April 1, 1958 J. BUYS 2,829,312

ARRANGEMENT FOR CONTROLLING A GAS-OR VAPOUR-FILLED DISCHARGE TUBE

Filed Jan. 3, 1955 3 Sheets-Sheet 1

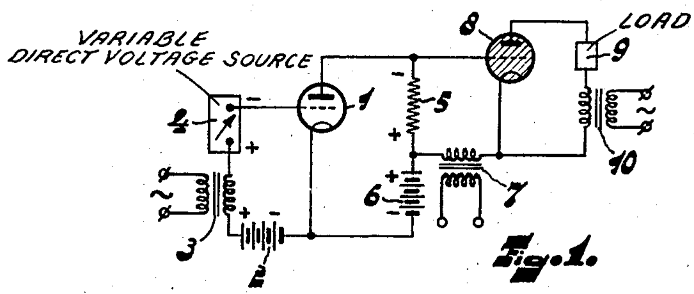

Fig. 1.

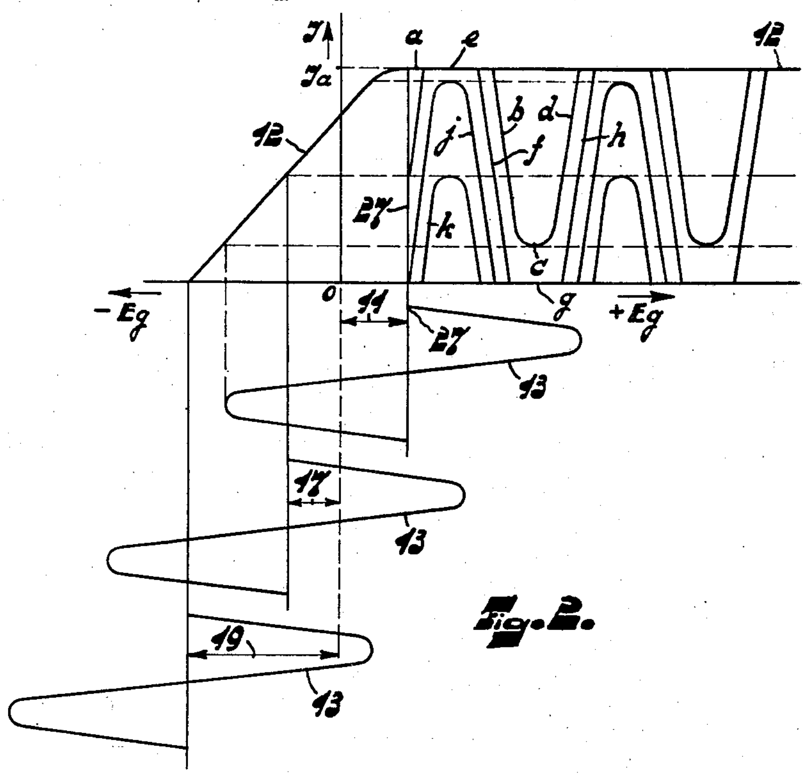

Fig. 2.

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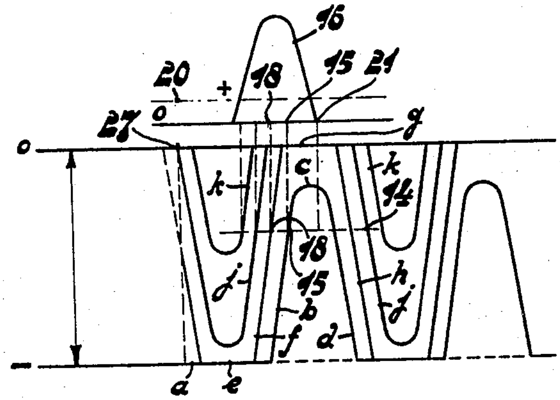

Fig. 3.

