

May 24, 1938.

E. T. BURTON

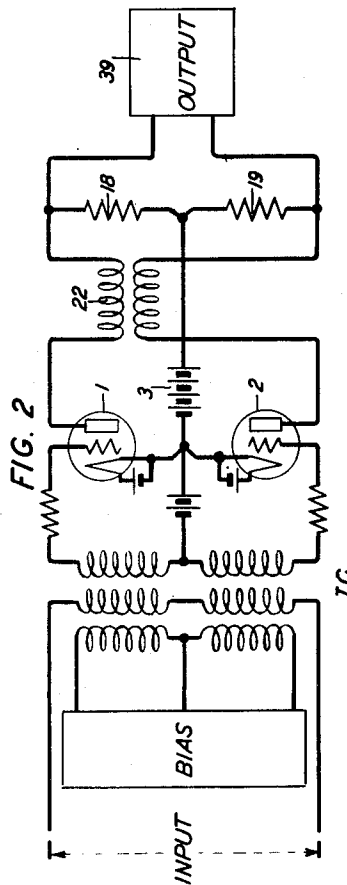
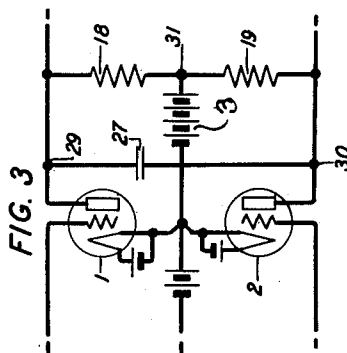
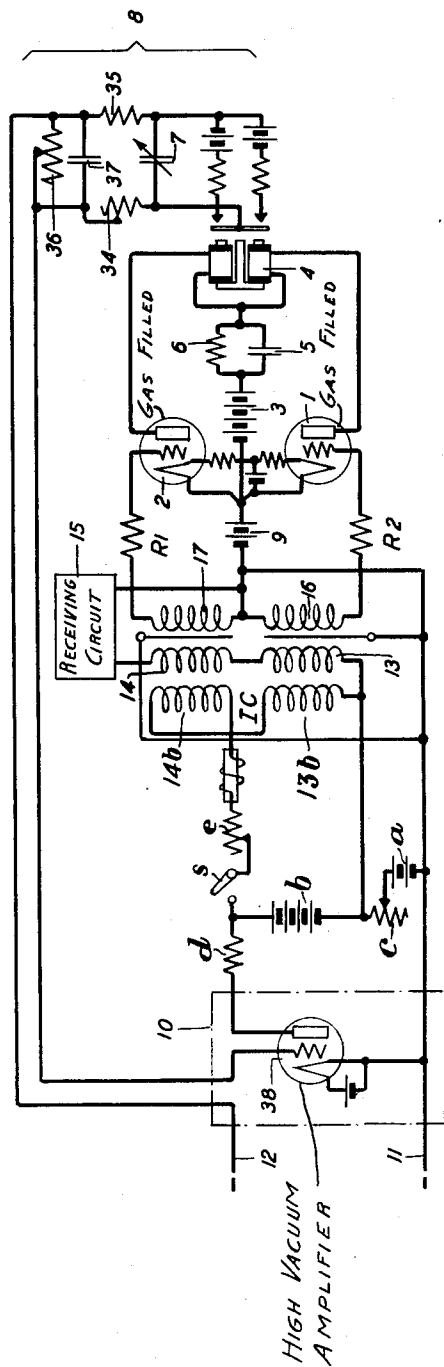
2,118,156

IMPULSE OPERATED SYSTEM EMPLOYING GLOW DISCHARGE TUBES

Filed May 21, 1930

3 Sheets-Sheet 1

FIG. 1



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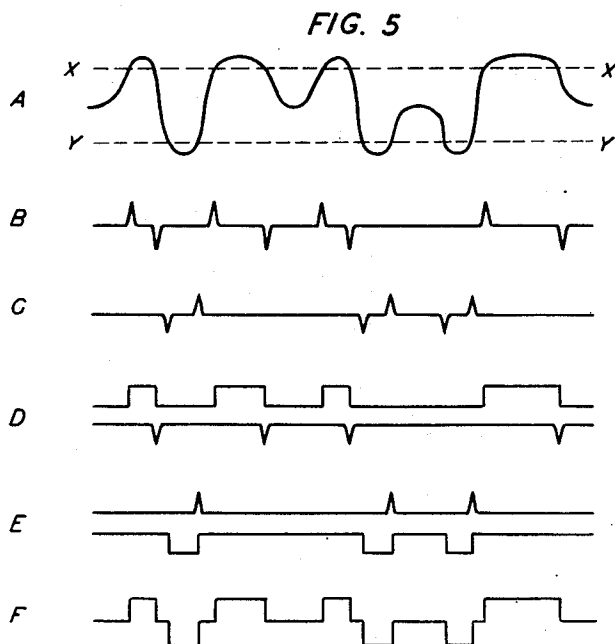
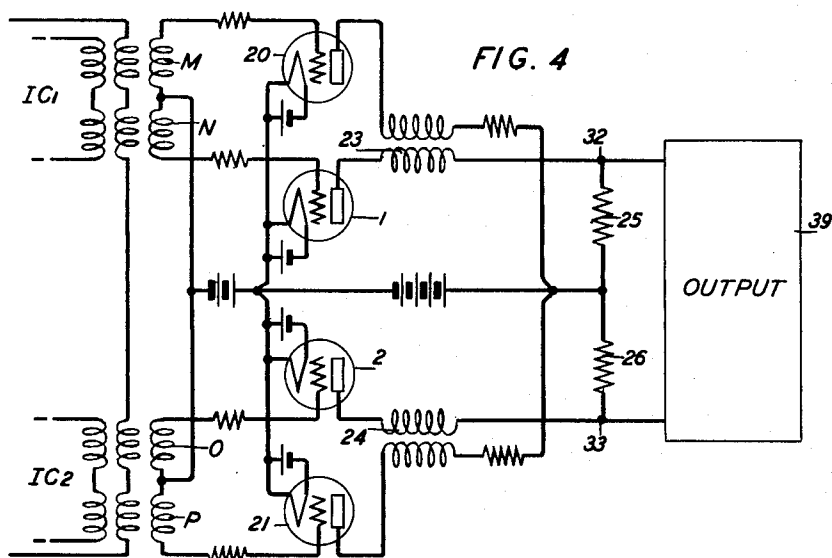
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2,118,156

