March 28, 1961 K. J. GERMESHAUSEN 2,977,508

GASEOUS-DISCHARGE DEVICE AND SYSTEM

Filed July 17, 1956 2 Sheets-Sheet 1

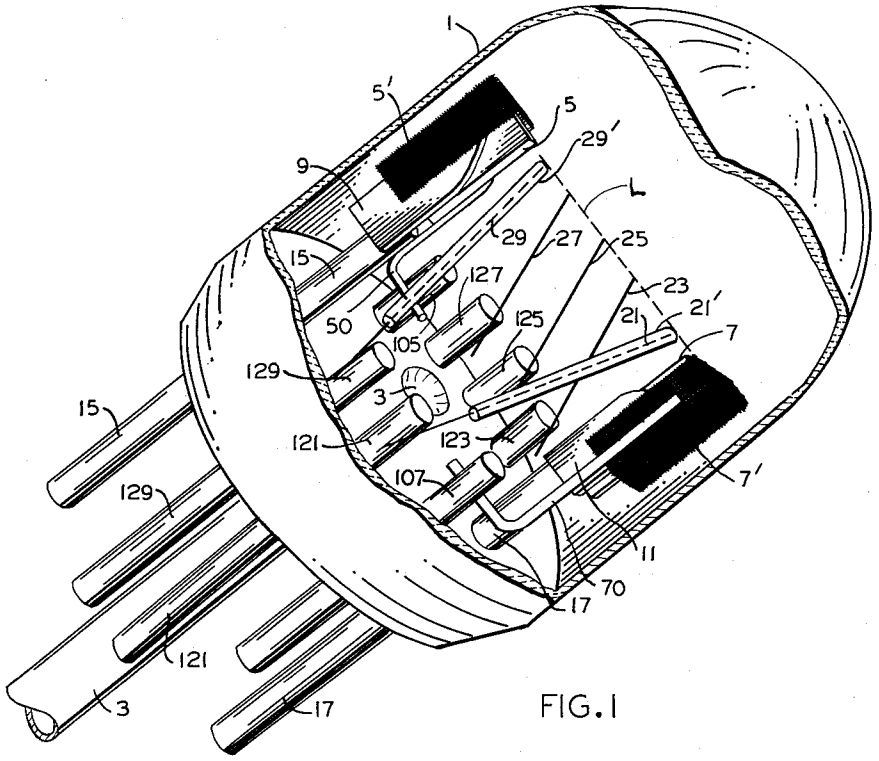

FIG. 1

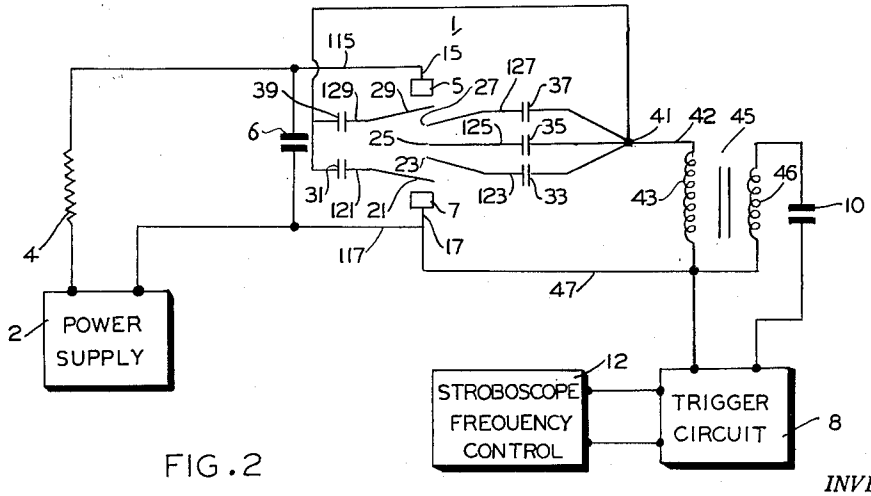

FIG. 2

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GASEOUS-DISCHARGE DEVICE AND SYSTEM

