

March 22, 1960

G. E. JACOBY ET AL
GAS DISCHARGE DEVICE

2,929,962

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2 Sheets-Sheet 1

FIG. 1

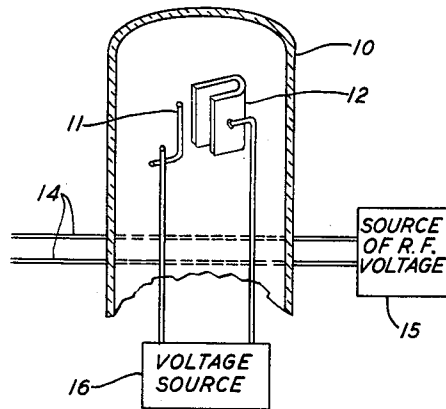


FIG. 2

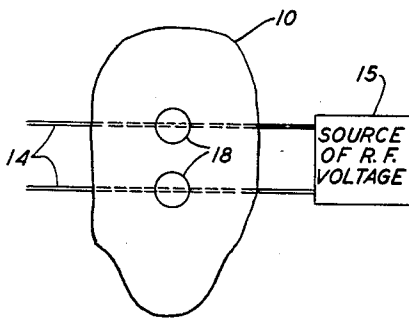
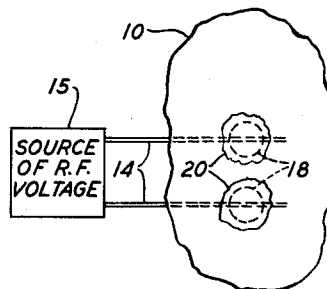


FIG. 3



INVENTORS

G. E. JACOBY
R. W. KETCHLEDGE

BY

James J. Feltz

ATTORNEY

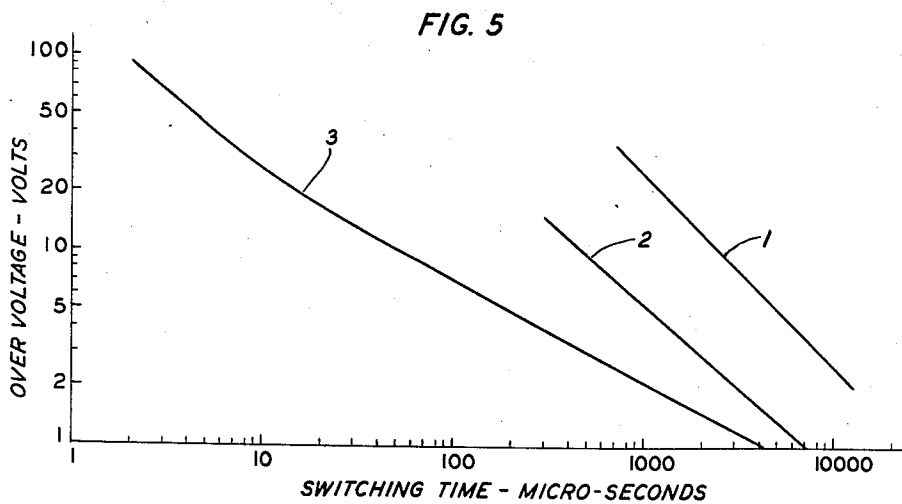
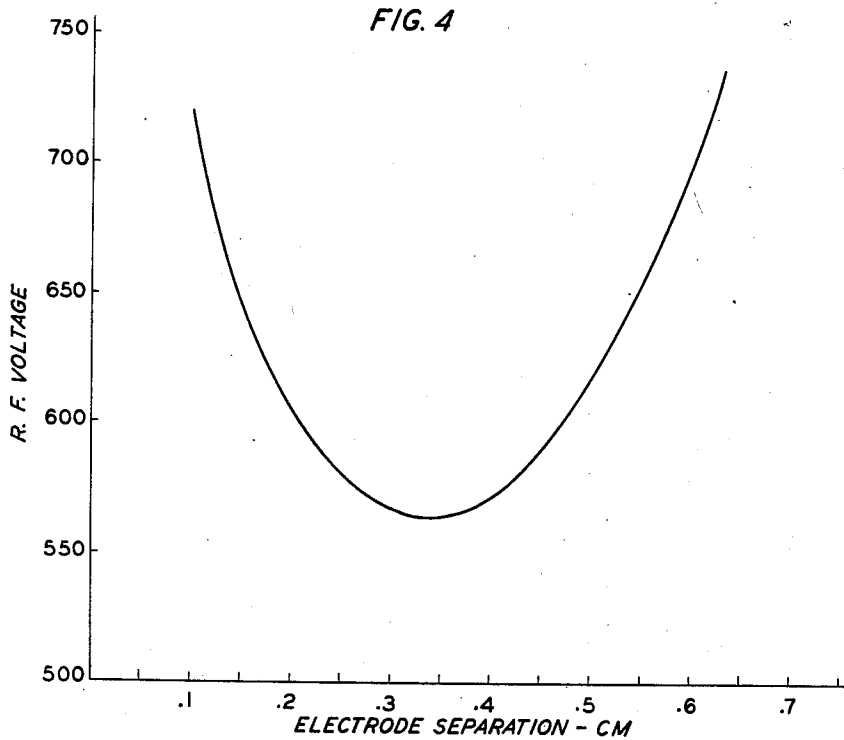
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INVENTORS **G. E. JACOBY**
R. W. KETCHLEDGE
BY *James W. Felt*
ATTORNEY

