

June 18, 1946.

A. M. SKELLETT

2,402,188

ELECTRONIC DEVICE AND CIRCUIT

Filed Dec. 9, 1941

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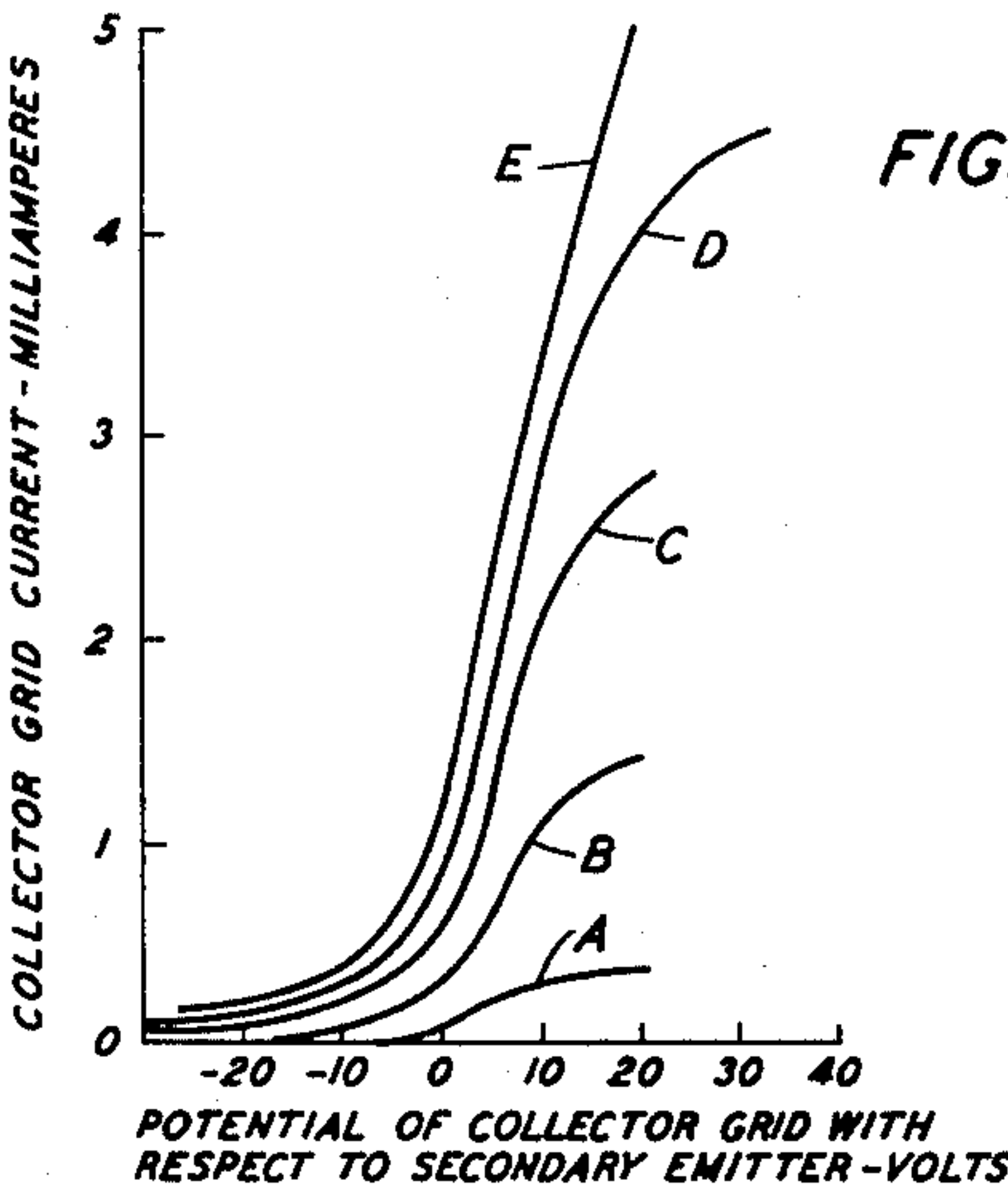
