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E. T. BURTON

1,778,377

TELEGRAPH REPEATING DEVICE

Filed July 18, 1928

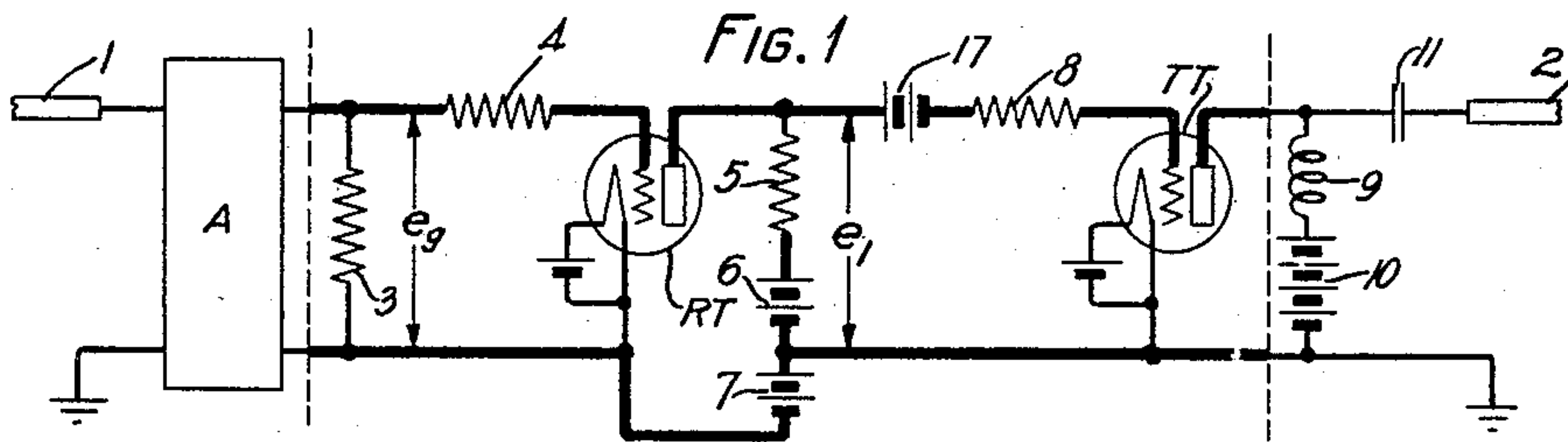


FIG. 2

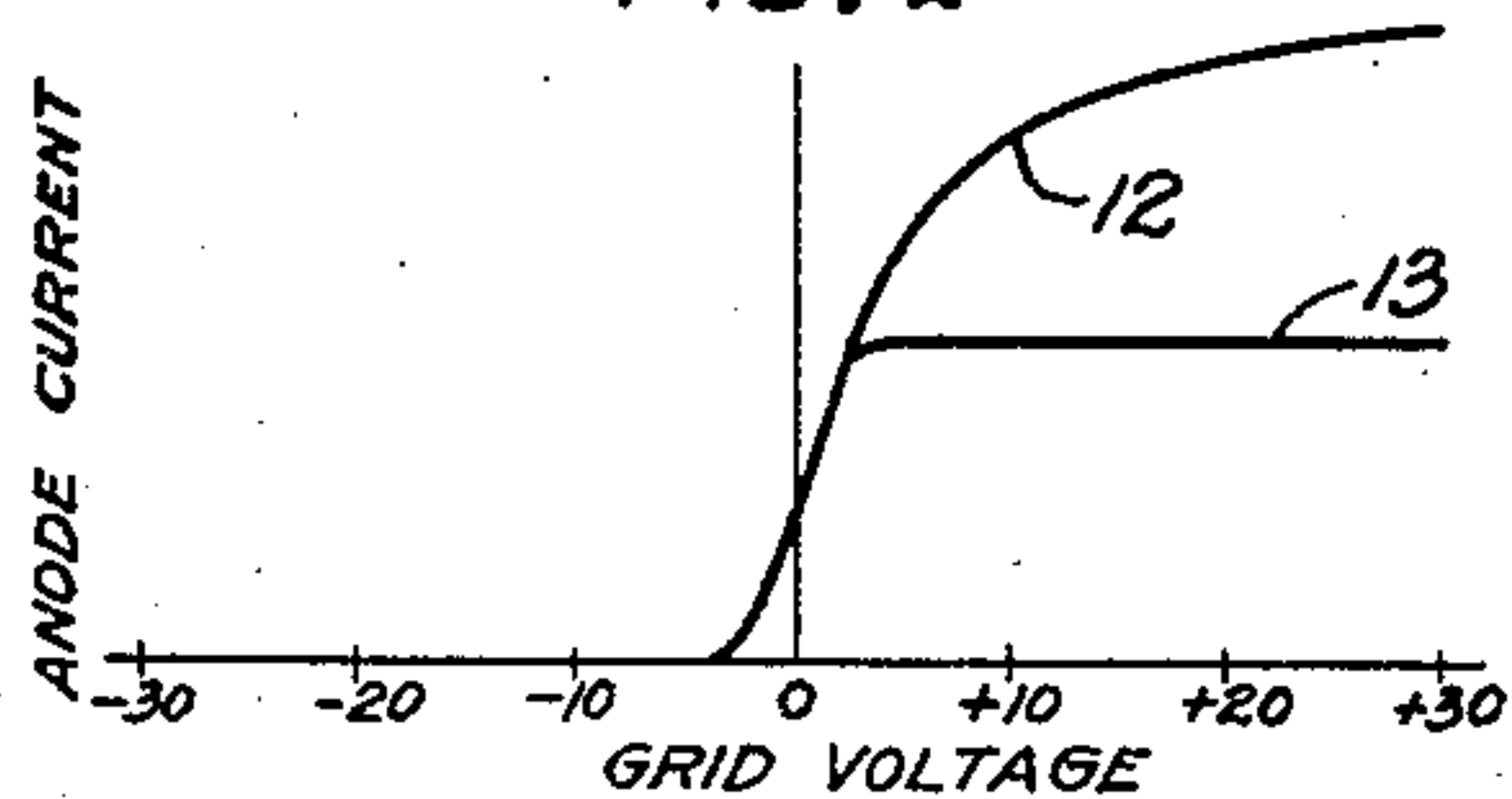


FIG. 3

