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ELECTROCARDIOGRAPH APPARATUS

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Fig. 1.

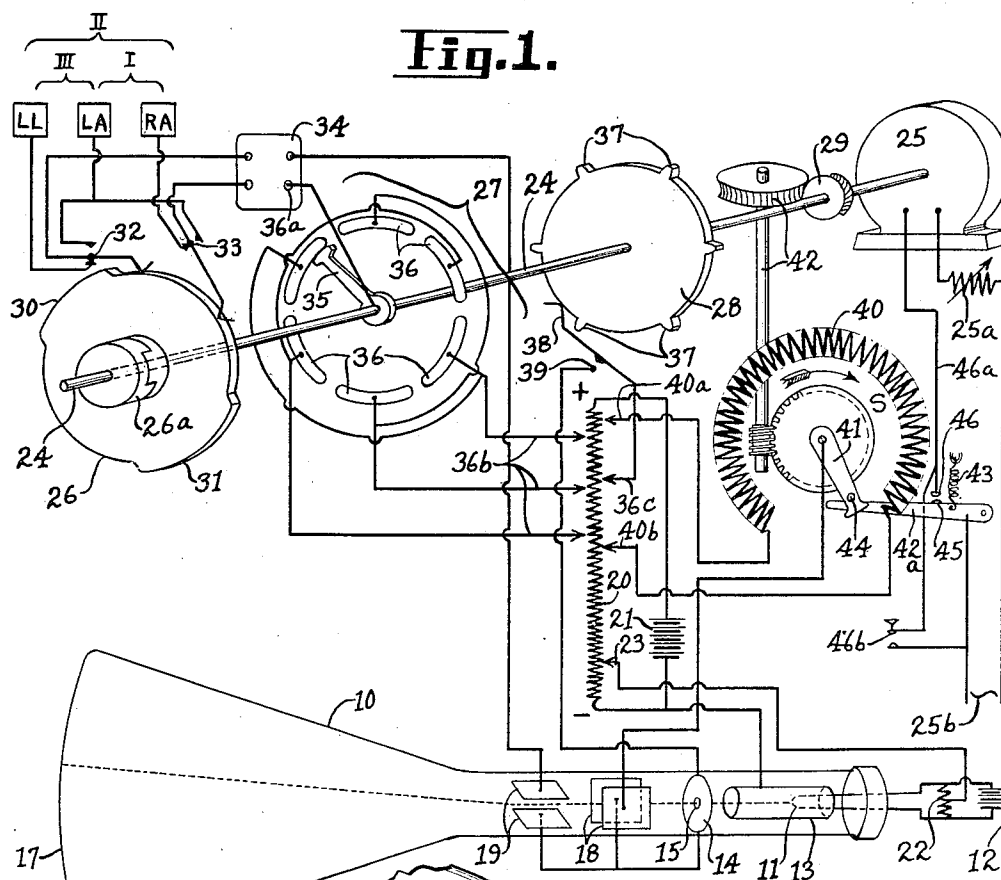
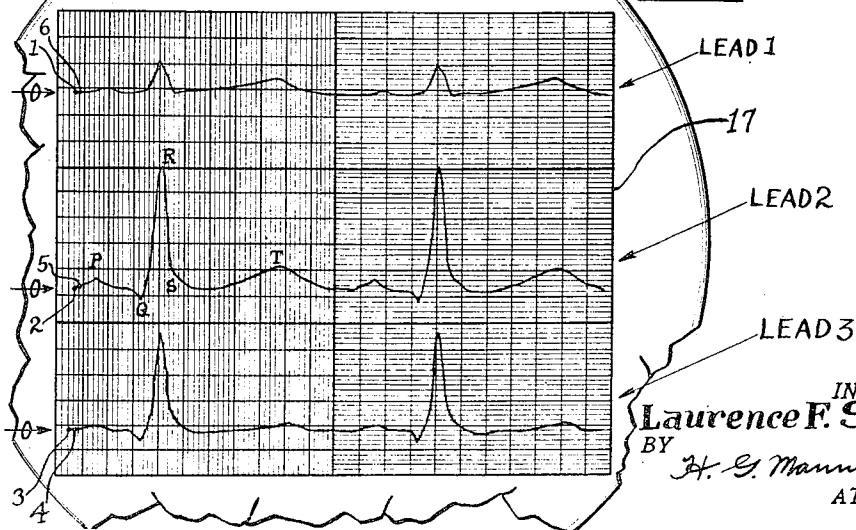


Fig. 2.