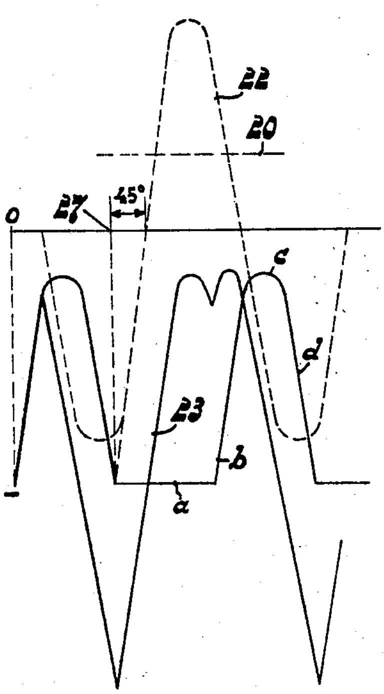

Fig. 4.

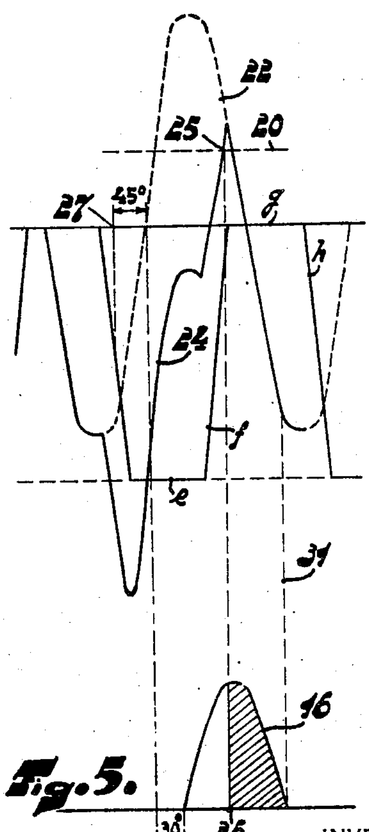

Fig. 5.

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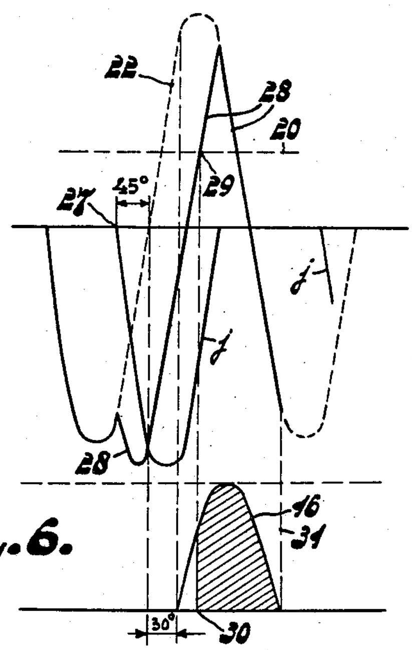

Fig. 6.

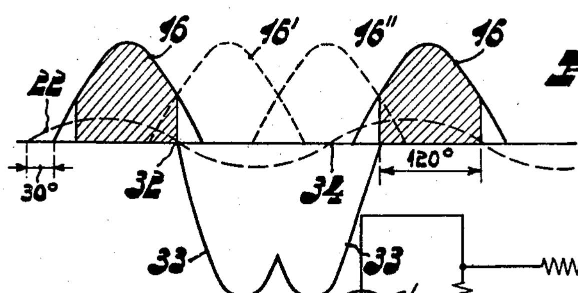

Fig. 7.

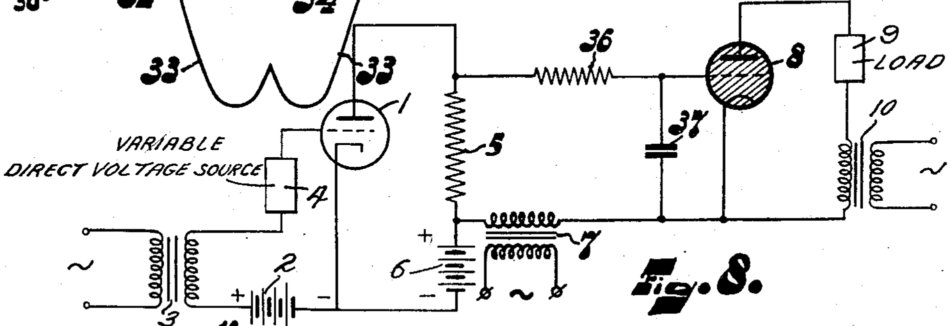

Fig. 8.