IMPULSE OPERATED SYSTEM EMPLOYING GLOW DISCHARGE TUBES

Filed May 21, 1930

3 Sheets-Sheet 2



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2,118,156

IMPULSE OPERATED SYSTEM EMPLOYING GLOW DISCHARGE TUBES

Filed May 21, 1930

3 Sheets-Sheet 3

FIG. 6

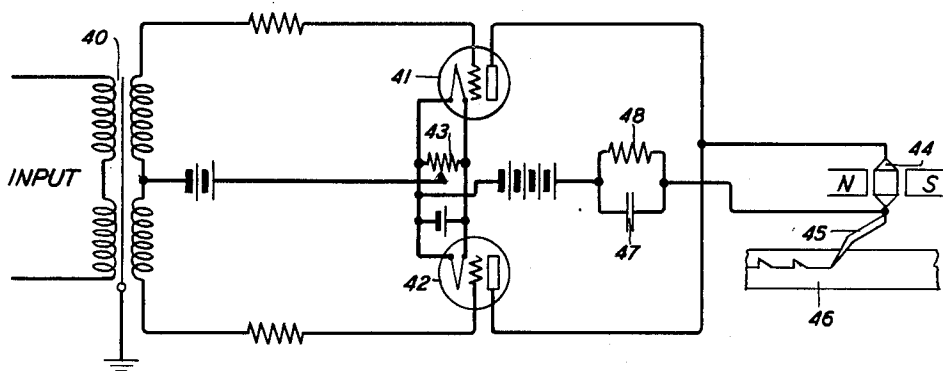
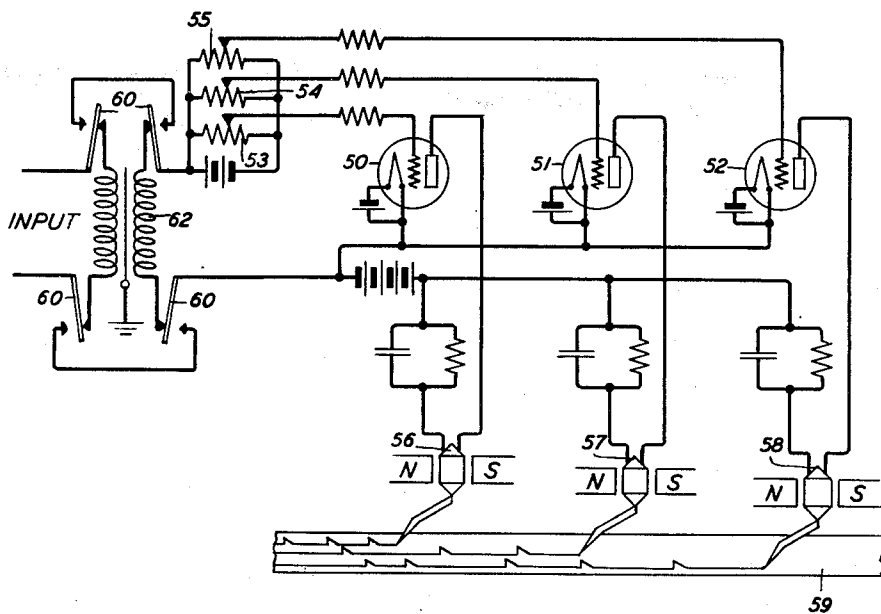


FIG. 7



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2,118,156

IMPULSE OPERATED SYSTEM EMPLOYING
GLOW DISCHARGE TUBESEverett T. Burton, Millburn, N. J., assignor to
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Application May 21, 1930, Serial No. 454,311

43 Claims. (Cl. 178-69)

This invention relates to signal transmission systems and more particularly to receiving systems for use in connection with submarine cables or other conductors of high attenuation or of high capacity.

One object is to correct for the effect known as zero wander in a highly efficacious manner.

Another object is to produce a novel type of regulator for automatically adjusting and controlling a circuit when there is a deviation of impulse amplitude from a predetermined normal.

A further object is to produce efficient two-element and three-element relays suitable for reliable operation on high speed signal impulses.

A feature of the invention is the combination of three-electrode gas-filled glow discharge tubes with suitable circuit arrangements to effect a compensating potential to restore the zero of the signal current to its true position.

Other features lie in the methods used for breaking the glow in a tube shortly after it is started.

It is known in the art of signaling over high capacity cables by means of positive and negative impulses that earth currents or a temporary preponderance of impulses of one polarity will cause an accumulative charging effect on the cable which manifests itself as an apparent shifting of the zero line of the signal wave. This is commonly known as zero wander and may be corrected by various methods. One method is that disclosed in U.S. Patent No. 1,675,096 granted to A. M. Curtis on June 26, 1928, wherein a correcting relay is operated directly by incoming signals every time the signal current, due to the addition thereto of earth currents or other low frequency currents causing "zero wander", exceeds its normal peak value. The operation of the relay is caused to produce low frequency voltage surges which are superimposed on the incoming signals in such manner as to restore the zero of the signal current to its true position. Another method is that disclosed in copending application of E. T. Burton Serial No. 293,816 filed July 19, 1928 now Patent No. 1,858,037, granted May 10, 1932, which consists in passing a signal current through the primary windings of a pair of transformers having cores of a magnetic material of high permeability, the cores being magnetized in opposite directions by direct currents, whereby the mutual inductance of the windings is maintained at a negligible value until the primary current exceeds its normal peak value, at which time the mutual inductance rises to a high value for an instant to produce in one of the trans-

former secondary windings a short pulse of voltage, producing a current, which after passing through a rectifier and charging a condenser is superimposed on the incoming signals in the form of a surge of low frequency of long duration, to restore the zero of the signaling current to its true position. Still another method is that disclosed in copending application of A. M. Curtis and E. T. Burton Serial No. 306,123 filed September 15, 1928, now Patent No. 1,818,463, granted Aug. 11, 1931, which consists in passing the secondary impulses through one of a pair of rectifiers every time the signal current exceeds its normal peak value in one direction or the other, and utilizing the rectified impulses to operate a relay through a transformer.

In the type of circuit described in the last two methods the intensity of the impulses produced varies directly as the nominal signal speed of the system, in other words the impulse intensity varies as the slope of the amplifier output signal. These circuits have difficulty in functioning properly when receiving signals at low speeds such as 4 cycles per second since they operate with but very little margin in impulse amplitude.

The application of the principles underlying the present invention enables one to design a zero wander correction circuit for receiving signals at very low speeds, for example, 3 cycles per second, with satisfactory results.

The three-electrode gas-filled glow discharge tubes used in the present invention may be produced by filling a highly evacuated small amplifier tube of the usual type with argon to a pressure of approximately 0.1 mm. of mercury. Other similar gases at suitable pressures may also be used. Such three-electrode tubes differ from tubes structurally the same but highly evacuated in that the grid is effective as a control element only for low values of plate current. If the grid is carried from the filament potential toward a more positive potential, a point is reached where the glow discharge within the tube begins and the plate current rises to a value determined by the "B" battery voltage and the plate circuit resistance. Once the glow discharge is started the control of the grid is greatly reduced and becomes very small as the plate current rises to an appreciable value. Since the grid control practically disappears for high values of plate current it is necessary to provide some means for breaking the glow very shortly after it is started. The methods employed for doing this will be described in connection with the detailed description of the drawings.

