April 10, 1945. W. A. DEPP 2,373,175

ELECTRON DISCHARGE APPARATUS

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FIG. 1

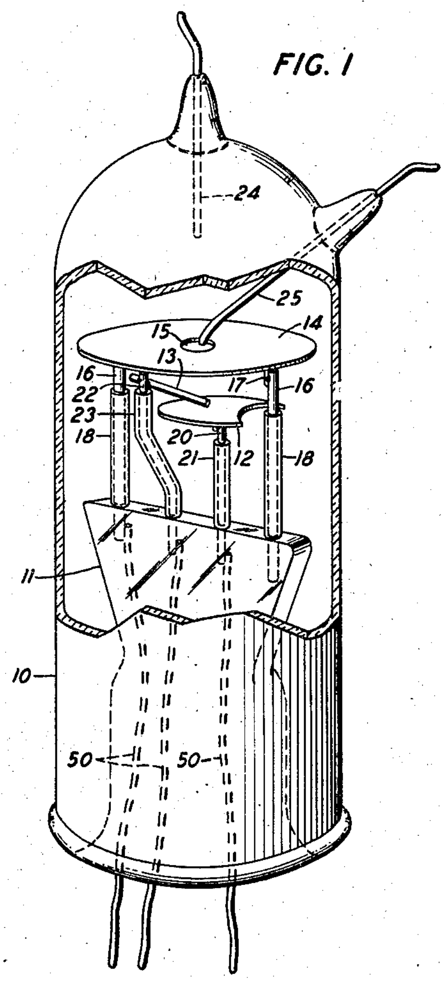

FIG. 2

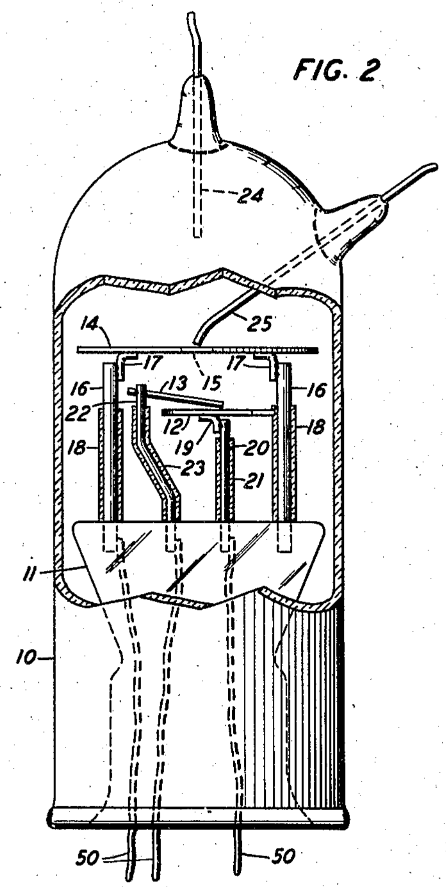

FIG. 3

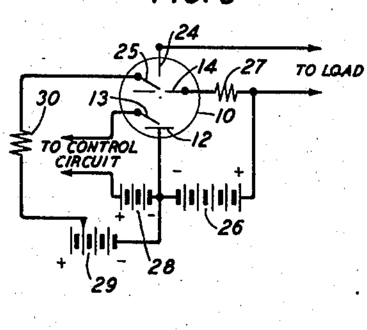

FIG. 4

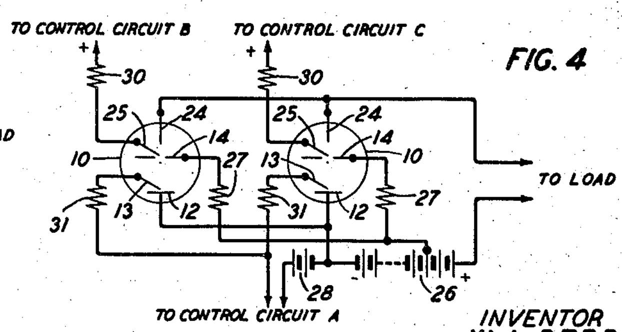

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FIG. 5

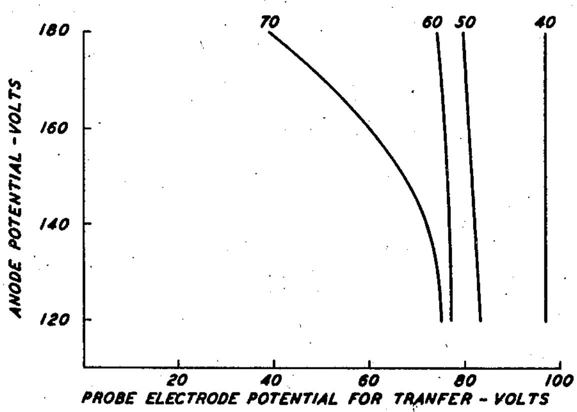


FIG. 6

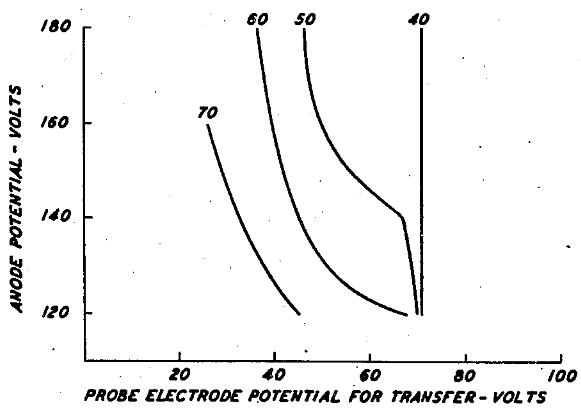
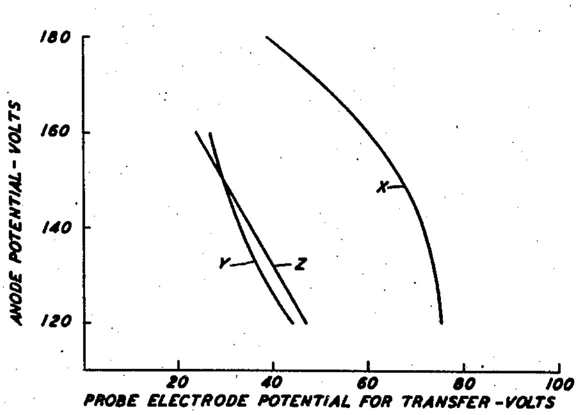


FIG. 7



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ELECTRON DISCHARGE APPARATUS

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Application September 29, 1942, Serial No. 460,085

6 Claims. (Cl. 250—27.5)

This invention relates to electron discharge apparatus and more particularly to electron discharge devices of the shield or screen grid type.

Shield or screen grid type electric discharge devices comprise, in general, a cathode, an anode, a control electrode and a shield electrode mounted in an envelope having a filling of a gas or other ionizable medium. The control electrode is effective to initiate a discharge between it and the cathode and the shield electrode performs the dual function of shielding the anode from the control gap region and of effecting transfer of the discharge to the main gap, that is the gap between the cathode and the anode. Satisfactory shielding of the anode in such devices entails the use of a shield electrode having a relatively large area in the main discharge path. Consequently, the current drawn by the shield electrode is relatively large, for example of the order of 20 per cent of the main gap current. As a result, when a plurality of such devices is operated with the shield electrodes in parallel and supplied from a high impedance source, as, for example, in switching circuits in automatic telephone systems, when one of the devices operates false operation of other of the devices may occur because of the increase in the potential of the shield electrodes thereof above the transfer value.

Further, in such devices of conventional design, the transfer characteristics are dependent largely upon the parameters of the device, particularly the kind and pressure of the gas filling of the envelope and the spacing of the shield electrode and the cathode so that the operating characteristics of any particular device are confined to prescribed limits.

