Oct. 11, 1960 G. O. CROWTHER ET AL 2,956,156

COLD CATHODE GAS DISCHARGE TUBE CIRCUIT-ARRANGEMENT

Filed July 5, 1956 4 Sheets-Sheet 1

FIG.1

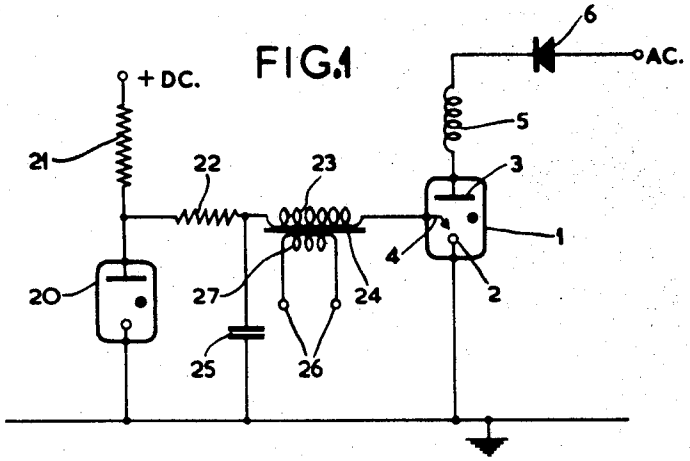


FIG.2

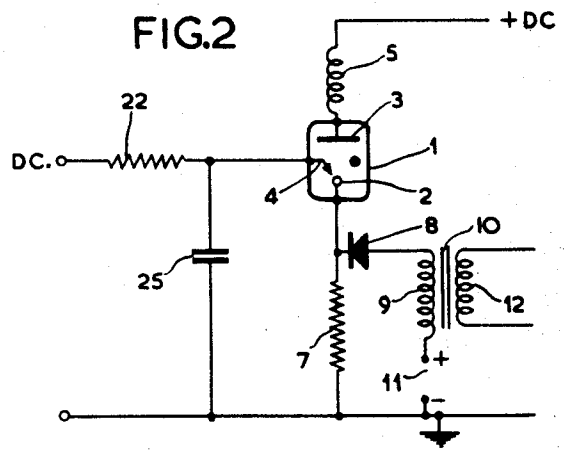
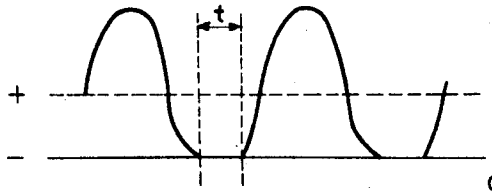


FIG.3



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COLD CATHODE GAS DISCHARGE TUBE CIRCUIT-ARRANGEMENT

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FIG.4

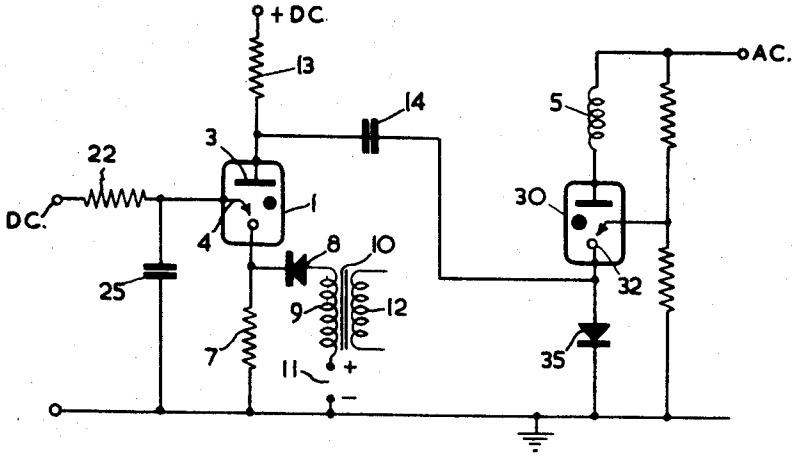
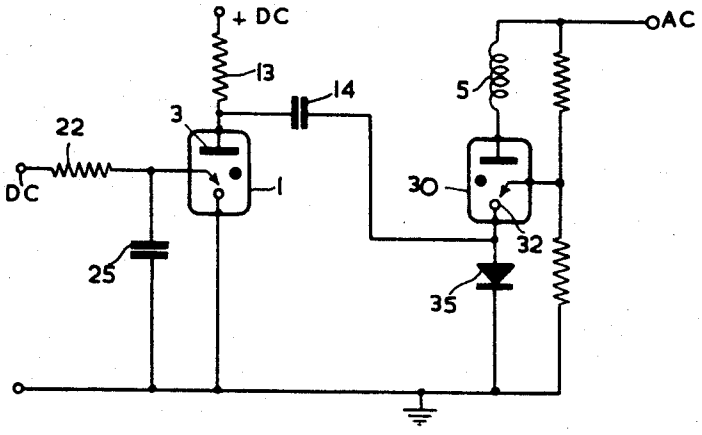