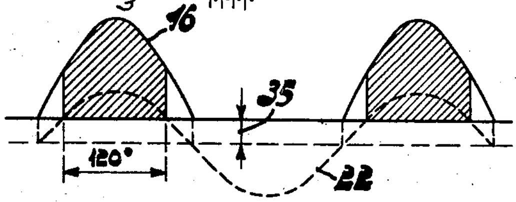

Fig. 9.

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2,829,312

ARRANGEMENT FOR CONTROLLING A GAS- OR VAPOUR-FILLED DISCHARGE TUBE

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Application January 3, 1955, Serial No. 479,580

Claims priority, application Netherlands February 13, 1954

5 Claims. (Cl. 315—165)

The present invention relates to arrangements for controlling gas or vapor-filled discharge tubes. More particularly, the invention relates to an arrangement for controlling a gas or vapor-filled discharge tube which is supplied with alternating current and preferably has a positive ignition characteristic, with the aid of a controllable high-vacuum tube. In accordance with the present invention, a direct voltage is provided in series with an alternating voltage in the control circuit of the high vacuum tube. The direct voltage is controllable preferably from a positive to a negative value. A resistor is connected in the anode circuit of the high vacuum tube, which resistor is connected in series with a control alternating voltage in the control circuit of the discharge tube.

Such an arrangement provides a very satisfactory control of the discharge tube permitting the output current strength to be controlled within a wide range. In a discharge tube which has a positive ignition characteristic, so that a positive ignition voltage pulse must be used, it is particularly desirable for the grid voltage to become negative after the anode voltage has been made negative in order to prevent the flow of an ion current to the negative anode, which might produce back-ignition. This is made possible by the arrangement of the invention, since the resultant control voltage at the control electrode of the discharge tube is approximately shaped in the form of a peaked voltage despite the fact that the resultant voltage is obtained from sinusoidal voltages. Although it would actually be more simple to use peaked voltages adapted to be displaced in phase for the control of the discharge tube, this frequently cannot be realized in practice in a simple manner when using certain circuit arrangements comprising unconventional apparatus (for example a quick-switch protection against back ignition of the discharge tubes and the like which is also manually controllable and adjustable). In such cases the arrangement in accordance with the invention can provide a solution of these difficulties.

In order that the invention may be readily carried into effect, it will now be explained more fully with reference to the accompanying drawings, wherein:

Fig. 1 is a schematic diagram of an embodiment of the circuit arrangement of the present invention;

Fig. 2 is a graphical presentation of the anode current and grid voltage curves of the tube 1 of the circuit arrangement of Fig. 1;

Fig. 3 is a graphical presentation of the grid control voltage curves of the tube 8 of the circuit arrangement of Fig. 1;

Figs. 4, 5 and 6 are graphical presentations of the grid control voltage curves of Fig. 3 combined with the alternating voltage curve of the source 7 of Fig. 1;

Fig. 7 is a graphical presentation of the ignition cycle of the tube 8 under selected conditions;

Fig. 8 is a schematic diagram of a modification of the embodiment of Fig. 1; and

Fig. 9 is a graphical presentation of the ignition cycle of the tube 8 under a modification of the conditions of Fig. 7.

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In Fig. 1 the control circuit of a high-vacuum tube **1** includes a direct voltage source **2** in series with an alternating voltage source **3** and a variable direct voltage source 4. The direct voltage source **2** provides a positive grid voltage and the direct voltage source **4**, for example from a quick-switch protection, provides an oppositely connected variable direct voltage. The resultant voltage of the two direct voltage sources **2** and **4** supplies a grid direct voltage which varies between a positive value (if the voltage of the source **3** is zero) and a negative value (if the source **4** has a higher negative value than the value of the voltage from the source **2**). Consequently, the resultant control voltage produced in the grid circuit of the high-vacuum tube **1** is a sinusoidal alternating voltage superposed on a direct voltage varying between a positive and a negative polarity.

The anode circuit of the high-vacuum tube **1** includes a resistor **5** in series with an anode voltage source **6**. The resistor **5** is connected in series with an alternating voltage source **7** in the control circuit of a gas or vapor-filled discharge tube **8**. The anode circuit of the discharge tube **8** includes a load **9** and an alternating voltage supply source **10**.

