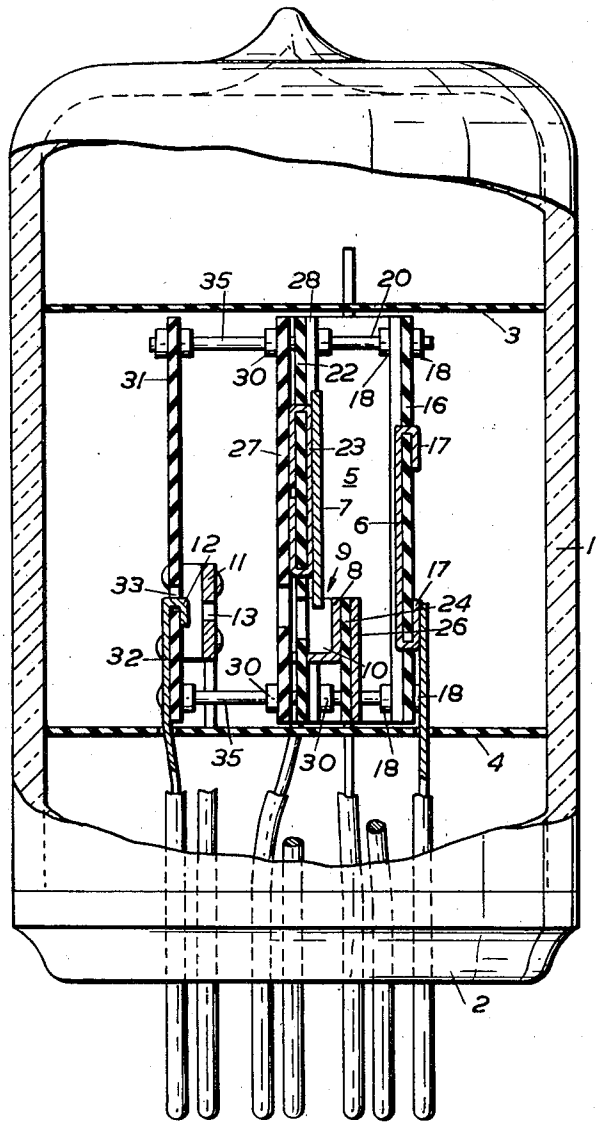
March 10, 1953 G. H. HOUGH ET AL 2,631,261

ELECTRIC DISCHARGE DEVICE

Filed Nov. 28, 1950 5 Sheets-Sheet 1

FIG. 1



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ELECTRIC DISCHARGE DEVICE

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FIG. 2.

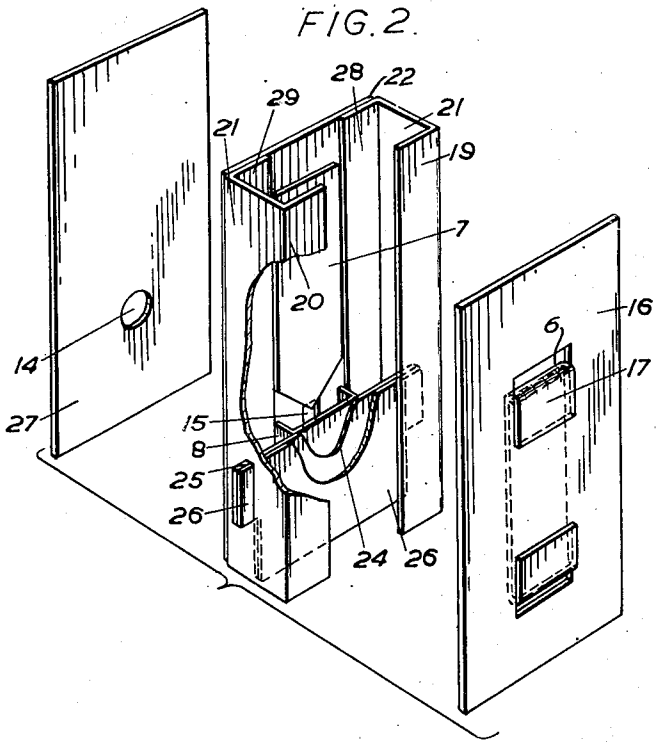
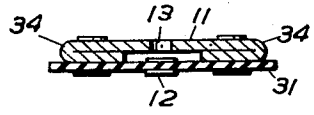


FIG. 3.



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ELECTRIC DISCHARGE DEVICE

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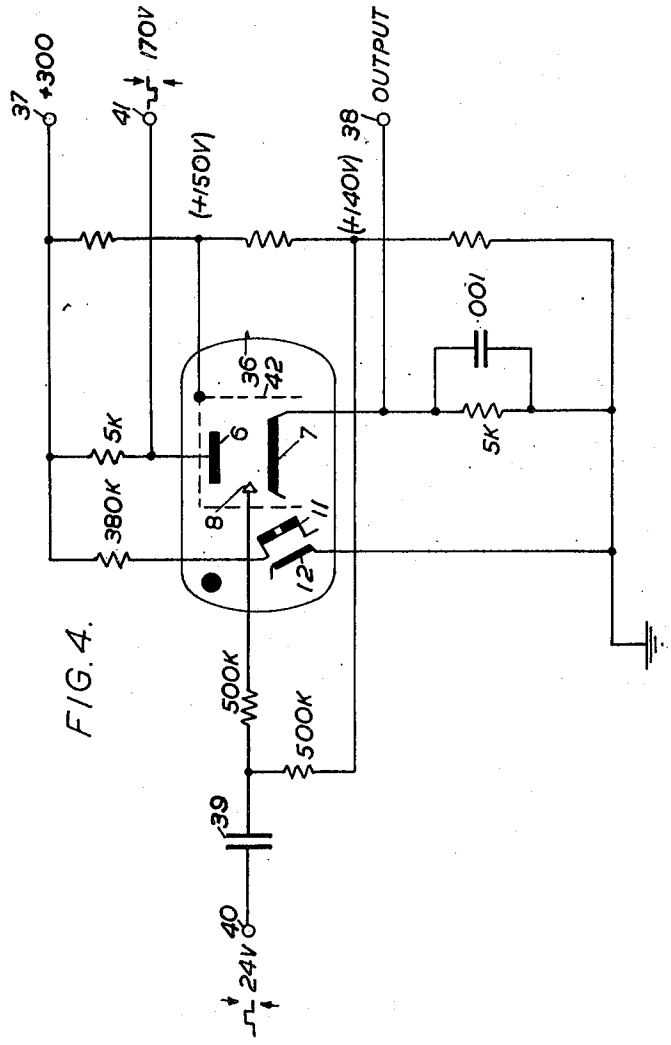


FIG. 4.