FIG.5



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COLD CATHODE GAS DISCHARGE TUBE CIRCUIT-ARRANGEMENT

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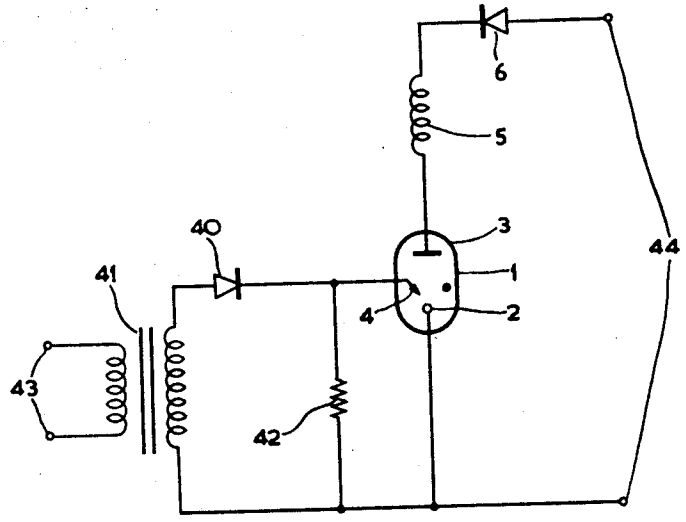


FIG.6

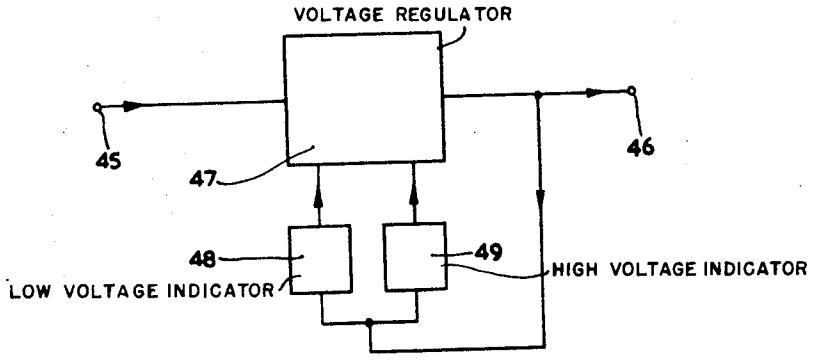


FIG.7

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COLD CATHODE GAS DISCHARGE TUBE CIRCUIT-ARRANGEMENT

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FIG.8

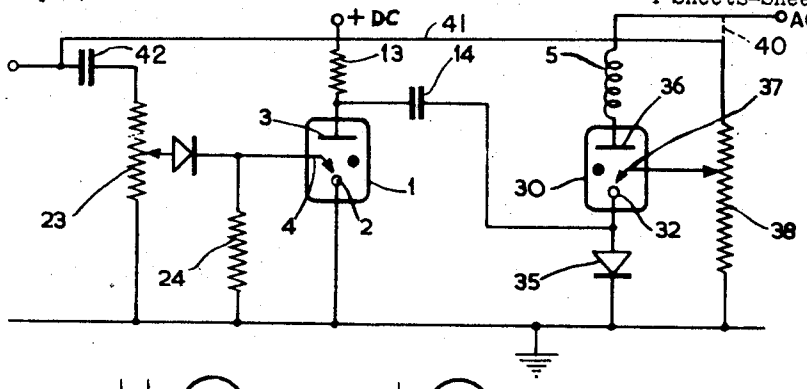
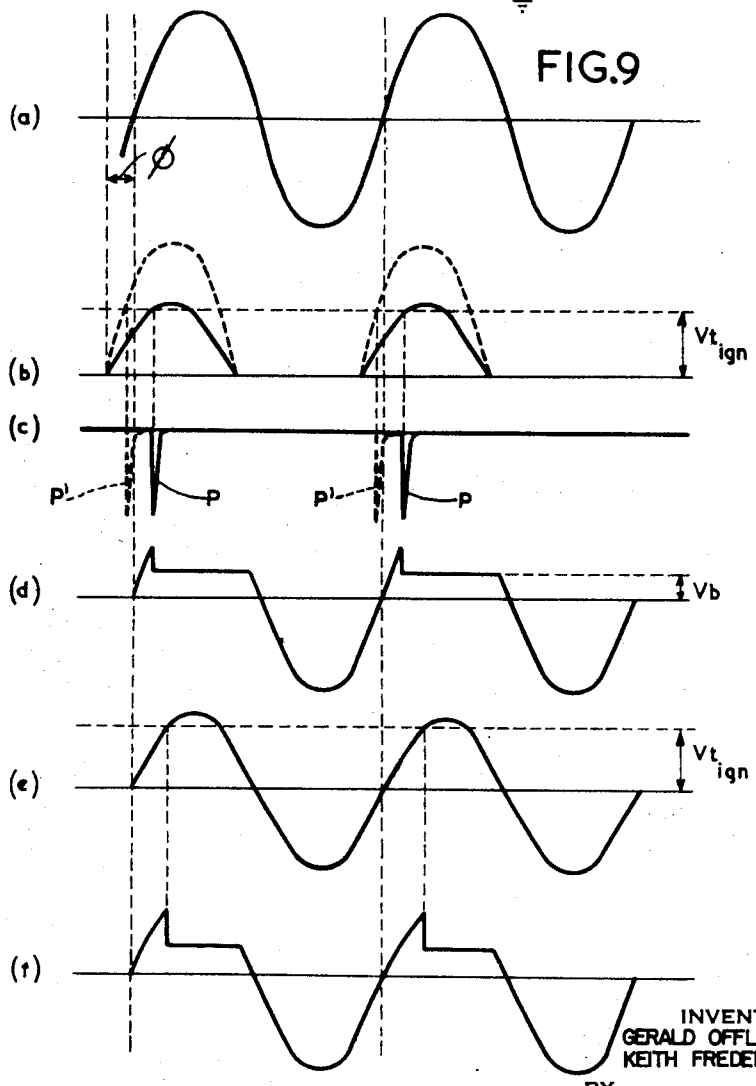