One general object of this invention is to improve the operating characteristics of electric discharge devices of the shield or screen grid type. More specifically, objects of this invention are to:

Decrease the current to the transfer control electrode in electric discharge devices of the shield or screen grid type whereby a high impedance transfer control is realized;

Increase the flexibility of operation of shield grid type electric discharge devices whereby a range of transfer characteristics for any particular device is obtainable;

Reduce variations in the transfer characteristic of such devices, with changes in the control gap current; and

Obtain multipotential control of the main gap discharge in such devices whereby the establishment of several, for example three, potential conditions is prerequisite to the initiation of a discharge across the main gap.

In one illustrative embodiment of this invention, an electric discharge device comprises a cathode, a control electrode adjacent the cathode, an anode, and a shield electrode between the cathode and the anode. The shield electrode may be a disc extending transversely with respect to the main discharge gap and having a central restricted aperture in alignment with the cathode and anode. An auxiliary or probe electrode is provided for controlling the transfer of the discharge to the main gap. In one form, the auxiliary or probe electrode is a slender wire or rod having one end immediately adjacent the aperture in the shield electrode and extending laterally outwardly adjacent the shield electrode.

The invention and the features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawings in which:

Fig. 1 is a perspective view of an electric discharge device illustrative of one embodiment of this invention, a portion of the enclosing vessel being broken away to show the electrodes more clearly;

Fig. 2 is a side view, partly in section, of the device shown in Fig. 1;

Fig. 3 is a circuit diagram illustrating one manner of operating the electric discharge device shown in Figs. 1 and 2;

Fig. 4 is a circuit diagram illustrating parallel operation of a plurality of devices constructed in accordance with this invention;

Fig. 5 is a graph showing typical transfer characteristics of an electric discharge device illustrative of this invention, for relatively low control gap current;

Fig. 6 is a graph, similar to Fig. 5, showing typical transfer characteristics of the same electric discharge device for relatively high control gap current; and

Fig. 7 is a graph illustrating the transfer characteristics for different shield electrode currents in an electric discharge device constructed in accordance with this invention.

Referring now to the drawings, the electric discharge device illustrated in Figs. 1 and 2 comprises an enclosing vessel 10 having a filling of an ionizable medium, for example a mixture of 95 per cent neon, 5 per cent argon at a pressure of about 40 millimeters of mercury, and provided with a stem 11 from which a cathode 12, a control electrode 13 and a shield electrode 14 are supported and in which leading-in conductors 50 are sealed.

The shield electrode 14 is annular, for example a metal disc provided with a restricted central aperture 15, and is supported by rigid metallic uprights or wires 16 embedded in the stem 11, the electrode being secured to the uprights by metallic angle pieces 17 and the uprights being encased in insulating, for example glass, sleeves 18. The cathode 12 may be a disc, as shown, secured by an angle piece 19 to a rigid metallic support 20 surrounded by an insulating, e. g. glass, sleeve 21 and embedded in the stem 11, the surface of the cathode 12 facing the shield electrode 14 being coated with a material, such as a mixture of barium and strontium oxides, having good electron emission properties. The control electrode 13 is a metallic wire or rod overlying and inclined with respect to the emissive surface of the cathode 12 and is supported by a rigid metallic conductor 22 encased in an insulating, e. g. glass, sleeve 23 and embedded in the stem 11.

Sealed to and extending through the end wall of the vessel 10 and axially aligned with the aperture 15 is a wire rod anode 24. Extending from immediately adjacent the aperture 15 and inclined with respect to the shield electrode 14 is a wire rod auxiliary or probe electrode 25, which is sealed to and extends through the enclosing vessel 10.

During operation of the device, one manner of operation being illustrated in Fig. 3, the anode 24 is maintained at a positive potential with respect to the cathode 12 as by a battery 26, the shield electrode 14 being connected to a point in the anode circuit through a resistance 27 which may be, for example, of the order of 1 or more megohms. The control electrode 13 is biased at a small potential, positive with respect to the cathode 12, as by a battery 28 and the auxiliary or probe electrode 25 is biased positive with respect to the cathode 12 as by a battery 29 in series with a high resistance 30, for example of the order of 100,000 ohms.