Filed July 17, 1956 2 Sheets-Sheet 2

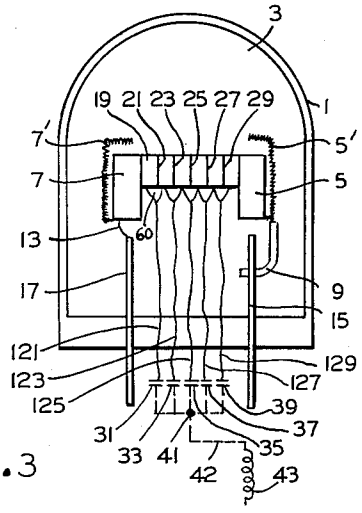

FIG. 3

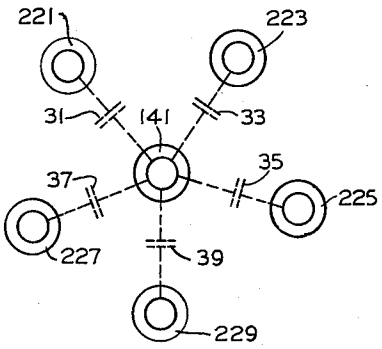

FIG. 6

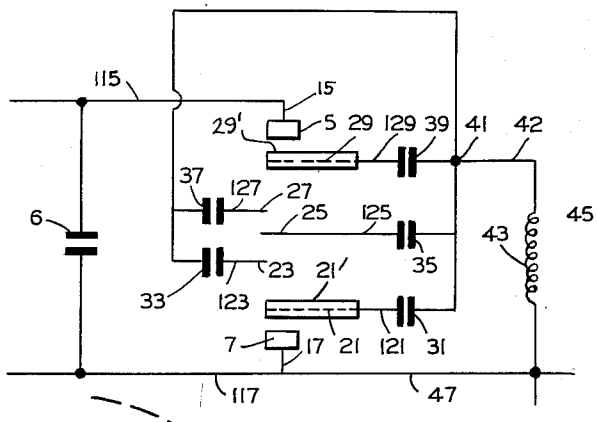

FIG. 4

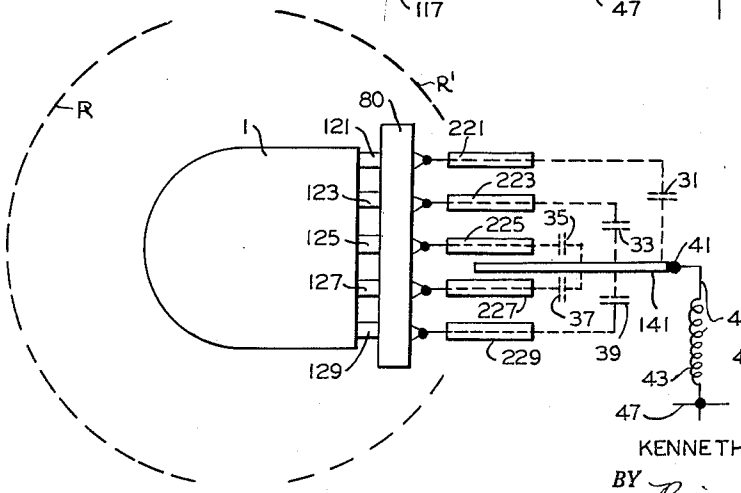

FIG. 5

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2,977,508

GASEOUS-DISCHARGE DEVICE AND SYSTEM

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Filed July 17, 1956, Ser. No. 598,325

43 Claims. (Cl. 315—241)

The present invention relates to gaseous-discharge devices and to electrical systems for operating the same, being more particularly directed to gaseous-discharge flashtubes of the type useful to produce flash illumination in stroboscopic systems, flash-photography systems and the like.

It is desirable in many stroboscopic and flash-photography systems and the like to provide a source of flash illumination that has a small illumination area of high uniform flash intensity. Prior-art light sources have sacrificed light efficiency through the reduction of gas pressure required for reasonably low operating voltages, and by the darkening of the walls of the flashtube through the sputtering of electrode material or, in the case of small-size flashtubes, the cracking of the flashtubes. While stroboscopes utilizing relatively high-pressure gas-discharge tubes operating with voltages of the order of a few thousand volts have been most successful, they have, none-the-less, demanded a compromise between gas pressure and voltage that provided adequate tube life but reduced light efficiency.

An object of the present invention is to provide a new and improved gaseous-discharge device and system for operating the same that permits the utilization of higher gas pressures and lower operating voltages and that provides increased light-illumination efficiency.

There has also existed the problem in the flashtube art of providing substantial uniformity of illumination in the complete discharge region between the anode and cathode of the gaseous-discharge device. The discharges, moreover, have a tendency to wander and frequently produce flickering operation, particularly when repetitively flashed in high-speed stroboscopes and the like and particularly when the envelope wall regions of the tube are considerably spaced from the anode and cathode and cannot thus assist in confining a discharge therebetween.