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ELECTRIC DISCHARGE DEVICE

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FIG. 5.

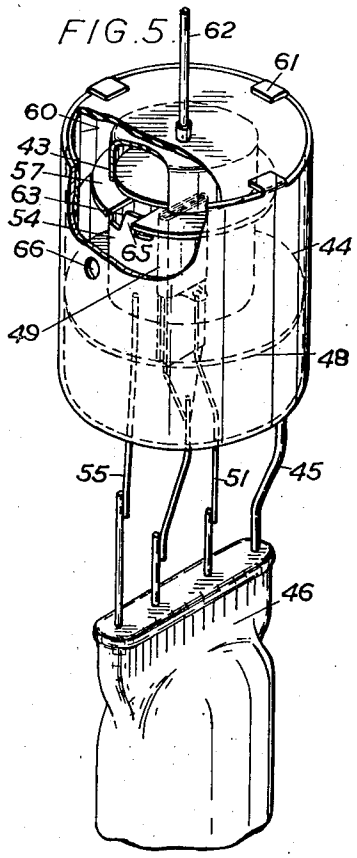


FIG. 6.

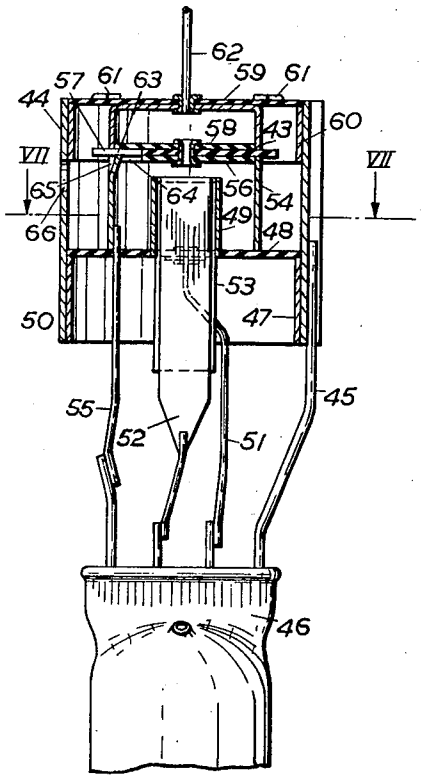
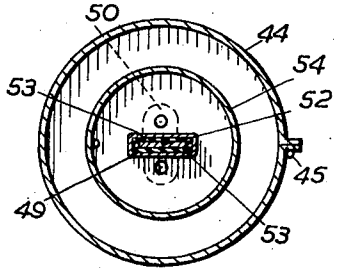


FIG. 7.



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ELECTRIC DISCHARGE DEVICE

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FIG. 8.

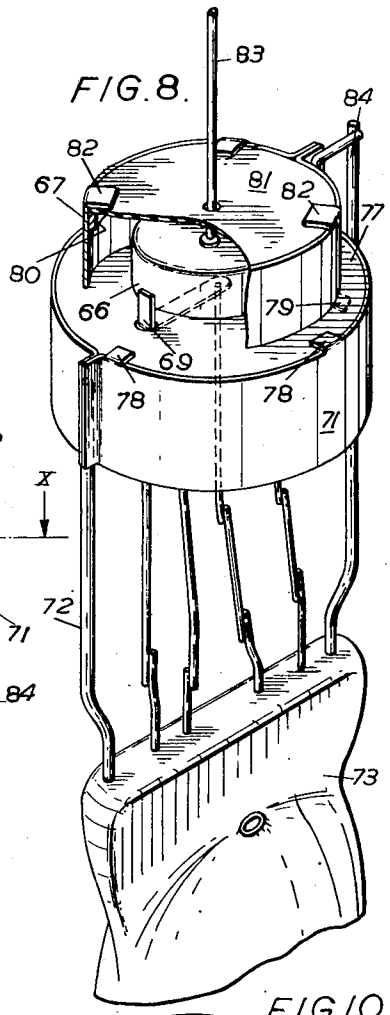


FIG. 9.

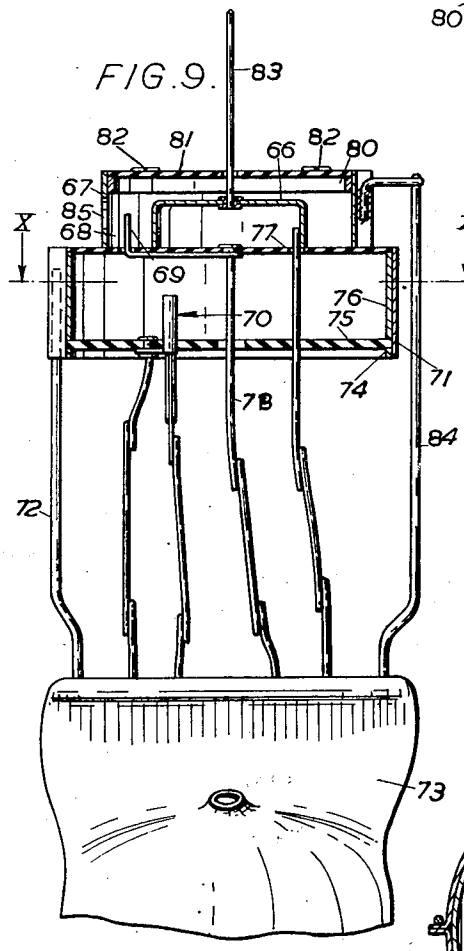
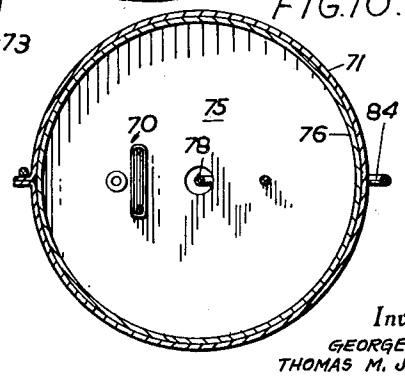


FIG. 10.