FIG.9



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United States Patent Office 2,956,156 Patented Oct. 11, 1960

2,956,156

COLD CATHODE GAS DISCHARGE TUBE CIRCUIT-ARRANGEMENT

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9 Claims. (Cl. 250—27)

This invention relates to circuit arrangements of the type incorporating one or more cold cathode discharge tubes and which may be used for indication purposes, for example for indicating when a physical quantity being observed exceeds a certain value. In circuit arrangements of this type the arrangement may be such that when the said quantity exceeds a predetermined value a gas discharge tube changes from being non-conductive to being conductive and thereby actuates an alarm system, for example by means of a relay in the circuit of the gas discharge tube. The physical quantity may be an alternating or a direct voltage, or alternatively is represented by a signal in the form of such a voltage, which is applied to a trigger electrode of a gas discharge tube so that when the trigger breakdown voltage is exceeded the tube becomes conductive. To give a continuous indication it is necessary to extinguish the tube at regular intervals, re-ignition of the tube being determined by the signal voltage at the trigger.

One of the problems of gas discharge tube circuits of this kind is that not only must the anode-cathode discharge be extinguished but the trigger-cathode discharge must also be extinguished.

An object of the present invention is to provide a circuit arrangement which is operable from the A.C. power supply and in which the anode-cathode and trigger-cathode discharges are extinguished at regular intervals, for example at power supply frequency, while at the same time advantage may be taken of the recent availability of trigger controlled cold cathode gas discharge tubes of the type having a relatively stable trigger breakdown voltage.

Such a circuit arrangement may for example be used to indicate when the power supply voltage exceeds or falls below a predetermined value.

According to one aspect of the invention a circuit arrangement for indicating when a signal voltage passes a predetermined value comprises a gas discharge tube having an anode, a cathode and a trigger electrode, means for applying said signal voltage to the trigger electrode of the gas discharge tube the said means being so arranged that when the said predetermined value is exceeded then the trigger-cathode breakdown voltage is also exceeded and the tube becomes conductive, an indicating device, means for causing the operation of the indicating device in dependence upon conduction of the said tube and means for extinguishing the anode-cathode and trigger-cathode discharges of the tube at regular intervals.

The phrase "passes a predetermined value" is herein used to define a condition where the signal voltage exceeds the predetermined value and also, or alternatively, a condition where the signal voltage falls below the predetermined value.

In order that the invention may be readily carried into effect embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which

Figure 1 shows an embodiment of the invention in which the quantity to be observed is represented by an alternating voltage which is superimposed on a direct voltage.

Figure 2 shows an embodiment of the invention in which the quantity to be observed is represented by a direct-voltage signal.

Figure 3 is a wave form which represents the variation of the cathode voltage of tubes in the circuits shown in Figures 2 and 4.

Figure 4 shows a further embodiment of the invention.

Figure 5 shows a further embodiment which is a modified form of that of Figure 4.

Figure 6 of the accompanying drawings shows a further embodiment.

Figure 7 of the accompanying drawings is a block schematic diagram of a voltage-regulating system incorporating two circuit-arrangements according to the invention.

Figure 8 shows a further circuit-arrangement according to the invention.

Figure 9 shows graphs of voltage appertaining to the circuit-arrangement of Figure 8.

The circuit-arrangement of Figure 1 comprises a trigger-controlled cold cathode gas-discharge tube **1** for example a "Mullard" type 2803V, comprising a cathode **2**, an anode **3** and a trigger electrode **4**. The cathode **2** is connected to a common point which hereinafter will be referred to as ground. The anode **3** is connected by way of the winding **5** of a relay and a rectifier **6** to a source of alternating voltage, for example the power supply. A gas discharge stabilizer tube **20** is fed from a source of direct voltage via a resistor **21** to provide a stable direct voltage via a resistor **22** and the secondary winding **23** of a transformer **24** to the trigger **4**. A capacitor **25** is connected between the junction of resistor **22** and secondary winding **23** and ground. An A.C. signal corresponding to the quantity to be measured is supplied via terminals **26** to the primary winding **27** of transformer **24**. Thus the voltage appearing at the trigger **4** consists of an alternating voltage superimposed on a direct voltage.