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GAS DISCHARGE DEVICE

Gerald E. Jacoby, Madison, and Raymond W. Ketchledge, Whippany, N.J., assignors to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Application May 7, 1956, Serial No. 583,201

7 Claims. (Cl. 315-168)

This invention relates to gas discharge devices and, more particularly, to methods and apparatus for decreasing the ionization time of such devices.

One of the problems encountered in the use of gas discharge devices as electronic switches is that introduced by the delay between the application of breakdown or ionization potentials to the electrodes and the establishment of a predetermined current through the gas discharge device. This time delay appears small in the instance of a single gas diode in that it is of the order of 1 to 4 milliseconds in a typical case. However, when a large number of these diodes are used in a system such as an electronic telephone system as disclosed in E. Bruce and H. M. Straube Patent 2,684,405, issued July 20, 1954, the establishment of a transmission path through the network is completed only after a delay equal to the total delay of all the serially connected gas discharge devices. Further, if additional gas discharge devices are employed as switches to control the application of ionization potential to these transmission path gas discharge devices, as disclosed in application Serial No. 504,433, filed April 28, 1955, of R. W. Ketchledge, the completion of the transmission path is further delayed.

It is well known that there are two physical phenomena which cause a time delay between the application of an ionization potential to the electrodes and the establishment of a stable discharge through the gas discharge device. These are called the statistical delay time and the formative delay time.

The statistical delay time is dependent upon the occurrence of a random event resulting in the presence of an ion or electron between the electrodes.

After the ion or electron comes between the electrodes, it begins to accelerate under the influence of the electrode potentials, colliding with the gas atoms or molecules, as the case may be, causing additional ionization. This collision-ionization process increases until a stable current is flowing between the electrodes. The time required for this operation to take place is called the formative delay time. This delay depends on certain physical constants of the tube such as type and pressure of the gas, geometry of the electrodes and also upon the overvoltage applied to the electrodes. The overvoltage is that voltage in excess of the ionization potential which is applied to the electrodes to assure ionization of the gas discharge device.

Various methods have been suggested for the reduction or virtual elimination of the statistical delay time. These methods include irradiating the gas with X-rays or ultraviolet light or photoelectric effects produced at the electrodes due to either of these agents or visible light. These methods further include the use of radioactive material such as radium within the tube envelope. A further method is to connect two or more identical gas discharge devices in parallel which results in an average delay approximately equal to the average delay of a single tube divided by the number of parallel tubes.