The name "thyatron" has been applied to tubes of this type in articles entitled "Gas-filled thermionic tubes" by A. W. Hull, published in the Journal of the American Institute of Electrical Engineers, November 1928, page 802; and "Hot-cathode Thyratrons" by A. W. Hull, published in the General Electric Review for April 1929 and July 1929, vol. 32, pages 213-223 and 390-399. In this specification tubes of this type will be called glow-discharge tubes, thermionic gas tube relays, thyratrons, gas-filled discharge devices, glow-discharge devices, gaseous discharge tubes, etc.

The present invention is not limited in application to low speed telegraph systems but the principles thereof may be applied in the design of efficient two-element and three-element relays which are capable of receiving signal impulses or waves at very high speeds such as 4000 cycles per second or more.

The invention will be described in connection with the accompanying drawings in which:

Fig. 1 illustrates the preferred embodiment of a zero wander correction circuit in connection with a submarine cable terminal;

Figs. 2 and 4 illustrate two embodiments of this invention in a two-element and three-element relay circuit;

Fig. 3 is a modification of a part of the plate circuit of Fig. 2, and

Fig. 5 graphically represents the operation of the circuit arrangement of Fig. 4;

Figs. 6 and 7 illustrate specific embodiments of this invention in two peak voltmeter circuits.

In Fig. 1 a multi-stage vacuum tube amplifier 10 connects a signaling line comprising conductors 11 and 12, through the primary windings 13 and 14 of a pair of high permeability transformers IC to a receiving circuit 15. The transformers are of the type disclosed in a copending application of E. T. Burton Serial No. 280,709 filed May 26, 1928, now Patent 1,936,153, granted Nov. 21, 1933, and are herein referred to as impulse coils. The operation of amplifier 38 to control the receiving circuit 15 and the impulse coils or transformers IC follows the standard practice employed where it is desired to convert positive and negative line signal pulses into variations in amplitude of unidirectional output current of a repeater tube and to control a polar device or devices according to the unidirectional current. See, for example, Curtis Patent 1,675,096, June 26, 1928, Curtis and Burton Patent 1,818,463, August 11, 1931 and Burton Patent 1,858,037, May 10, 1932. Current from batteries *a* and *b* in series flows through resistances *c* and *d* and the anode-cathode path of tube 38. This current is unidirectional and variable in amplitude in accordance with the received signals. Moreover, the battery *b* serves to supply steady current to the biasing windings 13b and 14b of impulse coils IC through a circuit including the switch *s* and the variable resistance *e* which may be adjusted to give the required value of bias current.

Resistance *c* is now adjusted so that the potential drop thereacross is about equal to the voltage of battery *a* for zero signals. The current flow through the input windings 13 and 14 of coils IC is then zero. Then for positive signal impulses on the grid of tube 38 the potential drop across resistance *c* increases because the anode current through tube 38 increases and a negative current is caused to traverse the input windings 13 and 14; this has no effect upon the particular impulse coil which is already polarized negatively,

but if and when it becomes large enough it affects the positively polarized coil as hereinafter stated. For negative signals on the grid of tube 38 the current in the plate circuit decreases and the current through resistance *c* is lessened which causes the potential drop across resistance *c* to decrease; the voltage of battery *a* then exceeds the potential drop across resistance *c* and a positive current is supplied through input windings 13 and 14; this does not affect the coil IC which is positively polarized but if and when it becomes large enough the current affects the negatively polarized coil as hereinafter stated. The amplitude of current supplied to the input windings 13 and 14 for any signal impulse is a function of the amplitude of the unidirectional current flowing in the output circuit of tube 38 and this in turn is a function of the polarity and amplitude of the signal impulse impressed across terminals 11, 12. Whenever the current flowing through input windings 13 and 14 reaches a sufficient amplitude to just neutralize the magnetic effect of the opposing biasing current in whichever of coils 13b or 14b it produces a magnetic field opposite thereto, an impulse is produced in the corresponding winding 16 or 17 in the manner fully described in said Patent 1,936,153. When a secondary impulse is produced in either of windings 16 or 17 by an incoming signal rising in amplitude from zero to a positive or negative value, which exceeds that for which the biasing current is adjusted, the secondary impulse carries the grid of one of the glow-discharge tubes 1 and 2 from the filament potential to a more positive potential. A point is then reached where the glow discharge within the tube begins and the plate current rises to a value determined by the "B" battery voltage 3 and the plate circuit resistance. Once the glow starts the high value of plate current which the tube may supply eliminates the necessity of using an output transformer such as is used in the Curtis-Burton Patent No. 1,818,463, supra and permits connection of the windings of relay 4 directly into the plate circuit. The control of the grid circuit is practically identical with that of the highly evacuated small amplifier tube of the usual type so long as little plate current flows. However, once the glow of the gas filled tube is started the control of the grid is greatly reduced and becomes very small as the plate current rises to an appreciable value. It therefore becomes necessary to provide some means for breaking the flow very shortly after it is started by the arrival of a positive impulse. At the same time it is desirable that the initial value of plate current be high in order to provide decisive operation of relay 4. This is accomplished by providing condenser 5 shunted by resistance 6. The operation of the circuit is as follows: the production of an impulse in one of the secondary windings carries the grid of one of the glow discharge tubes 1 or 2 from the filament potential to a more positive potential and causes the glow discharge to begin. For an instant nearly the full "B" battery voltage 3 is applied to the winding of relay 4 through the plate circuit condenser 5. This plate current surge operates relay 4 which is preferably of the type disclosed in Curtis Patent 1,675,096 supra, and causes the armature of the relay to touch one of its associated contacts holding it in this position sufficiently long to charge the condenser 7 of a resistance-capacity network 8 such as described in Curtis Patent 1,675,096, supra. The voltage impulses impressed on condenser 7 flow to con-

denser 37 through the resistance-capacity network 8 which comprises resistance elements 34 and 35 and condenser 37. This charge can leak off through resistance 36. The apparatus is connected so that the charge applied to grid 38 of amplifier 10 by condenser 37 is of such polarity as to oppose and of such magnitude as to approximately neutralize the original displacement of the average grid potential which caused the impulse coil to operate, and consequently restores the grid potential to its normal value. As condenser 5 charges, the plate current falls off rapidly until a point is reached where the grid of the glow tube, which in the meantime has returned to its negative potential, assumes control and breaks the glow discharge. When the plate current falls to zero, condenser 5 discharges through shunt resistance 6. The glow discharge tubes 1 and 2 are arranged in push-pull relation as shown in the drawings and consequently, impulses of positive polarity respectively produced in the windings 16 and 17 cause impulses in the plate circuits of the glow tubes 1 and 2 respectively.