In the quiescent condition of the circuit arrangement tube **1** remains non-conductive since the most positive value of the voltage at trigger **4** does not exceed the trigger breakdown voltage. When the A.C. component of the trigger voltage exceeds a predetermined value the positive peak amplitude exceeds the trigger breakdown voltage whereupon the anode-cathode discharge of tube **1** is initiated and continues until the anode voltage falls below the anode-cathode burning voltage of the tube. It will be seen that for this to occur the A.C. signal representing the quantity to be measured must be synchronized with the alternating voltage applied to the rectifier **6**. The current through tube **1** during conducion energizes relay **5** which in turn actuates a warning system. Tube **1** will conduct during all of the positive half cycles of the power supply during which the A.C. signal supplied to terminals **26** exceeds a predetermined value. When this

A.C. signal falls below this predetermined value tube 1 will not fire during the positive half cycle and the warning will cease to be given. The circuit may be adjusted initially by applying the alternating signal voltage through a variable potential divider to the terminals 26, the potential divider being adjusted so that only when the alternating signal voltage applied to the potential divider is above the said predetermined value, is the proportion of this voltage at the trigger 4 sufficient to cause the alarm to be given as described above. Alternatively, the proportion of the signal voltage at the trigger 4 may be adjusted by means of a potential divider connected across the secondary winding of the transformer 23. It will be appreciated that in each case the desired level is determined by means of a level-control member in the form of an adjustable potential divider located between the signal source and the trigger electrode of the tube.

A circuit arrangement of this kind may for example be used to monitor the power supply voltage and to give a suitable warning or even control a voltage adjustor when the power supply voltage exceeds a predetermined value.

The circuit arrangement of Figure 2 also comprises a tube 1 having a cathode 2, an anode 3 and a trigger 4. However in this arrangement the anode is supplied via the winding 5 of a relay from a D.C. source. The signal corresponding to the quantity to be measured is a D.C. signal and the extinguishing means for both the anode-cathode and trigger-cathode discharges is included in the cathode circuit. This cathode circuit comprises a resistor 7 connected between cathode 2 and ground. In parallel with this resistor there is connected a rectifier 8, the secondary winding 9 of a transformer 10 and a direct-voltage bias source 11. An alternating voltage, for example the power supply voltage, is fed to the primary winding 12 of transformer 10.

In this embodiment the circuit may be initially adjusted by applying the D.C. signal to resistor 22 through a level-control member in the form of a variable potential divider, not shown. The potential divider being adjusted, in a manner similar to that described in connection with the embodiment shown in Figure 1, so that the relay 5 only operates when the desired predetermined signal level is exceeded.

Figure 3 shows the variation of the cathode voltage of the circuit arrangement shown in Figure 2, the bias source being shown as a dotted line. During the interval *t* rectifier 8 becomes non-conductive and therefore cathode 2 remains at ground potential. It is during this time in any one cycle that the trigger-cathode breakdown voltage will be exceeded if a small increase in the D.C. signal occurs. If the trigger breakdown voltage is exceeded the tube will become conductive and relay 5 will be operated. The discharge will continue until the rise in cathode voltage due to the alternating voltage applied via transformer 10 extinguishes the anode-cathode and trigger-cathode discharges. The tube will re-ignite if the D.C. signal exceeds a predetermined value during subsequent cycles.

The circuit arrangements of Figure 1 and Figure 2 of the drawings have a disadvantage due to the fact that the tubes exhibit a hysteresis effect associated with the trigger breakdown voltage, which limits the accuracy in applications where the successive intervals between firing the tube are short and irregular. The effect is dependent on both the duration and the magnitude of the current in the tube prior to extinction.

To obtain a circuit arrangement having a high degree of constancy it is desirable that the interval during which current flows should be a minimum and that this current should have a minimum average value. However, it is necessary to have a relatively high current for operating the relay. To overcome this the circuit arrangements shown in Figures 4 and 5 have been devised, each of which circuit arrangements comprises two cold cathode gas discharge tubes.

Referring to Figure 4 it will be seen that the tube 1 is operated in a manner similar to that of Figure 2, with the exception that the anode is supplied via a resistor 13 from a direct voltage supply, through which resistor a capacitor 14 is charged. Capacitor 14 is discharged through tube 1 as will be explained below. As was explained in connection with Figure 2 the trigger cathode breakdown voltage is exceeded when the D.C. signal exceeds a predetermined value and the tube 1 becomes conductive during the interval *t* shown in Figure 3. The anode 3 now falls in value carrying the cathode 32 of tube 30 negative until the trigger-cathode breakdown voltage of tube 30 is exceeded, whereupon tube 30 becomes conductive and the capacitor 14 now discharges through tube 1 and tube 30. The A.C. supply to tube 30 and to transformer 10 are synchronized so that the conduction of tube 1 can occur only while the positive half cycle of the alternating voltage is being applied to the anode and trigger of tube 30. Resistor 13 and capacitor 14 are selected such that the discharge is self extinguishing. The discharge current of tube 30 which actuates relay 5 continues to flow through rectifier 35 until the anode and trigger voltages of the tube fall below the burning voltages. Thus the relay 5 is actuated when the D.C. signal, supplied to trigger 4 of tube 1, exceeds a predetermined value.

It will be seen that tube 1 passes relatively low average current for a very short space of time, the current for operating the relay passing through tube 30, and therefore the hysteresis effect of tube 1 is reduced to a minimum.

In this embodiment the required predetermined signal value may be set by means of a level-control member in the form of a potential divider, not shown, located between the signal source and the resistor 22.