Neglecting the control voltage source **7**, the arrangement operates as follows. It is assumed that the voltage from the device **4** is zero. In this case the grid voltage of the high vacuum tube is positive to such an extent that despite the alternating voltage from the transformer 3 superposed on it the tube **1** remains within the saturation range with respect to the anode current. The saturation current I_a (Figure 2) passing through the resistor **5** in said case produces a voltage drop across this resistor such that the discharge tube **8** is invariably kept cut-off (the transformer **7** being still neglected). If the device **4** supplies a small direct voltage, the positive grid voltage of the tube **1** decreases, for example, to a value shown in Fig. 2 by grid voltage magnitude **11**. In Fig. 2 the anode-current versus grid-voltage characteristic of the tube **1** is designated **12**. On the positive grid voltage **11** the alternating voltage **13** from the transformer **3** is superposed. Consequently the anode current will vary according to the curve *a—b—c—d*, that is, the voltage drop across the resistor **5** in Fig. 1 will be much less at the minimum value *c* of the anode current (Figure 2) with the result that at this instant the negative grid voltage of the discharge tube **8** is greatly decreased. The grid voltage of the discharge tube **8** with the current variation *a—b—c—d* is shown in Fig. 3 by the same reference symbols. If the ignition characteristic of the discharge tube **8** has a negative variation, as is shown for example in Fig. 3 by magnitude **14**, the tube **8** will ignite at the instant **15**; that is, during the second half of the positive half-cycle **16** of the anode voltage of said tube (the anode voltage **16** is raised in Fig. 3 for the sake of clarity).

If (by manual adjustment or automatically) the device **4** supplies a negative voltage exceeding the positive voltage from the source **2**, in the grid circuit of the tube **1**, for example, a resultant negative voltage **17** is obtained (Figure 2) and accordingly an anode current variation *e—f—g—h* of the tube **1** in Fig. 2 and a grid voltage curve *e—f—g—h* of the discharge tube **8** in Fig. 3 are obtained. The ignition of tube **8** will now take place at the point **18**, at an earlier instant in the half-cycle **16**.

If the voltage from the source **4** is driven even more negative so that, for example, the negative grid voltage **19** of Fig. 2 is obtained, the ignition instant of the discharge tube **8** will accordingly take place at a still earlier instant in the half-cycle **16**, and so on (see the curves *j—j* and *k—k* in Figs. 2 and 3).

However, if the discharge tube 8 has a positive ignition characteristic such as indicated by magnitude 20 in Fig. 3, the tube 8 cannot ignite. It will only ignite if an additional positive direct voltage is supplied in series with the control voltages. In this case, however, it is obvious that the control voltage curves *a—b—c—d*, *e—f—g—h*, *j—j* and *k—k* have a positive value with respect to the zero line, after the anode voltage has become zero at 21. However, it is frequently desirable that the grid voltage be negative when the anode voltage becomes negative in order to prevent the flow of residual ions to the negative anode, which might cause back-ignition in the discharge tube. Consequently the above-mentioned control voltage curves do not satisfy this requirement.

However, the desired grid voltage curve of the discharge tube 8 is obtainable by combining the above-mentioned control voltage curves with the alternating voltage from the transformer 7 (Fig. 1) which has been neglected thus far, as is shown in Figs. 4, 5 and 6.

In Figs. 4, 5 and 6, the alternating voltage from the source 7, which is slightly out of phase, is designated 22 and is combined with the control voltage curves *a—b—c—d*, *e—f—g—h* and *j—j* of Fig. 3.

A resultant control voltage, curve 23 in Fig. 4, is obtained which does not intersect with the ignition characteristic 20 so that the discharge tube 8 does not yet ignite.

In Fig. 5 the resultant control voltage curve 24 is obtained having a point of intersection 25 with the ignition characteristic 20. Consequently ignition is effected at the instant 26 during the positive half-wave 16 of the anode voltage.

The instant at which the positive half-wave of the control alternating voltage 13 from the source 3 (Fig. 2) is set up at the grid circuit of the high vacuum tube 1 is shown by 27 in Figures 2 to 6. In a practical embodiment of an arrangement in accordance with the invention the control voltage 13 leads the control alternating voltage 22 from the source 7 by approximately 45 electrical degrees, while the latter leads the anode voltage 16 of the discharge tube 8 by approximately 30 electrical degrees. In Figures 3 to 6 these phase displacements are not shown exactly, since different phase angles are also possible. Obviously, the choice of these phase angles depends on the position of the ignition characteristic of the discharge tube 8, the amplitudes of the alternating voltages 13 and 22, the controlling direct voltages from the sources 2 and 4 (Figure 1), an additional positive or negative direct voltage which may be set up in the grid circuit of the tube 8 and the desired ignition range of the discharge tube 8.