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ELECTROCARDIOGRAPH APPARATUS

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13 Claims. (Cl. 128—2.06)

This invention relates to electrical indicating, measuring, and recording apparatus, and more particularly to a portable electrocardiograph in which curves representing the minute heart voltage impulses are made visible on the fluorescent screen of a cathode-ray tube.

One object of this invention is to provide an electrocardiograph in which graphs representing the voltages from each of the three "leads" may be simultaneously observed on the fixed screen of the cathode-ray tube, and by which a permanent record of said graphs may be obtained if desired by direct printing upon a photographic plate or film held in contact with said screen.

A further object is to provide a device of the above nature, having means for magnifying any portion of the curves to any degree desired, within the limits of the size of the fluorescent screen.

A further object is to provide a device of the above nature, which will be simple in construction, inexpensive to manufacture, compact, readily portable, rugged to withstand rough handling, easy to assemble and manipulate, and very efficient and durable in use.

With these and other objects in view, there has been illustrated on the accompanying drawing one form in which the invention may be conveniently embodied in practice.

In the drawing:

Fig. 1 is a view, partly diagrammatic and partly in perspective, showing an electrocardiograph apparatus embodying the invention.

Fig. 2 is an end view of the cathode-ray tube, illustrating one form of the curves or graphs which may be exhibited thereon.

It is well known that the muscle movements of the human heart are accompanied by changes in electrical potential of the order of 0.001 volt, and which can be measured and recorded only by extremely sensitive instruments. Prior to the present invention, this was accomplished by the use of ultra-sensitive instruments provided with delicate galvanometers. These instruments were quite expensive due to the heavy and rigid frames required to prevent undesired vibrations, and the high power optical and camera systems necessary to magnify and record the indications.

While the action of the heart produces changes of potential at all parts of the body, it has been found that the most complete information is given from three electrocardiograms taken at the following points: right arm and left arm; right arm and left leg; and left arm and left leg. These pairs of connections are usually termed "Leads" I, II, and III respectively, and the corresponding

graphs are named accordingly. With previous electrocardiographs, it was not possible to obtain records from more than one lead at a time, and it was customary to obtain records of the three leads on a single film in succession. The three records thus obtained were not simultaneous, and failed to indicate the time-phase relationship among the phenomena associated with the respective "leads".

Moreover, due to inertia, the movable indicating parts of galvanometers had a natural period of vibration, which though it might be damped to some extent, could never be entirely eliminated, and when the resonant period of the string or other ponderable moving galvanometer part was approached, the deflections would be distorted.

While the development of the thermionic amplifier has enabled the use of a more rugged type of galvanometer, the inertia in the moving parts and the necessity for an optical train, a camera, and a separate source of illumination remain.

In the present invention the above and other disadvantages have been overcome by amplifying the heart voltages with an electron tube amplifier and then rendering them visible or suitable for photographing or printing by means of a cathode-ray tube. Moreover, by providing suitable rapidly operating switching apparatus, the inherently rapid response of the cathode-ray tube is utilized to simultaneously exhibit in parallel relationship the characteristic curves from all three leads commonly used in a complete electrocardiogram.

Referring now to the drawing in which like reference numerals denote corresponding parts throughout the several views, the numeral 10 designates a cathode-ray oscillograph tube of the conventional type now on the market having a heated filament 11, energized from a low voltage source, such as a battery 12, said filament being enclosed by a small cylindrical metal tube 13 open at both ends. A short distance in advance of the tube 13 is a metallic anode disc 14 having a central orifice 15.

In order to cause electrons emanating from the filament 11 to travel in a narrow beam through the orifice 15 of the disc 14, the tube 13 is connected to the negative terminal of a source of high voltage, preferably having a magnitude of several hundred volts, such as the battery 21. The tube 13 will thus be maintained at a potential somewhat lower than that of the filament 11, causing the beam of electrons to be impelled toward the anode disc 14 with a high velocity

depending upon the potential difference between the cathode filament 11 and the anode disc 14.