Figure 5 shows a simplified form of the circuit arrangement shown in Figure 4. In Figure 5 the synchronizing means in the cathode circuit of tube 1 in Figure 4 is omitted and synchronization is obtained by preventing tube 1 from extinguishing in the normal manner, until tube 30 is in a condition to pass current. When the D.C. signal exceeds the trigger breakdown voltage a discharge is initiated in tube 1 but because of the high value of resistor 13 and the presence of the rectifier 35 the normal discharge of the capacitor 14 cannot occur and therefore the discharge can only take the form of a priming discharge. The voltage of anode 3 falls in value and, by way of capacitor 14, cathode 32 of tube 30 is carried negative with respect to ground. If the voltages at the anode and trigger of tube 30 are not at a positive half cycle then tube 30 is unable to become conductive. The circuit arrangement waits in this mode until the anode and trigger voltages of tube 30 go positive and until the trigger breakdown voltage is exceeded whereupon tube 30 becomes conductive enabling capacitor 14 to be discharged through tube 1 and the tube 30. Thus automatic synchronization of the glow discharge in tube 1 with the A.C. supply to tube 30 has occurred. This rapid discharge of capacitor 14 is sufficient to extinguish the anode-cathode and trigger-cathode discharges in tube 1.

In this embodiment the required predetermined signal level may be set by means of a level-control member, in the same manner as that described with reference to Figures 2 and 4.

In the embodiments of Figures 2, 4 and 5, when the level-control member is in the form of a resistance potentiometer the resistor 22 may be dispensed with.

In the embodiment shown in Figure 6, an A.C. signal is applied, through a level-control member not shown, to terminals 43, which are connected to the primary winding of a transformer 41. The secondary winding of the transformer is connected to a rectifier 40 and a

resistor 42. The resultant half-wave rectified signal voltage is applied between the trigger 4 and the cathode 2 of a tube 1. The anode circuit of the tube includes a relay winding 5 and rectifier 6. The tube will become conductive if the trigger-cathode breakdown voltage is exceeded during a positive half-cycle, thus causing relay 5 to operate, and the discharge will extinguish, due to fall of the anode-cathode voltage, before the end of the half-cycle.

Figure 7 shows in block schematic form a voltage-regulating system employing two circuit-arrangements of the types described above.

In this system unregulated A.C. or D.C. supply is applied at terminal 45 to a servo-controlled voltage regulator 47 which may be of any suitable known type. The regulated output appears at terminal 46. This regulated output is applied to two indicating circuits 48 and 49 arranged according to the invention. The circuits 48 and 49 are set by means of their respective level-control members so that at the required regulated output voltage the circuit 48 is operating, that is to say the discharge tube thereof is periodically conductive, while the circuit 49 is quiescent that is to say the discharge tube thereof is non-conductive. If now the output voltage falls below the level at which circuit 48 is set then both circuits will be quiescent. The arrangement is such that in this condition the servo-control mechanism will cause adjustment of the voltage regulator to increase the output voltage, until circuit 48 once more operates and further adjustment of the voltage regulator ceases. If the output voltage increases above the level at which the circuit 49 is set then both circuits will be operating. The arrangement is such that in this condition the servo-control mechanism will cause adjustment of the voltage regulator to decrease the output voltage, until circuit 49 once more becomes quiescent and further adjustment of the voltage regulator ceases.

It will thus be observed that this system limits the voltage variation at the output of the system, the limits being defined by the settings of the level-control members of the circuits 48 and 49.

The embodiment described with reference to Figure 4 may be modified for use with a signal comprising an alternating voltage. In this case the tube 30 may have its anode and trigger circuits supplied from a voltage source of the same frequency and phase as the signal so that the two tube circuits are synchronized automatically, a practical example being the use of the system to monitor the alternating power supply voltage. In such an arrangement it is convenient to arrange the circuit of the signal tube so as to advance, in phase, the signal voltage applied at the trigger of the first or signal tube with respect to the phase of the power supply voltage, the purpose being to enable the second or relay tube to fire early in each operative half-cycle with consequent increase in the mean anode current which energizes the relay. However, if this is done, there is the disadvantage that, due to such phase-shift in the system, very large excess signal voltages may cause the pulse from the anode of the signal tube to be fed to the cathode of the relay tube before the latter receives the corresponding positive half-wave of alternating voltage at its anode, so that the relay tube fails to ignite.

The embodiment shown in Figure 8 overcomes this disadvantage and provides an improved circuit arrangement generally similar to the two-tube arrangement generally similar to the two-tube arrangement shown in Figure 4 but capable of operating satisfactorily with alternating signal voltages even in the presence of relatively large excess signals.

Referring to Figure 8 the signal tube 1 has its anode supplied via a resistor 13 through which a capacitor 14 is charged. Capacitor 14 is discharged through tube 1 as will be explained below. The trigger-cathode breakdown voltage of this tube is exceeded when the signal exceeds a predetermined value and the tube becomes conductive. The voltage at the anode 3 then falls carrying the cathode 32 of relay tube 30 negative until the trigger-cathode breakdown voltage of tube 30 is exceeded, whereupon tube 30 also becomes conductive after which the capacitor 14 discharges through tube 1 and tube 30. Resistor 13 and capacitor 14 are selected with such values that the discharge of tube 1 is self extinguishing. The discharge current of tube 30, which flows through relay winding 5, continues to flow through rectifier 35 until the anode and trigger voltages, both of which are supplied from an alternating current source, fall below the respective burning voltages. Thus the relay is actuated when the signal supplied to trigger 4 exceeds a predetermined value.