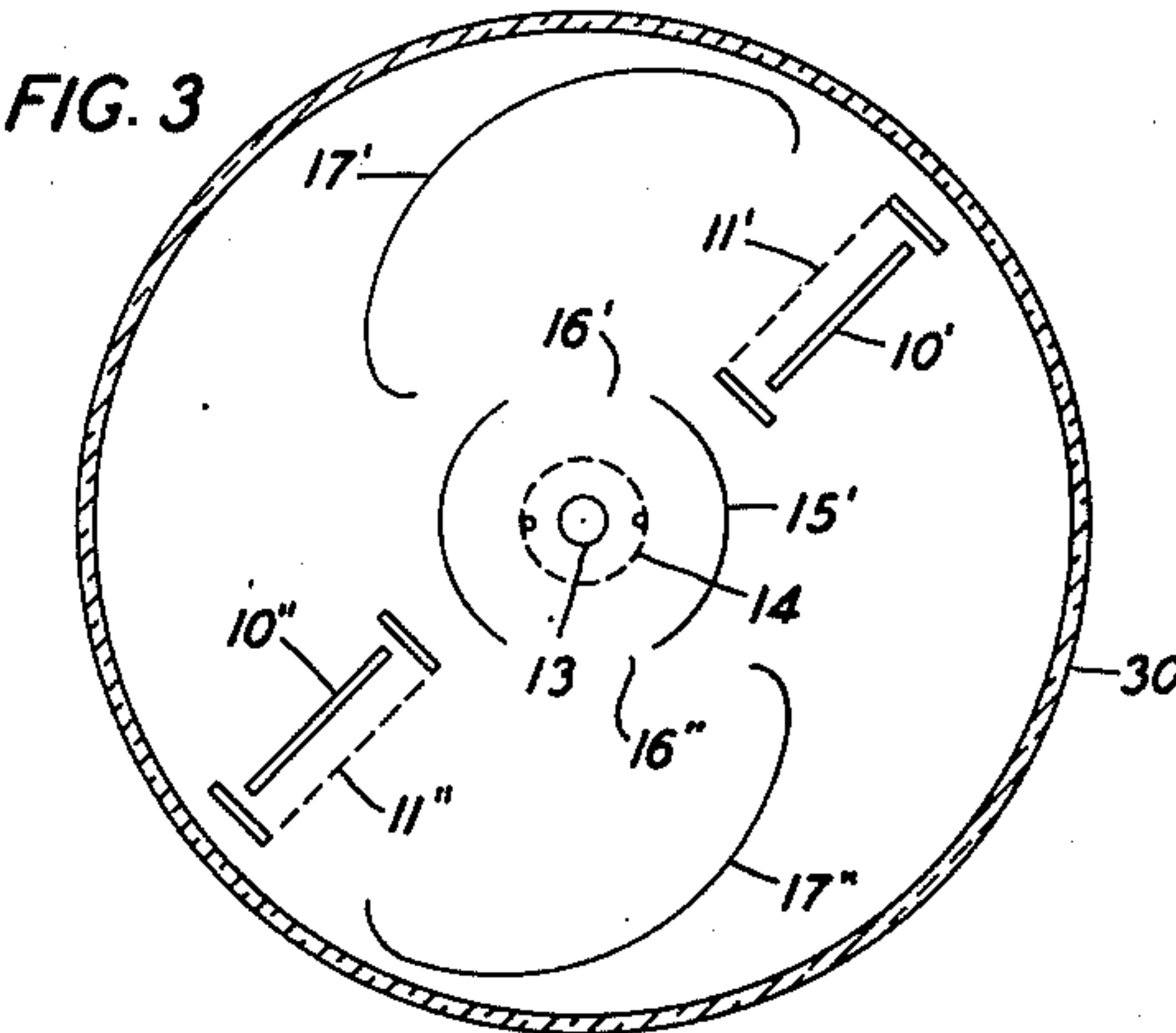
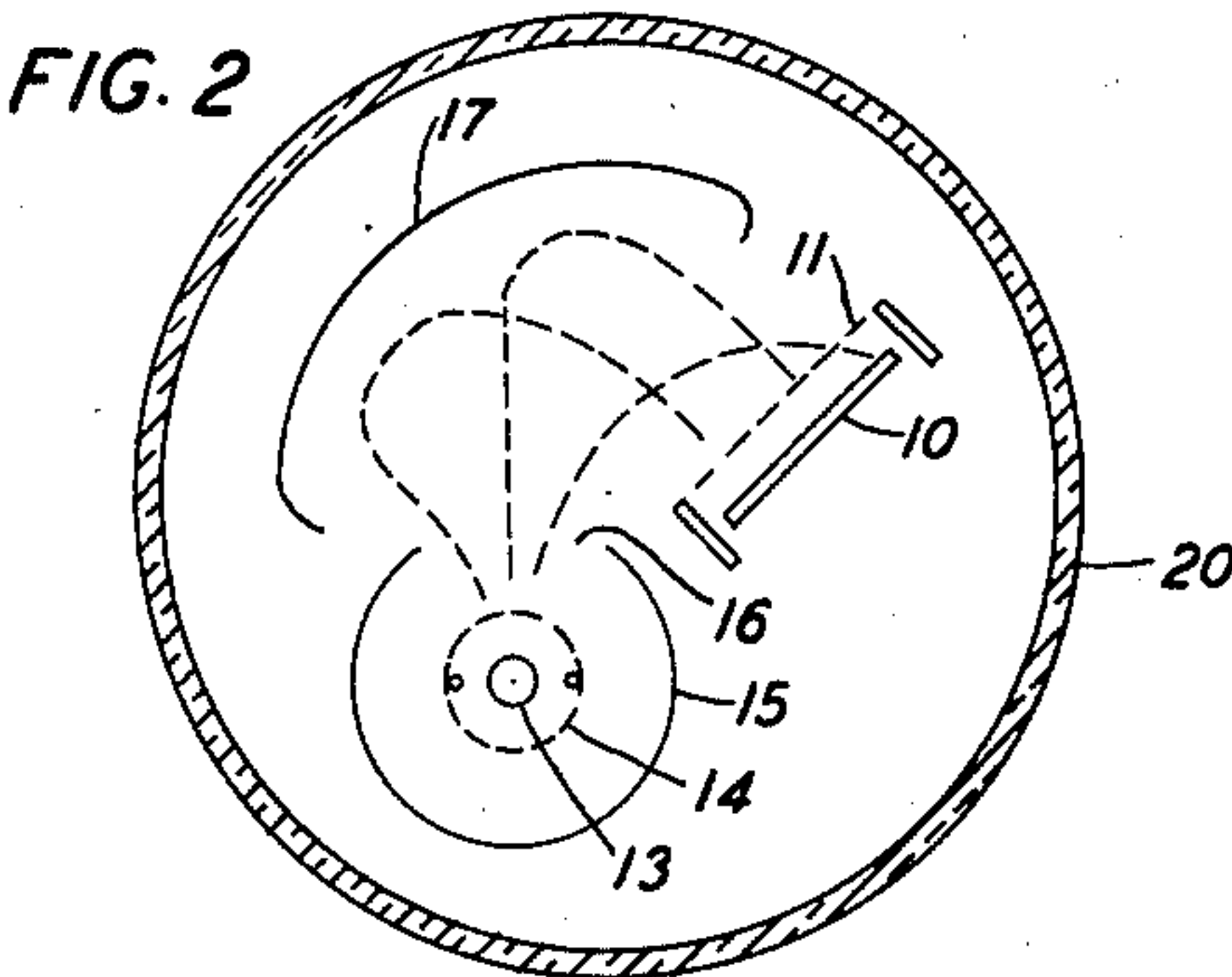
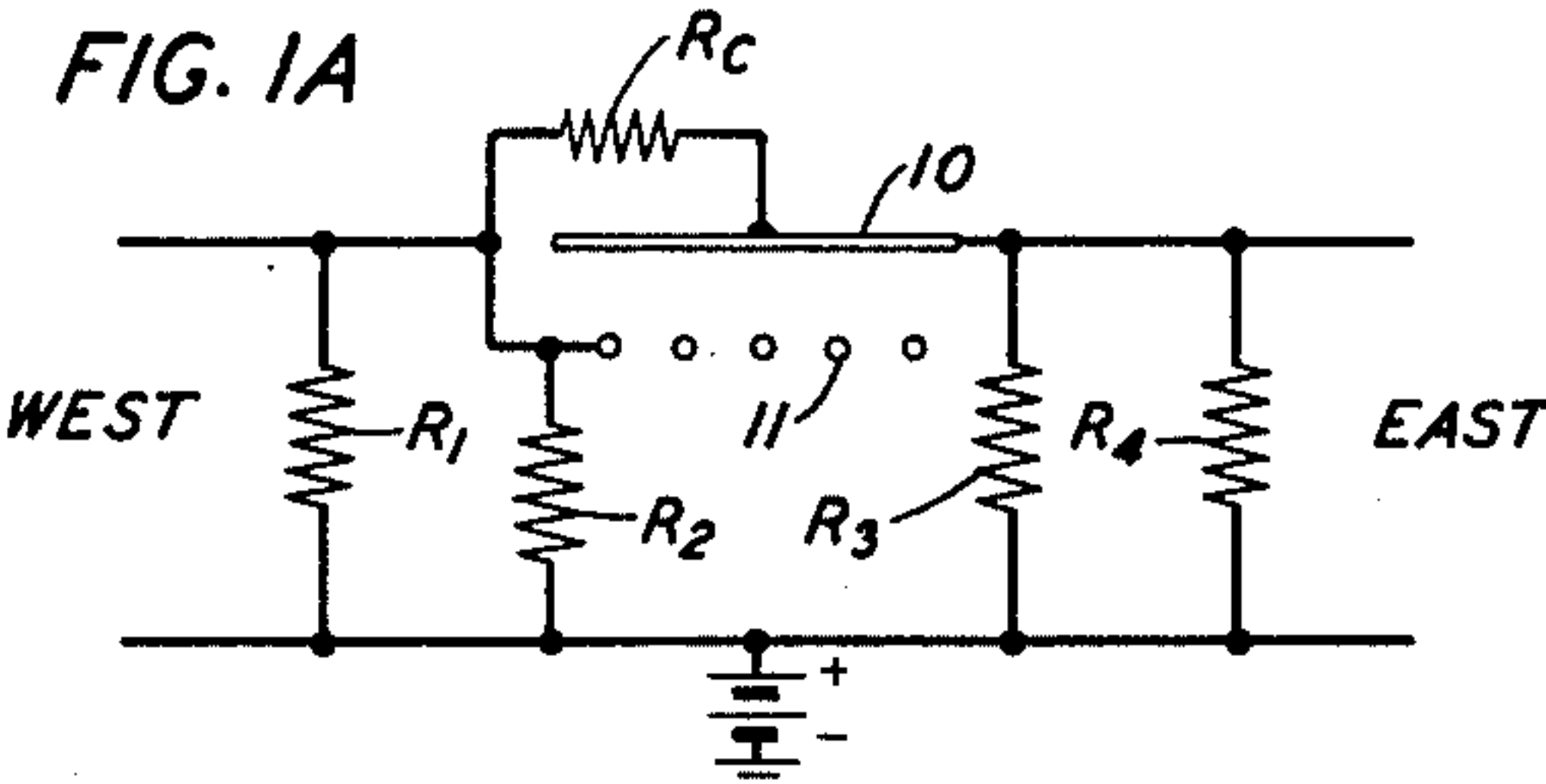
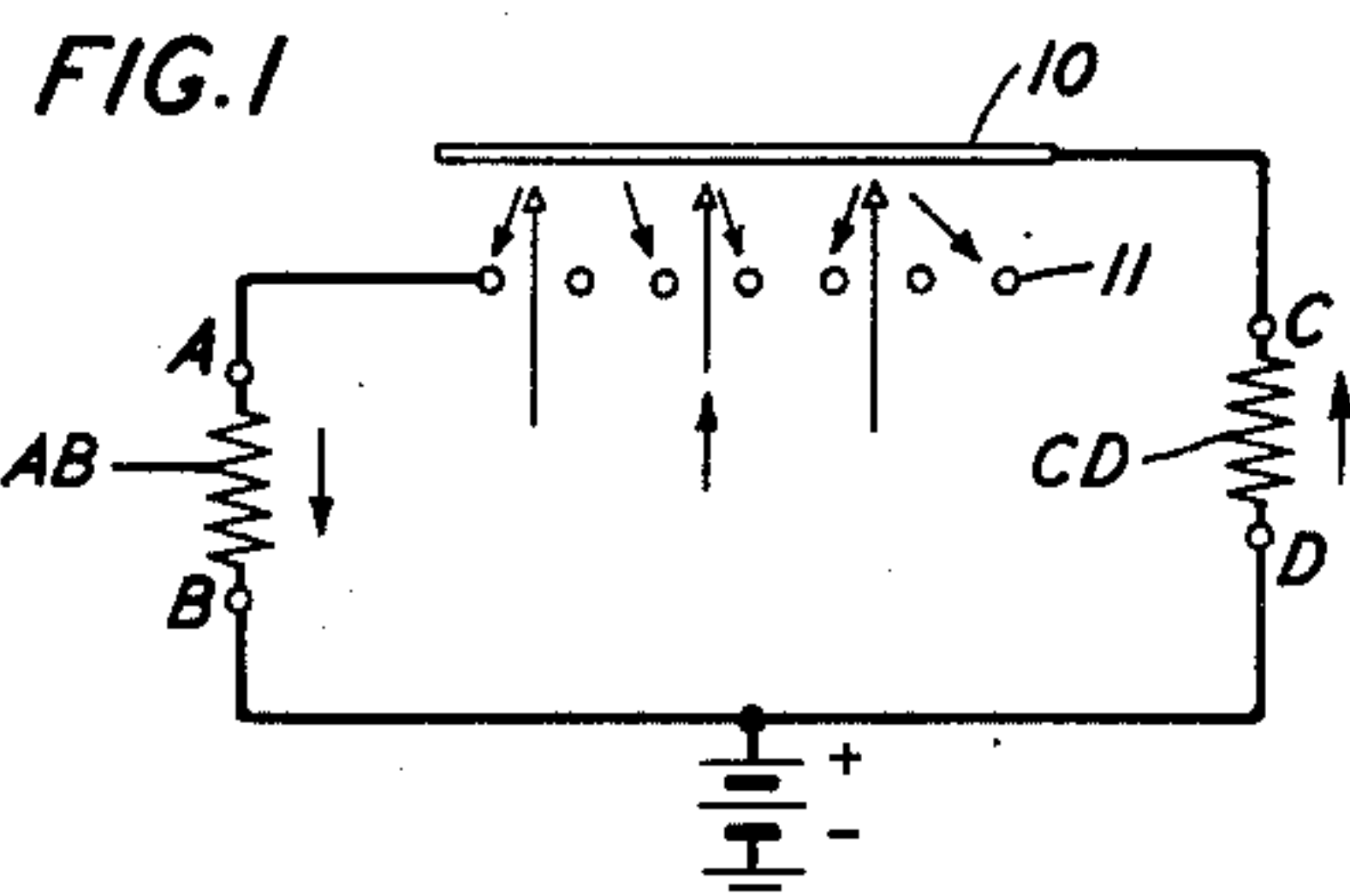
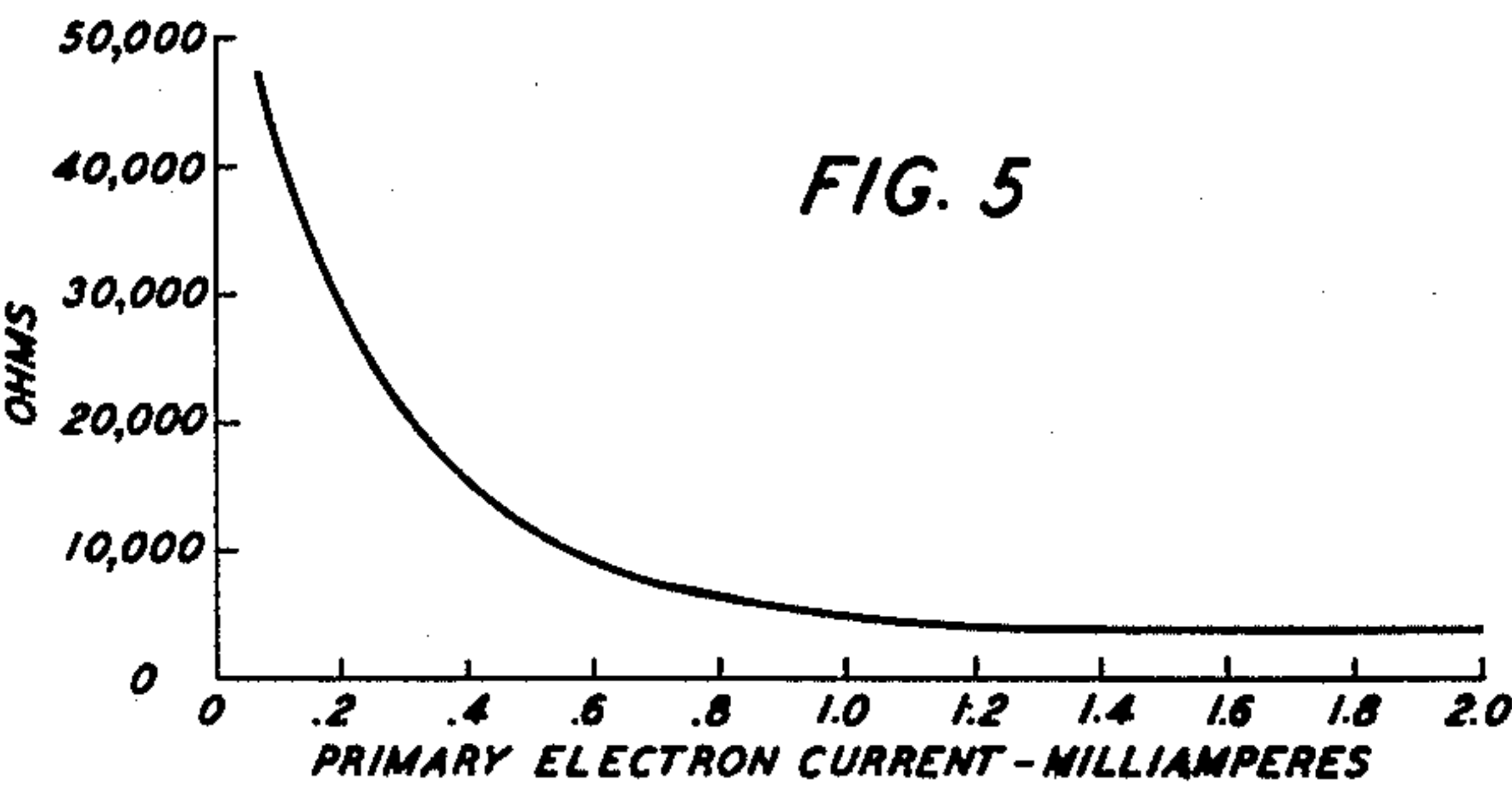