A further object of the present invention, accordingly, is to provide a novel gaseous-discharge device and electrical system for operating the same that shall not be subject to these disadvantages and that, to the contrary, shall provide uniform illumination over the complete discharge region without wandering or flickering of the discharge.

Still an additional object is to provide such a novel discharge device and system of dimensions sufficiently small to enable the utilization of the device as a point or line source of high-intensity flash illumination.

In summary, the results of the present invention are attained through the utilization of a plurality of trigger electrodes successively disposed in the space between the anode and cathode of a gaseous-discharge device and connected by a plurality of electrical connections to a common trigger circuit, each electrical connection containing an isolating impedance. Preferred constructional details and other features are hereinafter treated.

The invention will now be described in connection with the accompanying drawings Fig. 1 of which is a perspective view of a gaseous-discharge flashtube constructed in accordance with a preferred embodiment, the view being partly cut away to illustrate details of construction;

Fig. 2 is a schematic circuit diagram illustrating a preferred electrical system for operating the flashtube of Fig. 1;

Fig. 3 is a longitudinal section of a modified flashtube;

Fig. 4 is a view similar to Fig. 2 of a further modification;

Fig. 5 is a side elevation illustrating a mounting structure and electrical connection; and

Fig. 6 is an end elevation of the electrical connection of Fig. 5.

The flashtube is shown having a glass, fused quartz or similar light-transparent envelope 1 within which the gaseous medium, such as xenon and the like, may be sealed, as, for example, by closing off the gas-fill inlet tube 3, in the bottom wall of the envelope 1. For the purposes of high-speed stroboscopes and the like, it is preferable that the gas be maintained at a high pressure of the order of say one-half to three atmospheres, more or less. An anode electrode 5 and a cathode electrode 7, preferably both of the same construction, are supported spaced from the adjacent envelope wall regions bounding the space therebetween and spaced from one another within the envelope 1 by conductive supports 9 and 11 that communicate with pins 15 and 17 extending outside the base of the envelope through the bottom wall thereof. The cathode 7 and the anode 5 are preferably both of the sintered cold-cathode type disclosed in my prior United States Letters Patent No. 2,492,142 issued December 27, 1949, and they are illustrated in Fig. 1 as substantially similar rectangular-surface pills disposed substantially parallel to one another. Such sintered electrodes are capable of withstanding the high temperatures inherent in the operation of closely spaced electrodes at substantial voltages in a high-pressure gas.

Disposed within the space between the substantially parallel opposing surfaces of the anode 5 and the cathode 7 are a plurality of probe-type trigger or control electrodes 21, 23, 25, 27 and 29, as of tungsten, illustrated as substantially linear electrodes. While five such trigger electrodes are illustrated, more or less trigger electrodes may be employed consistent with the separation between the anode 5 and the cathode 7 and the hereinafter described required discharge-conducting or guiding function of the plurality of trigger electrodes. In accordance with the present invention, a voltage is applied between the anode 5 and the cathode 7 that is of itself insufficient to produce a discharge therebetween through the gas. A trigger impulse is thus applied to break down the gas in the neighborhood of either the anode 5 or the cathode 7 between the same and the adjacent trigger electrode 29 or 21, respectively. Assuming that, for example, breakdown is first initiated between the trigger electrode 21 and the cathode 7, an arc passes therebetween, dropping the potential of the trigger electrode 21 to the potential of the cathode 7. By providing sufficient isolating impedance between the trigger electrode 21 and the next adjacent trigger electrode 23, as later discussed, the potential of the trigger electrode 23 does not drop to the cathode potential at the instant of the discharge between the cathode 7 and the trigger electrode 21, but remains at a high potential with respect thereto. The space between the cathode-potential trigger electrode 21 and the adjacent trigger electrode 23 thus next becomes broken down. Again, by providing sufficient isolating impedance between the trigger electrode 23 and the next adjacent trigger electrode 25, the space between the trigger electrodes 23 and 25 will break down after the breakdown between the trigger electrodes 21 and 23,

Similarly, successive break downs will occur in series between the trigger electrode **25** and the trigger electrode **27**, and then between the trigger electrode **27** and the trigger electrode **29**, and finally between the trigger electrode **29** and the anode **5**, as later more fully discussed. The voltage applied between the anode **5** and the cathode **7** can thus become discharged in the space between them, producing a high-intensity flash. In view of the series-break-down conducting, guiding or stabilizing process of the trigger electrodes, moreover, the discharge takes place accurately along a fixed path, within the volume defined by the space between the anode and cathode, without wandering or fluctuating.