The anode potential is insufficient to initiate a discharge between the cathode 12 and anode 24 for a given bias upon the control electrode 13 but is large enough to sustain such a discharge after the initiation of a discharge between the control electrode 13 and cathode 12 as a result of the application to the control electrode 13 of a suitable potential by way of the control circuit and the application of a potential to the probe electrode 25 sufficient to effect transfer of the discharge. The potential of the screen electrode 14 is less than that requisite to sustain a discharge across the cathode-shield electrode gap. The auxiliary or probe electrode is effective to control the transfer of the discharge from the cathode-control electrode gap to the main gap between the cathode and the anode. In general, for a given control gap current and shield electrode potential, there is a fairly critical probe electrode potential below which transfer will be prevented and above which transfer is permitted.

The transfer characteristic of any device is dependent upon, inter alia, the control gap current and the shield electrode potential, as shown in Figs. 5 and 6. In Fig. 5 are shown the transfer characteristics for a device of the construction illustrated in Figs. 1 and 2 for four values of shield electrode potential, 40, 50, 60 and 70 volts as indicated on the curves, and a control gap current of 40 microamperes. In Fig. 6 are shown the transfer characteristics for the same device and the same shield electrode potentials for a control gap current of 200 microamperes. It will be noted that for both values of control gap current, the transfer characteristic can be varied over a fairly wide range by changing the potential of the shield electrode, so that substantial flexibility in the operation of the device is achieved and any particular device is suitable for a variety of applications. Stated in another way, a single device constructed in accordance with this invention enables realization, by virtue of the variation of the transfer characteristic with shield electrode potential, of the characteristics of a number of devices.

Because of the form of the probe electrode, the current drawn thereto is small so that a high impedance control, by the probe electrode, is achieved. As an example, it may be noted that in a particular device of the construction shown in Figs. 1 and 2, the current to the probe electrode was approximately 0.1 milliampere as compared with a shield current of approximately 2 milliamperes in a shield grid device of comparable power rating and of conventional construction. Thus, in the device constructed in accordance with this invention the impedance of the control element was about twenty times that of a device of conventional design.

When the gap between the cathode 12 and control electrode 13 is conducting, some current from the discharge is drawn to the shield electrode 14 and at high shield electrode potentials this current may become comparable with the control gap current. The current thus drawn to the shield electrode is largely determinative of the transfer characteristic for the probe electrode for high shield electrode potentials. Hence, if the current to the shield electrode is maintained substantially constant, the variation in the transfer characteristic of the probe electrode with current in the control electrode-cathode gap may be made very small. This is illustrated in Fig. 7, in which curve X shows the transfer characteristic of a device of the construction shown in Figs. 1 and 2 with a control gap current of approximately 40 microamperes, a shield current of approximately 40 microamperes and a shield electrode potential of approximately 70 volts and curve Y is the transfer characteristic of the same device with the same shield electrode potential but with a control gap current of about 200 microamperes and a shield electrode current of about 260 microamperes. Curve Z shows the transfer characteristic for the same device with substantially the same shield electrode potential and shield electrode current as in the case of curve Y but with a control gap current of approximately 40 microamperes. From curves Y and Z it will be noted that if the shield electrode current is maintained at a fixed value, a great change in the control gap current is accompanied by only a substantially negligible variation in the transfer characteristic. Specifically, in the example given, a change in control gap current from 200 to 40 microamperes results in a change of but about 5 per cent in the transfer characteristic.

A substantially constant current to the shield electrode may be realized by constructing and arranging the shield electrode and cathode so that the potential requisite for breakdown of the gap therebetween is high, for example of the order of 60 per cent of the main gap breakdown potential, and connecting the shield electrode through a high resistance, of the order of 1 or more megohms to a potential source such that the shield electrode potential is slightly less than the breakdown value.