FIG. 4A

CURVE	PRIMARY ELECTRON CURRENT
A	0.1×10^{-3} AMPS.
B	0.5 "
C	1.0 "
D	1.5 "
E	2.0 "



INVENTOR
BY A. M. SKELLETT
Robert J. Fluskey
ATTORNEY

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FIG. 7

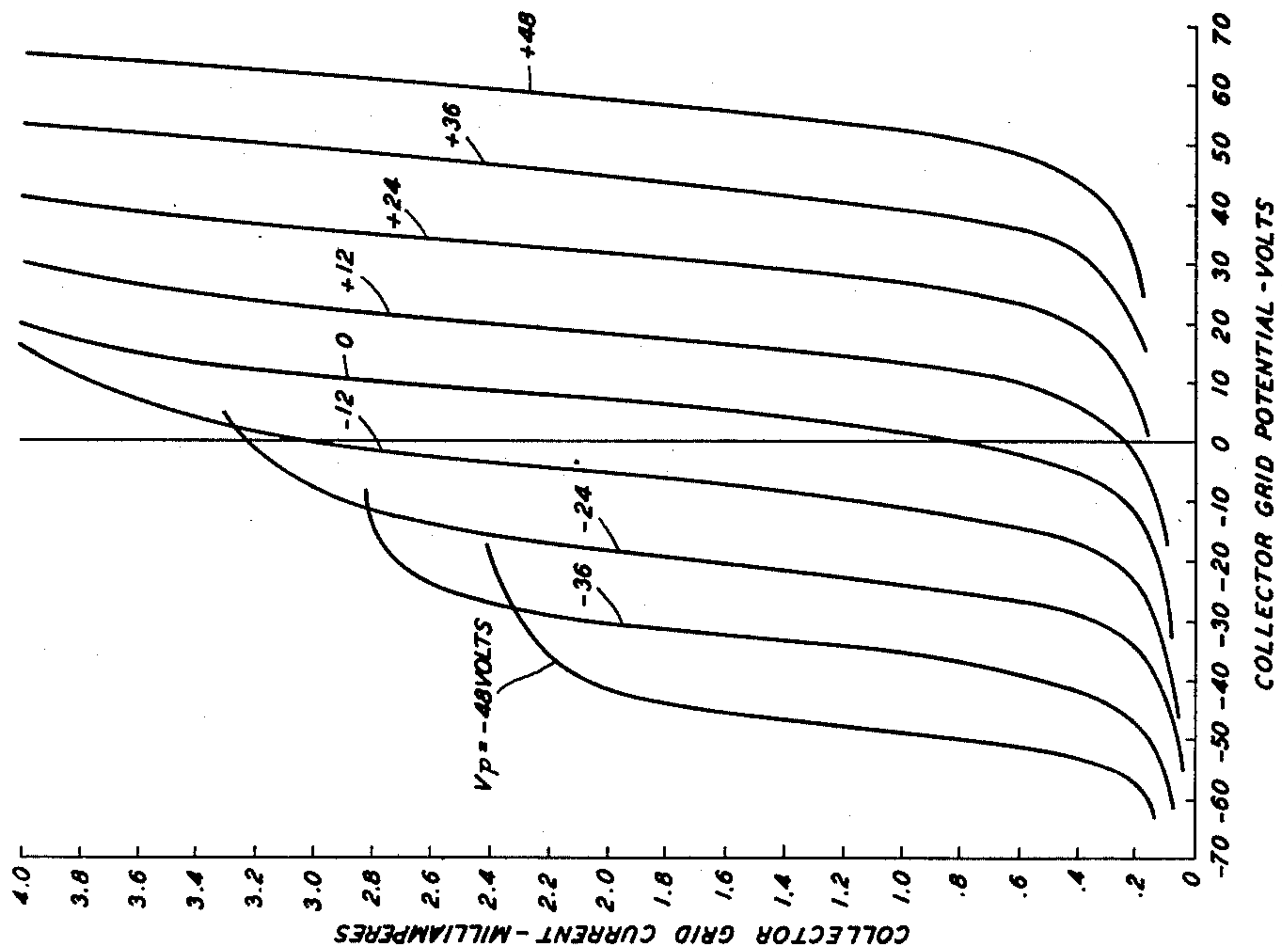
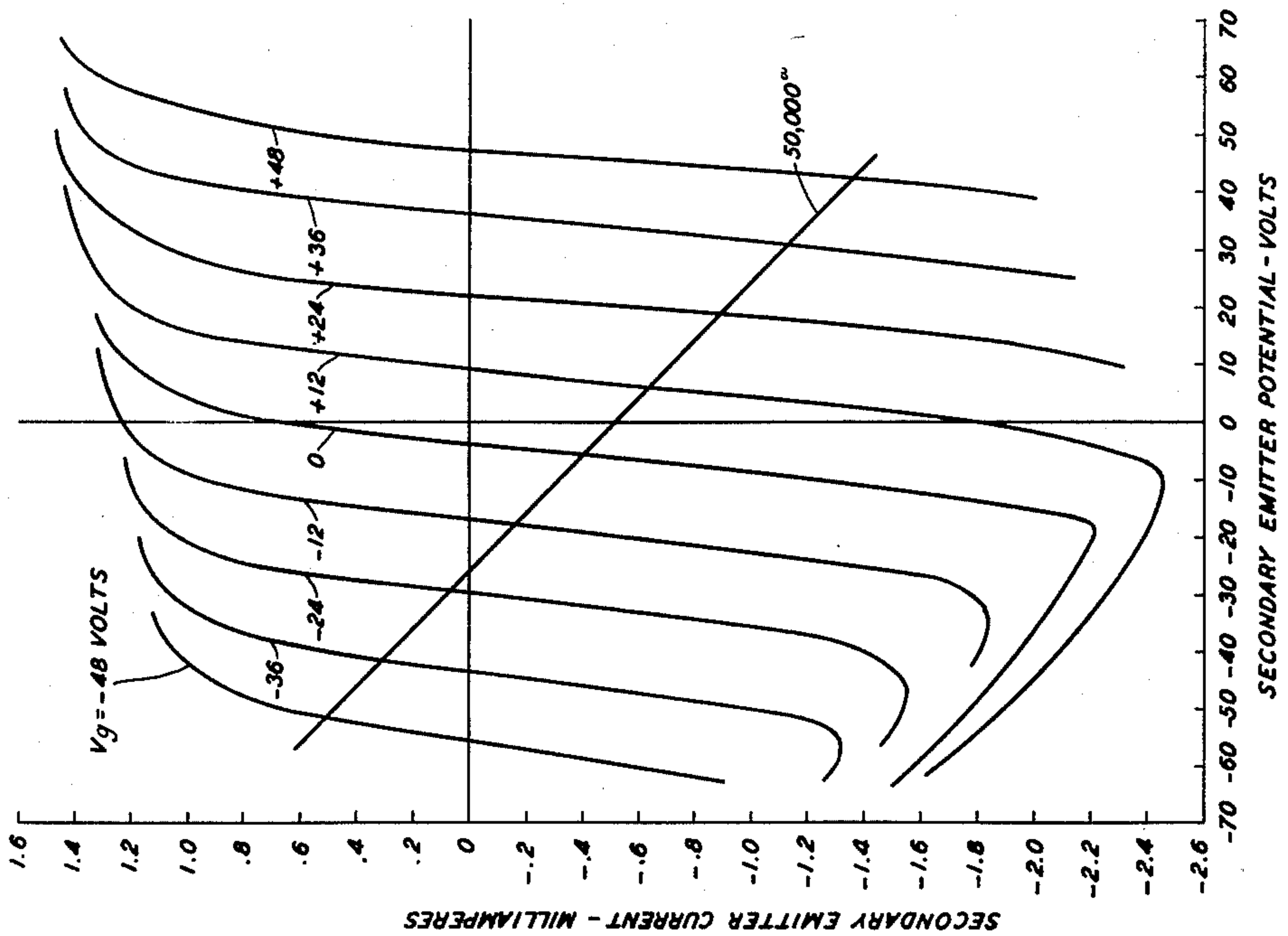


FIG. 6



INVENTOR
BY A. M. SKELLETT

Robert J. Aluskey
ATTORNEY

June 18, 1946.