A slender beam of electrons will thus be caused to emerge from the orifice 15 and travel to the end of the tube 10, where it will impinge upon the wall 17 thereof, which is preferably coated on the inside with fluorescent material. The end wall 17 preferably has a suitable scale marked on the exterior thereof (see Fig. 2), and constitutes a screen upon which the movements of the electron beam may be observed.

Two sets of perpendicularly disposed deflector plates 18 and 19 enclose the path of the electron beam, one plate of each set being electrically connected to the anode disc 14, so that by applying potentials to the other plates of each pair not so connected, the beam of electrons will be deflected horizontally by the potentials applied to the plates 18, and vertically by the potentials applied to the plates 19. The light spot produced by the electron beam will thus be caused to take a position on the screen corresponding to the instantaneous magnitudes of the two deflecting potentials.

An adjustable tapped resistor 20 of the "potentiometer" type is connected across the terminals of the battery 21 with the positive terminal adjustably connected to the disc 14. A resistor 22 is placed across the terminals of the filament 11, and is connected at its mid-point to a sliding contact 23 on the potentiometer 20. By means of this arrangement, the potential difference between the filament 11 and the cylinder 13 may be closely adjusted to the optimum value for accelerating the stream of electrons as much as desired.

A shaft 24 adapted to be rotated at a velocity of about 3,600 R. P. M. or higher, is driven by an electric motor 25 controlled by a variable resistance 25a connected to one side of a power line 25b. The shaft 24 carries a selector cam 26 (which is connected to said shaft by a clutch 26a), a distributor switch arm 35, a toothed contactor disc 28, and a worm gear 29.

Selector cam

The selector cam 26 has upon its periphery a pair of oppositely disposed lobes 30 and 31, each spanning substantially 60 degrees of the circumference of said cam. Associated with the lobes 30 and 31, and adapted to be engaged and actuated thereby, are a pair of double-throw contactors 32 and 33 which, as shown in the diagram, are electrically connected to the "patient" terminals "LL" (left leg), "LA" (left arm), "RA" (right arm), and also connected to a variable audion amplifier 34, which may be of any standard form well known in the art. It will be seen from this arrangement that as the selector cam 26 rotates, the three "leads" I (RA—LA), II (RA—LL), and III (LA—LL) will be successively connected to the input terminals of the variable amplifier 34.

The type of amplifier preferred is one having an oscillatory electric circuit, the output of which is modulated by the variable voltages under investigation, and in which said oscillatory current is filtered out after a sufficient number of stages of amplification, so that only the amplifier variable voltage will remain at the output terminals of the amplifier. This method of amplification possesses two great advantages in electrocardiographic work, one being that steady voltages due to the so-called skin effect, and the body resistance of the patient will not generally be car-

ried through the amplifier system, and hence will not affect the deflections of the cathode-ray tube.

A further advantage is that ordinary relatively inexpensive "radio" amplifying tubes may be employed, instead of special costly "low-noise level" tubes which were necessary in former types of electrocardiograph apparatus using non-modulating circuits.

Another advantage is that said amplification may be effected over a relatively wide range without distortion of the wave form of the applied voltage.

Distributor

The distributor 27 comprises a rotating contact-arm 35 traversing in succession six contact segments 36 and connected to one output terminal 36a of the amplifier 34. Thus, as the arm rotates, the output terminal 36a will be successively connected with each of the contact segments 36 and through them to three adjustable sliding contacts 36b, engaging the resistor 20. The arrangement is such that each of the three "lead" voltages, after amplification, is impressed upon the resistor 20 at a different one of three selected points 36b, and each lead thus has a different characterizing potential bias introduced into its circuit for locating the base lines of each curve, as indicated by the three arrows on Fig. 2. The distributor 27 and the selector 26 are so synchronized that the duration of contact of the arm 35 with each segment 36 corresponds with the time that one of the "leads" is connected to the amplifier circuit, and the transitions between connections in the two switches 32 and 33 occur at substantially the same instants of time.

Contactor

The contactor 28 carries upon its periphery a plurality of toothed projections 37 adapted to engage a resilient contact spring 38 for intermittently closing a contact 39 which is in series with the connection between the anode disc 14 of the cathode-ray tube and its point of connection 36c to the resistor 20. As the cathode-ray tube will function only when its anode disc 14 is maintained at the proper potential, it will be apparent that the electron beam will be caused to impinge upon the fluorescent end screen 17 only when the contact 39 is closed, and also that the pattern upon the screen will be a row of closely spaced light spots rather than a continuous line.

