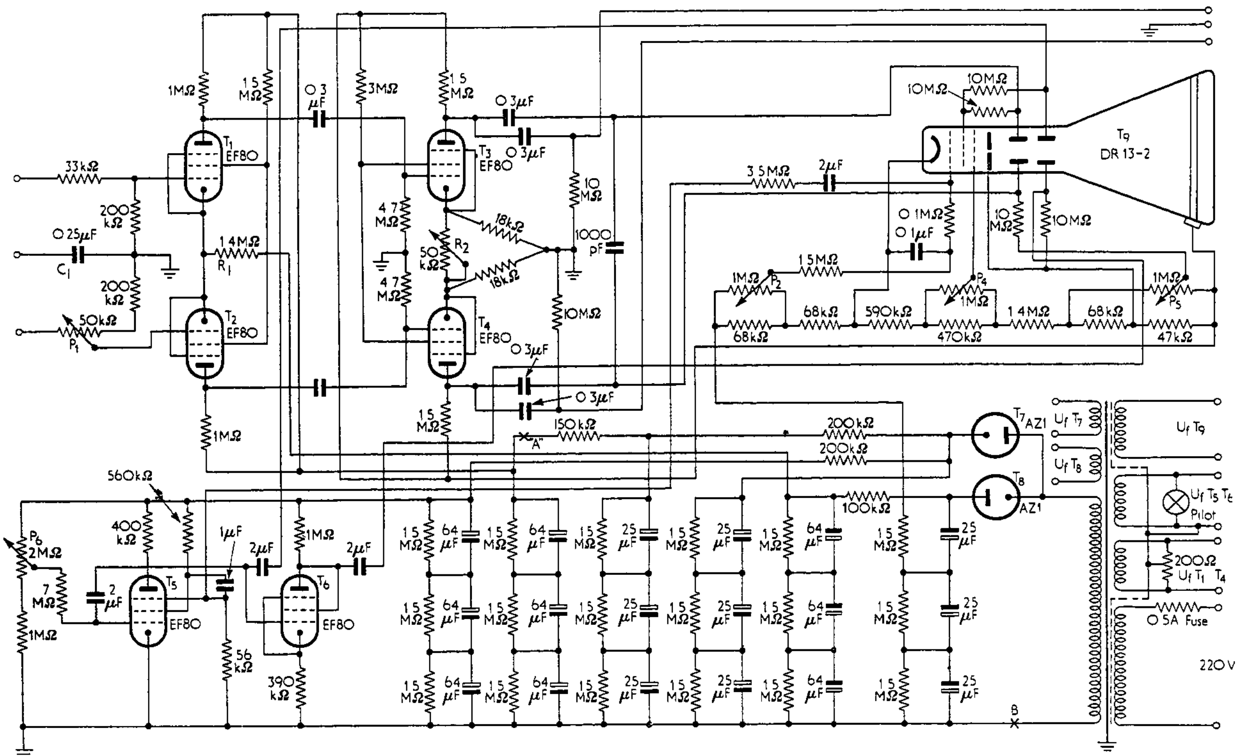

Fig. 1. Circuit of electrocardioscope

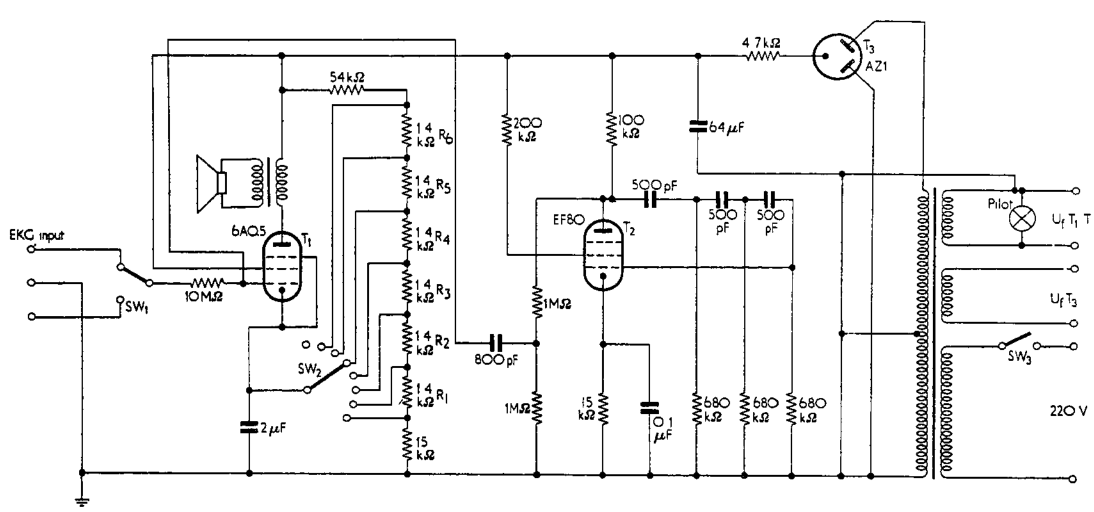

Fig. 2. Circuit of electrocardiophone

divert the surgeon's visual attention, an acoustical "display" can be made that would keep him informed about the heart-beat rate and the amplitude of voltages produced. A direct power amplification and a loudspeaker do not appear to be a good choice because of the low fundamental frequency (of the order of 1 c/s) and of relatively low content of higher harmonics of the electrocardiogram. Other possibilities have been considered and described. Recently a device has been described[2] that converts the bioelectric voltages into high frequency changes with subsequent mixing of this frequency with a constant frequency and feeding the loudspeaker with the resulting beat frequency. Instead of the frequency modulation, considerably simpler amplitude modulation has been used in the electrocardiophone described here.

The electrocardiophone is considered as an attachment to the cardioscope of Fig. 1. It consists (Fig. 2) of a *RC* generator (T_2) working at about 1 kc/s and of the modulator (T_1). The modulation takes place at the control grid of T_1. The two-position switch SW_1 connects either side of the push-pull amplifier output to the modulator. The plate load of the T_1 is the output transformer for a 2 W loudspeaker, the output of which was found adequate. The sound intensity is controlled by the amplifier with the resistor R_2 of Fig. 1. The intensity increases with the positive amplitude of the input voltage. For the negative amplitudes the intensity decreases accordingly. The input voltage that is still audible depends quite critically on the value of the cathode resistance $R_1 \ldots R_6$. Thus the cathode resistor control SW_2—modulation level control—was introduced. Its function in connexion with the electrocardiogram is shown in the Fig. 3 which represents what is called the normal human electrocardiogram. For high values of the cathode resistor, only large *R*-peaks are audible, corresponding to the level I–I. Decreasing the resistance makes the modulation level decrease also and levels II–II and III–III may be reached, making it possible to hear besides the *R*-peaks also the *T*-peaks and finally the *P*-, *R*- and *T*-peaks. This feature of the cardiophone has been found most useful, as also small changes in the peaks became perceptible.