It will be seen that tube 1 passes a relatively low average current for a very short space of time, the current for operating the relay being supplied by tube 30 and therefore hysteresis effects inherent in cold cathode tubes are reduced to a minimum.

If the trigger 37 of tube 30 were fed with A.C. from the anode supply point of the tube as shown by the dotted connection 40, then the operation of the circuit would be as now explained with reference to the waveforms *a* to *d* of Figure 9.

In Figure 9 graph *a* represents the alternating signal voltage, which may be the power supply voltage; *b* is the signal voltage at the trigger 4, with a phase shift ϕ introduced by the RC network 23—42 with reference to voltage *a* for the reasons stated above; *c* represents the firing pulses fed from anode 3 to cathode 32, and *d* represents the voltage at anode 36, which is in phase with voltage *a*, V*b* being the burning voltage.

If the input signal voltage is below the critical value, the peak voltage applied to the trigger 4 of tube 1 is less than the trigger-cathode breakdown voltage Vt_{ign} and the circuit is therefore quiescent. If however the signal voltage exceeds the critical value (as shown in full lines in graph *b*) the peak voltage at the trigger 4 exceeds Vt_{ign} and tube 1 fires and the negative pulse (shown at P in full lines) which occurs at the anode 3 is fed via capacitor 14 to the cathode 32. The voltage on tube 30, as shown in graphs *c* and *d* of Figure 9, are so phased that tube 30 is fired by the negative pulse P and conducts during the major portion of the positive half cycle of the anode supply source after which it is extinguished. Since tube 1 is connected in an R.C. self-extinguishing circuit comprising elements 13 and 14, it only conducts while capacitor 14 discharges. This sequence of events is repeated once every cycle and the mean current through tube 30 energizes relay 5 which operates an indicating or alarm circuit.

If now the signal voltage is large, as shown by the dotted curve of graph *b*, the phase shift ϕ causes tube 1 to fire very early in the cycle as shown at P' in Figure 9 (c) and the pulse at the cathode 32 arrives before the anode voltage on tube 30 has gone positive and therefore tube 30 does not fire. The relay 5 is not energized and the required indication is not given.

This difficulty is overcome by feeding the trigger 37 from the signal input point via a connection 41. The circuit is essentially the same except that the trigger voltage of tube 30 is now obtained from the varying signal input instead of the alternating anode supply voltage as previously. For small excesses of signal voltage the operation is similar to that of the previously discussed circuit using connection 40. However, for large voltage excesses the signal voltage acting as the trigger voltage of tube 30 is sufficiently large to fire tube 30 independently and thus energize relay 5; this is shown in graphs *e* and *f* of Figure 9 relating to the voltages at the trigger and anode of tube 30 respectively. Tube 1 continues to operate as previously but has no effect on tube 30. Potential divider 38 is adjusted so that tube 30 fires under all con-

ditions of excess voltage but only fires independently of tube 1 above a predetermined excess in signal voltage.

Such an arrangement may be used with advantage in thyratron circuits to overcome difficulties due to variations in phase angle.

What is claimed is:

1. A circuit arrangement comprising first and second gas discharge tubes each having an anode, a cathode and a trigger electrode, means for biasing the anode of said first tube with a direct voltage, means for applying an alternating voltage to the anode of said second tube thereby to render said second tube potentially conductive during consecutive intervals, means for applying a signal voltage to the trigger electrode of said first tube in a manner whereby the trigger-cathode breakdown voltage of said first tube is exceeded and the said tube becomes conductive when the magnitude of said signal voltage exceeds a predetermined value during the said potentially conductive intervals of said second tube, a load circuit connected to the anode of said second tube, and means for causing the trigger-cathode breakdown voltage of said second tube to be exceeded and the said second tube to become conductive when said first tube is conductive and for causing the anode-cathode and trigger-cathode discharges of the said second tube to be extinguished at predetermined intervals, said last-mentioned means including a capacitor coupled between said first and second tubes in a manner whereby said capacitor discharges through said first tube thereby to extinguish the said first tube and applies a pulse to the said second tube.

2. A circuit arrangement comprising first and second gas discharge tubes each having an anode, a cathode and a trigger electrode, means for biasing the anode of said first tube with a direct voltage, means for biasing the anode of said second tube with an alternating voltage, means for applying a direct signal voltage to the trigger electrode of said first tube in a manner whereby the trigger-cathode breakdown voltage of said first tube is exceeded and the said tube becomes conductive when the magnitude of said signal voltage exceeds a predetermined value, rectifying means, means connecting the cathode of said second tube to a point at constant potential through said rectifying means, a load circuit connected to the anode of said second tube, and means for causing the trigger-cathode breakdown voltage of said second tube to be exceeded and the said second tube to become conductive when said first tube is conductive and for causing the anode-cathode and trigger-cathode discharges of the said second tube to be extinguished at predetermined intervals, said last-mentioned means including a capacitor connected between the anode of said first tube and the cathode of said second tube in a manner whereby said capacitor discharges through said first tube thereby to extinguish the said first tube and applies a pulse to the said second tube.

