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APPARATUS FOR THE PICK-UP AND RECORDING OF THE CARDIAC FUNCTION, OR OF SLOW PROCESSES OF MOTION IN OTHER ORGANS OF THE HUMAN OR ANIMAL BODY, POSSIBLY IN LIFELESS BODIES

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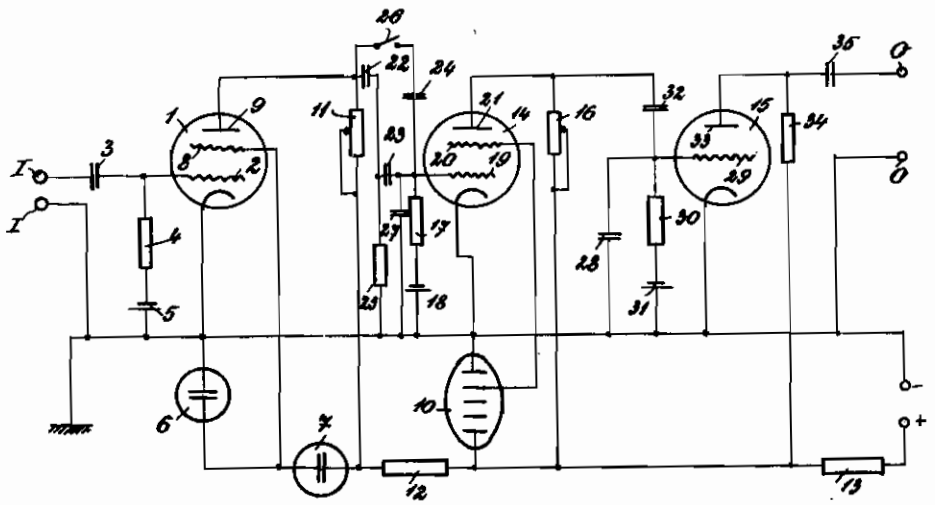

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APPARATUS FOR THE PICK-UP AND RECORDING OF THE CARDIAC FUNCTION, OR OF SLOW PROCESSES OF MOTION IN OTHER ORGANS OF THE HUMAN OR ANIMAL BODY, POSSIBLY IN LIFELESS BODIES

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So called electro-cardiographs for the pick-up and recording of the cardiac function are already known, in which the electric voltage impulses induced by the work of the muscles of the heart are transferred on the luminous screen of a cathode ray tube or on an electro-mechanical device e. g. on a galvanometer, and in which the variation as a function of time of the voltages is traced on a film band kept in uniform motion. In view of the fact that in electrocardiography the peak values of the differences of potential between the electrodes do not amount to more than to about 2–3 millivolts, an amplifying apparatus comprising a number of stages is required in order to enable these voltage impulses to operate the recording device which possesses a relatively low degree of sensitivity. In the equipments of known types the necessary supply of heating and anode current is supplied by batteries forming part of the equipment. A drawback of this arrangement is that owing to the rapid diminution of voltages possible in the case of these batterles the amplification is, immediately after putting the apparatus in circuit, exposed to fluctuations, by which recording is rendered unreliable, the voltage condition of the batteries themselves being in general unknown to the attendants. Experiments have shown that it is possible to avoid the fluctuations of amplification if the voltages required for feeding the amplifier tubes are derived from the electric mains system (if necessary from a motor-car storage battery) and if for stabilizing the anode and grid direct voltages of at least the first (input) amplifier tube at least two mutually consecutive filtering stages having high time constant are employed, at least one filtering stage consisting of a voltage-stabilizing tube or tubes, whilst the remaining filtering stages either consist of a voltage stabillzing tube or tubes likewise, or of a voltage-stabilizing transformer, a motor-generator having a sufficient degree of inertia, or a circult arrangement comprising electronic tubes, e. g. a reflex circuit arrangement of stabilizer tubes.

The diagram of connections of an embodiment shown by way of example of the apparatus according to the invention is represented on the accompanying drawing.

On the drawing, **1** denotes the first (input) amplifier tube, without the device for heating the cathode, whilst **14** denotes the second and **15** the third amplifier tube. As, in the case of apparatus for examining the cardiac function, it is essential that the fluctuation of the feeding voltages, expressed for the control grid of the first amplifier tube, should be smaller than 0.03 millivolt, a tube having a high degree of amplification, corresponding to D <3% preferably a screen grid tube is employed in the first amplifier stage. The voltage to be amplified which is admitted to the apparatus through the terminals J—J is impressed through the condenser **3** on the control grid **2** of this tube. The bias voltage of the control grid **2** is supplied by the battery **5** by means of the resistance **4**. The feeding voltage for the anode **9** and for the screen grid **8** of the amplifier tube **1** is stabilized in the first stage by the series resistance **13** and by the four-stage stabilizer tube **10**, whilst the second stage of stabilization is attended to by the stabilizer tubes **6** and by the series resistance **12**. The current consumption of the stabilizer tube **10** in the first filtering stage is higher (amounting to about 30–50 milliampères) than the current consumption of the stabillzer tubes **6** and **7** of the second filtering stage (amounting to about 5–10 milliampères), which circumstance preferably also finds expression in the dimensions of the tubes in question. The stabilizer tubes **6** and **7** employed in the second filtering stage may possibly be dispensed with, and in the remaining filtering stages it is possible to employ voltage stabilizing transformers, circuit arrangements comprising electronic tubes e. g. reflex circuit arrangements of stabilizer tubes or motor generators possessing an adequate amount of mechanical inertia, the feeding of the last-named apparatus being effected by means of the alternating or direct current mains system or possibly by means of a motor car storage battery of 6 to 12 volts.