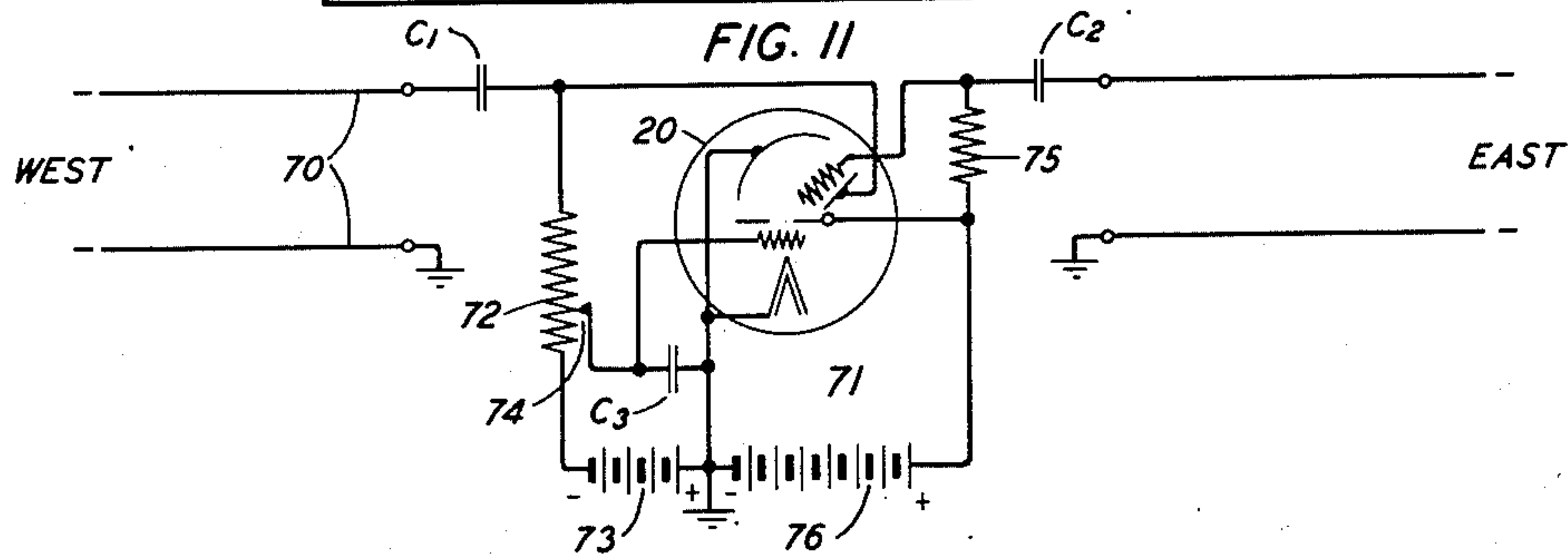
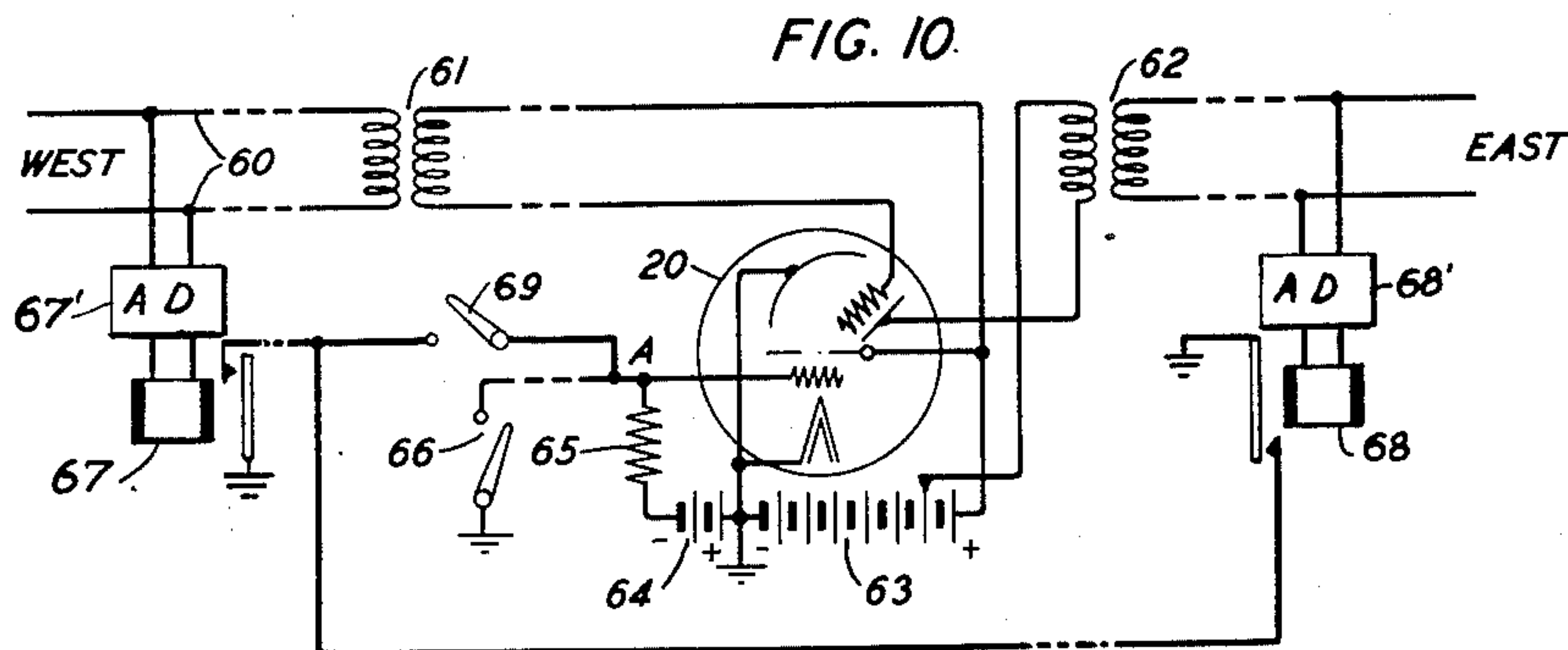
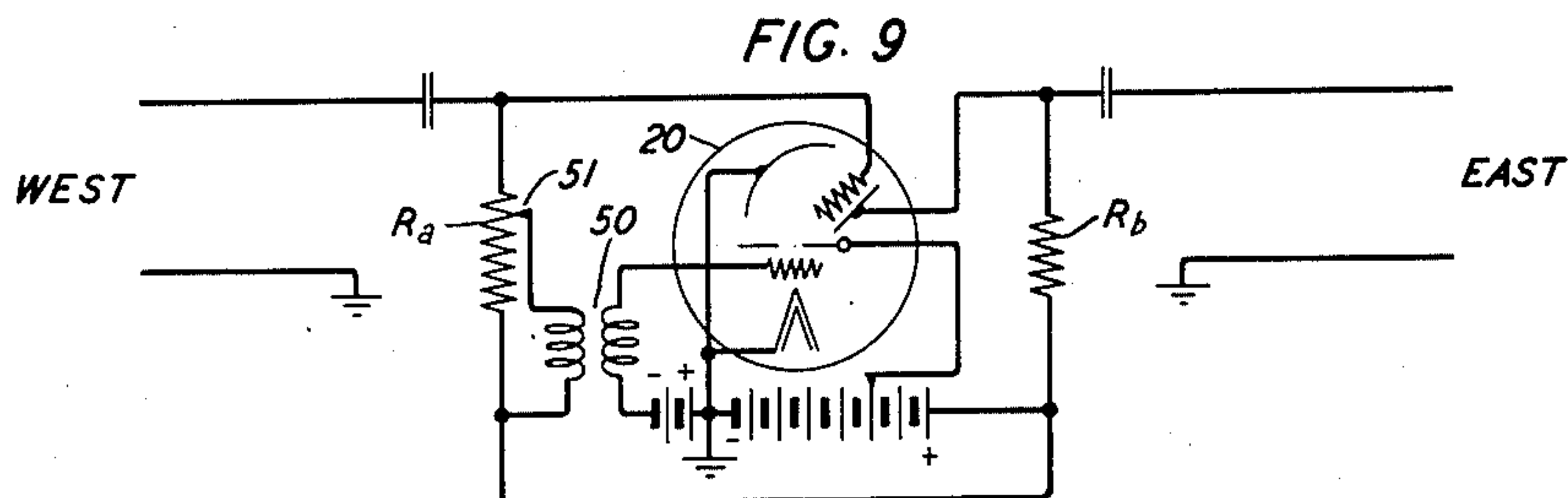
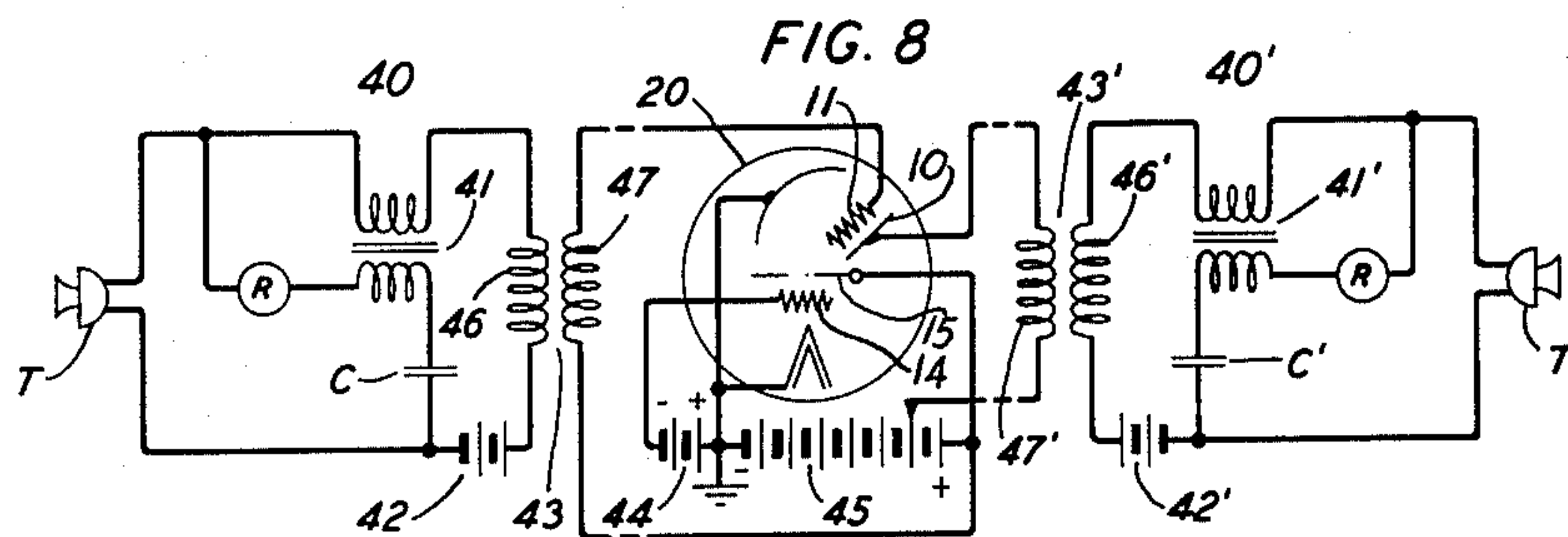
A. M. SKELLETT

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4 Sheets-Sheet 3



INVENTOR
A. M. SKELLETT
BY
Robert J. Fluskey
ATTORNEY

June 18, 1946.