The high impedance control feature noted hereinabove is of particular advantage in circuits, such as crossbar switching circuits in automatic telephone systems, wherein a plurality of devices is operated with their main and control gaps in parallel. In conventional screen grid devices, the screen current is large as noted heretofore and, thus, when several such devices are operated in parallel, when one device operates there is danger of the others operating due to the increase of the potentials of the screens thereof above the transfer value. In devices constructed in accordance with this invention, however, the shield current is small as noted heretofore, so that false operation of devices connected in parallel when one device is energized to become conductive, is prevented.

A typical circuit for parallel operation is shown in Fig. 4. The main gaps, that is the gaps between each cathode **12** and the associated anode **24**, are connected in parallel to the load circuit and the control electrodes **13** also are connected in parallel, through series resistances **31**, for example of the order of 100,000 ohms, to the control circuit A, which may include, for example, a periodic interrupter, not shown. The shield electrodes **14** are biased at a positive potential below the transfer value by the battery **26** to which they are connected through the high resistances **27**, which may be, for example, of the order of 50,000 ohms. The auxiliary or probe electrodes **25** are connected to individual control circuits B and C through the resistances **30**, which may be of the order of ½ megohm. The particular potential upon each probe electrode to cause transfer of the discharge to the main gap after the control gap becomes conducting will be dependent upon the shield electrode potential, as is apparent from what has been said heretofore.

It will be noted that the device requires that the potentials of three electrodes be above certain values before a discharge across the main gap may occur so that three controls are provided. That is, initiation of a discharge between the cathode **12** and the anode **24** requires first that the control gap, i. e., the gap between the cathode **12** and control electrode **13** break down, secondly that the shield electrode be at a particular potential, less than the sustaining potential of the shield electrode-cathode gap to prevent transfer to the shield electrode, and thirdly a particular probe electrode potential to effect transfer to the main gap after the control electrode-cathode gap becomes conducting. The device, therefore, may be used to advantage in interlocking circuits.

Although a specific embodiment of this invention has been shown and described, it will be understood that it is but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. Electron discharge apparatus comprising a gaseous discharge device including a cathode and an anode spaced to define a main discharge gap, a shield electrode between said cathode and said anode, means for producing a discharge adjacent said cathode, and means for transferring the discharge to said main gap including a slender auxiliary electrode having a portion immediately adjacent said shield electrode.

2. An electric discharge device comprising an enclosing vessel having an ionizable medium therein, a shield electrode within said vessel and having an aperture therein, a cathode on one side of said shield electrode, an anode on the other side of said shield electrode, means for producing a discharge in a region adjacent said cathode, and a transfer control electrode between said anode and said shield electrode and extending into immediate proximity to said aperture.

3. An electric discharge device comprising an enclosing vessel having an ionizable medium therein, a cathode and an anode within said vessel and spaced to define a main discharge gap, a shield electrode between said cathode and said anode and having a restricted aperture therein, a control electrode adjacent said cathode, and a probe electrode having a portion in immediate proximity to said aperture.

4. An electric discharge device comprising an enclosing vessel having an ionizable medium therein, a cathode and an anode within said vessel spaced to form a discharge gap, a trigger control electrode adjacent said cathode, means shielding said anode from said control electrode comprising an annular metallic member imperforate except for a restricted aperture therein, and a transfer control electrode between said anode and said shield electrode, said transfer control electrode having one end immediately adjacent said aperture.

5. An electric discharge device comprising an enclosing vessel having an ionizable medium therein, an anode and a cathode within said vessel spaced to form a main discharge gap, a shield electrode extending across said gap, said shield electrode being imperforate except for an aperture therein, means for establishing a discharge in a region adjacent said cathode, and means for effecting transfer of the discharge to said gap including a slender probe electrode having one end immediately adjacent said aperture.

6. An electric discharge device comprising an enclosing vessel having an ionizable medium therein, a shield electrode within said vessel and having a restricted aperture therein, a disc cathode to one side of said shield electrode, an anode on the other side of said shield electrode and aligned with said cathode through said aperture, a metallic rod control electrode adjacent said cathode, and a rod probe electrode between said shield electrode and having one end adjacent said aperture.

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