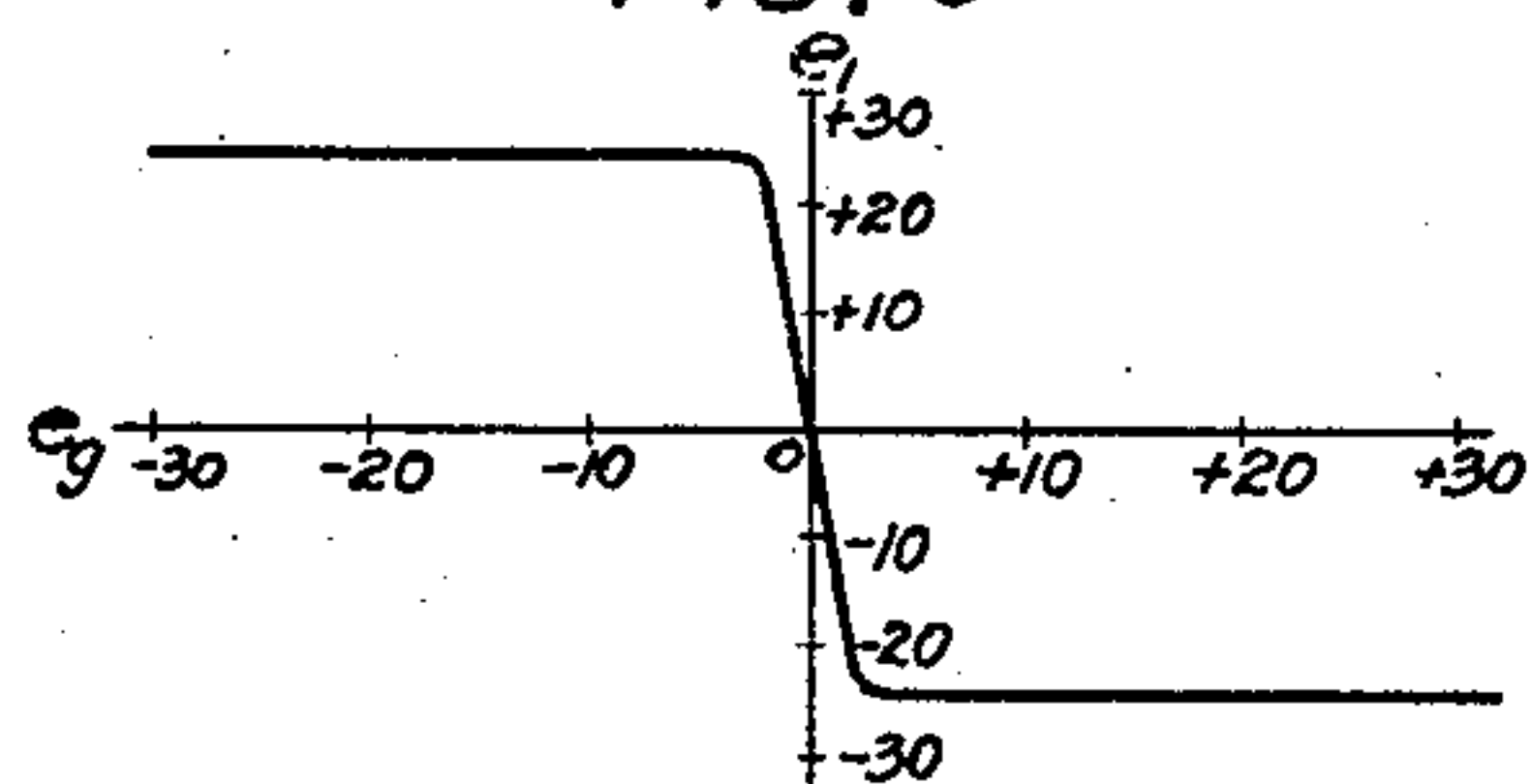


FIG. 4

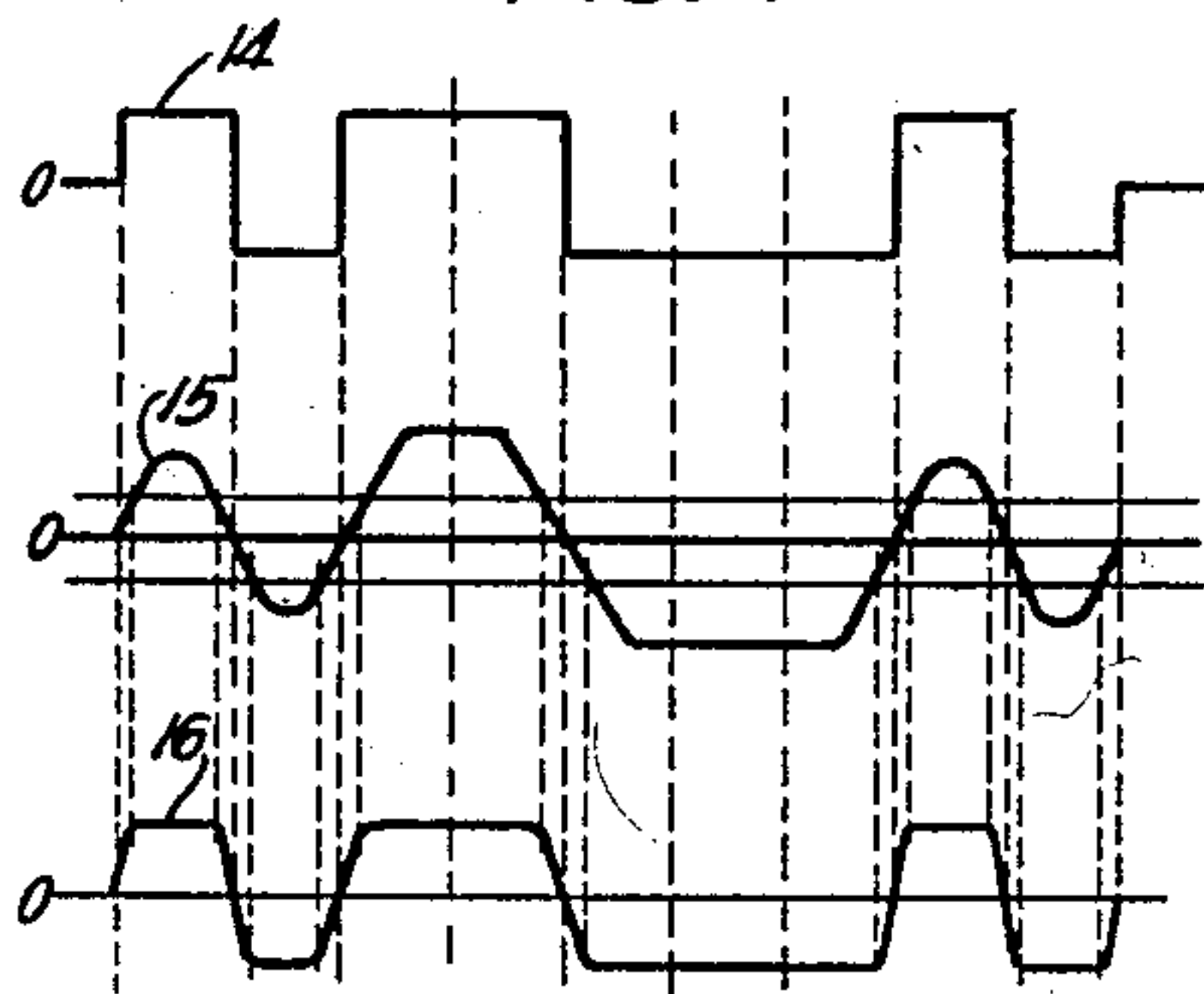


FIG. 5