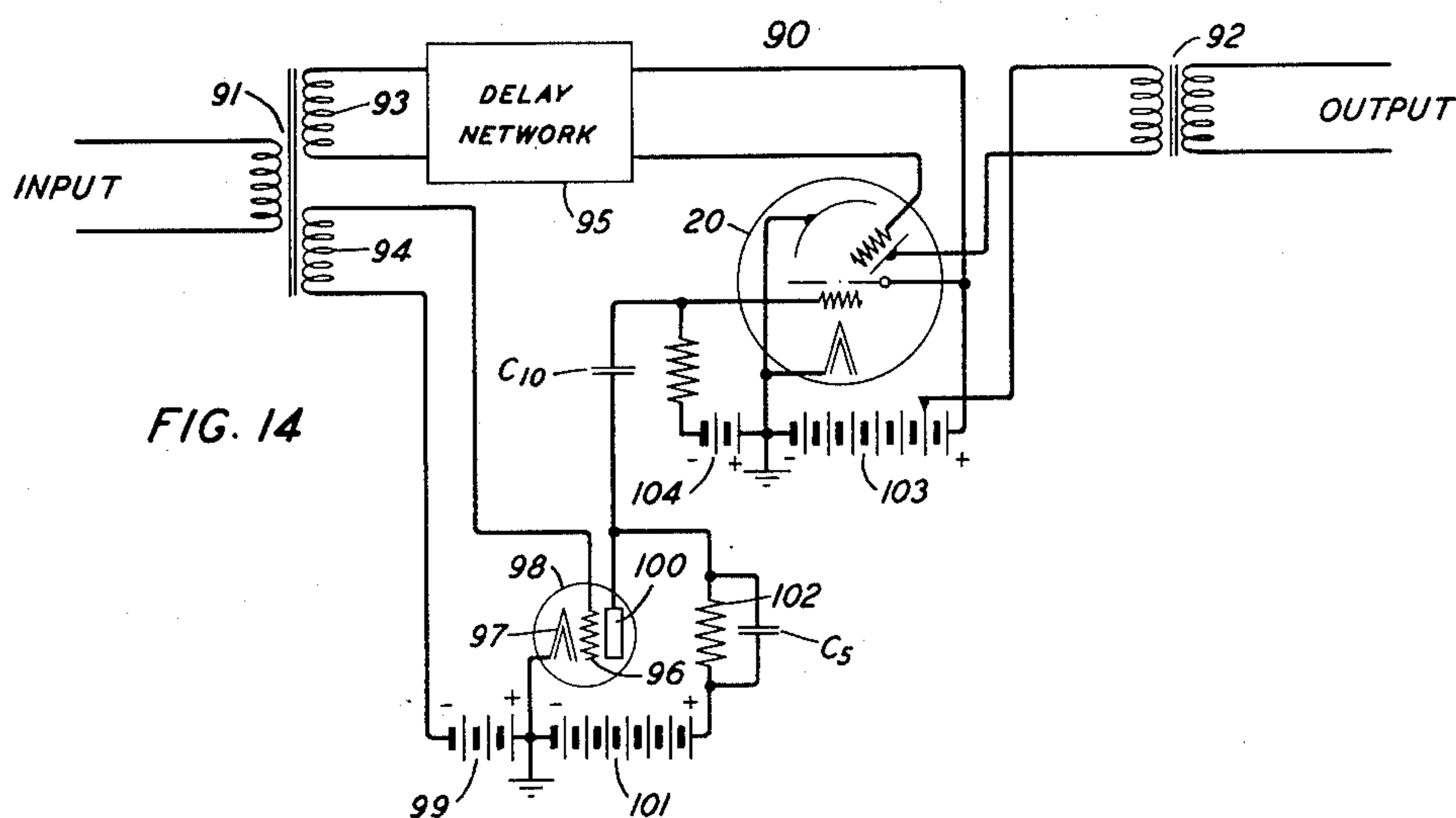
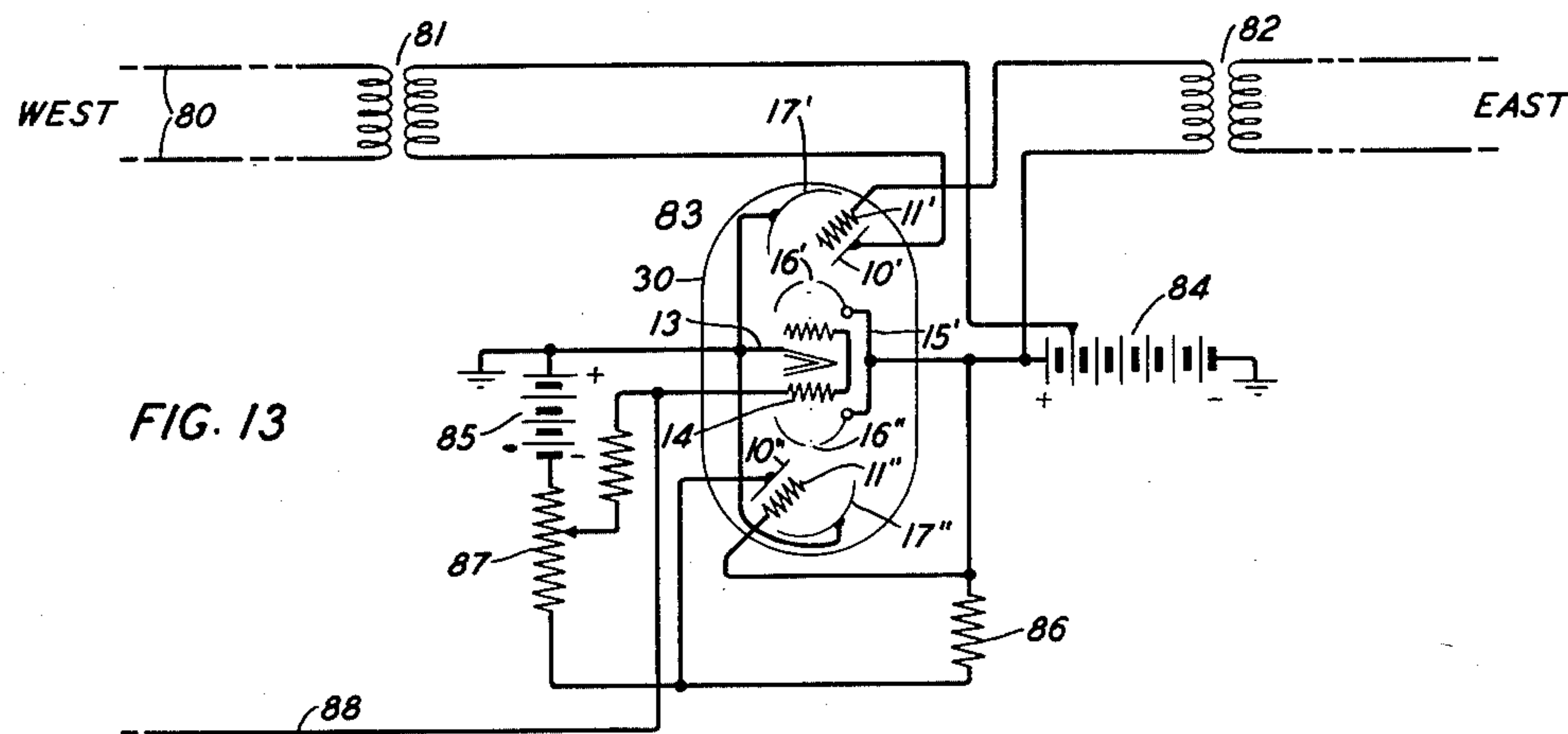
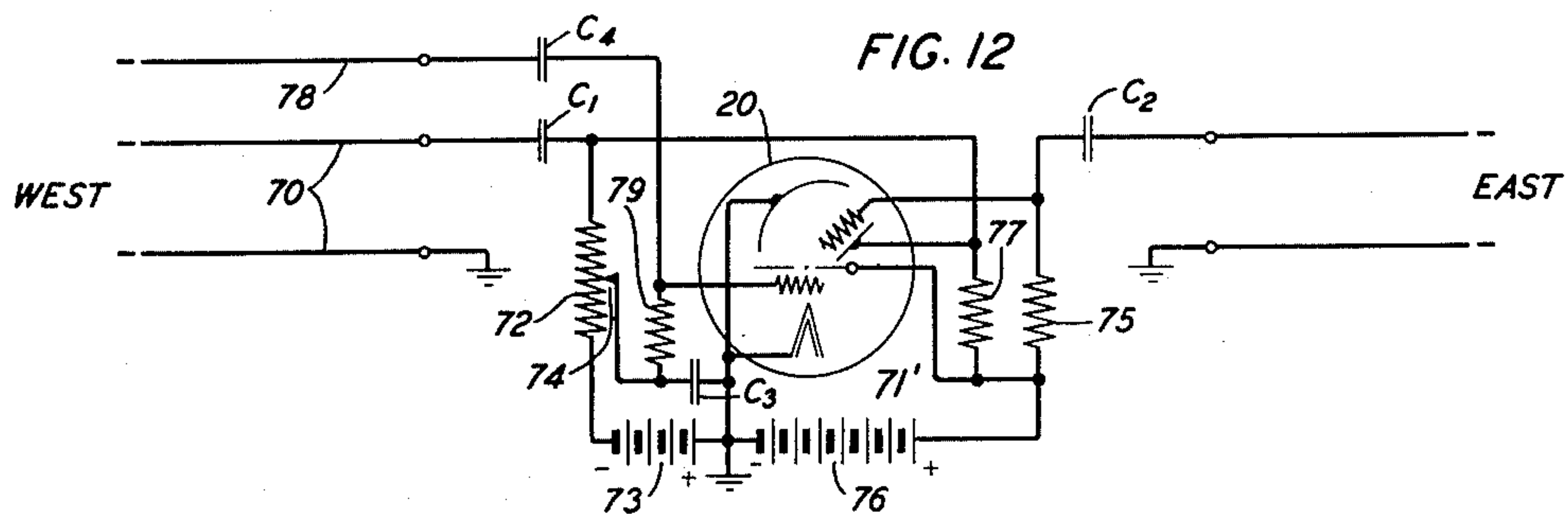
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4 Sheets-Sheet 4



INVENTOR
A. M. SKELLETT
BY
Robert J. Fluskey
ATTORNEY

UNITED STATES PATENT OFFICE

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ELECTRONIC DEVICE AND CIRCUITS

Albert M. Skellett, Madison, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application December 9, 1941, Serial No. 422,228

9 Claims. (Cl. 179—170)

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This invention relates to electronic devices of the type involving secondary electron emission and to circuits incorporating such devices.

An object of the invention is to enable bidirectional transmission of electric waves or signals through an electronic device of the vacuum tube type.

Another object is to regulate the transmitting condition of a transmission path and/or to control the amplitude of the electric wave or signal being transmitted over the transmission path.

A feature of the invention comprises including a secondary electron section in a vacuum tube having a primary electron source, the secondary electron section comprising a pair of electrodes so related that potential variations appearing on either one cause corresponding potential variations on the other.

Another feature comprises including such a vacuum tube in a transmission path or line whereby, when the secondary electron section is not activated or energized as a result of primary electron bombardment, the transmission path is opened or interrupted, and, when the secondary electron section is so energized, the transmission path is closed and conditioned for electric wave or signal transmission in either direction over the line.

An electronic device in accordance with the invention comprises an evacuated envelope containing a primary electron structure or section and a secondary electron structure or section. The primary electron structure may comprise a cathode, for example of the indirectly heated type, an input control grid and a primary anode. The latter contains an aperture or window to permit the escape of a substantial proportion of the primary electrons emitted by the cathode when the potential on the input grid is sufficiently removed from cathode-anode current cut-off. The secondary electron section may be located out of the direct path of the primary electrons, the latter being directed or deflected onto the secondary electron structure by a deflector electrode or other suitable means. The secondary electron section comprises a plate electrode and a grid electrode, the former having a surface treated so that, when bombarded with primary electrons, it will emit on the average more than one secondary electron per primary electron, the two electrodes being spaced apart a very small distance. The electrodes of the secondary electron section may be inserted in a transmission path or line so as to constitute a gap or interruption in the path so long as the secondary electron section is not acti-

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vated or energized by primary electron bombardment. When, however, a secondary electron stream is established between the plate and grid electrodes, the latter constitute or may be considered as analogous to a relatively low resistance contact that closes the circuit of the transmission path or line and permits electric wave or signal transmission, for example, of audio frequency electric waves, substantially equally well in either direction over the line, transmission being effected by virtue of the fact that potential variations appearing on either the plate or the grid electrode produce corresponding potential variations on the other.

A more complete understanding of the structural and the circuit features and aspects of the invention will be derived from the detailed description that follows hereinafter, taken in conjunction with the showing of the appended drawings, wherein:

Figs. 1 and 1A show elemental circuits to be referred to in explaining certain of the basic concepts involved in the invention;

Fig. 2 is a diagrammatic plan view of the electrode arrangement in an electronic device in accordance with the invention;

Fig. 3 is a diagrammatic plan view of another electronic device embodying the invention in which a plurality of secondary electron sections is provided;

Figs. 4, 4A, 5, 6 and 7 show the characteristic of an electronic device such as that shown in Fig. 2;

Fig. 8 shows a circuit arrangement intended for bidirectional transmission of audio frequency currents with the secondary electron section of a device according to Fig. 2 included in the transmission path;

Fig. 9 shows a circuit arrangement enabling the application of regenerative feedback to an electronic device in accordance with the invention;

Figs. 10, 11 and 12 show circuit arrangements involving a path or line for bidirectional transmission including an electronic device of the type shown in Fig. 2 and illustrating a number of expedients to trigger the electronic device on and off;

Fig. 13 shows another circuit arrangement for bidirectional transmission in which the transmitting condition of the transmission line is under the control of a circuit including an electronic device such as is shown in Fig. 3; and

Fig. 14 shows an amplitude limiting or static

reducing circuit incorporating an electronic device such as is shown in Fig. 2.