The spacing between the anode **5** and the adjacent trigger electrode **29** is substantially equal to the spacing between the successive trigger electrodes and the spacing between the cathode **7** and the adjacent trigger electrode **21**, and is less than the distance from the free ends of the trigger electrodes to any portion of the envelope, as shown. The reason for this substantially equal spacing resides in the fact that the minimum breakdown potential between successive trigger electrodes must be equal in order to ensure the successive guiding of the break down in the desired successive series path. The possibility of break-down commencing from the cathode and then starting from the anode, leaving an intermediate region of the space therebetween unionized, is thus eliminated. A desirable spacing for a xenon tube of the above-described character is about three-eighths of an inch. The free ends of the trigger electrodes **21**, **23**, **25**, **27**, **29** preferably lie along a substantially straight line, shown dotted at L, connecting the anode **5** and the cathode **7** between regions thereof near their upper surfaces, defining the upper limit or boundary of the space between the anode **5** and the cathode **7**. This construction maintains the arc discharge as far removed from the electrode supports therebelow as possible, insuring that the discharge takes place in the desired region only. Further to achieve this end, the trigger electrodes **21** and **29** may be supported on one side of the tube by respective conductive-pin supports **121** and **129**, and the trigger electrodes **23**, **25** and **27** may be supported at the other side upon respective conductive-pin supports **123**, **125** and **127**. The pin supports **121**, **123**, **125**, **127** and **129** may also extend through the base of the envelope **1**. By inclinedly securing the trigger electrodes to their supports, as illustrated, such as with the aid of solder, and by causing groups of the trigger electrodes to enter the discharge region between the anode **5** and the cathode **7** from opposite sides, the trigger electrodes may be spaced from one another by greater distances at their lower portions, adjacent their supports, than at the discharge region L. The resulting minimum trigger-electrode spacing along the region L gives rise to minimum discharge impedance between the trigger electrodes therealong and further insures that the discharge is confined to the desired path. These precautions are important since a large safety margin is essential to render substantially impossible arcing at the base of the tube.

It will be observed that the trigger electrodes **21** and **29** are shown preferably provided with respective sleeves or coverings **21'** and **29'**. These sleeves may be of insulating material, such as glass, and they serve to aid in the initial arc break-down to the adjacent cathode or anode by reducing the required break-down potential. Once that initial break-down occurs, of course, sufficient ions are present so that the other trigger electrodes do not require such sleeves.

As disclosed in my copending application, Serial No. 428,446, filed May 10, 1954, now Patent No. 2,812,465, and entitled Gaseous Discharge Device, electrical trapping devices, preferably in the form of conductive wire-mesh screens or cages, may be employed at the rear and side edges of the cathode **7** and the anode **5** external to the discharge space between the cathode and anode. If particles of the sintered material of the cathode and anode are sputtered off, or driven by the force of the discharge between the anode and cathode toward the walls of the envelope **1**, appreciable quantities of the sputtered material will be prevented by these traps from traveling back to the region between the anode and the cathode after the discharge. In the tube of Fig. 1, the substantially rectangular parallelopiped-type wire-mesh screens or cages are shown at **5'** and **7'** receiving the outer positions of the anode **5** and cathode **7**, respectively, and supported by members **50** and **70** that, in turn connect with respective pin supports **105** and **107**. The trapping screens **5'** and **7'** and their supporting elements **50—105** and **70—107** are maintained at floating potential, thus isolated from the potentials applied to the tube electrodes and incapable of supporting a spurious discharge to their surfaces.

The electric circuits for operating the flash tube of the present invention may assume the form illustrated in Fig. 2 in which a flash capacitor or capacitors **6** is or are charged through a limiting impedance **4** from a power-supply energy source **2**. The upper and lower terminals of the capacitor **6** are shown connected by conductors **115** and **117**, respectively, to the pins **15** and **17** connected with the anode **5** and the cathode **7**. The voltage thus developed between the anode and cathode is, as before explained, insufficient in and of itself to effect a discharge therebetween. A trigger circuit **8** may comprise a thyratron or other switching circuit adapted to discharge a capacitor **10** through the primary winding **46** of a trigger transformer **45** to produce a trigger pulse. The trigger circuit **8** may be controlled by a stroboscope frequency control **12**, as of the type disclosed in my United States Letters Patent No. 2,331,317 issued on October 12, 1943. The trigger pulse so produced may initiate or trigger the successive electrode break-down before discussed in order to permit the energy stored in the capacitor **6** to discharge between the anode **5** and the cathode **7**, thereby to produce a high-intensity brief flash or repetition of flashes. Trigger circuits of this character are also disclosed in United States Letters Patent No. 2,478,901 issued on August 16, 1949 to Harold E. Edgerton.