Finally, in Figure 6 the combination of the control alternating voltage 22 with the control voltage curve *j—j* provides a resultant control voltage 28 which at 29 has a point of intersection with the ignition characteristic 20, so that the ignition instant 30 in the positive half-wave 16 is obtained and a larger current is supplied from the discharge tube 8 than in the case shown in Figure 5.

At an even smaller amplitude of the control voltage curve *j—j* in Figure 6, the positive left-hand edge of the curve 28 is displaced more to the left until the control voltage 22 is reached so that an even earlier ignition in the anode voltage wave 16 is obtained. However, the positive right-hand edge of the curve 28 invariably remains in the same place similarly to the curve 24 in Figure 5. From Figures 5 and 6 it may be seen that the control voltage curves 24 and 28 invariably have a negative value at the instant at which the positive anode voltage 16 changes to a negative voltage when passing through zero at 31, so that back ignition is not likely.

With respect to the choice of the phase of the control alternating voltage 22 with respect to the anode voltage 16 the following may be taken into account:

In the entirely conductive condition of the discharge tube 8, in which the tube 1 has a negative voltage at its grid such that the anode current is zero for the entire duration of the cycle of the voltage 13, the grid of the discharge tube 8 only has the control alternating voltage 22 applied to it. If the discharge tube 8 is used in a three-phase arrangement or a three-phase Graetz arrangement, current flows through this tube during approximately 120 electrical degrees. (Figure 7.) If, now, the control alternating voltage 22 leads the anode voltage 16 by 30 electrical degrees, the first passage through zero, at point 32, of the control voltage 22, will coincide with the first passage through zero of the reverse voltage 33 so that, if the voltage 33 increases in a negative sense, the control alternating voltage 22 is driven negative and the grid-cathode space of the tube 8 is not ignited. Consequently, back-ignition in the tube 8 is not likely. Beyond the second passage through zero, at point 34, of the voltage 22 the control electrode of the tube 8 is driven positive to such an extent that the tube is enabled to ignite.

The ionization period of the gas in the tube delays this ignition process when the reverse voltage is decreasing.

The likelihood of back-ignition is very slight, since the anode-cathode space will only be enabled to ionize after the grid-cathode space is ignited, and at this point the reverse voltage is small. The period of time during the tube 8 is ignited may, if required, be reduced even further by causing the tube 8 itself to produce a negative voltage 35 (Figure 9) in its grid circuit due to the grid current and a suitable RC element of the kind shown in Figure 8 by 36 and 37.

In addition, this causes the voltage 22 from the transformer 7 (the voltage of the resistor 5 is zero) to reach the grid of the tube 8 with a lag of a determined number of electrical degrees due to the phase displacement of this RC element.

Consequently, it is possible that the voltage at the grid of tube 8 be in phase with the anode voltage of said tube, and said tube be ignited for approximately 140° (more than 120° due to the commutation).

Consequently, the initial voltage 22 must lead the anode voltage 16.

A 30° phase displacement between the voltages 16 and 22 may be produced in a simple manner by including a Δ—Y or a Y—Δ transformer between the low voltage and the high voltage.

It will be obvious that in a half-wave or full-wave system which may be connected in a Graetz arrangement the control alternating voltage 22 may be in phase with the anode voltage 16 since at full load the tube 8 must be ignited during the entire positive cycle of the anode voltage 16.

If required, a positive or a negative direct voltage may be connected in series with the voltage 22 depending upon the positive or the negative ignition characteristic and the commutation time.