The contactor 28 is so synchronized with the selector cam 26 and the distributor 27 that the contact 39 will be closed only when both of them have established their circuits. When no voltage is applied to the "leads", there will of course be no output from the amplifier and the position of the three spots will represent merely the voltage differences between respective segments on the distributor 27, such differences being determined by the adjustments of the sliding contacts 36b on the resistor 20 and the potential of the adjustable contact 36c connected to the contact 39. Thus, the spots will be flashed in rapid succession upon three vertically disposed points on the screen, and owing to the persistence of vision, will appear to the eye as three steady points of light.

When the "heart voltages" are introduced into the system from the "leads" I, II and III, said voltages will be successively amplified by the amplifier 34, one terminal of which is connected

to one of the plates 19, and, by means of the distributor 27, will be connected with the three sliding contacts 36b, so that the three points will spread out into three aligned vertical lines upon the screen constituting the ordinates of the curves which represent the variations of the potentials under investigation.

In order to provide abscissae for the curves, there is provided a "sweep circuit" apparatus S, adapted to impress upon the plates 18 a continuously varying potential for causing the electron beam to be progressively displaced in a horizontal direction across the screen, and thus spreading the resulting light spots from left to right. The three spots above referred to will thus be resolved into the three curves accurately representing the heart beat voltages of the patient.

As herein disclosed the sweep circuit apparatus S consists of a circular potentiometer-type rheostat 40 having a definite wide gap between its ends. The rheostat 40 is adapted to be traversed by a rotating contact arm 41, driven from the shaft 24 through the worm gear 29 and a speed-reducing train 42, at a speed about one-360th of that of the shaft 24. The terminals of the rheostat 40 are connected to adjustable sliders 40a and 40b widely spaced apart on the resistor 20, and the arm 41 is connected to one of the plates 18.

It will be understood that, if desired, a reversing switch, not shown, may be employed to change the polarity of the ends of the sweep resistor 40, in which case the direction of sweep will be from right to left and the cardiograms will appear right-side up when photographed upon a contact print.

It will be seen from this construction that as the arm 41 traverses the rheostat 40, its potential and that of the plate 18 connected therewith will vary from that of one of the terminals of the rheostat to that of the other, causing the electron beam to be swept horizontally across the screen. The curves thus thrown upon the screen will have an appearance somewhat as shown in Fig. 2. The zero positions of the three curves corresponding to the three "leads" are spaced in such a manner that each of the three leads will produce a separate curve on one of the three sections of the screen.

For example, when the circuits are completed for "lead III", the potentials at that instant will cause the beam to take up a momentary position, as (3), in the lower section of the screen. The beam will then be interrupted by the action of the contactor 28, and the electron beam extinguished until connections are made for "lead II". Contact will be then again made by the contactor 28, and the beam again flashed on the screen in the middle screen section. In the meantime, the potential of the plates 18 will have been varied by the movement of the arm 41 along the rheostat 40, giving a relatively slight horizontal displacement to the beam, and causing the spot to appear at the position (2) on the screen.

Similarly, the beam corresponding to "lead I" will appear at the point (1) in the upper screen section, after which the connections will return to that for "lead III", and the spot will appear at point (4) in the lower screen section. Similarly points (5) and (6), corresponding to "leads II and I", will be located in the middle and upper screen sections respectively. This cycle of operations will be repeated, producing a gradual progression of the curves across each of the three sections of the screen.

While the positions of the spots making up the curve representing any one "lead" are shown in the drawing as distinctly separate, they will actually occur in very close proximity to one another, and in such rapid succession as to give the impression of continuous lines.

In order to limit the operation of the contact arm 41 to a single sweep across the rheostat and thus avoid overlapping curves on the screen, provision is made of a circuit breaker comprising a lever 42a urged upwardly by a coiled spring 43 and adapted to be engaged by a pin 44 carried by the arm 41, said lever 42a also carrying a contact 45 which engages with a fixed contact 46 connected by a wire 46a to the motor 25. A push button switch 46b is also provided, the terminals of which are connected with the wire 46 and one side of the power line 25b.