Electronic devices generally admit of transmission of signals or electric waves in one direction only, that is, they have an asymmetrical or unidirectional transmission characteristic. Where two-way transmission is desired, it is a general practice to use two electronic devices so arranged that transmission in one direction is effected by the passage of a signal or electric wave through one of them, and transmission in the opposite direction is effected by the passage of the signal or electric wave through the other of them. In situations where electronic switching is desired or is desirable, this necessitates a duplication of the electronic devices as well as an elaboration or complication of the requisite circuits. This invention makes available an electronic device which transmits signals or electric waves in either of opposite directions, and which may be controlled by potentials applied to an electron stream. Considered most generally, the electronic device of this invention comprises a pair of electrodes in an evacuated envelope, one of the electrodes being in the form of a plate member preferably imperforate and treated at least on one surface so as to emit secondary electrons in ratio greater than unity when bombarded with primary electrons, i. e., on the average, to emit more than one secondary electron for each primary electron striking the treated surface, the other of which comprises a perforate or grid member in close spaced relation to the secondary electron emitting surface and adapted for the passage therethrough of primary electrons directed at the plate member, the grid member also acting as a secondary electron collector electrode. This pair of electrodes may be considered or be termed an electronic circuit maker or interrupter, and may be likened, in operation, to a pair of relay contacts. When the primary electron stream is caused to pass through the grid to the plate member, "contact" may be considered as established and electric signals or waves may pass through the contact in either direction. When the primary electron stream is discontinued or interrupted "contact" is interrupted and electric signals or waves cannot pass in either direction because of the "open" circuit.

The basic circuit arrangement for these electrodes is shown by Fig. 1, the numerals 10 and 11 designating the plate member or emitter electrode and the grid electrode, respectively. Primary-electrons and their direction are indicated by the open-headed arrows, and secondary electrons and their general direction are indicated by the solid-head arrows. In the following discussion it will be assumed that the primary electrons have sufficient energy when they strike the emitter electrode and that the latter is so treated that, on the average, more than one secondary electron is caused to be emitted per primary electron. If the resistance CD is high enough, the emitter electrode will "float" at a potential that is a few volts negative with respect to the potential of the electrode 11. This floating action is present when the number of secondary electrons N_s drawn to the grid minus the number of electrons N_r which arrive at the electrode 10 by way of the resistance CD is equal to the number of primary electrons N_p striking the electrode 10, that is,

$$N_s - N_r = N_p \quad (1)$$

Stated in another way, there is an equilibrium condition at which the potential of the electrode

10 has the correct value relative to the electrode 11 for drawing off to the latter the number of secondary electrons which, flowing through the resistance CD, will give a potential drop along it that results in this plate potential.

Let it be assumed that the potential of the electrode 10 starts to drift in the negative direction; there will be an increase in the potential difference between the electrodes 10 and 11 with the result that more secondary electrons will be drawn from the electrode 10, and these added electrons flowing along CD will increase its potential drop making the point C more positive and thus bringing the potential of the electrode 10 back to its equilibrium value. In a similar manner, if the potential of the electrode 10 starts to drift in a positive direction, fewer secondary electrons are drawn to the grid electrode and the potential drop along CD decreases lowering the potential of the point C and bringing the potential of the electrode 10 back to its equilibrium value.

Let it now be assumed that it is the potential of the electrode 11 that changes, that is, it increases by a small amount. This increases the potential difference between the electrodes, resulting in the drawing off of more secondary electrons which, flowing through the resistance CD, increase the potential drop across it and cause the potential of the electrode 10 to become more positive until a new equilibrium potential for the latter is reached. Similarly, if the electrode 11 should become more negative in potential, the potential difference between the electrode becomes less, fewer secondary electrons are drawn off, the electron flow through the resistance CD decreases and the potential of the electrode 10 will tend to drift to a more negative equilibrium value. Thus, the potential of the plate member follows that of the grid, maintaining a nearly constant difference of potential of a few volts between the electrodes. If electric signals or waves are impressed across resistance AB as the input they will appear across resistance CD as the output.

That the potential of the electrode 11 will follow the potential variation of the electrode 10 can also be shown, starting with the arrangement of Fig. 1 in its equilibrium condition. The potential of the grid is determined by the potential drop across the resistance AB, resulting from the flow of primary electrons caught by the grid and of the secondary electrons which the grid collects from the electrode 10. The secondary electron component is generally much larger than the primary electron component and, since the latter, in operation, will not vary appreciably, it may be neglected for this discussion. Let it be assumed that the electrode 10 is caused to become more positive resulting in a lower potential difference between the electrodes 10 and 11 whereby fewer secondary electrons will flow from the electrode 10 to the electrode 11 with a resultant decrease in current flow through the resistance AB. Since the electron flow in the resistances AB and CD is in opposite directions, the potential across resistance AB is opposite in sign to that across resistance CD. Decrease in the potential drop across the resistance AB means that the point A becomes less negative or more positive, that is, the electrode 11 also becomes more positive in potential. In a similar manner, if the electrode 10 is caused to become of less positive potential, that is, be driven or cause to drift in a negative direction, more secondary electrons are caused to flow to the elec-

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trode 11 to produce an increased potential drop along resistance AB and causing the electrode 11 to assume a more negative potential.

From the above, it is evident that potential variations of the emitter electrode result in corresponding potential variations of the collector electrode, and that potential variations of the latter cause corresponding potential variations of the emitter electrode, this action being a result of the presence of the secondary electron stream. The function of the primary electrons is to produce the secondary electrons.

The electrode arrangement of a vacuum tube 20 incorporating these electrodes is shown by Fig. 2. The primary electron stream is furnished by a triode structure or section comprising a cathode 13, an input control grid 14 and a primary anode 15. The latter contains an aperture or window 16 for the escape of about one-third of the primary electrons emitted by the cathode. Of course, a greater or lesser proportion of the primary electron emission of the cathode may be confined to the triode section of the tube. The secondary electron emitter 10 and the electron collector grid 11 are positioned out of the direct path of the escaped primary electrons so that the secondary electron emitting surface will not be contaminated by cathode particles, the escaped primary electrons being deflected or directed onto the electrode 10 by the deflector electrode or member 17. The optimum deflector shape is determined by the size and shape of the primary anode electron window and the angle of emission of the escaped electrons, and its contour may be ascertained by rubber model studies. The deflector electrode may be connected with the cathode so as to be maintained at cathode potential. The spacing between the electrodes 10, 11 may be of the order of $\frac{1}{16}$ inch.

With the electrode arrangement of the vacuum tube 30 of Fig. 3, two sets of symmetrically or bidirectionally transmitting electronic contacts or secondary electron sections are provided. The primary anode 15' contains a pair of oppositely disposed apertures 16', 16'' for the escape of primary electrons to be deflected by the deflector electrodes 17', 17'' to the secondary electron sections constituted by the electrodes 10', 11' and 10'', 11''. If desired, the triode section and the electrodes 10', 11' may be utilized in a particular circuit for bidirectional transmitting of electric waves or signals; and the same triode section and the electrodes 10'', 11'' may be utilized as a trigger device in the manner disclosed in my copending application Serial No. 321,852, filed March 2, 1940, for the enabling or disabling of the secondary electron sections of the tube. Circuit arrangements incorporating the electronic tubes or devices of Figs. 2 and 3 are described in detail hereinafter. The apertures 16', 16'' may be of the same or different sizes and shapes, and permit the same or different amounts of primary electron flow therethrough.

In the non-activated condition of the electrode 10, that is, during the period that primary electrons do not bombard it or do not impinge on it with sufficient intensity to cause emission of secondary electrons in ratio greater than unity, the effective resistance between the electrodes 10, 11 is very high and such as to prevent transmission of electric signals or waves therethrough. When, however, secondary electrons are emitted by the electrode 10 in ratio greater than unity, the effective resistance between the electrodes 10, 11 is of the order of some thousands of ohms. In

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circuit applications, therefore, to avoid excessive losses, impedances of considerable higher magnitude, for example, of the order of tens of thousands of ohms, should be associated with the device. Impedances of such magnitude, of course, are not high for electronic devices, and are within the range of readily available transformers.

The effective resistance between the electrodes 10, 11 is the reciprocal of the slope of its current-voltage characteristic. Fig. 4 shows a family of curves evidencing the relation between the current to the electrode 11 with variation in potential difference between the electrodes 10, 11 for different values of primary electron current. These curves were obtained by holding the potential of the electrode 10 constant at about 150 volts, the zero point on the abscissae corresponding to 150 volts on both of the electrodes 10, 11. The reciprocals of the slopes of these curves of Fig. 4 for a potential difference of 6 volts between the collector grid and secondary emitter are plotted against primary electron current in Fig. 5. The resistance varies markedly with primary electron current. Above a primary electron current of about 1 milliamperes the resistance changes very little. This may be due to the presence of a space charge in front of the secondary electron emitting surface due to the secondary electrons themselves. A similar curve to that of Fig. 5 is obtained if the resistance between the electrodes 10, 11 is plotted against the potential of the input control grid. For bidirectional transmission with negligible distortion, a primary electron current of one or more milliamperes is indicated.

There are two sets or families of output curves for the secondary electron section of the device of Fig. 2. Fig. 6 shows curves for transmission in the direction of collector grid to the secondary emitter and evidences the variation of current in the circuit connected to the secondary emitter with variation in secondary emitter potential for different values of collector grid potential. The primary electron current was about 1.5 milliamperes and the recorded potentials for collector grid and secondary emitter were measured above and below 150 volts, which was the potential of the primary anode of the tube. A load resistance line of 50,000 ohms is shown passing through the working point on the curve for V_G equal to zero, which is at a biasing potential of -6 volts for the secondary emitter relative to the collector grid. Evidently an output voltage of 100 volts may be used with very little departure from linearity, that is, with only a small amount of distortion. To obtain such an output the collector grid would swing or vary from -54 to +50 volts, a total variation of 104 volts, the excess being due to the loss through the secondary electron section. Load lines for other impedances may be drawn in the usual way and similar results determined. Fig. 7 shows collector grid potential above and below primary anode potential plotted against collector grid current in milliamperes for different values of secondary emitter potential above and below primary anode potential.