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UNITED STATES PATENT OFFICE

2,631,261

ELECTRIC DISCHARGE DEVICE

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Application November 28, 1950, Serial No. 197,861
In Great Britain December 2, 1949

21 Claims. (Cl. 315—168)

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The present invention relates to cold cathode gas-filled electric discharge tubes having a plurality of discharge gaps contained within the same envelope so that the gaps may be fired sequentially with the discharge at one gap influencing the firing conditions of another. The invention is particularly concerned with the construction and method of operation of trigger discharge tubes in which the striking potential of a main gap is conditioned by discharge at an auxiliary trigger gap having a striking potential lower than that of the main gap, and is concerned with the problem of high speed operation of such devices. In its general aspect, however, the application of the invention is not confined to trigger tubes.

The nature of the present invention can best be understood and the terms used in the specification defined by considering the phenomena attendant upon the initiation and maintenance of glow-discharge across gaps in a multi-gap tube. When a glow discharge is being maintained between the electrodes of a discharge gap, the anode-cathode voltage is, in general, less than that needed to start the discharge. In the steady state a cloud of positive ions is maintained in the region of the cathode. An ion which falls along the potential gradient towards the cathode liberates therefrom electrons which tend to be accelerated along the lines of force between cathode and anode. After their emission from the cathode these electrodes ionise by collision molecules of the gas in their path, so that equilibrium is maintained between the number of ions which in a given time fall to the cathode or diffuse, to other parts of the tube and the number which forms in the same time due to collisions of the electrons emitted from the cathode surface. A proportion of the electrons emitted by the cathode, or liberated by the collision processes in the gap, reach the anode and set up a current in the external circuit. In the region of the aforesaid ionic cloud, there is also radiation of light energy so that a glow covers part of the cathode surface but is in fact separated therefrom. Although the standard text books list several regions of glow in a discharge column, in tubes of the type we are here considering the aforesaid cathode glow is predominant. Provided the cathode glow does not cover the whole of the cathode surface, the discharge is said to be "normal." The potential distribution between anode and cathode for normal glow discharge is such that the major part of the potential variation occurs between the cathode and the region of the cathode glow,

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and has a value which is characteristic of the material of the cathode surface and of the ionising gas. The value of the potential fall in this region, to be referred to hereinafter as the "cathode fall of potential," is a few volts less than that of the minimum striking voltage on the Paschen curve relating striking voltage with the product of gap length and gas pressure for the gas and electrode material involved. The physical length between the cathode and the point in the discharge path where them potential first rises to a maximum is the same as that corresponding to the minimum striking voltage on the aforesaid Paschen curve when the pressure of the gas is kept constant. In the present specification this length will be referred to as the length of the cathode fall of potential. Between the cathode glow and the anode, the potential, after falling slightly rises uniformly to that of the anode, the amount of potential rise beyond that of the cathode fall being a function of the gap length, the nature of the gas and gas pressure.

Between certain limits of discharge current, defining the current range for normal glow discharge, the voltage between anode and cathode tends to be independent of current and is referred to as the maintaining voltage for the gap. The maintaining voltage for any gap is thus a function of the gap length, and the curve relating maintaining voltage with gap length, other factors being kept constant, is similar in shape to the Paschen curve referred to above, but lies below it, and is less steep. The minimum maintaining voltage is that of the cathode fall of potential a few volts less than the minimum striking voltage.

The area of the cathode covered by glow in a normal discharge is proportional to the discharge current. When the whole of the available cathode surface is covered with glow, the gap voltage rises, the discharge being said to be "abnormal." In order to maintain the space charge conditions in the gap, a minimum current is necessary, as otherwise more ions are removed from the gap than are provided by the collision processes; thus, if the current in a gap be restricted, as the current is reduced, the gap voltage necessary to maintain the discharge rises very rapidly.

The application of a voltage greater than the striking voltage as shown by the appropriate Paschen curve for the gas mixture and electrode materials employed is not in itself sufficient to initiate a discharge at a given gap; it is found that no discharge can occur in the complete absence of ionisation, or of some form of incident

radiation of the cathode. Thus, in general, when a voltage sufficient to fire a gap, is first applied, some time will elapse before discharge occurs, the presence of at least one charged particle within the field across the gap being required.

In the present specification, we shall say that a gap has been "fired," when a discharge of such magnitude has been set up across the gap that it may be maintained by an applied voltage equal to the maintaining voltage of the gap. The time interval which elapses between the application of a voltage sufficient to fire the gap and the gap being fired may be divided into three; the statistical delay time and the formative delay time and the build up time. Before the space charge conditions within the gap can commence to be built up, as stated above, at least one charged particle must exist within the field of the gap; this charged particle may be brought into being by a number of means, such as by cosmic rays, irradiation of the cathode by ultra-violet light, emanations from a radio active substance introduced into the tube envelope and so on. The time interval between the application of the firing voltage and the arrival in the gap of the initial charged particle is normally dependent upon the randomly occurring events, and is referred to as the statistical delay time. A further time is then needed in which the space charge required for maintenance of the discharge is built up around the cathode; this is referred to as the formative delay time and is dependent upon the applied voltage and upon the amount and distribution of any previously existing ionisation in the gap. Finally for the requisite current to become established to maintain the space charge conditions within the gap, a time interval known as the build-up time is required. The build up time depends upon the external circuit time constants.