The limiting speed at which this circuit can operate is determined by the length of time required for condenser 5 to charge and discharge. For values of 4 mf. for condenser 5 and 40,000 ohms for resistance 6, this circuit has been found to operate very satisfactorily at the rate of 3 or 4 impulses a second. Other suitable values may be used. The voltage of plate battery 3 and the voltage of grid battery 9 each may be varied over a wide range provided the voltage of the other is adjusted to a suitable value. In the circuit illustrated in Fig. 1 the plate voltage was varied in a range from 45 volts to 120 volts and the grid voltage varied at the same time from -4.5 volts to -30 volts with satisfactory operation of the circuit. Both grid and plate voltages need not be varied in proportion. Consequently, this factor tends toward reliable operation of the circuit. Small changes of voltage in the grid or plate circuit will not affect the operation of the circuit.

It is known that when the grid impedance of the glow tube is very low a high current may flow back through the grid circuit whenever a glow begins. With an impulse coil connected to the grid circuit this will disturb the adjustment of the impulse coil. Resistances R_1 and R_2 are therefore inserted in the grid circuits of the glow tubes as protective elements to reduce the grid current, when the glow in a tube begins, to an amplitude ineffective to disturb the bias adjustment of impulse coils IC.

Fig. 2 diagrammatically illustrates a two tube relay circuit operating through an impulse coil IC in the input circuit. Glow discharge tubes 1 and 2 are shown in push-pull relation. When a positive impulse is applied to the grid circuit of tube 1 a glow strikes in the tube in a manner hereinbefore described and plate current flows through high frequency transformer 22. An electro-motive force pulse is thereby induced in transformer 22 in the plate circuit of tube 2 which momentarily opposes and practically equalizes the voltage of the "B" battery 3 of tube 2. This causes any current which may have been flowing in tube 2 plate circuit to cease while the current in the tube 1 plate circuit rises at once to a steady value. This condition continues until an impulse of positive polarity is applied to the grid of tube 2. In this event the process is reversed; the starting of the plate current in tube 2 plate circuit produces a counterelectro-

motive force through high frequency transformer 22 to the plate circuit of tube 1 which opposes and equalizes the "B" battery voltage of tube 1 thereby terminating the flow of plate current in tube 1. In this manner there are produced across resistances 18 and 19 in the output circuit of this relay circuit two-element square top signals.

Resistances 18 and 19 are of sufficiently low value that the output voltage of the relay is not greatly disturbed by any ordinary variation in impedance of the output circuit or load device 39. For example, when an output current of 0.030 ampere was required, resistances 18 and 19 were each 4000 ohms and when an output current of 0.5 ampere was required the values of 18 and 19 were as low as 200 ohms. The choice of resistance values depends upon the type of load across the output and is preferably determined experimentally. Such load may be any type of suitable circuit such as a rotary distributor circuit, a condenser signal storing circuit, etc., U. S. Patent 1,670,461 issued to G. A. Locke May 22, 1928 discloses an arrangement adaptable for use with this invention.

Transformer 22 may be any high frequency type capable of carrying the plate current without overloading and having a value of inductance suitable for transmitting make and break impulses without repeating the lower frequencies of the signals. In a practical embodiment of the circuit of Fig. 2 an ordinary transformer designed for carrier frequencies above the voice frequency range was used.

It is to be understood, of course, that an ordinary transformer may be used in the input circuit instead of the impulse coil IC. Relays which can produce square top signals of two voltage amplitudes only, are herein referred to as two element relays; and relays which can produce three amplitudes of voltage, for example, a positive, negative and a neutral or zero polarity are herein referred to as three-element relays.

Fig. 3 illustrates a modification of a part of Fig. 2. A low capacity condenser 27 of the order of 0.005 mf. (other suitable values such as 0.1 mf. may be used) is shown connected across the plate circuits of glow tubes 1 and 2, at points 29 and 30. This condenser is used as a substitute for the high frequency transformer 22 in Fig. 2. In its broad aspect the discharge of condenser 27 is employed to extinguish the arc in the glow tube. Its operation is as follows: when an incoming signal impulse carries the grid of tube 1 toward a more positive potential than its grid-filament potential and causes the glow discharge in tube 1 to begin, then current will flow in the plate circuit of tube 1 through resistance 18. If, at this instant, no current is flowing in the plate circuit of tube 2, then point 31, which connects battery 3 with resistances 18 and 19, will have the same potential as point 30 and condenser 27 will become charged to the same potential as that existing across resistance 18 (which may be of the order of 100 volts when battery 3 is approximately 120 volts). If at this time, an incoming signal impressed upon the relay causes the glow in tube 2 to strike then point 30 will have impressed upon it a potential which will raise it to approximately the same potential as point 29. Condenser 27 will discharge in a very short interval of time and extinguish the arc in tube 1 as the discharge of the condenser opposes the plate battery voltages and creates a lower potential across the arcing space of the tube than that necessary to continue the

glow. With a circuit of this type the speed of operation of the two-element relay circuit is as high as that of Fig. 2.

In Fig. 4 is shown an arrangement similar to Fig. 2 and designed for three-element operation. In this case two sets of impulse coils are provided, each set having two secondary windings. These windings are connected to two pairs of tubes. Tubes 1 and 2 are gas-filled and furnish the signal output through their respective plate circuit resistances 25 and 26. Tubes 20 and 21 are auxiliaries which are useful only in stopping the plate currents of tubes 1 and 2 by operation through their respective plate circuit transformers 23 and 24. These auxiliaries may be either gas-filled or of the usual high vacuum type. The operation of this circuit is described in detail in connection with Fig. 5 which graphically illustrates the signal input voltage and the resulting voltages and currents in the three-element tube relay.