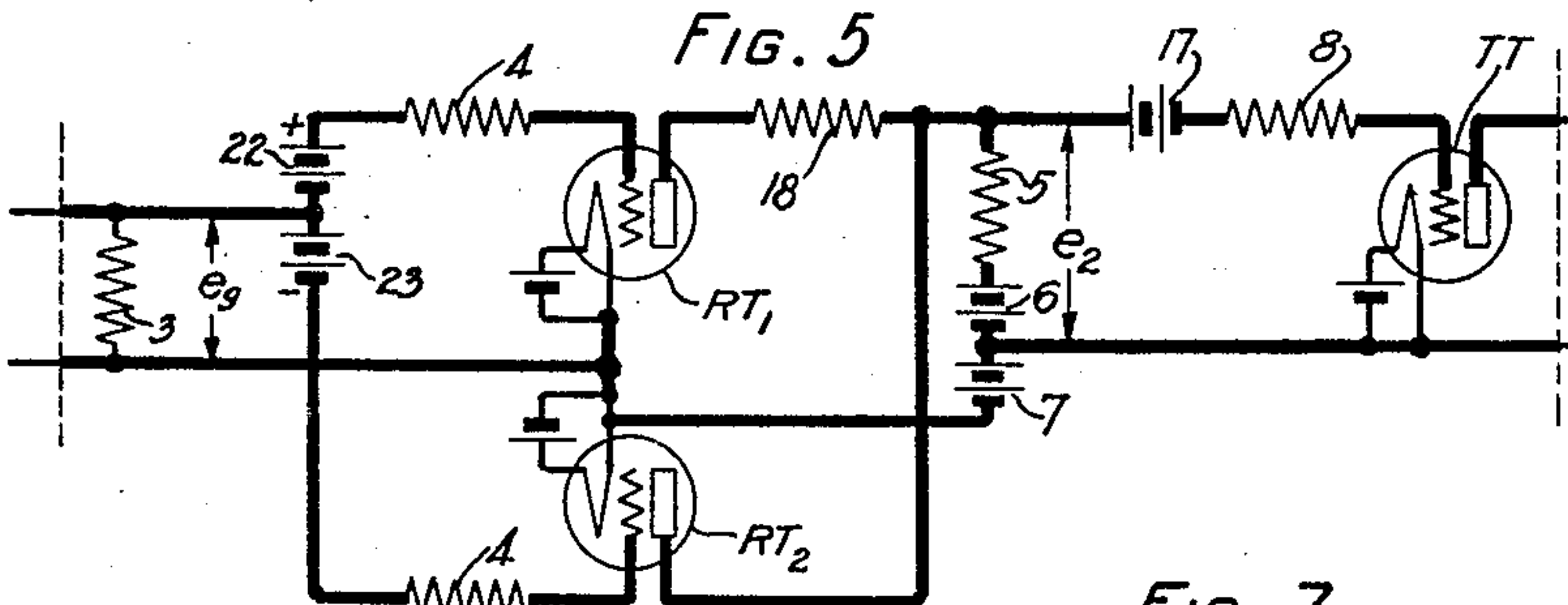


FIG. 6

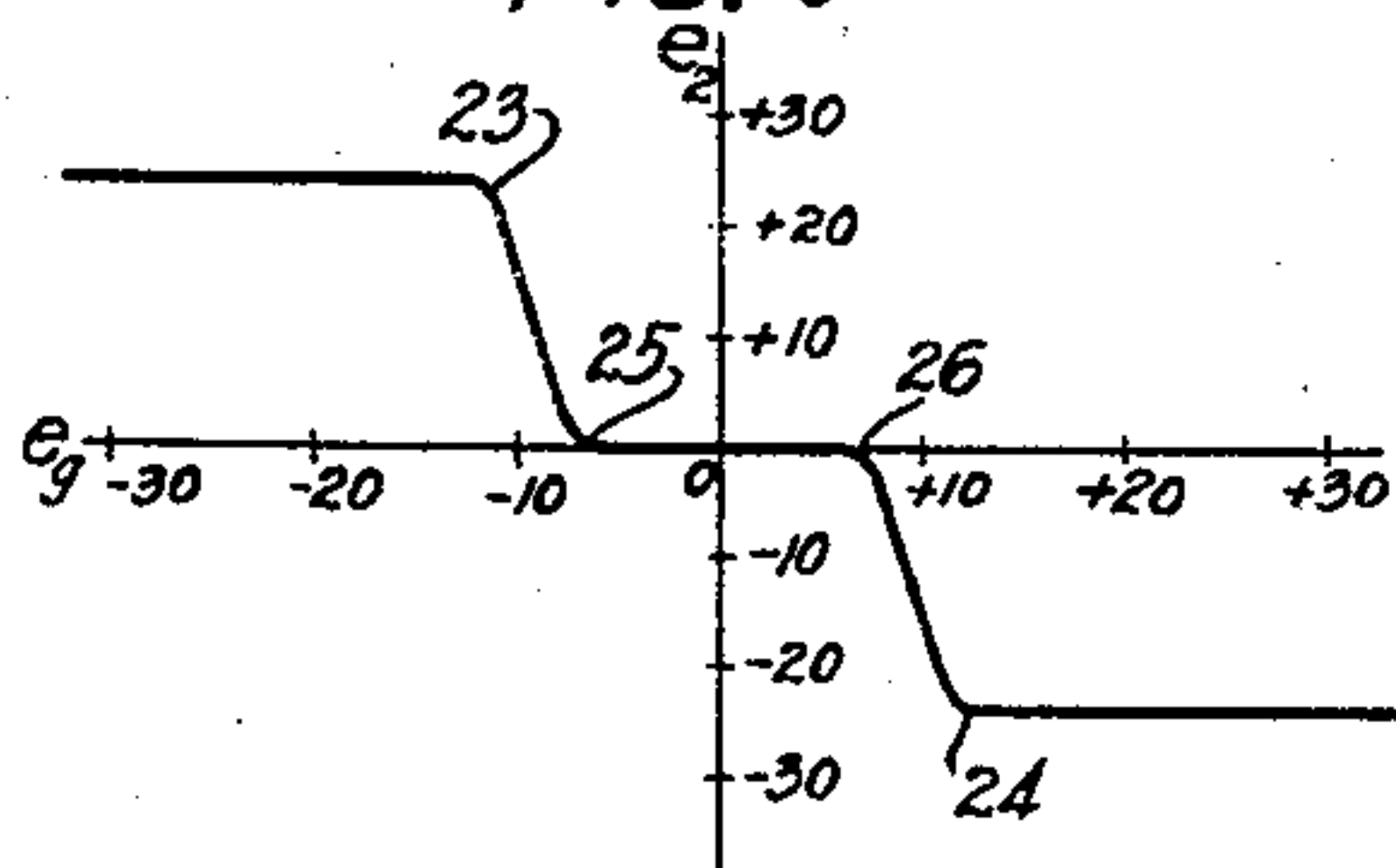
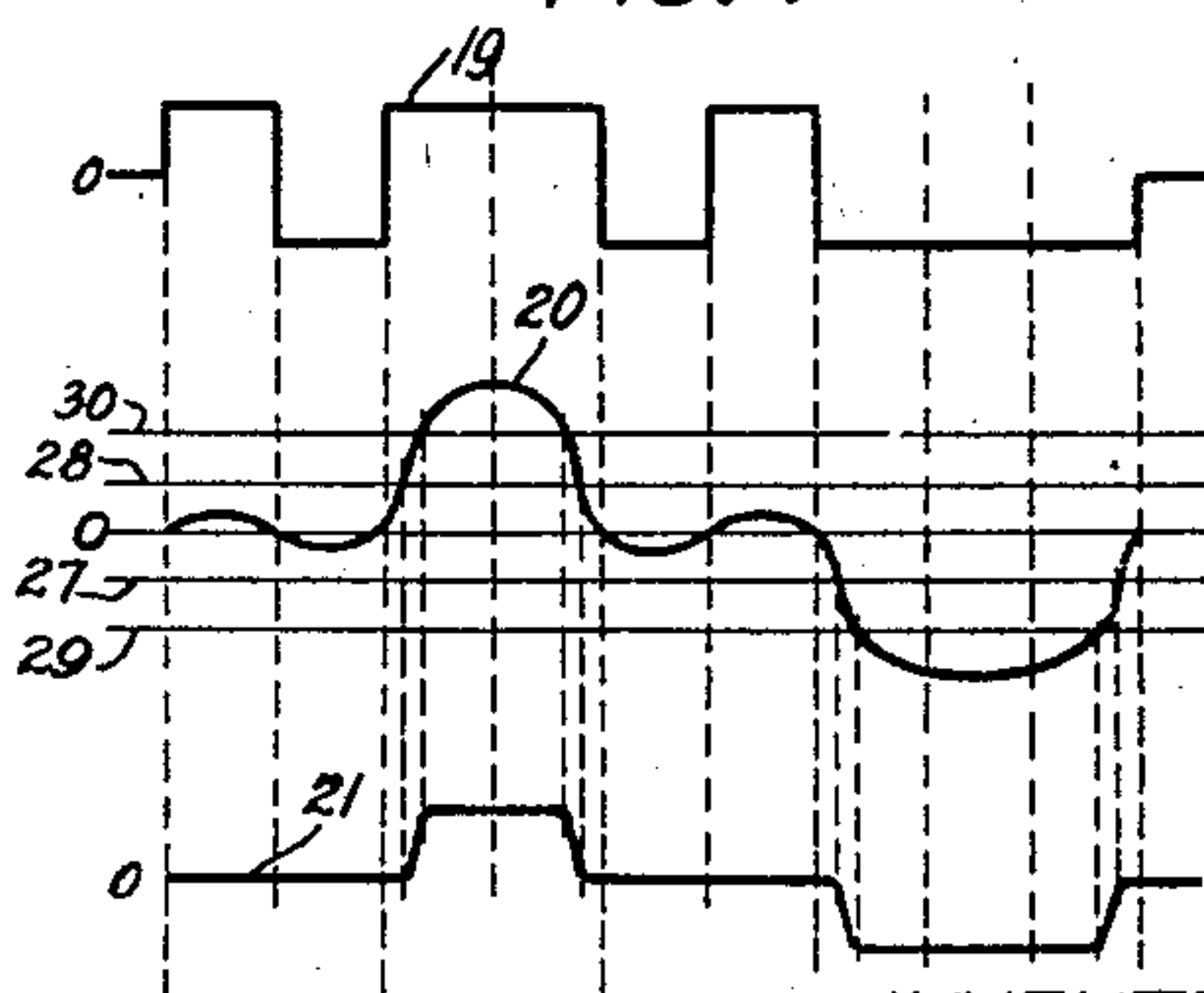