In treating the basic or elementary circuit arrangement of Fig. 1 as a network, it should be kept in mind that the primary electron current constitutes an impedance across the load resistances AB and CD which cannot be evaluated exactly because of the fact that the primary electron currents divide between the collector grid and the secondary emitter in an unknown ratio. Looked at from either direction of transmission, there is a part of this impedance directly across the input

and the other part in series with the secondary electron section. The equivalent circuit is shown in Fig. 1A. The shunt resistance looking in the direction from west to east may be written as:

$$\frac{1}{R_W} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_C + R_3} + \frac{1}{R_C + R_4} \quad (2)$$

and that looking in the direction from east to west may be written as:

$$\frac{1}{R_E} = \frac{1}{R_4} + \frac{1}{R_3} + \frac{1}{R_C + R_2} + \frac{1}{R_C + R_1} \quad (3)$$

R_1 and R_4 represent the load resistances corresponding to resistances AB and CD, respectively, and R_2 and R_3 represent the resistances ascribable to the primary electron stream, and R_C represents the effective resistance of the secondary electron section. Most of the primary electrons flow to the secondary emitter so that, for an approximate solution, R_2 may be neglected, and a value for R_3 obtained by measuring the slope of the primary electron current versus collector grid for secondary emitter potential. The potential of the collector grid has considerably more effect on the primary electron current than does the potential of the secondary emitter because the latter is shielded by the grid. A complete solution for the resistance looking in from either direction is therefore complex but not difficult if an assumption is made for the ratio of primary electron current to collector grid and secondary emitter. The order of magnitude of these resistance values may be obtained from the following:

$$\frac{\delta E_P}{\delta I} = 1 \text{ megohm}$$

$$\frac{\delta E_G}{\delta I} = 250,000 \text{ ohms}$$

where I is the primary electron current to both the collector grid and the secondary emitter, and E_P and E_G are the secondary emitter and the collector grid potentials, respectively. At very high frequencies, the more complex impedances, including the interelectrode capacitances, will have to be taken into consideration, but in the voice frequency range, these may be neglected.

Fig. 8 shows a circuit arrangement constructed in accordance with the invention for effecting bidirectional transmission between a pair of telephone stations 40, 40' through a vacuum tube or electronic device of the type described hereinabove with specific reference to Figs. 1, 1A and 2. Each telephone station comprises a transmitter T, for example, of the granular carbon type, a receiver R, a transformer 41 or 41', a blocking condenser C or C' and a source of talking current 42 or 42'. The telephone station 40 may be coupled to the electronic device 20 through a transformer 43, and the telephone station 40' may be coupled to the electronic device 20 through a transformer 43'. With reference to the device 20, the cathode is of the indirectly heated type, biasing potential for the control grid 14 is provided by the source 44, and potential for the primary anode, the collector grid and the secondary emitter is provided by the source 45. As shown in Fig. 8, the device 20 is in its energized condition, that is, the triode section is supplying a primary electron stream for deflection by the deflector electrode onto the secondary emitter whereby a secondary electron stream is established between the secondary electron emitter and the collector grid.

The operation of the circuit arrangement of Fig. 8 is as follows: In transmitting in one direc-

tion, for example, from the station 40 to the station 40', the user at the former station talks into the transmitter T thereat and varies the direct current supplied by the source 42 in accordance with the sound waves generated. The audio or voice frequency component thus generated in the local circuit comprising the transmitter T, source 42, first winding 46 of the transformer 43, and primary winding of induction coil 41, appears across the second winding 47 of the transformer 43 and causes variation in the potential of the collector grid. As already explained, the variations in the potential of the collector grid produce corresponding variations in the potential of the secondary electron emitter and of the current flow in the winding 47' of the transformer 43'. The audio frequency variations in the current flow in the winding 47' appear across the terminals of the winding 46' of the transformer 43', and are translated by the receiver R at the station 40' into sound waves. For transmission in the opposite direction, that is, from station 40' to station 40, the user at the station 40' talks into the transmitter T thereat to vary in accordance with the sound waves generated, the direct current flowing in the local circuit comprising the transmitter T, the source 42', the winding 46' of the transformer 43' and the primary winding of the induction coil 41'. The audio or voice frequency component of the current flowing in the winding 46' appears across the terminals of the winding 47' of the transformer 43' and causes variation in the potential of the secondary emitter electrode. As already explained, the variations in the potential of the secondary emitter cause corresponding variations in the potential of the collector grid current flowing in the winding 47 of the transformer 43. The variations in the collector grid current appear across the winding 46 of the transformer 43 and are translated into sound waves by the receiver R at the station 40.

Fig. 9 shows a circuit arrangement whereby some of the energy passing through the electrodes 10, 11 may be fed back to the grid 14 so as to introduce regeneration with respect to transmission in each direction through the device. The resistances R_a and R_b comprise the load impedances for the collector grid and the secondary emitter circuit. Feedback to the grid 14 is accomplished through the transformer 50, the primary winding of which is connected across resistance R_a and provided with an adjustable contact or slide 51 to permit adjustment in the amount of feedback. The transformer is provided because, for regeneration, the fed back voltage should be 180° out of phase with the transmitted signal. With the arrangement shown, the amount of feedback was increased by moving the contact 51 upwardly along the resistance R_a . In a particular circuit arrangement constructed in accordance with Fig. 9, the loss through the electrode 10, 11 was of the order of about 10 per cent. As the amount of feedback was increased by adjustment of the contact 51 and starting from zero feedback, stable regeneration was obtained up to a point where the loss was annulled or eliminated or, in other words, when the signal out was equal to the signal in. Above this point the circuit tended to become unstable and to oscillate independently. The regeneration was operative equally well for transmission in either direction through the device 20. Similar results are obtainable when the feedback voltages are obtained from the resistance R_b instead of from the resistance R_a .

Fig. 10 shows an electric wave circuit comprising a transmission path or line 60 that may include a plurality of transformers or repeating coils 61, 62 and a single, by way of example, vacuum tube or electronic device 20. Potential for the electrodes 10, 11 and 15 is supplied by the source 63 and biasing potential for the input grid 14 is provided by the source 64 through resistor 65. The grid 14 is normally biased from source 64 to a potential such as to block primary electron flow to the electrodes 10, 11 or so to reduce the flow of primary electrons to the electrode 10 that secondary electron emission from the latter is negligible. Under such circumstances transmission in either direction, that is, from west to east or east to west, along the line 60 is blocked or prevented because of the open circuit between the electrodes 10, 11. If the point A is connected to ground so as to place the grid 14 at cathode potential, primary electron flow to the secondary emitter establishes secondary electron flow between the electrodes 10, 11 and closes the circuit between the latter. A switch 66 connected to the point A and to ground is indicated as one expedient for nullifying the initial bias on the grid 14. Such a switch may be located at either end of the transmission path or line, or one may be located at each end of the line, or at some point along the line and, of course, the switch could comprise the contacts of a relay operable by the electric wave or signal to be transmitted along the line. Such a relay is shown at 67 for the west-line section, and a similar relay is shown at 68 for the east-line section. These relays are actuated by the presence of voice or other signal currents on the respective line section, through the agency of amplifier-detectors 67' and 68', respectively. When switch 69 is permanently closed and switch 66 is left in its open position, either relay 67 or 68 when actuated by voice currents connects point A to ground and nullifies the initial disabling bias on grid 14. With the secondary electron stream established between the electrodes 10, 11, bidirectional transmission along the line of, for example, an audio frequency wave, may take place until the device 20 is deenergized or restored to its initial condition by removal of ground at the point A by restoration of the switch 66 to its open condition or by the opening of the contacts of relays 67 and 68. No appreciable power is required to produce the on and off functioning of the device 20, and such functioning could take place in a fraction of a microsecond.

Fig. 11 shows an electric wave circuit comprising a transmission path or line 70, for example, for transmitting audio frequency electric waves, having a bidirectional transmission control circuit 71 inserted therein. The circuit 71 comprises a vacuum tube or electronic device 20 in which the electrode 10 is connected through blocking condenser C₁ to one line conductor extending west, through resistor 72 and source 73 of grid biasing potential to grounded cathode, and through the adjustable contact or slide 74 on resistor 72 to the grid 14. The collector grid 11 is connected through blocking condenser C₂ to one line conductor extending east, and through resistor 75 to the primary anode and the source 76 of anode and collector grid potential. Condenser C₃ by-passes the audio frequency electric wave so that the latter has a negligible effect on the grid 14. By way of example, let it be assumed that the normal condition desired is that transmission along the line 70 be blocked.

The bias on the grid 14 would be so chosen that primary electron flow to the electrode 10 is blocked or so that the number of electrons reaching the electrode 10 is negligible. The circuit between the electrodes 10, 11, therefore, is open. To close the circuit between these electrodes, that is, by establishing secondary electron flow therebetween, a positive pulse is transmitted along the line from its west terminal. Such pulse momentarily reduces the negative bias on the grid, that is, makes it more positive with respect to the cathode and enables a sufficient quantity of primary electrons to bombard the electrode 10 such that the secondary electron emission therefrom is appreciable, the electrode 10 rising in potential thereby causing the grid 14 to become still more positive with respect to the cathode with resulting greater primary electron flow. The electrode 10 rises to a stable floating potential and the tube 20 remains energized, that is, the circuit between the electrodes 10, 11 remains closed, until a negative pulse of sufficient magnitude is transmitted from the west terminal of the line to apply momentarily to the grid 14 a potential sufficiently negative with respect to the cathode so as to block primary electron flow to the electrode 10. Until such a negative pulse is transmitted, however, electric waves or signals, as already explained hereinabove, may be transmitted in either direction over the line 70 and through the electrodes 10, 11. When the negative pulse is impressed on the control circuit 71 the blocking of the primary electron flow restores the tube to its initial condition by interrupting the secondary electron flow between the electrodes 10, 11, and the circuit between the latter opens and transmission in either direction over the line is blocked or interrupted until the device 20 is again energized.

The circuit arrangement of Fig. 12 is similar to that of Fig. 11 except that the electrode 10 is included in a bleeder circuit comprising the resistances 72 and 77 and the sources 73 and 76 whereby it is at a positive potential conditioning it for a rapid rise to its stable floating potential when primary electrons are directed against it. The energizing positive pulse or the deenergizing negative pulse is transmitted from the west terminal of the circuit over a conductor 78 separate from the line 70. The conductor 78 connects with the grid 14 through the condenser C₄. A resistor 79 is connected between the slide 74 and the grid 14. The control circuit 71' is adapted to be energized and deenergized with considerably smaller control voltages than are required in the case of the control circuit 71 of Fig. 11. If it is assumed that the normal condition of the circuit 71' is such that the circuit between the electrodes 10, 11 of the device 20 is open, that is, there is an absence of secondary electron flow between those electrodes, the grid 14 is biased sufficiently negatively with respect to the cathode to block primary electron flow to the electrode 10. The transmittal over the conductor 78 of a positive pulse of appropriate magnitude momentarily causes the grid 14 to become sufficiently less negative with respect to the cathode to permit the primary electron flow to the electrode 10, whereby secondary electron emission from the electrode 10 to the electrode 11 is established and the electrode 10 rises in potential and thereby tends to cause the grid 14 to become even less negative with respect to the cathode. The electrode 10 rises to its stable floating potential and the circuit between the elec-

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trodes 10, 11 remains closed and permits bidirectional transmission therethrough until the primary electron stream is blocked by the transmittal over the conductor 78 of a negative control pulse.

The electric wave circuit of Fig. 13 comprises a transmission path or line 80 including a plurality of transformers or repeating coils 81, 82 and a transmission control circuit 83 comprising a vacuum tube or electronic device 30 such as has been described with reference to Fig. 3. The electrodes 10', 11' are connected in the line 80, potential for them being supplied from the source 84. The cathode is connected to ground. Biasing potential for the grid 14 is provided by the source 85. Potential for the anode 15' and the collector grid 11'' is provided by the source 84 and potential for the electrode 10'' is provided by the bleeder circuit comprising the resistances 86, 87 and the sources 84, 85. The initial condition of the control circuit may be such that the grid 14 is biased so negative with respect to the cathode that primary electron flow to the two secondary electron sections is blocked. Hence the electrodes 10', 11' are in open circuit condition and the line 80 is open or interrupted with respect to electric wave transmission in each direction thereover. Also, the absence of primary electron bombardment of the electrode 10'' causes the latter to remain at the potential determined by the bleeder circuit, a potential preferably such that when primary electrons do impinge on the electrode 10'' the latter rises rapidly to a stable floating potential.