In a multi-gap tube, when a first gap has been fired, discharge at the remainder will, in general, be conditioned by the discharge of the first gap. Charged particles or photons from the discharge may migrate to a second gap where they may reduce, or eliminate entirely, the statistical time for that gap, and depending upon their spatial and time distribution, may reduce the potential needed to fire the second gap. This reduction of striking potential and of the statistical delay time in the second gap due to the discharge of the first, is referred to herein as priming, the amount (in volts) of reduction of striking potential of the second gap, due to the discharge at the first, is referred to as the ionisation coupling factor, and is a function of the relative positions of the two pairs of discharge gap electrodes. By suitable arrangement of the discharge gap electrodes the ionisation coupling between a fired and an unfired gap may be made sufficient to reduce the striking voltage of the unfired gap to its maintaining potential.

In trigger tubes there is usually provided a main discharge gap to which is applied a steady voltage sufficient to maintain discharge thereat, and an auxiliary trigger discharge gap designed to pass a small current and to have a lower striking voltage than the main gap, so that a low energy impulse applied across the trigger gap may cause the main gap to fire. The time interval which must elapse between the firing of a trigger gap and the build up of the space charge conditions across the main discharge gap is referred to as the transfer time between trigger and main gap. Hence, in a trigger tube, the time

which elapses between the application of an impulse to the trigger gap and the firing of the main gap may be broken down into: statistical time delay of the trigger gap, formative delay time of the trigger gap, transfer time and the main gap build up time. In general the build up time is not under the control of the tube designer, but a tube may be designed to make the transfer time negligible.

It has long been known, as an alternative to the measures previously mentioned, in order to reduce or eliminate the statistical delay time, to maintain in a glow discharge tube an auxiliary priming discharge, whose function it is to provide the initial charged particles required before a gap can be fired. In general discharge at the priming gap also reduces the striking potentials of all other gaps within the tube. For certain purposes, it may be desirable that the priming discharge shall reduce the striking potential of one or more gaps in the tube, to a prescribed value: on the other hand, it may only be desired to eliminate the statistical time delay of firing of a single gap.

In accordance with the present invention, there is provided a cold cathode gas filled electric glow discharge tube having electrodes defining three discharge gaps disposed so that a continuous glow discharge at the first of the said gaps eliminates the statistical delay time of firing when a break down potential is applied to the second gap but does not affect the striking voltage of the third gap.

When in use, such a tube provides, according to the present invention, an arrangement comprising a cold cathode gas filled electric glow discharge tube having electrodes defining at least three discharge gaps, means adapted to maintain a continuous discharge across one of the said gaps, means adapted to fire a second gap, and means adapted to fire a third said gap when the said second gap has been fired, the electrodes of the said second gap being so constructed and the gap being so disposed with respect to the first and third gaps that the firing of the second gap reduces the striking potential of the third gap, while the continuous discharge at the first gap may be adjusted substantially to eliminate the statistical delay time in firing of the second gap without reducing the striking voltage of the third gap.

In carrying out the present invention, we construct the discharge tube so that the continuous discharge is shielded from gaps which it is not desired to influence thereby.

As applied to a trigger tube, the present invention provides a cold cathode gas filled electric glow discharge tube comprising electrodes adapted and arranged to form a main discharge gap, an auxiliary trigger gap of lower striking voltage than the said main discharge gap and a third priming discharge gap, the electrode arrangement being such that, when suitably polarised under operating conditions, the trigger gap electrodes shield the main gap from ionisation products from a continuous discharge at the said third gap, which discharge is of sufficient magnitude substantially to eliminate the statistical delay time in firing of the said trigger gap.

It is important that the auxiliary priming discharge be continuous. In many of the previous proposals utilising an auxiliary discharge, the discharge has been discontinuous, or of the relaxation oscillation type, referred to herein as

"squegging." Thus in some prior proposals the discharge has been in the form of a corona discharge, which is essentially discontinuous having bursts of current known as Trichel discharges. We have observed, when working with rapidly de-ionising discharge gaps, that a squegging auxiliary priming discharge gives rise to a definite uncertainty of the time of firing of the primed gap, which uncertainty disappears when the auxiliary priming discharge is continuous.

The invention will now be described with the aid of the accompanying drawings in which:

Fig. 1 shows, diagrammatically, a trigger tube according to the invention;

Fig. 2 is an enlarged view of part of the tube of Fig. 1;

Fig. 3 shows the assembly of the auxiliary priming gap of Fig. 1;

Fig. 4 shows a typical circuit arrangement according to the invention;

Fig. 5 shows a cut-away view of the electrode structure of another embodiment of a tube according to the invention;

Fig. 6 shows a section in elevation through the structure of Fig. 5;

Fig. 7 shows a section in plan through the line VII—VII of Fig. 6;

Figs. 8, 9 and 10 show views, corresponding to those of Figs. 5, 6 and 7 respectively, of a further embodiment of the invention.

In considering the construction of a high speed trigger tube according to the present invention, having eliminated the effect of statistical delay, we must consider the other time factors involved in the operation of the trigger tube which lie within the control of the tube designer. These are the trigger-gap formative delay time, the transfer time and the de-ionisation time of trigger and main gaps. When the voltage applied to discharge gap electrodes is reduced below that needed for maintenance of the space charge conditions, the charge particles within the gap are eventually removed by the following process: recombination of ions and electrons in the gas, diffusion out of the gap and absorption on the electrode surfaces. Both diffusion and recombination of gaseous ions are slow processes; for the charge distributions obtaining in one of the embodiments to be described below, it is calculated that in half-a-second, recombination throughout the volume concerned would reduce the number of free ions by one-half only. It is evident, therefore, that when high speed operation is required, the ions should be accelerated onto the electrode surfaces as rapidly as is possible subject to there being negligible release of fresh ionising electrons. For rapid deionisation, it is found necessary not to reduce the electric field between the gap electrodes more than a certain amount. In order that the ions may be removed by being accelerated towards the cathode, deionisation is most rapid when the ions are constrained, during the extinguishing period, to move along divergent paths, and for this reason, fast deionisation times are obtainable when cylindrical gap electrodes are used with the outer cylinder forming the cathode. On the other hand, in general, a voltage in excess of its maintaining voltage must be applied across a gap in order that it may be fired by discharge at a trigger gap. In practice, of course, due to the absence of voltage drop across the main gap load, the voltage between the main gap electrodes in the absence of discharge will always exceed the maintaining potential. With most electrode constructions, however, there is a minimum voltage higher than the main gap maintaining voltage below which transfer of discharge from trigger to main gap will not occur; this includes cases, as in embodiments of the present invention, when the transfer time, when transfer does occur, is negligible or zero. From the point of view of low transfer voltage, the construction should be such that during the build up of the main gap space charge conditions, ions tend to converge towards the cathode; in a coaxial discharge gap electrode arrangement, the cathode should, therefore form the inner conductor. It follows that when short de-ionisation times and low transfer voltages are both required, the optimum arrangement involves the use of planar electrodes.