Curve A represents the signal input as it is impressed upon impulse coils 1 and 2. As the signal currents exceed the value for which the impulse coils are biased, indicated by lines $x-x$ and $y-y$, short pulses of voltage are produced in the secondary windings of impulse coils 1 and 2. For illustration, it is assumed that an impulse is produced in the secondary windings of IC1, when the signaling current is positive and in the secondary windings of IC2 when the signaling current is negative. Therefore, according to curve A, impulses are produced in IC1 each time the trace of curve A rises through and above the value represented by line $x-x$ and in IC2 each time the trace of curve A falls through and below the value represented by line $y-y$. Two impulses of voltage will be produced in the secondary windings of IC1, one each time the signaling current rises above $x-x$ and another when the signaling current falls below $x-x$. This is illustrated in curve B, which represents the electromotive force induced in the secondary windings M and N of the set of impulse coils IC1. The upper portion of curve B shows the sharp positive pulses which are produced in secondary coil N of IC1 and which affect the grid of glow tube 1. Simultaneously with the occurrence of a positive pulse in the secondary N, a negative pulse occurs in secondary coil M of the set of impulse coils IC1. Since only positive pulses applied to the grids of glow tubes are effective to produce or initiate a discharge through them, it is not considered essential in describing the operation of the circuit to make reference to the negative pulses occurring simultaneously in the secondary windings of the associated impulse coil. It will be understood, of course, that when the associated extinguishing tubes 20 and 21 are of the high vacuum type, in which the grid continuously controls the output current, and when these tubes are operated on a straight line portion of their characteristic as an amplifier, the negative pulses occurring in the secondary windings M and P simultaneously with the positive pulses occurring in the secondary windings N or O respectively will be repeated through these tubes and induce a potential in the anode circuit of the gas-filled tubes 1 and 2 through the associated transformers 23 and 24. These potentials aid the operation of the tubes and circuits. These positive pulses occurring in coil N carry the grid of glow tube 1 more positive and cause the glow discharge in the tube to begin. The lower portion of curve B shows the positive pulses produced in secondary

coil M of IC1 which places a more positive potential on the grid of glow tube 20 and causes the glow discharge in tube 20 to begin. The flow of plate current in tube 20 through the high frequency transformer 23 creates an opposing electromotive force which stops the flow of plate current in tube 1 in a manner hereinbefore described in connection with Fig. 2. Similarly, two impulses of voltage will be produced in the secondary windings of IC2, one each time the signaling current falls through and below the value represented by line $y-y$ and another when the signaling current rises through and above $y-y$. This is illustrated in curve C. The lower portion of curve C represents the positive pulses which are produced in secondary coil O of IC2 which are impressed upon glow tube 2 to carry its grid more positive and cause the glow in tube 2 to begin. The upper portion of curve C shows the positive pulses produced in secondary coil P of IC2 which carry the grid of tube 21 more positive causing a flow of plate current in tube 21 which, flowing through high frequency transformer 24, stops the glow in tube 2. The output circuit 39 may be taken across resistances 25 and 26 in a manner similar to that described in connection with Fig. 2. The square top signal of curve D represents the output of the plate current of gas-filled tube 1 across resistance 25 and the sharp pulses illustrated by the lower portion of curve D show the plate current in the tube 20. Similarly, the lower portion of curve E is the plate current of gas-filled tube 2 across the resistance 26 and the upper portion of curve E is the plate current in tube 21. The output signal across resistances 25 and 26 at points 32 and 33 is represented by curve F.

Such circuit arrangements as illustrated in Figs. 2, 3, and 4 are capable of receiving signal impulses at a rate of speed such as 4000 double alternations per second and more. By a double alternation is meant a single positive pulse followed by a single negative pulse. The embodiments illustrated in Figs. 2, 3, and 4 may be used in zero wander correction circuits. However, when these embodiments are used in zero wander correction circuits, the operating speed would normally be very low.

Fig. 6 illustrates a peak voltmeter for determining voltages in excess of a predetermined value. This embodiment closely approaches that of Fig. 1 except that an ordinary input transformer 40 with two secondary windings is used instead of the impulse coil. Input transformer 40 may be any transformer which is designed to pass the frequencies of the incoming signals. Glow tubes 41 and 42 are shown in push-pull relation with grid control rheostat 43 across the filament battery supply. Relay 44 is a special magnetic device with a stylus 45 attached to it and resting on a moving strip of paper 46.

The manner of operation is almost the same as hereinbefore described in connection with the zero wander correction circuit. An incoming impulse impressed on the grid of a glow tube of an amplitude sufficiently large to carry the grid of the tube to the more positive potential required to cause the glow in the tube to begin, which in turn actuates relay 44. In operating, relay 44 moves stylus 45 across the moving strip of paper 46 and causes a jagged line to be recorded. Condenser 47 and shunt resistance 48 are utilized to break the glow in the tube shortly after it is started, as mentioned hereinbefore in connection with the zero wander correction circuit. Grid

rheostat 43 controls the potential at which the glow in the tube is desired to begin. In this manner one may easily determine the number of times an impulse impressed upon the grid of a glow tube exceeds a predetermined normal amplitude.

Fig. 7 is a slight modification of Fig. 6. Each of the glow discharge tubes 50, 51, and 52 have their respective grid circuits adjusted to different values on rheostats 53, 54, and 55 respectively, so that the glow in each of the three tubes will begin at different amplitudes of current. Relays 56, 57, and 58, associated with tubes 50, 51, and 52 and actuated thereby, will therefore record different peak voltages. For example, assuming that the grid circuit of tube 50 is adjusted to have the glow in its tube begin when an incoming signal exceeds one volt and that the grid circuits of tubes 51 and 52 are adjusted to have the glow in their tubes begin at two volts and three volts respectively, then relays 56, 57, and 58 will each record upon reception of an incoming signal which exceeds the voltage for which its associated tube is adjusted to glow. Relay 56 will be actuated and will record when the input voltage exceeds one volt. Naturally, this relay will operate whenever the amplitude of the input signal is sufficient to cause the operation of relays 57 and 58 on voltages in excess of one volt. In some cases it may be desirable to omit input transformer 62 from this embodiment. This is accomplished by operating key 60 which cuts out the transformer and connects the incoming leads directly to the grid circuit. It is to be understood that the strip of paper 59 moves at a certain rate of speed and consequently there will be several visual records of the number of peak voltages in excess of the predetermined values for which the glow in the glow tubes are adjusted to begin per unit length of time.

It is understood, of course, that these arrangements may be used for many other purposes such as gain regulators for vacuum tube circuits, automatic control apparatus, etc. and that the glow tubes may be used individually or in pairs without departing from the scope of this invention. In adapting any of the circuit arrangements hereinbefore described to various special uses, minor adjustments may be made in the impulse coil biasing current or in the grid control rheostat so as to cause the glow discharge of the tubes to begin at any desired value of voltage which may be impressed upon the grid circuit.

What is claimed is:

1. A signal impulse amplifier having means for correcting zero wander, said means comprising a reentrant circuit extending from the output circuit of said amplifier to the input circuit thereof, characterized in this, that at least one glow discharge tube with an input circuit control element is included in said means with an input circuit for said tube comprising impedance elements normally impressing upon said tube a voltage below the breakdown value but above the breakdown value upon the receipt of changes in current due to zero wander, and means for applying a correcting voltage through said reentrant circuit upon the breakdown of said tube.