FIG. 7



INVENTOR
EVERETT T. BURTON
BY *J. W. Schmied*
ATTORNEY

UNITED STATES PATENT OFFICE

EVERETT T. BURTON, OF MILLBURN, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

TELEGRAPH REPEATING DEVICE

Application filed July 18, 1928. Serial No. 293,772.

This invention relates to marginal repeating devices and particularly to thermionic relays of the type which, in response to an input voltage exceeding a predetermined value, produces in an output circuit a voltage of substantially constant value independent of the exact value of the input voltage.

An object is to increase the reliability and to reduce the maintenance expense of a repeating device of the above type.

Another object is to adapt a thermionic marginal repeating device for three element operation.

Heretofore, two general types of repeaters have been employed, i. e., electromagnetic relays and vacuum tube amplifiers. Electromagnetic relays have been commonly used for reproducing square top waves such as are used in telegraphy, while vacuum tube amplifiers have been preferred for reproducing without distortion, waves of varying intensity.

However, a repeating circuit for telegraph signals has been proposed which utilizes vacuum tubes in place of electromagnetic relays and which may produce in its output circuit a substantially square topped wave. United States patent to Krause 1,537,682, May 12, 1925, discloses such a system in which flat topped waves are produced in the output circuit of a vacuum tube whenever the input voltage exceeds a certain value. Negative grid voltages in excess of that value produce no further change in the output voltage because the space current is completely blocked. On the other hand, positive grid voltages in excess of that value produce no further change in the output current because of filament saturation. A disadvantage of this arrangement is that the value of positive grid potential at which the space current becomes constant depends on the characteristics of the filament and on its temperature. The characteristics of the filament may change during its life, and the temperature, which is a function of the filament current, may change from time to time.

In accordance with this invention the maximum space current of a square top wave

repeater tube is limited by a resistor in the plate circuit and/or a resistor in the grid circuit which eliminate variations in the maximum space current due to variations in the emissivity of the filament. Another feature of this invention is a circuit utilizing two vacuum tubes for repeating three element signals, that is, signals comprising positive, negative, and zero impulses.

Fig. 1 of the accompanying drawings is a diagram showing one arrangement of apparatus suitable for practicing the invention.

Fig. 2 is a diagram containing a curve which shows the grid voltage-anode current characteristic of a suitable type of vacuum tube when used in the circuit of Fig. 1.

Fig. 3 is a diagram containing a curve which shows the relation between the input voltage e_g and the output voltage e_1 of the thermionic relay tube circuit in Fig. 1.

Fig. 4 is a diagram containing curves representing two-element telegraph signals before transmission over a cable, after transmission, and after being repeated by the relay circuit of Fig. 1.

Fig. 5 shows a modification of the circuit of Fig. 1.

Fig. 6 is a diagram containing a curve which shows the relation between the input voltage e_g and the output voltage e_2 of the two tube relay circuit in Fig. 5; and

Fig. 7 is a diagram containing curves which show two element telegraph signals before transmission over a cable, after transmission, and after being repeated by a relay circuit in accordance with Fig. 5.

Operation of the circuit of Fig. 1.—In the system diagrammatically shown in Fig. 1, signals received over a cable conductor 1 are amplified, by an amplifier A, and applied to the input circuit of a vacuum tube relay circuit comprising a relay tube RT. This tube is preferably of a type which has a high amplification factor and which, with the proper value of anode potential for use in this circuit, has a grid voltage-anode current characteristic curve similar to curve 12 in Fig. 2. This characteristic is very steep so that the anode current becomes zero with a negative potential of only a few volts on the grid.

Greater negative values of grid potential can therefore produce no further changes in the output current of the tube. On the other hand, when the grid becomes positive the anode current would normally increase until limited by the electron emission of the cathode. To prevent further changes in the plate current when the grid potential exceeds a predetermined positive value, a resistor 5, having a resistance considerably higher than the normal output impedance of the tube, is inserted in the anode circuit, and a resistor 4 is inserted in the grid circuit. These limit the anode current to a definite maximum value as shown by curve 13 in Fig. 2. The manner in which they function will be explained later.