3. A circuit arrangement comprising first and second gas discharge tubes each having an anode, a cathode and a trigger electrode, means for biasing the anode of said first tube with a direct voltage, a source of direct voltage, means for applying a direct signal voltage to the trigger electrode of said first tube in a manner whereby the trigger-cathode breakdown voltage of said first tube is exceeded and the said first tube becomes conductive when the magnitude of said signal voltage exceeds a predetermined value, means for extinguishing the anode-cathode and trigger-cathode discharges of said first tube at predetermined intervals, said last-mentioned means comprising means for supplying a cathode bias voltage at said predetermined intervals, means for combining said cathode bias voltage with the voltage of said source of direct voltage to produce a first resultant voltage and means for applying said first resultant voltage to the cathode of said first tube, rectifying means, means connecting the cathode of said second tube to a point at constant potential through said rectifying means, means for biasing the anode of said second tube with an alternating voltage, said alternating voltage being synchronized with said means for supplying a cathode bias voltage at said predetermined intervals, means for biasing the trigger electrode of said second tube with said alternating voltage, a load circuit connected to the anode of said second tube, and a capacitor connected between the anode of said first tube and the cathode of said second tube whereby the trigger-cathode breakdown voltage of said second tube is exceeded and the said second tube becomes conductive when said first tube is conductive and the anode-cathode and trigger-cathode discharges of the said second tube are extinguished at predetermined intervals, said capacitor being connected in a manner whereby said capacitor discharges through said first tube thereby to extinguish the said first tube and applies a pulse to the said second tube.

4. A circuit arrangement comprising first and second gas discharge tubes each having an anode, a cathode and a trigger electrode, means for biasing the anode of said first tube with a direct voltage, a source of direct voltage, means for applying a direct signal voltage to the trigger electrode of said first tube in a manner whereby the trigger-cathode breakdown voltage of said first tube is exceeded and the said first tube becomes conductive when the magnitude of said signal voltage exceeds a predetermined value, means directly connecting the cathode of said first tube to a point at constant potential, rectifying means, means connecting the cathode of said second tube to a point at constant potential through said rectifying means, means for biasing the anode of said second tube with an alternating voltage, means for biasing the trigger electrode of said second tube with said alternating voltage, a load circuit connected to the anode of said second tube, and a capacitor connected between the anode of said first tube and the cathode of said second tube whereby the trigger-cathode breakdown voltage of said second tube is exceeded and the said second tube becomes conductive when said first tube is conductive and the anode-cathode and trigger-cathode discharges of the said second tube are extinguished at predetermined intervals, said capacitor being connected in a manner whereby said capacitor discharges through said first tube thereby to extinguish the said first tube and applies a pulse to the said second tube.

5. A circuit arrangement comprising first and second gas discharge tubes each having an anode, means for biasing the anode of said first tube with a direct voltage, a cathode and a trigger electrode, means for applying an alternating voltage to the anode of said second tube thereby to render said second tube potentially conductive during consecutive intervals, means for applying a signal voltage to the trigger electrode of said first tube in a manner whereby the trigger-cathode breakdown voltage of said first tube is exceeded and the said tube becomes conductive when the magnitude of said signal voltage exceeds a predetermined value during the said potentially conductive intervals of said second tube, a load circuit connected to the anode of said second tube, means for applying said signal voltage to the trigger electrode of said second tube, and means for causing the trigger-cathode breakdown voltage of said second tube to be exceeded and the said second tube to become conductive when said first tube is conductive and for causing the anode-cathode and trigger-cathode discharges of the said second tube to be extinguished at predetermined intervals, said last-mentioned means including a capacitor coupled between said first and second tubes in a manner whereby said capacitor discharges through said first tube thereby to extinguish the said first tube and applies a pulse to the said second tube.

6. A circuit arrangement comprising first and second gas discharge tubes each having an anode, a cathode and a trigger electrode, means for biasing the anode of said first tube with a direct voltage, a source of direct volt-

age, means for applying a direct signal voltage to the trigger electrode of said first tube in a manner whereby the trigger-cathode breakdown voltage of said first tube is exceeded and the said first tube becomes conductive when the magnitude of said signal voltage exceeds a predetermined value, means directly connecting the cathode of said first tube to a point at constant potential, rectifying means, means connecting the cathode of said second tube to a point at constant potential through said rectifying means, means for biasing the anode of said second tube with an alternating voltage, a load circuit connected to the anode of said second tube, a capacitor connected between the anode of said first tube and the cathode of said second tube whereby the trigger-cathode breakdown voltage of said second tube is exceeded and the said second tube becomes conductive when said first tube is conductive and the anode-cathode and trigger-cathode discharges of the said second tube are extinguished at predetermined intervals, said capacitor being connected in a manner whereby said capacitor discharges through said first tube thereby to extinguish the said first tube and applies a pulse to the said second tube and means for applying said signal voltage to the trigger electrode of said second tube whereby the trigger-cathode breakdown voltage of said second tube is exceeded and the said second tube becomes conductive independently of the conductive condition of said first tube when the magnitude of said signal voltage exceeds a predetermined value relatively higher than said first-mentioned predetermined value.