Though the electrocardiophone has been designed together with the electrocardioscope described, the design is such that it should be useful with any electrocardiograph—or -scope amplifier, providing a high enough amplitude at the input

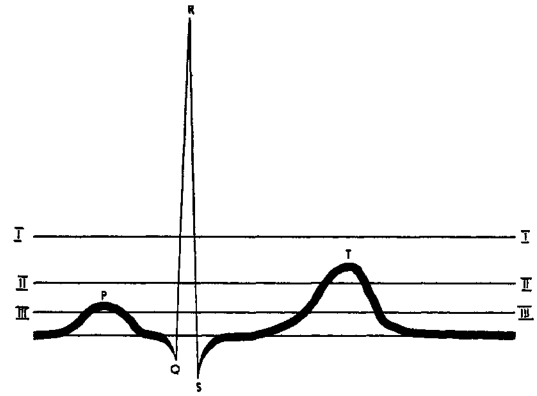

Fig. 3. Normal human electrocardiogram

and both polarities is available. Since most modern electrocardiographs use the push-pull technique this should be in general achieved without considerable changes at the amplifier output.

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A very sensitive relay, able to withstand heavy overloading

By F. H. PLANKEEL, Phys.Drs., Royal Dutch/Shell Laboratory, Delft, Netherlands

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A galvanometer relay is described which consists of a mirror galvanometer with limited deflexion, an optical system, a photoconductive cell, a Wheatstone bridge and a polarized relay. The input is a small d.c. current supplied to the galvanometer coil. The output is the energy available at the switch contacts of the polarized relay. The power amplification, i.e. the ratio between minimum input energy necessary to actuate the relay and maximum output energy available at the contacts of the polarized relay, is, in the simple prototype, $1 : 10^{13}$; the figure for a commercially produced version could be much higher. Large input overloading is allowable, e.g. a current 100 000 times greater than the minimum failed to damage the instrument. The instrument described is already quite small ($4 \times 4 \times 6$ in.), but improvements in its design could reduce the size still further.

Progress in polarized relay development has been towards ever more sensitive instruments. This has resulted in so-called moving-coil relays as now manufactured by several firms.[1,2,3,4,5] The power needed to actuate such relays amounts to about 10 μW, their sensitivity of response is roughly 0·2 mA and their maximum allowable input current about 40 mA. The highest power which may be applied to such instruments is 8 W. Here, therefore, the ratio between the maximum output and the input which just suffices to actuate the instrument, the so-called power amplification, is equal to about 800000 : 1, while the overload capacity, the ratio between the maximum current which may be supplied to the coil of the relay and the minimum current to which the relay will respond, is about 200 : 1.

If both these quantities were appreciably bigger, the relay could be incorporated into many different kinds of measuring instruments. It could be used to give an alarm when activated by very small signals or to drive a servomechanism which