Each trigger electrode **21**, **23**, **25**, **27** and **29** is provided with an electrical connection from the respective pins **121**, **123**, **125**, **127** and **129** that includes an isolating impedance, as previously mentioned. The isolating impedances are illustrated as respective capacitors **31**, **33**, **35**, **37** and **39** which, in accordance with the present invention, are all connected together at **41** and by a conductor **42** to the upper terminal of a preferably step-up secondary winding **43** of the trigger transformer **45**. The lower terminal of the secondary winding **43** is connected by conductor **47** to the cathode **7** and is connected, also, to the lower terminal of the primary winding **46**. The trigger pulse developed in the trigger transformer **45** will therefore cause the successive series trigger-electrode breakdown before described, terminating in the discharge of the flash capacitor **6** between the anode **5** and cathode **7**. Repetitive trigger pulses will effect repetitive discharges of this character, the frequency of repetition being limited solely by the charging time constant of the flash capacitor charging circuit **2**, **4**, **6**.

It has not heretofore been explained in detail how, once the guided break-down phenomenon reaches the trigger electrode **29**, further breakdown will occur in the space between the trigger electrode **29** and the anode **5** to complete the triggering effect. This result is achieved through designing the triggering circuit comprising the trigger electrodes, their isolating capacitances, the secondary winding **43** and the conductors **42** and **47** to be oscillatory at a relatively high radio-frequency when shock-excited by the trigger pulse. Under such circumstances, a high rate of rise of voltage will be momentarily maintained at the trigger electrode **29** that will break down the last gap to the anode **5**.

A somewhat modified construction is illustrated in Fig. 4 in which substantially parallel outer trigger electrodes **21, 29** and center trigger electrode **25** enter the discharge space from one side of the tube and substantially parallel second and fourth trigger electrodes **23** and **27** enter from the other side. Since none of the trigger electrode mountings or supports is adjacent the mounting or support of the next successive electrode, the lowest impedance path between successive trigger electrodes is again along the desired discharge path between the anode **5** and the cathode **7**. The trigger electrodes may thus be disposed substantially perpendicular to the direction of the said discharge path between the anode and cathode.

In Fig. 3 there is shown another arrangement in which the trigger electrodes are substantially parallel to one another and substantially normal to the discharge path between the anode and cathode. Between the anode and cathode there is disposed an insulating member **19**, as of alumina ceramic and the like, that preferably extends horizontally along substantially the complete space between the anode **5** and the cathode **7**. The insulating member **19** supports the plurality of substantially vertical trigger electrodes **21, 23, 25, 27** and **29**. Insulating beads **60**, depending from the lower surface of the insulating support **19** that defines the lower boundary of the discharge space between the anode and cathode, provide a greater and hence higher-impedance path between adjacent trigger electrodes than along the upper boundary thereof, thus again insuring that the discharge takes place along the desired path only. The same trigger breakdown phenomenon before-described takes place in sequence between the successively positioned trigger electrodes, guiding or stabilizing the discharge along the line of the free ends of the trigger electrodes and thus preventing wandering. The sputter traps **5'** and **7'** are in this case connected at their bases to the anode **5** and cathode **7**, respectively, to assume the potentials thereof. The spacing between the other portions of the sputter traps and the other portions of the adjacent anode and cathode, however, are made sufficiently large compared with the spacing from the anode and cathode to the respective adjacent triggering electrodes **29** and **21**, that a discharge cannot take place between the anode and cathode and their respective traps.

While the trigger-electrode isolating impedances have been illustrated as physical capacitors **31, 33, 35, 37** and **39**, they may assume other forms such as inductive or other impedance elements, including distributed capacitance elements. Appropriate spacing of the leads **121, 123, 125, 127** and **129** or conductive extensions thereof, such as the respective preferably coaxial-line sections **221, 223, 225, 227** and **229** of Figs. 5 and 6, can provide the necessary isolating-impedance distributed capacitance **31, 33, 35, 37** and **39**. In Figs. 5 and 6, a further coaxial-line section **141**, connected to the point **41**, is inserted in the center of the extensions **221, 223, 225, 227** and **229** in order to be capacitively coupled thereto to the desired degree. The tube **1**, moreover, may be disposed in a socket **80** mounted in the focal region of forward or rearward parabolic reflectors R or R' to provide directive beams of flashing light.