When no signals are received over cable 1 the voltage e_g between the cathode and grid of the relay tube RT is zero and the anode current is at its mean value as may be seen by referring to Fig. 2. Under these conditions the total voltage of the two equal sections of the anode battery 6 and 7 is equally divided between the space path in the tube and the resistor 5, since their resistances are the same. Therefore the voltage drop across resistor 5 is equal and opposite to the voltage of battery 6 and voltage e_1 impressed upon the grid of the transmitting tube TT is zero.

When a negative impulse is received from the cable it completely blocks the space current in relay tube RT because the amplitude of the signal is increased by amplifier A to a value greatly in excess of that which, when applied to the grid of RT, is sufficient to reduce the space current to zero. With the anode current reduced to zero the voltage drop across the resistor 5 becomes zero, thus raising the value of e_1 from zero to the voltage of battery 6.

On the other hand, a positive impulse from the cable of approximately the same value as the preceding negative impulse reduces the output impedance of the tube RT to a value small as compared to that of resistor 5 so that the anode current is determined, to a large extent, by the latter impedance alone. Since, as stated above, the resistance of resistor 5 is made high in respect to the normal cathode-anode impedance of the tube, the anode current with a positive grid is substantially twice that with zero grid, and the voltage drop across the element 5 is twice that of battery 6 and in the opposite sense. The voltage e_1 is, therefore, equal in value but of opposite polarity to what it was when the grid of tube RT was negative. The relation between e_g and e_1 is shown graphically in Fig. 3. For all values of e_g in excess of small fixed positive and negative values e_1 is constant.

The grid resistor 4 may, or may not, have an appreciable limiting effect on the maxi-

mum space current, depending on its resistance relative to that of the resistor 5 and to the cathode-grid and cathode-anode resistances of the tube when the grid is positive with respect to the filament. Thus, when a positive impulse is received the grid becomes positive with respect to the filament and attracts electrons. If resistor 4 has a sufficiently low impedance the electrons can leave the grid as fast as they accumulate and the grid will remain positive. Under these conditions the maximum current will be controlled largely by the anode resistor 5. If, however, the resistance of resistor 4 is sufficiently great, the grid potential becomes much less than the input potential, due to the drop of potential along resistor 4, and the grid will no longer alter the space current.

In Fig. 4 the curve 14 indicates a series of square-topped waves representing telegraph signals. After being transmitted over a conductor such as a submarine cable these waves become rounded as shown in curve 15, and if they are not restored, or at least partially restored, to their original square-topped shape before being retransmitted over a second cable, they may be unintelligible when finally received. A repeater in accordance with the circuit of Fig. 1 repeats waves received in the form shown by curve 15 as flat-topped waves of the type shown in curve 16. The horizontal lines above and below the zero line in curve 15 represent the values of e_g at which e_1 becomes constant. Except for short periods when e_g is changing from positive to negative, or vice versa, the output wave is flat topped and of constant amplitude.

Since the output resistance of relay tube RT and the resistance of resistance element 5 are relatively large, the relay is incapable of supplying an appreciable amount of current without reducing the value of the output voltage e_1 . It therefore should work into an extremely high impedance, voltage operated device such as a vacuum tube amplifier. Such an arrangement is shown in Fig. 1. The transmitting vacuum tube TT may be a tube of relatively low output impedance and therefore capable of handling considerable power. A grid biasing battery 17 is inserted to prevent distortion and particularly to prevent the grid of transmitting tube TT from becoming positive and drawing current from battery 6. As an additional protection against the grid drawing current a large resistance 8 is inserted in series with it.

If the repeater tube RT has a sufficiently high amplification factor and the voltage of the anode batteries 6 and 7 is sufficiently low, both the upper and the lower inflection points of the characteristic curve 13 in Fig. 2 may be very sharp. On the other hand if a tube having a lower amplification factor, together with an anode battery of high voltage, is used, the lower inflection point of curve 13

in Fig. 2 may become less abrupt. Since when the anode current of tube RT is zero, the voltage e_1 is at its maximum possible value, any rounding off of the lower inflection point of curve 13 rounds off the upper inflection point of the curve in Fig. 3. This in turn would tend to round off the positive halves of the retransmitted waves in curve 16.

The above objectionable features may be avoided by making the voltage of biasing battery 17 slightly less than the maximum value of voltage e_1 , and making the impedance of resistor 8 very large compared to the filament-grid impedance of tube TT when the grid of the latter is positive with respect to its filament. In operation, when e_1 approaches its maximum positive value, current flows through resistor 8 and produces a voltage drop which checks any further change in the potential of the grid of tube TT, and in the output current represented by curve 16 in Fig. 4. In brief, with this arrangement tube RT squares up the positive halves of the waves represented by curve 15 and inverts the wave. Tube TT thereupon squares the positive half of the inverted wave and reinverts it so that the output wave represented by curve 16 is in phase with the input wave and has both its positive and negative halves restored to a flat topped shape more nearly resembling the original wave shown in curve 13.

A shunt resistance 3, which is small as compared to the average input impedance of the tube, is connected across the input circuit of tube RT. Therefore, variations in the input impedance of the tube as the potential of its grid changes from one polarity to the other have negligible effect on the input voltage e_g .

Operation of the circuit of Fig. 5.—Fig. 5 discloses a modification of the circuit of Fig. 1. It contains two tubes with their input circuits in parallel and with equal, but opposite, biasing voltages on the two grids. It is designed for use as a three-element relay, that is, one capable of repeating either positive, negative, or zero impulses depending on whether the input voltage exceeds given positive or negative values or lies between the two. The output circuit of the lower tube RT2 is similar to that of tube RT in Fig. 1. The upper tube RT1 has its anode connected to the anode of the lower tube RT2 through an additional resistor 18 which has the same resistance as resistor 5.