7. A circuit arrangement comprising first and second gas discharge tubes each having an anode, a cathode and a trigger electrode, means for biasing the anode of said first tube with a direct voltage, a source of direct voltage, means for applying a direct signal voltage to the trigger electrode of said first tube in a manner whereby the trigger-cathode breakdown voltage of said first tube is exceeded and the said first tube becomes conductive when the magnitude of said signal voltage exceeds a predetermined value, said last-mentioned means including a resistance-capacitance network, means directly connecting the cathode of said first tube to a point at constant potential, rectifying means, means connecting the cathode of said second tube to a point at constant potential through said rectifying means, means for biasing the anode of said second tube with an alternating voltage, a load circuit connected to the anode of said second tube, a capacitor connected between the anode of said first tube and the cathode of said second tube whereby the trigger-cathode breakdown voltage of said second tube is exceeded and the said second tube becomes conductive when said first tube is conductive and the anode-cathode and trigger-cathode discharges of the said second tube are extinguished at predetermined intervals, said capacitor being connected in a manner whereby said capacitor discharges through said first tube thereby to extinguish the said first tube and applies a pulse to the said second tube and means for applying said signal voltage to the trigger electrode of said second tube, said last-mentioned means including a potentiometer whereby the trigger-cathode breakdown voltage of said second tube is exceeded and the said second tube becomes conductive independently of the conductive condition of said first tube when the magnitude of said signal voltage exceeds a value determined by said potentiometer, the value determined by said potentiometer being relatively higher than said first-mentioned predetermined value.

8. A voltage regulating system comprising voltage regulating means having an input and an output, means for applying an input signal voltage to the input of said voltage regulating means, means for deriving an output signal voltage from the output of said voltage regulating means, first and second circuit arrangements each comprising a gas discharge tube having an anode, a cathode and a trigger electrode, means for applying said output signal voltage to the trigger electrode of each of said tubes in a manner whereby the trigger-cathode breakdown voltage of the first tube is exceeded and said first tube becomes conductive when the magnitude of said output signal voltage exceeds a first predetermined value and the second tube is non-conductive and whereby the trigger-cathode breakdown voltage of said second tube is exceeded and the said second tube becomes conductive when the magnitude of said output signal voltage exceeds a second predetermined value relatively higher than said first predetermined value, a load circuit connected to the anode of each of said tubes in a manner whereby said load circuit is energized when the corresponding tube becoming conductive and means for extinguishing the anode-cathode and trigger-cathode discharges of each of said tubes at predetermined intervals, and means comprising the load circuit of said first and second circuit arrangements for controlling the operation of said voltage regulating means whereby when the magnitude of said output signal voltage is below said first predetermined value said first and second tubes are non-conductive and the said voltage regulating means operates to increase the magnitude of the said output signal voltage and whereby when the magnitude of the said output signal voltage is above said second predetermined value said first and second tubes are conductive and the said voltage regulating means operates to decrease the magnitude of the said output signal voltage, said first tube being conductive and said voltage regulating means operating independently of said circuit arrangements when the magnitude of said output signal voltage is above said first predetermined value and below said second predetermined value.

9. A voltage regulating system comprising voltage regulating means having an input and an output, means for applying an input signal voltage to the input of said voltage regulating means, means for deriving an output signal voltage from the output of said voltage regulating means, first and second circuit arrangements each comprising first and second gas discharge tubes each having an anode, a cathode and a trigger electrode, means for applying said output signal voltage to the trigger electrode of each of said first tubes in a manner whereby the trigger-cathode breakdown voltage of the first tube of the first circuit arrangement is exceeded and said first tube becomes conductive when the magnitude of said output signal voltage exceeds a first predetermined value and the first tube of the second circuit arrangement is non-conductive and whereby the trigger-cathode breakdown voltage of said first tube of said second circuit arrangement is exceeded and the said first tube becomes conductive when the magnitude of said output signal voltage exceeds a second predetermined value relatively higher than said first predetermined value, a load circuit connected to the anode of each of said second tubes in a manner whereby said load circuit becomes energized when the corresponding second tube becoming conductive and means for causing the trigger-cathode breakdown voltage of each of said second tubes to be exceeded and each of the said second tubes to become conductive when the corresponding first tube is conductive and for causing the anode-cathode and trigger-cathode discharges of each of the said second tubes to be extinguished at predetermined intervals, said last-mentioned means including a capacitor coupled between said first and second tubes, and means comprising the load circuit of said first and second circuit arrangements for controlling the operation of said voltage regulating means whereby when the magnitude of said output signal voltage is below said first predetermined value the first and second tubes of said first and second circuit arrangements are non-conductive and the said voltage regulating means operates to increase the magnitude of the said output signal voltage and whereby when the magnitude of the said output signal voltage is above said second predetermined

value said first and second tubes of said first and second circuit arrangements are conductive and the said voltage regulating means operates to decrease the magnitude of said output signal voltage, said first and second tubes of said first circuit arrangement being conductive and said voltage regulating means operating independently of said first and second circuit arrangements when the magnitude of said output signal voltage is above said first predetermined value and below said second predetermined value.

References Cited in the file of this patent

UNITED STATES PATENTS

1,967,896	Morack	July 24, 1934
2,348,555	Mathes	May 9, 1944
2,406,429	Mahoney	Aug. 27, 1946
2,451,361	Smith	Oct. 12, 1948
2,646,542	Robinson	July 21, 1953
2,776,400	Crowther	Jan. 1, 1957