As an illustration, a flashtube of the above-described character containing xenon gas at about one atmosphere pressure and having a short space between the anode and cathode of about three-eighths of an inch, has been operated stroboscopically with a capacitor **6** of about 0.5 microfarad, producing a flashing voltage of about 400 volts, with a trigger voltage of about 3000 volts. Over a period of 20 hours of repetitive-flashing life-testing operation at sixty flashes per second, the light energy transmitted from the flashtube was found to drop negligibly. The efficiency and light output with the 400-volt voltage before mentioned was about four times that of comparable present-day flashtubes utilized for stroboscopic purposes.

Further modifications will occur to those skilled in the art and all such are considered to fall within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A high-pressure gaseous-discharge device having a gas-filled envelope within the gas of which are disposed an anode and a cathode spaced from the anode, the envelope having wall regions considerably spaced from the anode and cathode and the volume defined by the space therebetween so that such wall regions cannot assist in confining a discharge between the anode and cathode to a column of gas restricted substantially only to the said volume, and a plurality of trigger electrodes the free ends of which are successively disposed at substantially equal intervals in the space and direction between the anode and the cathode, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the said volume only.

2. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of wire probe-type trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

3. A gaseous-discharge device having a gas-filled envelope within the gas of the device an anode, a cathode spaced from the anode, and a plurality of substantially linear trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line between the anode and the cathode, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

4. A gaseous-discharge device having a gas-filled envelope within the gas of the device an anode, a cathode spaced from the anode, and a plurality of substantially linear trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line in close proximity to a line defining one boundary of the said space between corresponding edges of the anode and cathode, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

5. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line displaced from one boundary of the said space between the anode and cathode and the breakdown discharge-impedance between the successive trigger electrodes at the said one boundary of the said space being greater than that along the said line, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

6. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode

spaced from the anode, particle-trapping means disposed adjacent the anode and cathode at regions removed from the space between them, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

7. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, particle-trapping means disposed adjacent the anode and cathode at regions removed from the space between them, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line between the anode and the cathode, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

8. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, particle-trapping means disposed adjacent the anode and cathode at regions removed from the space between them, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line displaced from one boundary of the said space between the anode and cathode and the breakdown discharge-impedance between the successive trigger electrodes at the said one boundary of the said space being greater than that along the said line, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

9. A geasous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode, the trigger electrodes adjacent both the anode and cathode each being provided with means for reducing the break-down potential between it and the adjacent anode or cathode, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

10. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode, the trigger electrodes adjacent both the anode and cathode each being provided with an insulating covering for reducing the break-down potential between it and the adjacent anode or cathode, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

11. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode, the trigger electrode adjacent the anode being provided with means for reducing the break-down potential between it and the anode, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

12. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode, the trigger electrode adjacent the cathode being provided with means for reducing the break-down potential between it and the cathode, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

13. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at intervals in the space and direction between the anode and the cathode, the trigger electrodes being supported at points external to the space between the anode and cathode and extending inclinedly into the said space, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

14. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at intervals in the space and direction between the anode and the cathode, the trigger electrodes being supported at points external to the space between the anode and cathode and extending inclinedly into the said space with their free ends lying along a substantially straight line between the anode and the cathode, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

15. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at intervals in the space and direction between the anode and the cathode, the trigger electrodes being supported at points external to the space between the anode and cathode and extending inclinedly into the said space with their free ends lying along a substantially straight line between portions of the anode and the cathode furthest removed from the said points, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

16. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line between the anode and cathode and the spacing between the successive trigger electrodes being less at the said free ends than at other portions thereof to provide less breakdown discharge-impedance between the successive trigger electrodes along the said line, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine

the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

17. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, an insulating member disposed in the space and direction between the anode and the cathode, and a plurality of trigger electrodes successively supported by the insulating member at succesively disposed intervals therealong, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

18. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, an insulating member disposed in the space and direction between the anode and the cathode, and a plurality of trigger electrodes successively supported by the insulating member at successively disposed intervals therealong with the free ends of the trigger electrodes lying along a substantially straight line displaced from one boundary of the said space and the portions of the trigger electrodes at the said one boundary being provided with insulation coverings that provide greater breakdown discharge-impedance between the successive trigger electrodes than along the said line, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

19. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode electrode, a cathode electrode spaced from the anode electrode, conductive-screen trapping means disposed adjacent at least one of the said electrodes at regions removed from the space between them and maintained at floating potential with respect to the said one electrode, and a plurality of trigger electrodes disposed at successive intervals in the space and direction between the anode and the cathode, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

20. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode electrode, a cathode electrode spaced from the anode electrode, conductive-screen trapping means disposed adjacent at least one of the said electrodes at regions removed from the space between them, and a plurality of trigger electrodes disposed at successive intervals in the space and direction between the anode and the cathode, the trapping means being electrically connected at a region thereof to the said one electrode but spaced therefrom at other regions a sufficient distance relative to the spacing between the said one electrode and the trigger electrode closest thereto to insure a discharge to the closest trigger electrode and not to the trapping means, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

21. A gaseous-discharge device having within the gas of the device an anode electrode, a cathode electrode spaced from the anode electrode, conductive-screen trapping means disposed adjacent at least one of the said electrodes at regions removed from the space between them, and trigger electrode means associated with the space between the anode and the cathode, the trapping means being electrically connected at a region thereof to the said one electrode but spaced therefrom at other regions a sufficient distance relative to the spacing between the said one electrode and the trigger electrode means to insure a discharge to the trigger electrode means and not to the trapping means.

22. A gaseous-discharge device having within the gas of the device an anode electrode, a cathode electrode spaced from the anode electrode, and conductive-screen trapping means disposed adjacent at least one of the said electrodes at regions removed from the space between them, the trapping means being connected at one region to the said one electrode and spaced from other regions thereof.

23. A gaseous-discharge device having within the gas of the device an anode electrode, a cathode electrode spaced from the anode electrode, and open-cage conductive-screen trapping means for receiving at least one of the said electrodes with the opening of the cage facing the said space between the anode and cathode electrodes, the trapping means being maintained at floating potential with respect to the said one electrode.

24. A gaseous-discharge device having within the gas of the device an anode electrode, a cathode electrode spaced from the anode electrode, and open-cage conductive-screen trapping means for receiving at least one of the said electrodes with the opening of the cage facing the said space between the anode and cathode electrodes, the trapping means being connected at a predetermined region to the said one electrode.

25. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode, the anode and cathode each comprising sintered members of the cold-cathode type, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

26. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line between the anode and the cathode, the anode and cathode each comprising sintered members of the cold-cathode type, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

27. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line displaced from one boundary of the said space between the anode and cathode and the breakdown discharge-impedance between the successive trigger electrodes at the said one boundary of the said space being greater than that along the said line, the anode and cathode each comprising sintered members of the cold-cathode type, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

28. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, particle-trapping means disposed adjacent the anode and cathode at regions removed from the space between them, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line between the anode and the cathode, the anode and cathode each comprising

sintered members of the cold-cathode type, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

29. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode, the trigger electrodes adjacent both the anode and cathode each being provided with means for reducing the break-down potential between it and the adjacent anode or cathode, the anode and cathode each comprising sintered members of the cold-cathode type, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

30. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, and a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line between the anode and cathode and the spacing between the successive trigger electrodes being less at the said free ends than at other portions thereof to provide less breakdown discharge-impedance between the successive trigger electrodes along the said line, the anode and cathode each comprising sintered members of the cold-cathode type, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

31. A gaseous-discharge device having within the gas of the device an anode electrode, a cathode electrode spaced from the anode electrode, and conductive-screen trapping means disposed adjacent at least one of the said electrodes at regions removed from the space between them, the trapping means being connected at one region to the said one electrode and spaced from other regions thereof, the anode and cathode each comprising sintered members of the cold-cathode type.

32. A gaseous-discharge device having within the gas of the device an anode electrode, a cathode electrode spaced from the anode electrode, and open-cage conductive-screen trapping means for receiving at least one of the said electrodes with the opening of the cage facing the said space between the anode and cathode electrodes, the trapping means being maintained at floating potential with respect to the said one electrode, the anode and cathode each comprising sintered members of the cold-cathode type.

33. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cold cathode spaced from the anode and a plurality of substantially linear trigger electrodes successively disposed at intervals in the space and direction between the anode and the cathode, a plurality of electrical lead-connections each connected at one end to one of the plurality of trigger electrodes and each containing isolating impedance, the other ends of all the lead-connections being connected together, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

34. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cold cathode spaced from the anode and a plurality of substantially linear trigger electrodes successively disposed at intervals in the space and direction between the anode and the cathode, a plurality of electrical lead-connections each connected at one end to one of the plurality of trigger electrodes and each containing isolating capacitance, the other ends of all the lead-connections being connected together, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

35. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cold cathode spaced from the anode, a plurality of substantially linear trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line between the anode and the cathode, and a plurality of electrical lead-connections each connected at one end to one of the plurality of trigger electrodes and each containing isolating impedance, the other ends of all of the lead-connections being connected together, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

36. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line displaced from one boundary of the said space between the anode and cathode and the breakdown discharge-impedance between the successive trigger electrodes at the said one boundary of the said space being greater than that along the said line, and a plurality of electrical lead-connections each connected at one end to one of the plurality of trigger electrodes and each containing isolating impedance, the other ends of all of the lead-connections being connected together, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

37. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, particle-trapping means disposed adjacent the anode and cathode at regions removed from the space between them, a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line between the anode and the cathode, and a plurality of electrical lead-connections each connected at one end to one of the plurality of trigger electrodes and each containing isolating impedance, the other ends of all of the lead-connections being connected together, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

38. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode, the trigger electrodes adjacent both the anode and cathode each being provided with means for reducing the break-down potential between it and the adjacent anode or cathode, and a plurality of electrical lead-con-

nections each connected at one end to one of the plurality of trigger electrodes and each containing isolating impedance, the other ends of all of the lead-connections being connected together, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

39. A gaseous-discharge device having a gas-filled envelope, within the gas of the device an anode, a cathode spaced from the anode, a plurality of trigger electrodes successively disposed at substantially equal intervals in the space and direction between the anode and the cathode with the free ends of the trigger electrodes lying along a substantially straight line between the anode and cathode and the spacing between the successive trigger electrodes being less at the said free ends than at other portions thereof to provide less breakdown discharge-impedance between the successive trigger electrodes along the said line, and a plurality of electrical lead-connections each connected at one end to one of the plurality of trigger electrodes and each containing isolating impedance, the other ends of all of the lead-connections being connected together, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

40. An electric system having, in combination, a gaseous-discharge device provided with an envelope containing an anode, a cathode spaced from the anode and a plurality of trigger electrodes successively disposed at intervals in the space and direction between the anode and the cathode, energy-supplying means connected between the anode and the cathode, a trigger circuit connected to one only of the anode and cathode for initiating the discharge of energy from the energy-supplying means between the anode and the cathode, and a plurality of electrical connections, one for connecting each of the plurality of trigger electrodes to the trigger circuit, each electrical connection containing isolating impedance, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

41. An electric system having, in combination, a gaseous-discharge device provided with an envelope containing an anode, a cathode spaced from the anode and a plurality of trigger electrodes successively disposed at intervals in the space and direction between the anode and the cathode, energy-supplying means connected between the anode and the cathode, a trigger circuit connected to one only of the anode and cathode for initiating the discharge of energy from the energy-supplying means between the anode and the cathode, and a plurality of electrical connections, one for connecting each of the plurality of trigger electrodes to the trigger circuit, each electrical connection containing isolating capacitance, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

42. An electric system having, in combination, a gaseous-discharge device provided with an envelope containing an anode, a cathode spaced from the anode and a plurality of trigger electrodes successively disposed at intervals in the space and direction between the anode and the cathode, energy-supplying means connected between the anode and the cathode, a trigger circuit connected to one only of the anode and cathode for initiating the discharge of energy from the energy-supplying means between the anode and the cathode, and a plurality of electrical connections, one for connecting each of the plurality of trigger electrodes to the trigger circuit, each electrical connection containing isolating impedance and the trigger circuit and associated trigger electrode connections having a high radio-frequency natural oscillation frequency, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

43. An electric system having, in combination, a gaseous-discharge device provided with an envelope containing an anode, a cathode spaced from the anode and a plurality of trigger electrodes successively disposed at intervals in the space and direction between the anode and the cathode, energy-supplying means connected between the anode and the cathode, a trigger circuit connected to one only of the anode and cathode for initiating the discharge of energy from the energy-supplying means between the anode and the cathode, and a plurality of electrical connections, one for connecting to each of the plurality of trigger electrodes, the electrical connections being capacitively connected to the trigger circuit, the said intervals being less than the distance from the free end of each trigger electrode to any portion of the envelope in order to confine the anode-to-cathode discharge substantially to the volume between the anode and cathode only.

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