2. A zero wander correction circuit comprising a source of signaling current, a pair of high permeability transformers, two gas-filled three-electrode glow discharge tubes including means to automatically break the glow in the tubes very shortly after it is started by the arrival of a plus impulse, a relay circuit arranged to operate in re-

sponse to current impulses received from said glow discharge tubes, and means to superimpose a suitable surge of current of wave form on the signaling current to correct zero wander, whenever said relay functions.

3. A thermionic regulator for automatically controlling circuits by impressing a current of suitable form across the output of said regulator when the incoming currents exceed a predetermined positive or negative value, comprising in combination a pair of high permeability transformers, a plurality of glow discharge tubes connected in push-pull relation, means to automatically break the glow in a tube very shortly after it is started by the arrival of an impulse, and means to impress a current of suitable form upon the circuits to be controlled whenever a glow discharge tube functions.

4. A transmission signaling device for repeating signals comprising an impulse coil, a circuit supplied with impulses thereby comprising a glow discharge tube, another glow discharge tube in push-pull relation with the first tube, means in the plate circuits of each of said tubes for automatically breaking a glow in the other tube very shortly after said glow starts, and means to obtain a current of suitable form from the plate circuit of a tube whenever said tube functions.

5. A transmission signaling device for repeating signals comprising impulse coil means connected in the input circuit thereof functioning to produce impulses of current only as signals received by said impulse coil exceed a predetermined value, three-electrode glow discharge tubes arranged to operate whenever positive potential sufficient to strike a glow in said tubes is impressed upon said tubes by said impulse coil means, additional means for automatically breaking the glow in a tube very shortly after it is started by the arrival of the positive impulse, and means for obtaining the envelope of the plate current which flows in the glow discharge tubes whenever said tubes function.

6. A system for relaying voltages exceeding a definite minimum value and remaining insensitive to voltages less than said value comprising input terminals across which the voltages to be relayed occur, a gas-filled discharge device having a grid and grid circuit connected to said terminals, said device having the characteristic of setting up a glow discharge at a specified grid voltage, a cathode-anode circuit controlled by said grid, said circuit being operatively related to an actuable instrument which is actuated by the glow discharge current, characterized in this that resistance and capacity elements are included in said anode-cathode circuit to restore said instrument by limiting the flow of current in said anode-cathode circuit to a critical value below that necessary to continue the flow.

7. In combination an instrument for recording voltages in excess of a definite minimum value comprising, a transformer, a glow discharge tube connected thereto, means connected to said tube for breaking the glow shortly after it is started, an electromagnetic device responsive to the beginning of a glow in said glow discharge tube, and recording means attached to said device for causing a visual indication whenever said device is actuated.

8. In combination in a device for recording current in excess of a predetermined amplitude, a transformer, a glow discharge device connected thereto comprising a cathode, an anode and a controlling electrode, an adjustable member

connected to said controlling electrode for limiting the current flowing to said electrode, means connected to said device for breaking the glow in the tube shortly after it is started by the arrival of an impulse, and recording means responsive to the glow in the tube for indicating said response.

9. In combination, a glow discharge device comprising a cathode, an anode and a control element, an input circuit connected to said control element, an output circuit connected to said anode, an impedance means in said output circuit adapted to break the glow discharge by reducing the output current to a value below that necessary to continue the glow discharge.

10. In combination, an instrument for recording voltages of definite minimum values comprising a plurality of glow discharge tubes, each of said glow tubes having a cathode, anode and control element, an adjustable element individual to each of said control elements for regulating the minimum voltage at which the glow in each respective tube is arranged to strike, recording means individual to each of said anodes for causing a visual indication whenever a glow strikes, and means for breaking the glow shortly after it is started.

11. An instrument for determining a potential in excess of a predetermined value comprising a glow discharge device having a cathode, an anode and a control element, input terminals connected to said control element across which the voltage to be determined occurs, output terminals connected to said anode, indicating means associated with said output terminals for causing an indication whenever said device functions, additional circuit means in said output including a condenser for breaking the glow in said device shortly after it is started.

12. A transmission signaling device in accordance with claim 5, characterized in this that each of said three electrode glow discharge tubes has an input circuit and an output circuit, and said additional means for automatically breaking the glow in a tube very shortly after it is started comprises a condenser connected across the output circuit of said tube.

13. A thermionic regulator in accordance with claim 3, characterized in this that said means to automatically break the glow in a tube comprises a condenser and a resistance connected in shunt to said condenser.

14. A signaling system for repeating signals comprising a gas-filled discharge device having a grid and grid circuit connected to input terminals, said device having the characteristic of setting up a glow discharge at a specified grid voltage, a cathode-anode circuit for said device controlled by said grid, said circuit being operatively related to mechanism for receiving the glow discharge current, characterized in this that a condenser and a resistance connected in shunt to said condenser are provided to break the glow discharge whenever the current in the cathode-anode circuit falls below a critical value necessary to continue said glow discharge.

15. A transmission signaling device for repeating signals comprising two glow discharge tubes arranged in push-pull relation, each of said tubes having a cathode, an anode and a control element, an input circuit connected to the control elements of said tubes, an output circuit connected to the anodes of said tubes, a transformer in said output circuit, windings for said transformer, one winding of said transformer being connected to the anode of one of said glow tubes,

another winding of said transformer being connected to the anode of the other glow tube, said two windings being so connected that the glow discharge in one of said tubes is immediately broken when the glow discharge in the other of said tubes strikes.

16. A transmission signaling device for repeating signals comprising in combination, terminals adapted to be connected to an incoming line, impulse coil means connected to said terminals to produce impulses of current only when signal impulses impressed upon said terminals and received by said impulse coil means exceed a predetermined value, two electron discharge devices each comprising a cathode, an anode and a control element and arranged in push-pull relation with their input circuits controlled by said impulse coil means, at least one of said tubes having the characteristic of setting up a glow discharge at a specified grid voltage, an output circuit connected to the anodes of said electron discharge devices, a transformer in said output circuit, windings for said transformer connected to respective anodes of said electron discharge devices in such manner that an increase of current through one of said devices induces an electromotive force in the anode circuit of the other of said devices in a direction to oppose the normal direction of current flow in the anode circuit of said other device.

17. In a transmission circuit, an impulse coil comprising an input circuit and an output circuit, a glow discharge tube connected to said output circuit by a path in a fixed state of continuity, in combination with elements operatively related to the circuits of said tube for breaking the glow in said tube shortly after it is started.

18. In combination, a glow discharge device comprising a cathode, an anode and a control element, an input circuit connected to said element, an output circuit connected to said anode, and a path in said output circuit including impedance means in a fixed state of continuity to break the glow discharge by reducing the output current to a value below that necessary to continue the glow discharge.