The working point of the screen grid tube **1** in the first amplifier stage should according to the invention preferably be adjusted in such a manner that relatively to the anode the fluctuations of the anode and of the screen grid direct voltages should exactly mutually balance. This desired adjustment will be reached if

$$\Delta Eg_2 \frac{\partial ia}{\partial eg_1} R_a - \Delta E_a = 0$$

in which formula ΔEg_2 is the fluctuation of the screen grid direct voltage, ΔE_a the fluctuation of the anode feeding voltage.

$$\frac{\partial ia}{\partial eg_2}$$

is the degree of steepness of the anode current expressed as a function of the screen grid voltage and R_a the working resistance in the anode cir-

cult, which latter is marked 11 on the drawing. In order to enable the compensation described above of the voltage fluctuations to be achieved, the anode resistance 11 is constructed as an adjustable resistance. The calculation shows that in the case of the usual high-frequency pentodes the working resistance has to be adjusted between 50,000 and 100,000 ohms, in order to achieve compensation.

In the second amplifier stage the screen grid tube 14, and, respectively, in the third amplifier stage the triode 15 are working with voltages stabilized in one stage only, the said stabilization being taken care of by the stabilizer tube 10 and by the series resistance 13. The anode resistance 16 of the screen grid tube 14 is adjustable likewise, in the same way as the anode resistance 14 in the first amplifier stage in order to enable the working point of the amplifier tube 14 to be adjusted in such a manner as to ensure that the fluctuations of the feeding voltages of the anode and of the screen grid, respectively, should just exactly mutually balance. The control grid 19 of the amplifier tube 14 receives the bias voltage from the battery 10 by means of the resistance 17. The feeding voltages for the anode 21 and for the screen grid 20 of the amplifier tube 14 are stabilized by means of the stabilizer tube 10 and the series resistance 13. The control grid 29 of the triode 15 receives the bias voltage from the battery 31 by means of the resistance 39, whilst the control voltage itself is admitted to the control grid 29 through the condenser 32. The anode 33 works on the resistance 34, whilst the amplified voltage is admitted to the recording device at the terminals O—O by means of the condenser 35.

The condensers 22, 23, 24, 27 and 26 as well as the resistance 25 and the switch 26 are employed for influencing the width of, i. e. for altering, the band of frequencies passed by the amplifier. It is possible to assure by these means that the amplifier should pass those frequencies only, which are essential, e. g., in the recording of the cardiac function, the frequencies of the heart sound: 20 to 400 Hertz, and the frequencies of the electro-cardiogram: 0.5 to 40 Hertz. The adjustment of the desired band of frequencies is preferably effected by means of a number of members (C—R) composed of condensers and resistances.

Experiments have shown that at least by way of first amplifier tube and of stabilizer tubes it is necessary to employ tubes of such a kind the essential electrodes of which are constructed as low in microphony as possible and/or to fix these tubes in a resilient manner. The anode and grid bias voltages of the amplifier tubes in the second and further amplifier stages should be stabilized at least in one stage by means of low-frequency filtering with the aid of stabilizer tubes, it being possible to employ, partly or entirely, the same stabilizer tube or tubes for the stabilizing of the feeding voltages of the various amplifier stages. The control grid bias voltage of the amplifier tubes can be produced by means of the voltage drop in one cathode resistance, or supplied from a stabilized voltage; the bias voltage of the first amplifier tube and possibly also those of further amplifier tubes should preferably be taken from a battery, possibly by means a voltage divider of high resistance.

For the calibration of the amplifier it is possible to derive alternating voltage, preferably by means of a resistive voltage divider, from the heating voltage of the amplifier tubes, it being possible to impress the said calibrating voltage on the control grid of the first amplifier tube.

If in the apparatus, recording is effected by means of a cathode ray tube, it is preferable to employ a cathode ray tube of such a type the fluorescent screen of which emits blue light for the purposes of taking photographs, and green, yellow or white light for the purposes of direct observation, or in which a secondary luminous surface is employed. As the inertia of the human eye amounts to about one-eighth of one second, the time constant of the luminous substance emitting the green, yellow or white light should be greater than one-third of one second. The voltage to be graphically recorded is impressed to one of the pairs of deflecting plates of the cathode ray tube, whilst in the case of direct observation a saw-tooth voltage is impressed on the other pair of deflecting plates, the frequency of which saw-tooth voltage can be synchronized with that of the heart-beat. As the period of one heart-beat may vary between about 0.2 and 2 seconds, the saw-tooth voltage generator should be constructed in such a manner as to enable the period of oscillation to be adjusted at least between 0.5 and 2 seconds. The capacity of the condenser, periodically charged and discharged for producing the saw-tooth voltage should be assumed at a value higher than 2 micro-farads.

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