It will be seen that when the contact arm 41, which rotates in a clockwise direction, completes its traverse of the rheostat 40, the pin 44 will engage the extremity of the lever 42a and force it downwardly against the influence of the spring 43, causing the contacts 45 and 46 to separate and open the circuit through the motor 25. The parts of the apparatus will then occupy the positions shown in Fig. 1.

In order to start the apparatus again, it will be necessary to close the push button switch 46b, manually or otherwise, to energize the motor. The arm 41 will then commence to move clockwise and will pass beyond the position of engagement with the lever 42a which will be snapped upwardly again by the spring 43, and will cause the contact 45 to once more engage the contact 46. The push button of the switch 46b can then be released and the sweep circuit arm 41 will continue to rotate across the rheostat 40.

While for the sake of convenience, batteries have been herein shown for the purpose of supplying current to the cathode-ray tube filament and voltage to the electrodes of said tube, it will be understood that in actual practice, such batteries will be generally replaced by a conventional transformer, rectifier, and filter system deriving power from an alternating current source.

One advantage of the present invention is that there will appear upon the screen of the cathode-ray tube three simultaneous graphs of the heart voltage from the three "leads" in their proper time-phase relationship, and these graphs will remain visible for a time sufficient to permit visual observation. If desired, a permanent record of the three curves may easily be made by a camera. It will also be possible to make direct prints of the graphs by placing a sensitized film, plate or printing paper in contact with the end wall of the cathode-ray tube.

While the present invention has been illustrated with reference to the indicating and recording of the electrical potentials produced during auricular and ventricular systole, it will be understood that it is not limited to such use, but can be applied for indicating and recording muscular potentials developed in any other part of the human body.

It may also be utilized to indicate and record potential changes occurring in the bodies of the lower animals. Moreover, it may also be employed to indicate and measure variations in potential developed during any other molecular, atomic, or electronic changes.

While there has been disclosed in this specification one form in which the invention may

be embodied, it is to be understood that this form is shown for the purpose of illustration only, and that the invention is not to be limited to the specific disclosure but may be modified and embodied in various other forms without departing from its spirit. In short, the invention includes all the modifications and embodiments coming within the scope of the following claims.

Having thus fully described the invention, what is claimed as new, and for which it is desired to secure Letters Patent is:

1. In an instrument for simultaneously exhibiting a plurality of graphs representing a plurality of variable electrical potentials, an audion tube amplifier, selector means adapted to successively impress upon said amplifier the voltage impulses derived from said potentials, circuits for superimposing characteristic biases on each of said impulses after amplification, distributor means for associating the individual potentials with their respective biases, a cathode-ray tube, and means for successively impressing said amplified and biased potentials upon the end wall of said cathode-ray tube.

2. In an electrocardiograph, a cathode-ray tube having an end screen upon which a beam of electrons is adapted to impinge, two pairs of deflector plates for providing horizontal and vertical displacement of the electron beam, an audion-amplifier, selector means to impress upon said amplifier in succession a plurality of varying heart potentials to be simultaneously exhibited upon said screen, means for superimposing a characteristic bias on each of said potentials after amplification, distributor means for associating individual potentials with their respective biases and impressing said amplified and biased potentials upon one pair of said deflector plates in succession, and a sweep circuit means for impressing upon the other pair of deflector plates a progressively varying voltage to cause said beam to trace upon said screen a plurality of graphs representing said electrical potentials.

3. In an electrocardiograph, a cathode-ray tube having an end screen upon which a beam of electrons is adapted to impinge, two pairs of deflector plates for providing horizontal and vertical displacement of the electron beam, an audion-amplifier, selector means to impress upon said amplifier in succession a plurality of varying heart potentials to be simultaneously exhibited upon said screen, means for superimposing a characteristic bias on each of said potentials after amplification, distributor means for associating individual potentials with their respective biases and impressing said amplified and biased potentials upon one pair of said deflector plates in succession, a sweep circuit means for impressing upon the other pair of deflector plates a progressively varying voltage to cause said beam to trace upon said screen a plurality of graphs representing said electrical potentials, and means for limiting said tracing action to a single period of variation of said sweep circuit voltage.