An embodiment of the invention using planar electrodes is shown in Figs. 1, 2 and 3. In these figures, in order to show the details of construction, the thicknesses of the various electrodes and insulators and their separations have been considerably exaggerated. The tube comprises a conventional glass envelope 1 having a pressed glass base 2 upon which the electrode structure is mounted between a pair of mica insulators 3 and 4, as in conventional radio-valve practice. The main discharge gap 5 is formed between an anode 6 and cathode 7, a trigger electrode 8 being mounted in the space between the anode and cathode so as to form a trigger gap 9. The trigger 8 is shaped to form an enclosure 10 shielded from the field of the anode 6, the trigger gap 9 being located at the boundary of the enclosure. An auxiliary priming discharge gap is formed between an auxiliary anode 11 and an auxiliary cathode 12, the actual discharge surface of the anode 11, as will be explained later, being confined to the walls of an aperture 13. The auxiliary discharge gap is thus mounted behind the main gap 5, so as to be shielded from it, a path being provided for the passage of ionisation products—in practice a beam of electrons—into the trigger gap enclosure 10 by means of the passages 13, 14 and 15 in the various members.

The main and trigger gap structure is constructed as one unit assembly and the auxiliary priming discharge gap as another unit assembly. The anode 6 is formed from a sheet of metal whose ends are bent over to project through slots in a mica sheet 16, these ends being bent over at the back of the sheet as shown at 17. The mica sheet 16 is clamped by means of eyelets 18 to opposite upturned sides 19 and 20 of a pair of opposed metal channel members 21. The cathode 7 is secured to a mica sheet 22 in somewhat similar manner to anode 6, but in order to avoid any effect due to sputtering of cathode material onto the mica insulator, the edges of cathode 7 are raised above the surface of insulator 22 by member 7 being mounted on a thin strip of metal 23 the ends of which pass through slots in the insulating mica and are folded over at the back. This metal strip 23 is of a thickness less than the length of the cathode fall of potential for normal glow discharge at cathode 7 so that the glow is confined to the side of the cathode electrode facing the anode. The trigger electrode 8 is shaped to form an enclosure, open at one end, and is mounted on the sheet 22 in the manner of a wall container. Projecting tags on the trigger 8 pass through slots in the mica 23 and are bent outwards i. e. normal to the plane of the drawing of Fig. 1.

In order to eliminate fluctuation in the formative delay time at the trigger gap, the trigger discharge is arranged to occur over a limited, well-defined area of the cathode as opposed to being a point discharge. For this purpose the end of the cathode is tapered and just protrudes inside the enclosure formed by the trigger 8, thus presenting thereto an opposed triangular surface. Both from the points of view of making the trigger striking voltage as low as possible, and the transfer time a minimum, the separation between the cathode and trigger electrodes is arranged to be substantially that of the cathode fall of potential for normal glow discharge at the cathode.

To prevent a possibility of discharge between trigger 8 and anode 6 the trigger surface facing the anode is covered by an insulator 24, mounted in slots in the channel members 21 as shown at 25 in Fig. 2. As an additional precaution the inside of the trigger electrode 8 may be calorized except for a narrow region opposite the cathode projection.

A metal plate 26 whose function will be explained later, may cover the front of insulator 24, being held in the same slots in the channel members 21 so as to be in electrical contact therewith.

To prevent discharge between the cathode and trigger connections at the rear of insulator 22, a further sheet of insulating material 27 covers the bent-over portions of the cathode and trigger fixing tags. The insulators 22 and 27 are mounted on the upturned sides 28 and 29 respectively of the channel members 21 by means of eyelets 30. The construction described for the main and trigger gap assembly, the main gap electrodes being spaced apart by the sides of the channel members 21, ensures that close limits may be obtained with minimum variation in characteristics from tube to tube.

The priming gap assembly comprises a mica-insulator 31 on which are mounted the auxiliary anode 11 and cathode 12. The cathode 12 is formed from a piece of ribbon like metal 32, having its end threaded through a slot 33 in the insulator and bent over to lie flush against the surface of the insulator, the small bent over end portion forming the cathode electrode. The anode 11 consists of an apertured piece of metal sheet having its ends turned over upon itself and rivetted to the insulator 31 as shown at 34 in Fig. 3. The metal of the anode is thicker than that of the cathode so that the anode clears the cathode leaving a gap shorter than the length of the cathode fall of potential for normal glow discharge at cathode 12. An aperture 13 is provided in the anode 11 opposite the cathode 12. The insulator 31 is mounted by means of eyelets to rods 35 which are welded to the corresponding eyelets 18 and 30 on the main and trigger gap assembly. By this means the auxiliary priming gap is accurately located with respect to the trigger enclosure 10.

By virtue of the close electrode spacing, normal glow discharge is confined to the region of the cathode opposite aperture 13, the discharge gap being formed between this region and the wall of the aperture.

The main and trigger assembly, together with the priming gap assembly, are supported in position by means of wires and tags connected to the electrodes and channel members. These project to pass through apertures in the mica discs 3 and 4.