The grid biasing batteries 22 and 23 have values such that when e_g is zero the cathode-anode resistance of tube RT1 is low in comparison to that of the two anode circuit resistors 5 and 18. Therefore, the two anode battery units 6 and 7 are, in effect, connected directly across the two plate circuit resistances 5 and 18 and the voltage drop in resistor 5 due to the anode current flowing there-

through is practically equal, and opposite, to the voltage of battery 6. When e_g is zero, the grid of tube RT2 is maintained at such a negative voltage by biasing battery 23 that its space current is blocked. The voltage e_2 measured across resistance element 5 and battery 6 is therefore approximately zero.

When the input voltage e_g becomes negative no change occurs in the output voltage e_2 so long as the grid of tube RT1 remains positive with respect to its filament. However, as the grid approaches zero potential (as e_g becomes equal and opposite to the voltage of battery 22) with respect to the filament, the anode current rapidly decreases and passes from its previous maximum value to zero with a change of only a few volts in the grid potential. The anode current is then reduced to zero, and since there is no current flowing through and no voltage drop in resistance element 5, e_2 rises to the value of battery 6.

On the other hand, when the input voltage e_g changes from zero to positive no change occurs in the output voltage e_2 until the input voltage e_g becomes nearly equal and opposite to the voltage of battery 23, whereupon space current begins to flow through the lower tube RT2. With a slight additional increase in e_g , the output impedance of the tube becomes low with respect to the resistance of element 5. The effect of the lower tube RT2 becoming conductive is to short-circuit resistance element 18 and connect battery 6 and 7 directly in series with resistor 5. This practically doubles the current flowing from battery 6 and 7 through element 5 and changes e_2 to a value equal but opposite in polarity to the value it had when e_g was negative.

The operating characteristics of the relay circuit of Fig. 5 are shown graphically in Fig. 6. Within certain positive and negative values of e_g , e_2 is zero, whereas if e_g is increased in either a positive or negative direction beyond those limits, e_2 rapidly rises to a new constant value. The operating margin of the relay, which determines the values of e_g for which e_2 remains zero, may be regulated, within limits, by properly choosing the potentials of the grid biasing batteries 22 and 23. Thus if the biasing batteries are removed entirely the curve of Fig. 6 assumes the same shape as that of Fig. 3.

The curves of Fig. 7 illustrate one useful application of the circuit of Fig. 5. Curve 19 represents, graphically, square-topped telegraph signals consisting of various combinations of positive and negative impulses of unit or multiple unit length. When such signals are transmitted over a long conductor such as a submarine cable the unit impulses of alternately opposite polarity are attenuated to a much greater extent than are the longer impulses. The relative magnitude of short and long impulses as they may be re-

ceived after transmission over a long cable is shown in curve 20. There is a greater disparity between the amplitudes of the short and the long impulses than is shown in curve 15 of Fig. 4 because it is assumed the signals have been transmitted over a cable of greater length, or greater attenuation per unit length, or both. The unit impulses in curve 20 are too weak to operate a recording device and must be restored by a regenerative receiving device. Since in a system employing a regenerative receiver the impulses of unit length are not needed at the receiving end of the circuit and are too weak in any case to be of any value, there is no object in regenerating them at a repeating point between the transmitting and receiving ends of the cable. In fact it may be disadvantageous to repeat them because some of the impulses might get through to the receiver slightly out of phase and with sufficient amplitude, due to distortion, to interfere with their uniform reproduction by the regenerating apparatus. The undesired unit impulses may be readily suppressed at a repeating point by passing the signals corresponding in shape to curve 20 through a repeating circuit in accordance with Fig. 5.

When the circuit of Fig. 5 is used for the above purpose the voltages of biasing batteries 22 and 23 are so chosen that the inflexion points 25 and 26 in the curve of Fig. 6 occur at values of e_g greater than the maximum value of the received unit impulses. These values of e_g are represented by lines 27 and 28 in Fig. 7. The values of e_g corresponding to the inflexion points 23 and 24 in Fig. 6 are represented by lines 29 and 30 in Fig. 7. The latter values of e_g are naturally greater than those corresponding to inflexion points 25 and 26 of Fig. 6 but are substantially less than the maximum voltages of the received waves representing impulses of greater than unit length.

Since, as disclosed by curve 20 of Fig. 7, the the maximum values of the received unit impulses are always less than the values of e_g corresponding to the inflexion points 25 and 26 in the curve of Fig. 6, these impulses will have no effect on e_2 , which is normally zero. Therefore, a zero impulse is repeated, as shown by curve 21 of Fig. 7.

When a positive impulse of greater than unit length is transmitted the received impulse is of such magnitude as to exceed the values of e_g corresponding to inflexion points 25 and 23 and a flat-topped wave is retransmitted. Likewise, a negative impulse of greater than unit length is received with such strength that its voltage exceeds that of e_g corresponding to inflexion points 26 and 24 of Fig. 6 and another flat-topped wave of opposite polarity to the preceding one is retransmitted.

The circuit of Fig. 5 is not limited in its

utility to the repeating of two element signals in which short impulses are to be suppressed but may be used to advantage in many places where three element signals are to be repeated. Like the circuit of Fig. 1 it is of particular advantage where the frequencies of the impulses to be repeated are higher than those at which mechanical relays operate satisfactorily.

What is claimed is:

1. In a device for repeating electric waves which comprises a vacuum tube having a cathode, grid and anode, the method of attenuating all portions of said waves between an amplitude capable of saturating the tube and a predetermined lesser amplitude which comprises applying said waves between the grid and cathode of said tube through an impedance high relative to the cathode-grid impedance of the tube when the grid is positive with respect to the cathode.