4. In an electrocardiograph, a cathode-ray tube having an end screen upon which a beam of electrons is adapted to impinge, two pairs of deflector plates for spreading providing horizontal and vertical displacement of the electron beam of rays into a plane, an audion amplifier, selector means to impress upon said amplifier in succession a plurality of varying heart potentials to be simultaneously exhibited upon said screen, means for superimposing a characteristic bias on each of said potentials after amplification, distributor

means for associating individual potentials with their respective biases and impressing said amplified and biased potentials upon one pair of said deflector plates in succession, a sweep circuit means for impressing upon the other pair of deflector plates a progressively varying voltage to cause said beam to trace upon said screen a plurality of graphs representing said electrical potentials, and means for initiating and automatically terminating the action of said sweep circuit.

5. In an electrocardiograph, an amplifier embodying an oscillatory electrical circuit, a cathode-ray tube, means to associate three potential "leads" of a patient successively with said amplifier, and means for exhibiting upon the end wall of said tube representations of the variable potential differences occurring in said "leads" in such rapid succession that said representations appear simultaneous.

6. In an electrocardiograph, an amplifier, a cathode-ray tube, means to associate three potential "leads" of a patient successively with said amplifier, and means for exhibiting upon the end wall of said tube representations of the variable potential differences occurring in said "leads" in such rapid succession that said representations appear simultaneous.

7. In an electrocardiograph, an audion amplifier, a cathode-ray tube, means to successively impress small heart voltages from three "leads" of a patient upon said amplifier, and means to cause the magnified voltages at the output of said amplifier to be separately displayed on the screen at the end of said cathode-ray tube at such a speed as to produce a plurality of apparently continuous cardiograms at the same time.

8. In an electrocardiograph, an audion amplifier, a cathode-ray tube, a rotary selector cam having high and low sections, a pair of double-throw switches having movable elements engaging said cam, said movable elements being successively operated by said high and low sections, the stationary elements of said switches being so connected to the three "leads" of the patient that the voltages from said leads will be successively impressed upon said amplifier, and means to separately impress the amplified voltages from said leads upon the cathode-ray tube to produce three simultaneous curves in actual time phase relationship.

9. In an electrocardiograph, an audion amplifier, a cathode-ray tube having an electron-emitting filament, two sets of deflector plates, means for amplifying small heart voltages from three "leads" of a patient in said amplifier in rapid succession and impressing them on one set of said plates, means for applying three biasing voltages to said set of plates in synchronism with said amplified voltages to separate the voltage indications into three aligned vertical lines on the screen of said tube, and means to apply a more slowly varying voltage to the other set of plates to cause said lines to spread out laterally and produce continuous cardiograms of the three "leads" at the same time.

10. In an instrument for exhibiting graphs of a plurality of variable electrical impulses, a cathode-ray tube, an amplifier, means to successively impress said impulses upon said amplifier, circuits to superimpose different biases on each of said impulses after amplification, and means for successively impressing said amplified and biased impulses upon the end wall of said cathode-ray

tube in such rapid succession that said impulses appear simultaneous.

11. In an instrument for exhibiting a plurality of graphs representing a plurality of variable quantities, an electric circuit, selector means adapted to successively impress upon said circuit the impulses derived from said quantities, means for superimposing characteristic biases on each of said impulses, distributor means for associating the individual quantities with their respective biases, a cathode-ray tube, and means for successively impressing said biased potentials upon the end wall of said cathode-ray tube.

12. In an instrument for separately exhibiting graphs of a plurality of variable quantities, a cathode-ray tube, means to produce a succession of electrical potentials corresponding to said quantities, means to superimpose different biases upon said separate quantities, and means for suc-

cessively impressing said separated biased potentials upon the end wall of said cathode-ray tube in such rapid succession that said impulses appear substantially simultaneous.

13. In an instrument for exhibiting in side-by-side relationship a plurality of graphs representing a plurality of variable electrical quantities, an amplifier, selector means adapted to successively impress upon said amplifier voltage impulses derived from said quantities, circuits for superimposing characteristic biases on each of said impulses after amplification, a cathode-ray tube, and means for successively impressing said amplified and biased impulses upon the end wall of said cathode-ray tube in such rapid succession that said impulses appear substantially simultaneous.

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CERTIFICATE OF CORRECTION.

Patent No. 2,098,695.

November 9, 1937.

LAURENCE F. SOUTHWICK.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, first column, line 68, claim 4, strike out the word "spreading"; lines 69 and 70, same claim, strike out "of rays into a plane"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 25th day of January, A. D. 1938.

(Seal)

Henry Van Arsedale,
Acting Commissioner of Patents.