It will be appreciated that, while in the embodiments described electrons from the auxiliary priming gap may enter into the enclosure 10 and in fact, are beamed towards it through the apertures 13, 14 and 15, under operating conditions it may be arranged that none will emerge past the trigger gap 9 by reason of the potential gradient between electrodes 7 and 9 which electrodes, therefore, collect any charged particles which would otherwise diffuse past them.

Besides their function in affording accurate separation of the main gap electrodes, the channel members 21, together with the metal sheet 26, have important functions in the operation of the tube. In the first place they serve to shield the main gap from external electric fields and ensure that charged particles, other than those from the trigger gap 9, do not enter into the field of the main gap. By the application of a suitable bias voltage, the metal sheet 26 in particular, assists in reducing the transfer voltage to a minimum. Of greatest importance during operation, however, is the effect of the channel members and of the metal sheet 26 on the deionisation time of the tube. As was explained previously, for rapid deionisation the positive ions in the gap should be accelerated towards the cathode. It is found that if the channel members and sheet 26 are given as large a positive bias as is permissible without it being possible to maintain a discharge from them to the cathode or other electrode, the resulting electrostatic field affords a marked improvement in the deionisation time of the tube.

A typical tube such as described above is dimensioned as follows:

Main gap length	3.0 mm.
Trigger gap length	0.3 mm.
Priming gap electrode separation	0.25 mm.
Priming gap anode aperture 13	1.0 mm. diameter.
Capacity of trigger to cathode	1.6 $\mu\mu$f.
Capacity of trigger to cathode and all other electrodes	< 5.0 $\mu\mu$f.

The electrode structure is housed in a standard (B7G) miniature valve envelope which is filled with a mixture of 92% neon, 7% hydrogen and 1% argon at a pressure of 80 mm. of mercury. Using nickel electrodes the discharge gap voltages are as follows:

	Volts
Main gap breakdown voltage	330
Main gap maintaining voltage	165

The minimum main gap current is 2 milliamperes and the tube is rated to pass up to 15 ma. discharge current at the main gap and to work from a source of 360 volts maximum. The continuous priming discharge may be limited to 0.5 ma.

The trigger breakdown and maintaining voltages are nominally 160 and 150 volts respectively. In practice however, we find it more useful to specify that with a stated standing bias, the trigger gap shall fire and transfer to the main gap shall take place under specified conditions of anode voltage and trigger pulse conditions. These operating limits will be referred to again in connection with the circuit arrangement now to be described.

In the circuit of Fig. 4 the trigger tube 36 has

its main anode 6 connected through a resistance of 5000 Ω to the 300 v. positive supply terminal 37. The main gap cathode 7 is connected to ground through a load resistance of 5000 Ω shunted by a 0.001 μf. condenser and to an output terminal 38. The trigger electrode 8 is connected via load resistances totalling 1 megohm to a bias tapping 140 v. above earth potential and is also connected via condenser 39 to a pulse input terminal 40. Terminal 41 connected to anode 6 allows extinguishing pulses to be applied to the main gap. The continuously discharging priming gap has it cathode 12 connected to ground and its anode 11 is connected through a 380,000 Ω resistor to the supply terminal 37.

The channel members 21 and metal sheet 26 of Figs. 1 and 2 are represented by the screen electrode 42 connected to a bias tapping 150 volts above earth.

With the above circuit, a positive pulse of 40 volts amplitude applied to terminal 40 fires the tube within 1.25 μ sec. There being no statistical time-delay and negligible transfer time, this interval is thus the trigger formative delay time. The trigger formative delay time does not vary by more than 20% when the trigger pulse amplitude is reduced to a minimum (the trigger pulse width being made longer).

The design limits of operation of the trigger gap are such, that when the supply voltage to terminal 37 is raised to 360, the trigger being biased at 145 volts, a 20 μ sec. trigger pulse of 12 volts fails to fire the main gap; when the supply voltage is reduced to 250 volts, the trigger bias being kept constant, the main gap fires with a 20 μ sec. trigger pulse of 24 volts amplitude. Due to the construction of the trigger gap, a very high input impedance is obtainable and, in the circuit of Fig. 4, with the 1 megohm trigger load resistances a squegging discharge occurs (the period of oscillation being longer than the trigger pulse width) so that a high peak current is obtained in spite of the high mean input impedance.

To extinguish the main gap, a negative pulse of 170 volts amplitude is applied to the anode. This pulse takes the anode 25 volts below the maintaining potential for the gap. When the supply voltage is raised to 325 volts a rectangular extinguishing pulse need not be longer than 30 μ sec. to extinguish discharge of the maximum value of 15 ma. For smaller currents the full battery voltage may be re-applied to the tube after a shorter time interval.

The tube described above has been designed as a general purpose high speed trigger tube having wide supply voltage tolerances. For applications in which either shorter de-ionisation times or a lower minimum transfer voltage is required, a cylindrical main gap electrode structure may be used.

An embodiment of the invention designed to provide a low minimum transfer voltage is shown in Figs. 5, 6 and 7 in which the main gap cathode 43 and anode 44 are coaxial cylinders. The anode 44 is mounted on a rod 45 sealed in the glass press 46 of the envelope, the remainder of which is not shown. An inner metal band 47, secured to the anode, provides a seat for a mica insulator 48 which carries a metal sleeve 49 forming the anode of the auxiliary priming discharge gap. The sleeve 49 is secured to insulator 48 by means of extensions 50 rivetted thereto. A lead 51 makes connection to sleeve 49 through one of the extensions 50. An auxiliary cathode 52 is mounted as a push fit between two mica insulators 53 within sleeve 49. A metal cylinder forming the trigger electrode 54 rests upon the insulator 48 and has welded to it a lead 55 brought out through the base of the tube. The cathode 43 is in the form of an inverted cup whose cylindrical wall is of the same diameter as that of the trigger electrode 54. Trigger 54 and cathode 43 are aligned with one another by means of three insulating discs 56, 57 and 58 which are eyeletted together, the discs 56 and 58 fitting inside the ends of the trigger electrode 54 and cathode 43, respectively, with the disc 57, of larger diameter, sandwiched between them and separating the two electrodes. The cathode 43 is eyeletted to a top mica insulator 59 which seats inside the anode 44 upon a spring collar 60, projections 61 on the anode being bent over to lock the assembly. A lead 62 welded to the eyelet securing the cathode to insulator 59 is taken out at the top end of the tube.