19. In combination, a glow discharge device comprising a cathode, an anode and a control element, an input circuit connected to said element, an output circuit connected to said anode, a condenser and a resistance in shunt of said condenser, both said condenser and resistance being connected in said output circuit and adapted to break the glow discharge by reducing the output current to a value below that necessary to continue the glow discharge.

20. A system comprising an electromagnetic device having an input circuit and an output circuit, said device being effective to produce a current flow in said output circuit when the voltage applied to said input circuit traverses a certain range of values but ineffective to produce current flow in said output circuit when the voltage applied to said input circuit lies in other ranges of values in combination with a repeater connected to said output circuit comprising a grid-controlled arc discharge device controlled by current flowing in said output circuit, and devices in the output circuit of said repeater causing the current flowing therein to cease after a time independent of the time said applied voltage remained within said certain range.

21. In an impulse relaying system an incoming circuit, two electron discharge devices connected to said circuit, said devices having electrode cir-

cuits including anode circuits connected thereto, one of said devices being connected oppositely with respect to the other, one of said devices being of the glow discharge type and having its anode circuit connected to a load device, the other of said devices being of the high vacuum type, an impedance means common to the electrode circuits of the said two devices in such manner that voltage impulses in the anode circuit of said high vacuum discharge device induce voltages in the anode circuit of the glow discharge device in a direction to oppose the anode voltage, thereby serving to break an existing glow discharge in said glow discharge device.

22. A repeater for telegraph impulses comprising an incoming path to supply impulses and an outgoing path to receive repeated impulses in which a plurality of gas-filled tubes of the breakdown discharge type having an anode, a cathode and a control element have their control elements connected to the incoming path and their anode-cathode circuits connected to the outgoing path, means whereby an impulse received over said incoming path causes a discharge through one of said tubes to repeat a corresponding impulse to said outgoing path and means whereby an impulse of opposite polarity received over said incoming path causes a discharge through said other tube to repeat an impulse of opposite sign to said outgoing path.

23. An impulse repeating system comprising an incoming line and an outgoing line, transformer means connected to said incoming line, said transformer means having secondary winding means, a plurality of gaseous discharge tubes having anodes, cathodes and control elements, said control elements being oppositely connected to said secondary winding means and said cathodes being also connected to said secondary winding means, said output circuit including an impedance, and said impedance being included in a closed path which also includes the anode-cathode paths of said tubes.

24. A repeater consisting of a plurality of gaseous discharge tubes each having an anode, a cathode and a control element connected in push-pull relation, an incoming line connected oppositely to the cathode-control element paths of said tubes through separate transformers, and connections whereby a discharge through one of said tubes impresses a potential upon the output circuit of the other thereof to interrupt any existing discharge therethrough.

25. In an impulse relaying system; a circuit supplying impulses; a signal responsive device comprising a thermionic tube relay having anode, cathode, and control electrode elements and circuits so constructed and arranged that current continues to flow in the anode-cathode circuit unaffected by the potential of said control electrode after being started by the application, to said control electrode, of a potential more positive than a critical value; a second thermionic tube relay having anode, cathode, and control electrode elements and circuits so constructed and arranged that the potential applied to said controlling electrode continuously controls the anode-cathode current; and connecting means for connecting said controlling circuits to the circuit in a push-pull arrangement supplying impulses.

26. In an impulse relaying system; an impulse supplying circuit; a signal responsive device comprising a thermionic gas tube relay having anode, cathode, and grid elements and cir-

cuits so constructed and arranged that the anode-cathode current is substantially independent of the grid potential after it is started by a grid potential more positive than a critical value; a thermionic vacuum tube relay having anode, cathode, and grid elements and circuits so constructed and arranged that the anode-cathode current is continuously dependent upon the grid potential; and impulse coils for changing supplied impulses into peaked impulses connecting said grid circuits in a push-pull arrangement to the impulse supplying circuit.

27. In an impulse relaying system; a circuit supplying impulses; a signal responsive device comprising a thermionic gas tube relay having anode, cathode, and grid elements and circuits in which the anode-cathode current is independent of the potential of said grid after being started by a grid potential more positive than a critical value; a thermionic vacuum tube relay having anode, cathode, and grid elements and circuits in which the anode-cathode current is dependent, at all times, upon the potential of said grid; connecting means for connecting said grid circuits to said circuit supplying impulses; and means interconnecting said anode circuits whereby an increase in current in one of said anode circuits causes a reduction in the potential of the anode with respect to the associated cathode of said other anode circuit.

28. A telegraph signal impulse responsive device comprising an input circuit for supplying telegraph signal impulses; a thermionic gas discharge tube relay having anode, cathode, and grid elements and circuits in which the anode-cathode current is substantially independent of the grid potential after the grid potential has exceeded the critical value required to start the anode-cathode current; a thermionic vacuum tube relay having anode, cathode, and grid elements and circuits in which the anode-cathode current is at all times dependent upon the grid potential; impulse coils for changing telegraph signal impulses into peaked impulses connecting both of said grid circuits to said input circuit in a push-pull arrangement, and means interconnecting said anode circuits whereby an increasing current in one of said anode circuits causes a sufficient reduction in the potential between the anode and cathode of the other of said anode circuits to reduce the current flowing in said other anode circuit to substantially zero.

29. A telegraph repeater connecting an incoming line and an outgoing line comprising an input circuit to receive telegraph impulses; an output circuit; a thermionic gas discharge tube relay having anode, cathode, and grid elements and circuits in which the anode-cathode current is substantially independent of the grid potential after the grid potential has exceeded the critical value required to start the anode-cathode current; a vacuum tube relay having an anode, cathode, and grid elements in which the anode-cathode current is at all times dependent upon the grid potential; connecting means for connecting said circuits to said input circuit in a push-pull arrangement, and additional connecting means for connecting said anode circuits to said output circuit in a push-pull arrangement; and means interconnecting said anode circuits whereby an increase in current in one of said anode circuits causes a sufficient reduction in the potential between the anode and associated cathode of the other of said anode circuits to reduce the current flowing therein to substantially zero.

30. A telegraph signal impulse repeater for amplifying and repeating telegraph signal impulses from an incoming line circuit to an outgoing line circuit which comprises an input circuit for receiving telegraph signal impulses from the incoming line; an output circuit for transmitting impulses to the outgoing line; a thermionic gas discharge tube having an anode, cathode, and grid elements and circuits in which the anode-cathode current is substantially independent of the grid potential after the grid potential has exceeded the critical value required to start the anode-cathode current; a thermionic vacuum tube relay having an anode-cathode and grid elements and circuits in which the anode-cathode current is at all times dependent upon the grid potential; impulse coils for converting telegraph signal impulses into sharply peaked impulses connecting said grid circuits to said input circuit in a push-pull arrangement; means for connecting said anode circuits to said output circuit in a push-pull arrangement; and means interconnecting said anode circuits whereby an increase in current in one of said anode circuits causes a sufficient reduction in the effective potential of the anode of the other of said anode circuits to reduce the current flowing therein to zero.