2. In a device for repeating electric waves which comprises a vacuum tube having a cathode, grid and anode, the method of attenuating all portions of said waves between an amplitude capable of saturating the tube and a predetermined lesser amplitude which comprises superimposing a polarizing voltage on said waves and applying them between the grid and cathode of said tube through an impedance high relative to the cathode-grid impedance of the tube when the grid is positive with respect to the cathode.

3. The method of relaying an alternating current wave by means of a vacuum tube repeating device comprising two tubes connected in cascade relationship which comprises attenuating all portions of said wave between the amplitudes capable of saturating the vacuum tube and predetermined positive and negative amplitudes less than said saturating amplitudes and not attenuating portions not in excess of said predetermined amplitudes by limiting the maximum anode current of each tube.

4. The method of converting a rounded wave of alternating current into a substantially flat topped wave which comprises attenuating the positive portions of said wave between the maximum and a predetermined amplitude, inverting said wave, attenuating the positive portion of said inverted wave in excess of said predetermined amplitude, and reinverting said wave.

5. In combination, means for attenuating all portions of an alternating current wave between the maximum and a predetermined positive amplitude and for inverting said waves, and second means for attenuating all portions of the inverted wave in excess of the predetermined positive amplitude, and for reinverting the wave.

6. In combination means comprising a vacuum tube having a cathode, a grid and an anode with a resistor connected in series

with the grid thereof for attenuating all portions of an alternating current wave between the maximum amplitude and a predetermined positive amplitude and for inverting said waves and second means for attenuating all portions of the inverted wave in excess of the predetermined positive amplitude and for reinverting the wave.

7. A means for attenuating all portions of an alternating current wave between the maximum and predetermined amplitudes comprising a vacuum tube having a cathode, a grid and an anode with a source of biasing potential and a resistor connected in series with the grid of said tube, said resistor having an impedance high as compared to the cathode-grid resistance of the tube when the grid is positive with respect to the cathode.

8. In combination, a source of E. M. F., the potential of which varies in each direction in excess of predetermined limits, with a marginal translating device and a potential responsive device, characterized in this that said marginal translating device comprises a vacuum tube having a cathode, grid, and anode with said source of varying E. M. F. connected between said cathode and grid, a source of plate potential of constant value and a resistance element connected in series between said cathode and anode, said voltage responsive device being connected in shunt across said resistance element and part of said source of plate potential of constant value, the grid potential-plate current characteristic of the tube and the value of the plate circuit resistance being such that for positive grid potentials in excess of said predetermined limit the cathode-anode impedance of said tube is small compared to said resistance and for negative grid potentials in excess of said predetermined limit the cathode-anode impedance of said tube is large compared to said resistance.

9. In combination, a source of E. M. F., the potential of which varies in each direction in excess of predetermined limits, with a marginal translating device and a potential responsive device, characterized in this that said marginal translating device comprises a vacuum tube having a cathode, grid and anode, with two resistances connected in series between said cathode and grid, one of said resistances having an impedance large as compared to the cathode-grid impedance of the tube with positive grid, the other resistance being small relative to the first impedance and having connected in shunt to it said source of E. M. F., a source of anode potential of constant value and said potential responsive device connected in the cathode-anode circuit of said tube, the characteristics of the tube being such that for applied positive potentials in excess of said predetermined limits the grid-cathode voltage is substantially constant and for applied negative

potentials in excess of said predetermined limits the cathode-anode current is substantially zero.

10. A marginal relay comprising a vacuum tube having a cathode, a grid, and an anode, two resistors connected in series between the cathode and grid, one having an impedance large as compared to the cathode-grid impedance of said tube with positive grid and that adjacent the cathode having an impedance substantially less, a source of input voltage connected in shunt to said second resistor, a source of plate potential of constant value and a third resistor connected in series between said cathode and anode, the resistance of the third resistor being large as compared to the direct current resistance between the cathode and anode of the tube when a positive voltage in excess of a definite value less than the maximum value of said input voltage is impressed across said second resistor and small as compared to the cathode-anode impedance when a negative voltage corresponding in magnitude is impressed across said resistor, and a voltage responsive device connected across said third resistor and a portion of said source of plate potential.

11. A marginal potential translating device having input and output terminals, comprising a first and a second vacuum tube each having a cathode, control electrode and anode, the cathodes of said tubes being connected together and to one input terminal and the grids associated with each other and with the other input terminal, a resistance element and source of constant potential connected in series between the cathode and anode of the first tube, said resistance element and source of constant potential and a second resistance connected in series between the cathode and anode of the second tube, said output terminals being connected in shunt across said resistance element and a portion of said source of anode potential, and the value of said resistance element being large compared to the cathode-anode impedance of said tubes when their grids are positive with respect to their filaments.

12. A marginally operative potential translating device for repeating three element signals comprising apparatus as set forth in claim 11 further characterized in that there is inserted in a grid circuit of each tube a source of polarizing potential whereby the grid of the first tube is normally negative with respect to the cathode and the grid of the second tube is normally positive with respect to the cathode.

13. A marginal potential translating device having input terminals and output terminals comprising a first and a second vacuum tube each having a cathode, grid and anode, an impedance element connected between said output terminals and a connection from the cathode of each tube to the

anode of the same tube through said impedance element, a second impedance element connected between said input terminals, a connection between one of said input terminals and the cathodes of said tubes, a third impedance element and a fourth impedance element and connections between said other input terminal and a grid of each tube through said third and fourth impedance elements respectively.

14. A marginally operative potential translating device as described in claim 13 further characterized in this, that the grids of the tubes are equally and oppositely biased with respect to the cathodes.

In witness whereof, I hereunto subscribe my name this 16th day of July, 1928.

EVERETT T. BURTON.

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