While the invention has been described by means of specific embodiments, I do not wish to be limited thereto, for obvious modifications will occur to those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A circuit arrangement for controlling a gas discharge tube having an anode, a cathode and a control grid, said tube having a positive ignition characteristic, said circuit arrangement comprising means for applying an alternating voltage to the anode of said gas tube, an electron discharge tube of high vacuum type having an anode and a control grid, a first source of alternating voltage, means for supplying a direct voltage of variable polarity connected in series combination with said first source of alternating voltage, said series combination being connected to the control grid of said vacuum tube, coupling means connecting the anode of said vacuum tube to the control grid of said gas tube, a resistor connected

to said coupling means, and a second source of alternating voltage connected in series with said resistor whereby a resultant control voltage determined by the anode voltage of said vacuum tube and the second alternating voltage is applied to the control grid of said gas tube, said resultant control voltage having a phase displacement with respect to the alternating voltage applied to the anode of said gas tube whereby said resultant control voltage has a negative polarity relative to the voltage on the cathode of said gas tube at the instant when the alternating voltage applied to the anode of said gas tube changes from a positive polarity to a negative polarity.

2. A circuit arrangement as claimed in claim 1, further comprising a source of direct voltage coupled to the control grid of said gas tube by said resistor.

3. A circuit arrangement for controlling a gas discharge tube having an anode, a cathode and a control grid, said tube having a positive ignition characteristic, said circuit arrangement comprising means for applying an alternating voltage to the anode of said gas tube, an electron discharge tube of high vacuum type having an anode and a control grid, a first source of alternating voltage, means for supplying a direct voltage of variable polarity connected in series combination with said first source of alternating voltage, said series combination being connected to the control grid of said vacuum tube, phase shifting means coupled to the grid of said gas tube, means coupling the anode of said vacuum tube with said phase shifting means, a resistor connected to said coupling means, and a second source of alternating voltage connected in series with said resistor whereby a resultant control voltage determined by the anode voltage of said vacuum tube and the second alternating voltage is applied to the control grid of said gas tube, said resultant control voltage having a phase displacement with respect to the alternating voltage applied to the anode of said gas tube whereby said resultant control voltage has a negative polarity relative to the voltage on the cathode of said gas tube at the instant when the alternating voltage applied to the anode of said gas tube changes from a positive polarity to a negative polarity.

4. A circuit arrangement for controlling a gas discharge tube having an anode, a cathode and a control grid, said tube having a positive ignition characteristic, said circuit arrangement comprising means for applying an alternating voltage to the anode of said gas tube, an electron discharge tube of high vacuum type having an anode and a control grid, a first source of alternating voltage, means for supplying a direct voltage of variable polarity connected in series combination with said first source of alternating voltage, said series combination being connected to the control grid of said vacuum tube, coupling means connecting the anode of said vacuum tube to the control grid of said gas tube, a resistor connected to said coupling means, and a second source of alternating voltage connected in series with said resistor whereby a resultant control voltage determined by the anode voltage of said vacuum tube and the second alternating voltage is applied to the control grid of said gas tube, said resultant control voltage having a phase displacement with respect to the alternating voltage applied to the anode of said gas tube whereby said resultant control voltage has a negative polarity relative to the voltage on the cathode of said gas tube at the instant when the alternating voltage applied to the anode of said gas tube changes from a positive polarity to a negative polarity, said direct voltage having a maximum magnitude of positive polarity which renders said vacuum tube conductive substantially in the saturation range of the grid voltage versus anode current characteristic of said vacuum tube and a maximum magnitude of negative polarity which renders said vacuum tube nonconductive.

5. A circuit arrangement for controlling a gas discharge tube having an anode, a cathode and a control grid, said tube having a positive ignition characteristic, said circuit arrangement comprising means for applying an alternating voltage to the anode of said gas tube, an electron discharge tube of high vacuum type having an anode and a control grid, a first source of alternating voltage, means for supplying a direct voltage of variable polarity connected in series combination with said first source of alternating voltage, said series combination being connected to the control grid of said vacuum tube, coupling means connecting the anode of said vacuum tube to the control grid of said gas tube, a resistor connected to said coupling means, and a second source of alternating voltage connected in series with said resistor, the first alternating voltage leading the second alternating voltage in phase by substantially 45 electrical degrees and said second alternating voltage leading the alternating voltage applied to the anode of said gas tube in phase by substantially 30 electrical degrees whereby a resultant control voltage determined by the anode voltage of said vacuum tube and said second alternating voltage is applied to the control grid of said gas tube, said resultant control voltage having a negative polarity relative to the voltage on the cathode of said gas tube at the instant when the alternating voltage applied to the anode of said gas tube changes from a positive polarity to a negative polarity.

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