31. An impulse repeater comprising an incoming circuit to supply impulses to be repeated, an outgoing circuit to receive repeated impulses, instrumentalities connected between said circuits comprising one discharge tube of the gas-filled thyatron type, and one discharge tube of the type whereof the control element maintains continuous control over the discharge, each of said tubes having its controlling input circuit connected to said incoming circuit and its output controlled circuit connected to said outgoing circuit, and an arrangement whereby an electrode circuit of one of said tubes is coupled to an electrode circuit of the other of said tubes.

32. A telegraph signal responsive device comprising an input circuit for receiving telegraph signal impulses; a plurality of gas discharge relay tubes of the thyatron type having anode, cathode, and grid elements and circuits; means for connecting said grid circuits to said input circuit; means for terminating a discharge through said discharge tubes which includes a vacuum tube individual to each of said gas discharge relay tubes, said vacuum tubes having anode, cathode, and grid elements and circuits; means for connecting said vacuum tube grid circuits to said input circuit so as to receive impulses therefrom in an opposite direction from the grid circuit of the gas discharge tube to which it is associated, and means inter-connecting the anode circuits of said gas discharge tube and associated vacuum tube to reduce the potential between the anode and cathode of one of said associated tubes when the anode current in the other of said tubes increases.

33. A telegraph signal responsive device comprising an input circuit for receiving telegraph signals of different polarities; a gas discharge tube of the thyatron type having anode, cathode, and grid elements and circuits for responding to impulses of each polarity; means for connecting said grid circuits to said input circuit so each of said gas discharge tubes responds to impulses of only one polarity; means for terminating a discharge through said gas discharge tubes which includes a vacuum tube individual to each of said gas discharge tubes, said vacuum tubes having anode, cathode, and grid elements and circuits;

connecting means for connecting said vacuum tube grid circuits to said input circuit in a push-pull arrangement with the gas discharge tube with which it is associated; and interconnecting means between the anode circuits of said associated tubes which causes a reduction in the potential between the anode and cathode of one of said tubes in response to an increase in current in the anode circuit of said other tube.

34. A telegraph signal impulse repeater for repeating positive and negative impulses from one circuit to another circuit comprising an input circuit for supplying positive and negative telegraph signal impulses; an output circuit; and instrumentalities connected between said circuits comprising a first gas discharge tube having anode, cathode, and grid elements and circuits so constructed and arranged that the anode-cathode current is independent of the grid potential after the grid potential has exceeded the potential required to start the anode-cathode current; a first vacuum tube having anode, cathode, and grid elements and circuits so constructed and arranged that the anode-cathode current is continuously dependent upon the grid potential; connecting means for connecting both of said grid circuits to said input circuit so that said tubes respond to negative impulses; a first interconnecting means connected between said anode circuits for reducing the potential between the anode and cathode of one of said tubes in response to an increase in the anode-cathode current of the other of said tubes, a second gas discharge tube and circuits having substantially the same properties and constants as said first gas-discharge tube and circuits, a second vacuum tube and circuits having substantially the same properties and constants as said first vacuum tube and circuits; means for connecting both grid circuits of said second tubes to said input circuit so that said second tubes respond to positive impulses; a second interconnecting circuit having the same properties and constants as said first interconnecting circuit interconnecting the anode circuits of said tubes; and a circuit connecting all of said anode circuits to said output circuit.

35. A system for converting a non-continuous wave made up of peaked current impulses into a square-top continuous wave, comprising a pair of thyatron tubes and matched input and output circuits therefor, said input circuits comprising means for applying peaked non-continuous current impulses to said thyatron tubes as starting voltages therefor, said output circuits comprising means for causing the starting of either tube to stop the other tube, whereby the peaked impulses cause the production in the combined output circuit of the thyatron tubes of contiguous square-top impulses to produce a wave continuous in character.

36. In a signaling system, a signaling circuit, a gaseous conduction tube, means for converting signals of different polarities, received over said circuit, into signals of varying magnitude of current, means for producing discharges through said tube, in accordance with said current, and current responsive means in the output circuit of said tube.

37. In a signaling system, a source of telegraph signals of varying magnitude of current, a gaseous conduction tube, means for producing discharges through said tube, in accordance with said current and current responsive means in the output circuit of said tube.

38. In a telegraph system, a source of three-

element telegraph signals, a gaseous conduction tube and means responsive to said three-element signals for controlling the operation of said tube, whereby discharges will be produced therein in accordance with said three-element signals.

39. An impulse circuit comprising in combination, an input circuit, a pair of grid-controlled arc discharge tubes connected thereto, output circuits for said tubes and an electromagnetic coupling between said output circuits for extinguishing a discharge through one of said tubes when a discharge is initiated through the other of said tubes.

40. An impulse circuit comprising in combination, a control circuit, a grid-controlled arc discharge tube connected thereto, a grid-controlled high vacuum tube also connected to said controlling circuit, output circuits for each of said tubes and an electromagnetic coupling between said tubes for momentarily interrupting the current flow in either of said output circuits when the current flowing in the other of said output circuits increases.

41. An impulse circuit comprising in combination, a control circuit, a grid-controlled arc discharge tube connected thereto, a grid-controlled high vacuum tube also connected to said controlling circuit, output circuits for each of said tubes, circuit elements connected between said output circuits for applying a voltage in series with either of said circuits for reducing the current flowing therein when the current increases in the other of said output circuits.

42. A repeater for repeating impulses comprising

ing two space discharge devices each comprising a cathode, an anode and a control element, one of said devices being so highly evacuated as to operate substantially independently of gas ionization and the other of said devices containing such a quantity of ionizable gas that the working potential difference between the cathode and the anode during discharges through said device is accompanied by such substantial gas ionization as to materially affect the operating characteristics thereof, an output circuit and an operative connection for oppositely connecting said devices to said output circuit.

43. A repeater for repeating impulses from an input circuit to an output circuit comprising an input circuit, an output circuit, two space discharge devices each having a cathode, an anode and a control electrode, one of said devices being so highly evacuated as to operate substantially independently of gas ionization and the other of said devices containing such a quantity of ionizable gas that the working potential difference between the cathode and the anode thereof during discharges through said device is accomplished by such substantial gas ionization as to materially affect the operating characteristics of said device, an operative connection of the control elements for coupling them oppositely to said input circuit, and an operating connection between said devices and said output circuit for oppositely connecting said devices to said output circuit.

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