The device 30 may be energized by transmitting a positive pulse over the conductor 88, the pulse being of a magnitude sufficient to reduce the negative bias on the grid 14 and thereby to initiate primary electron bombardment of the electrodes 10', 10''. With emission of secondary electrons from the electrode 10'' in ratio greater than unity the electrode 10'' rises in potential to its stable floating potential and causes the grid 14 to become sufficiently positive with respect to the cathode so that the primary electron flow to the electrode 10'' is continuous. Simultaneously with the establishment through the aperture 16'' of the primary electron stream from the cathode to the electrode 10'', a primary electron stream is established through the aperture 16' between the cathode and the electrode 10'. The secondary electron stream established thereby between the electrodes 10', 11' terminates the open condition of the line 80 and bidirectional transmission of electric waves or signals, for example, audio frequency electric waves, along the line 80 and through the electrodes 10', 11' becomes possible. The circuit 83 may be restored to its initial condition by transmitting a negative pulse over the conductor 88 to render the grid 14 momentarily so negative with respect to the cathode that primary electron flow to the secondary electron section is blocked. Cessation of secondary electron emission from the electrode 10'' causes the potential of the latter to fall to its original value and the source 85 again controls the bias on the grid 14. The use of the device 30 instead of the device 20 obviates the need for a by-pass condenser C₃ and segregates the pulsing circuit and triggering action (on and off) from the electric wave or signal transmission path.

In the circuit of each of Figs. 10, 11, 12 and 13 the initial or normal condition thereof has been described as that in which the secondary electron section or sections are in their open condi-

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tion. Obviously, the initial or normal condition could be that in which the device 20 or 30 is energized, that is, with its secondary electron section or sections in closed condition. Furthermore, although the pulsing circuit to trigger the device 20 or 30 on or off is shown in Figs. 10, 12 and 13 as extending from the west terminal only of the line, obviously it could extend from the east terminal, or the arrangement could be such that the device 20 or 30 could be triggered on or off from each terminal of the line.

Fig. 14 shows a circuit arrangement for a static reducer or amplitude limiter 90 incorporating the vacuum tube or electronic device 20. The signal wave input is by way of a transformer 91 and the signal wave output is through a transformer 92. The transformer 91 includes a pair of secondary windings 93, 94 one of which is connected to the delay network 95 and the other of which is connected to the input grid 96 and the cathode 97 of a vacuum tube 98. The grid 96 is normally biased by a source 99 to a potential sufficiently negative with respect to the cathode 97 to block space current flow in the tube 98. The anode 100 derives its operating potential from the source 101 through the resistor 102 which is by-passed by a condenser C₅. The electrodes 10, 11 of the device 20 are connected in the circuit between the network 95 and one winding of output transformer 92. Potential for the electrodes 10, 11 and for the primary anode 15 is supplied by source 103, and biasing potential for the grid 14 is supplied by the source 104. The grid 14 is normally biased to a potential with reference to the cathode such that primary electron flow through the aperture in the anode 15 is enabled and secondary electron emission is established between the electrodes 10, 11, that is the latter are in condition for electric wave transmission between them. A condenser C₁₀ connects the anode of the tube 98 and the grid 14 of device 20.

In the operation of the circuit of Fig. 14, signal waves entering it through the transformer 91 are divided between the secondary windings 93, 94. For ordinary signals, the portion appearing across the winding 94 and, therefore, across the input electrodes of the tube 98 is not sufficient to overcome the normal bias on the grid 96. When, however, the input to the transformer 91 includes an abnormal pulse such, for example, as might be occasioned by static, that portion of the wave appearing across the winding 94 swings the potential of the grid 96 sufficiently in a positive direction so that the tube 98 becomes momentarily conducting. The potential drop in the resistance 102 is fed through the condenser C₁₀ to the grid 14 of the tube 20, to cause the potential of the latter to become sufficiently negative with respect to the cathode 13 so that primary electron flow in the tube 20 is blocked or interrupted. Hence, the delayed abnormally large pulse or static is not transmitted by the tube 20 since the electrodes 10, 11 are in open condition.

With certain modifications, the circuit of Fig. 14 could be used for volume compression or expansion purposes. For example, if the tube 98 were normally biased just to cut-off so that it rectifies at all times, and the grid 14 of the tube 20 had variable mu properties, volume compression would be obtained, the transmission through the electrodes 10, 11 being reduced to a larger extent for strong signals incoming through the transformer 91 than for weak signals. For volume expansion, another stage or tube would be

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inserted between the tube 98 and tube 20 to reverse the phase of the control signal developed by the tube 98 for application to the input grid 14 of the tube 20.

As has already been pointed out, the effective resistance between the electrodes 10, 11 and, therefore, the transmission between these electrodes, varies with the magnitude of the primary electron current as indicated by Fig. 5. This characteristic may be availed of for modulation purposes. For example, in the arrangement of Fig. 10 a carrier wave could be fed into the circuit in either direction, that is, from east to west or from west to east, and modulated by voltages impressed on the grid 14, assuming the switch 66 to be closed.

Although this invention has been disclosed with reference to a number of embodiments and applications thereof, it is to be understood, of course, that they are illustrative of what is believed at this time to be the preferred practice of the invention and that the latter is not limited thereto but is of a scope evidenced by the appended claims.

What is claimed is:

1. In combination, a transmission line and a pair of spaced members connected to provide a discharge gap in series in said line and contained in an evacuated enclosure, a source of primary electrons therein, one of said members being adapted to emit secondary electrons to establish an electron stream between said members when said one member is bombarded with primary electrons from said source, and means to cause potential variations applied to either member after establishment of the secondary electron stream to produce corresponding potential variations on the other member.

2. In combination, a transmission line and a pair of spaced members connected to provide a discharge gap in series in said line and contained in an evacuated enclosure, one of said members being adapted to emit secondary electrons to establish an electron stream between said members when said one member is bombarded with primary electrons, said members in the absence of said secondary electron stream preventing electric wave transmission along said line, a source of primary electrons in said enclosure for bombardment of said one member, and means normally blocking primary electron flow to said one member, but responsive to a control pulse of momentary duration for overcoming such blocking action.

3. An electric wave circuit comprising a transmission path, a pair of telephone stations coupled to said path, a transmitting circuit and a receiving circuit in each of said stations, and an electronic device in said path between said stations for transmitting in each direction over said path communication currents originating in each station, said electronic device comprising an evacuated enclosure containing a plurality of electrodes providing a discharge space serially connected in said path, one of said electrodes being adapted to emit secondary electrons when bombarded with primary electrons, means to supply primary electrons to bombard said one electrode, the other of said electrodes being a collector of said secondary electrons and coupling means between the portion of said path on either side of said device and a respective one of said electrodes for varying the potential thereof for causing voice fluctuations on one portion of the path

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to vary transmission into the opposite portion of the path.

4. In combination, a line for transmitting an electric wave, and an electronic contact serially inserted in said line for opening and closing said line to transmission of said electric wave in opposite directions over said line, said electronic contact comprising a plate member and a grid member in an evacuated enclosure, a source of primary electrons therein, said plate member emitting secondary electrons in ratio greater than unity when bombarded with primary electrons from said source and said grid member collecting said secondary electrons and means for coupling the portion of line on either side of said contact in two-way energy-transfer relation with, respectively, said plate member and said grid member to both impress voltage variations on and receive voltage variations from the respective member.

5. An electric wave circuit comprising an electron discharge device, including a source of primary electrons, a source of secondary electrons to be bombarded by said primary electrons and having an emission ratio greater than unity, an electrode for collecting secondary electrons emitted by said secondary source, an east and a west line conductor, means including said east line conductor to vary the potential of said secondary source to produce corresponding variations in the potential of the collecting electrode for impression of said variations on said west line, and means including said west line conductor to vary the potential of the collecting electrode to produce corresponding variations in the potential of said secondary source for impression of said variations on said east line.

6. In combination, a transmission line divided into two portions, and an electronic device comprising a primary electron section and a pair of secondary electron sections, each of said secondary electron sections including a pair of electrodes, one electrode emitting secondary electrons in ratio greater than unity when bombarded by primary electrons from said primary electron section and the other electrode being a collector of the secondarily emitted electrons from said one electrode, one of said secondary electron sections having its emitter electrode and its collector electrode respectively coupled in energy-transfer relation to opposite portions of said line for interconnecting portions of said transmission line, means for controlling the supply of primary electrons from said primary electron section to said secondary electron sections to energize and deenergize the latter, comprising a control element in said device, and means to supply control pulses thereto to shift the potential on said control element to a new value, and means comprising the other of said secondary electron sections for maintaining the potential on said control element at said new value.

7. An electric wave circuit comprising a transmission line comprising different portions, an electronic device comprising a primary electron section and a secondary electron section, said secondary electron section interconnecting portions of said line and comprising an electrode emitting secondary electrons in ratio greater than unity when bombarded by primary electrons from said primary electron section and an electrode for collecting said secondary electrons, means for supplying positive voltage to said electrodes and means for coupling one portion of said line in energy-transfer relation to one of said electrodes and means for coupling the other portion of said

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line in energy-transfer relation to the other electrode, said primary electron section normally bombarding said secondary electron section with primary electrons to establish a secondary electron stream between said electrodes to close the circuit between said line portions, and means coupled to said transmission line and to said primary electron section for suppressing said primary electron bombardment and thereby opening the line circuit during periods in which the electric wave being transmitted along said line exceeds a preassigned amplitude.

8. A two-way repeater of signal waves for insertion between two sections of a two-way line, said repeater comprising a vacuum electronic device containing a primary electron section, a secondary electron section having spaced electrodes, and means to direct primary electrons from said primary section into said secondary section to establish secondary electron emission therein, said secondary electron section comprising an electronic contact serially included in said line for blocking signal wave flow in opposite directions therethrough in the absence of secondary electron emission therein, but offering a low impedance to signal wave flow in opposite directions therethrough during secondary electron emission therein, two-way transmission means coupling one of said electrodes to one only of said line sections to transmit voltage variations to and receive voltage variations from said one sec-

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tion, and two-way transmission means coupling the other of said electrodes to only the other line section to transmit voltage variations to and receive voltage variations from said other line section.

9. An electric wave circuit comprising a transmission path, a pair of telephone stations coupled to said path at separated locations, a transmitting circuit and a receiving circuit in each station, and means for repeating voice current fluctuations in both directions over said path between said stations comprising an electronic device including a pair of spaced electrodes forming an electronic path serially included in said transmission path between said stations, said device including means to produce primary electrons and to drive them against one of said electrodes, said latter electrode having its surface treated to give off secondary electrons in abundance from impact of said primary electrons, the other of said pair of spaced electrodes constituting a collector of secondary electrons emitted from the other-mentioned electrode of the pair, and means controlled by the voice current fluctuations transmitted from either of said stations over said transmission path to said device for controlling transmission through said electronic path to the transmission path beyond said device leading to the opposite station.

ALBERT M. SKELLETT.