In the embodiments of Figs. 5 to 7 the trigger gap is formed between opposing portions of the trigger electrode 54 and cathode 43 through slots cut in insulators 57 and 56 and indicated by the reference numerals 63 and 64 respectively. Part of the edge of the trigger electrode 54 is cut away leaving a tongue 65 which is slightly bent over to engage in the slot 64 and forms the discharge surface of the trigger electrode. For convenience in observing glow conditions at the trigger and priming gap, a hole 66 is cut in the anode 44 opposite the trigger gap.

It will be seen that except for the aperture at the trigger gap, the auxiliary priming gap is completely shielded from the main gap by the surrounding trigger electrode and the insulator 56. Hence, as in the previous embodiment, charged particles from a continuous discharge at the priming gap may prime the trigger gap but are prevented from entering the main gap between cathode 43 and anode 44.

The operating conditions and characteristics of a tube such as described with reference to Figs. 5 to 7 may be similar to those for the tube of Figs. 1 to 4 but the improved transfer voltage of the cylindrical construction enables wider limits on the supply voltage to be accepted at the cost of lower repetition rates of firing in consequence of the slower deionisation obtainable with the cylindrical construction described.

Exactly the opposite considerations apply to the embodiment now to be described with reference to Figs. 8 to 10; a faster repetition rate of firing is obtained at the expense of narrower limits on the supply voltage. In this embodiment, the main gap anode 66 is mounted within the cathode 67; the trigger gap 68 is formed between the cylindrical wall of cathode 67 and a trigger electrode 69, which is formed from a metallic strip. The auxiliary priming gap assembly 70 is offset from the axis of the tube so as to be more nearly below the trigger gap than if it were mounted as in the previous embodiment.

In the assembly of the tube structure of Figs. 8, 9 and 10, a hollow metal cylinder 71 is mounted on a support rod 72 which is sealed into a glass press 73 forming the base of the tube envelope. An internal collar 74 supports a mica insulator 75 to which the priming gap assembly 70 is secured. The assembly of the priming gap is the same as in the embodiment of Figs. 6 to 8. A further metal collar 76 supports a mica insulator 77 which is held in place by the bent-over tags 78 projecting from the metal cylinder 71. The insulator 77 carries the trigger electrode 69 se-

cured by means of a central eyelet to which a leadout wire 78 is welded, the wire 78 being passed through a central aperture in the insulator 75. The insulator 77 also carries the inverted cup-shaped anode 66 which is secured to it by means of projecting tags which pass through slots in the insulator and are then bent over as indicated at 79. The cathode 67 carries an internal collar 80 providing a seating for an insulator 81 which is clamped in position by the tags 82. A central aperture, through which passes the anode lead 83, serves to locate the cathode with respect to the anode, the cathode being held in position by its connections to the rigid rod 84 which is sealed through the press 73. An inspection hole 85 permits the cathode, glow to be observed.

As in the two embodiments previously described, the main gap is shielded from charged particles diffusing from the priming gap, whose effect therefore, may be limited to the trigger gap 68.

While the principles of the invention have been described above in connection with specific embodiments and particular modifications thereof, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of the invention.

What we claim is:

1. A cold cathode gas-filled electric glow discharge tube comprising a first pair of electrodes defining a main discharge gap therebetween, a second pair of electrodes defining a priming gap therebetween, trigger electrode means defining a trigger gap with one of the electrodes of said first pair, means to isolate said priming gap from said main gap, means providing a free path between said priming gap and said trigger gap, whereby a glow discharge at said priming gap eliminates the statistical delay time of firing when a breakdown potential is applied to said trigger gap, but does not affect the striking voltage of said main gap.

2. A discharge tube according to claim 1, wherein said trigger electrode means comprises means to isolate said trigger electrode means from the other of the electrodes of said first pair.

3. A discharge tube according to claim 1 in which said second pair of electrodes comprises a cathode plate and an anode having an aperture therethrough, said electrodes separated by a distance less than the length of the cathode fall of potential for normal glow discharge between said electrodes, the priming discharge gap thus being formed between the aperture walls and the cathode plate at the aperture.

4. A discharge tube according to claim 3 in which the cathode of said second pair of electrodes is formed from a metal strip mounted on a sheet of insulating material and the anode of said second pair of electrodes comprises an apertured metal strip thicker than that of the cathode electrode mounted on the same sheet of insulating material across the cathode, the ends of the anode strip being bent back upon itself to raise the discharge surface thereof clear of the cathode discharge surface by the required amount.

5. A discharge tube according to claim 3 in which the two said unitary structures are mounted parallel to one another between a pair of locating discs which abut against the cylindrical wall of the said tube.

6. A circuit arrangement comprising a cold cathode gas-filled electric glow discharge tube comprising a first pair of electrodes defining a main discharge gap therebetween, a second pair of electrodes defining a priming gap therebetween, means to maintain a continuous discharge across said last named gap, trigger electrode means defining a trigger gap with one of the electrodes of said first pair, means to isolate said priming gap from said main gap including means providing a free path between said priming gap and said trigger gap, means coupled to and adapted to fire said trigger gap, and means coupled to and adapted to fire said main gap after said trigger gap has been fired, the discharge across said priming gap adapted to eliminate the statistical delay time of firing of said trigger gap when fired by said trigger gap firing means without affecting the striking voltage of said main gap.

7. A cold cathode gas filled electric glow discharge tube comprising a first pair of electrodes adapted and arranged to form a main discharge gap, auxiliary trigger electrode means defining a trigger gap with one of the electrodes of said pair, said trigger gap having a lower striking voltage than the said main discharge gap and a second pair of electrodes adapted and arranged to define a priming discharge gap therebetween, means providing a free path between said priming gap and said trigger gap, said trigger electrode including means to shield the main gap from ionisation products from a discharge at the said priming gap, which discharge is of sufficient magnitude substantially to eliminate the statistical delay time in firing of the said trigger gap.

8. A cold cathode gas filled electric glow discharge tube comprising an anode electrode, a cathode electrode substantially parallel to said anode forming therewith a main discharge gap, a trigger electrode having a discharge surface parallel to and forming with said cathode a trigger discharge gap in the space between the said anode and cathode, said trigger electrode being shaped to form an enclosure shielded from the field of said anode, said trigger gap being located at a boundary of the enclosure; and a pair of auxiliary electrodes forming therebetween an auxiliary priming discharge gap shielded from the said main discharge gap by said trigger electrode enclosure, a path being provided for the passage of ionisation products from said priming discharge gap into said trigger electrode enclosure to provide at least the requisite initial charged particles in the field of the said trigger gap to enable said trigger gap to fire.

9. A discharge tube according to claim 8 in which the discharge surfaces of said anode, cathode and trigger electrodes are planar, said anode electrode being mounted on a first sheet of insulating material, the cathode and trigger electrodes being mounted on a second opposed sheet of insulating material, said trigger electrode being shaped to form a container open at one end projecting from said second sheet of insulating material with said cathode electrode projecting into the open end of the container, and in which said priming gap is located behind said second sheet of insulating material, said second sheet of insulating material being apertured behind said trigger electrode and said projecting portion of said cathode to permit passage of the said ionisation products.

10. A discharge tube according to claim 9 in which the edges and adjacent under-surface of said cathode electrode are spaced from said second sheet of insulating material by a distance less than the length of the cathode fall of potential for normal glow discharge at these surfaces.

11. A discharge tube according to claim 10 in which said cathode electrode comprises a thin

metal strip to which a metal plate is secured, said metal strip being secured to said second sheet of insulating material and said plate projecting beyond the edges of said strip.

12. A discharge tube according to claim 11 in which said plate is tapered in width at the end projecting into the open end of the said container.

13. A discharge tube according to claim 12 in which the spacing between the opposed discharge surfaces of said trigger electrode and said cathode is substantially the length of the cathode fall of potential for normal glow discharge therebetween.

14. A discharge tube acording to claim 13 in which said main and trigger gap electrodes and supports are formed as a unitary assembly, and further comprising a pair of rigid channel-shaped members, said first and second sheets of insulating material being secured to the respective sides of said last-named members.

15. A discharge tube according to claim 14 in which said trigger electrode is covered on the side facing said anode by a strip of insulating material.

16. A discharge tube according to claim 15 in which a conducting surface is provided over said strip of insulating material and is connected to said channel-shaped members.

17. A circuit arrangement comprising a cold cathode gas-filled electric glow discharge tube comprising a first pair of electrodes defining a main discharge gap therebetween, a second pair of electrodes defining a priming gap therebetween, means to maintain a continuous discharge across said last-named gap, trigger electrode means defining a trigger gap with one of the electrodes of said first pair, means isolating said trigger electrode means from the other of the electrodes of said first pair, conductive means surrounding said isolating means, a pair of rigid channel shaped members, said isolating means and said conductive means in connection therewith, means for applying a positive bias to said members, means to isolate said priming gap from said main gap including means providing a free path between said priming gap and said trigger gap, means coupled to and adapted to fire said trigger gap, and means coupled to and adapted to fire said main gap after said trigger gap has been fired, the discharge across said priming gap adapted to eliminate the statistical delay time of firing of said trigger gap when fired by said trigger gap firing means without affecting the striking voltage of said main gap, the positive bias applied to said members adapted to assist in the rapid de-ionization of said tube.

18. A cold cathode gas filled electric glow discharge tube comprising an outer cylindrical anode electrode, an inner cathode electrode having an outer cylindrical surface coaxial with the said anode and forming a main discharge gap therewith, a trigger electrode forming with said cathode a trigger discharge gap of lower breakdown voltage than that of said main gap, said trigger electrode being formed by a cylinder of substantially the same diameter as that of the said cathode aligned end-to-end therewith, insulating means disposed between said cathode and said trigger electrode and separating same, thereby permitting discharge to occur only at a localised region of said cathode and trigger electrode, a pair of auxiliary electrodes defining an auxiliary discharge gap therebetween, said insulating means forming with said trigger electrode an enclosure about said auxiliary discharge gap so that ionisation products from a continuous discharge at said auxiliary discharge gap may be prevented from entering the field between said anode and cathode electrodes while priming said trigger gap between said cathode and trigger electrodes.

19. A discharge tube according to any of claim 18, wherein said auxiliary electrodes comprise a hollow metal sleeve, a plurality of strips of insulating material within said sleeve and a metal strip held between said strips of insulating material within said sleeve.

20. A cold cathode gas filled electric glow discharge tube comprising an outer cylindrical cathode electrode, an inner anode electrode having an outer cylindrical surface coaxial with said cathode and forming a main discharge gap therewith, a trigger electrode disposed between said cathode and anode electrodes, a pair of auxiliary electrodes defining an auxiliary gap therebetween, an enclosure surrounding said auxiliary electrodes so that ionisation products from a continuous discharge at said auxiliary discharge gap are prevented from entering said main gap except in the region of said trigger electrode, whereby, during operation, said ionisation products may be confined to said enclosure and said trigger gap between said cathode and said trigger electrode.

21. A discharge tube according to claim 20 in which the said enclosure comprises a disc of insulating material and a cylindrical metal member closed at one end by said disc, said disc being provided with an aperture, said cathode and said anode being mounted upon one side of said disc, said trigger electrode comprising a strip of metal mounted upon the other side of said disc within the said enclosure, said trigger electrode having a bent-over end portion which protrudes through said aperture into the main gap space.

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No references cited.