While some of these methods may represent satisfactory solutions of the delay problem in the instance of a few

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such tubes, they are impractical and in some instances even hazardous when employed in extensive installations such as telephone central offices or large computers. For example, it would be hazardous to have personnel working in an area immediately adjacent a large number of gas tubes containing radioactive material or having X-rays directed upon them. It would also be economically impractical to connect two or more gas tubes in parallel in each circuit requiring such devices solely for the purpose of reducing the statistical delay time. Further, some of these solutions reduce the ionization potential of the gas discharge device which, when used as a switch would be subject to false operation.

Priorly, radio frequency energy has been employed in combination with gaseous discharge devices to initiate the discharge between the main gap defining electrodes or to reduce the value of ionization potential needed to actuate the device. Also, radio frequency energy has been employed to produce a stable discharge in a gaseous tube containing no electrodes.

Radio frequency energy may also be employed after ionization to sustain a conducting path between the electrodes in a gaseous discharge device as disclosed in application Serial No. 496,749, filed March 25, 1955, now Patent No. 2,779,822, issued January 29, 1957, of R. W. Ketchledge.

In each of the above-mentioned types of devices utilizing radio frequency energy during ionization, this energy produces a substantial effect upon the voltage required to initiate a discharge through the tube. Any solution of the delay problem which would decrease the value of the ionization voltage of the gas discharge device would be unsatisfactory for use in complex systems such as disclosed in the previous mentioned patent to E. Bruce and H. M. Straube. For example, this decrease of ionization voltage would give rise to false operation of the cross-point devices, cross-connecting established paths through the network. However, we have discovered that radio frequency energy may be employed to reduce the statistical delay time in a gaseous discharge device without substantially affecting the value of ionization voltage required by the electrodes.

Accordingly, it is an object of this invention to reduce the delay time in a gaseous discharge device without substantially affecting the ionization voltage of the electrodes.

It is a further object of this invention to reduce the statistical delay time in a gaseous discharge device without incurring any of the previously mentioned difficulties.

Briefly, in accordance with aspects of this invention, a small radio frequency discharge is maintained within the gas tube envelope at a point remote from the main gap defining electrodes. While this discharge is sufficient to produce and maintain a localized ionization within the tube, substantially eliminating the statistical delay time, this localized ionization does not substantially affect the ionization potential. The effect of this localized ionization is to maintain just sufficient ions or electrons between the electrodes which assure rapid ionization but are insufficient to permit any flow of current through the tube until the otherwise normal value of ionization potential is applied to the electrodes.

This localized discharge in accordance with an aspect of this invention is a localized radio frequency discharge and may be effected by any one of several methods, such as by passing two wires in close proximity with the tube envelope and applying a radio frequency voltage to these wires. Another method is to place these wires adjacent to a pair of high resistance glass points on the envelope such that the radio frequency energy is coupled through the high resistance glass. Utilizing this latter combination, the actual discharge is concentrated between these two high resistance glass points within the envelope. A

3 still further method is to couple radio frequency energy to a pair of metallic spots on the inner wall of the envelope by means of high resistance glass spots, thus more accurately locating the discharge. Other methods will be apparent to those skilled in the art, the prime requisite being that a localized ionization is produced within the tube at a point remote from the electrodes.

Accordingly, it is a feature of this invention to apply a localized radio frequency discharge within the envelope of a gas discharge device at a point remote from the main gap defining electrodes to reduce the delay time of the gas discharge device without substantially affecting the ionization voltage of the main gap.

It is a further feature of this invention to apply a radio frequency voltage to a pair of high resistance glass spots on the envelope of a gas discharge to produce a partial ionization by a radio frequency discharge within the envelope in a region immediately adjacent the high resistance glass spots.

It is a still further feature of this invention to couple radio frequency energy through a pair of high resistance glass spots on a gas tube envelope to a pair of metallic spots on the envelope inner wall more accurately to locate the radio frequency discharge.

A complete understanding of this invention and of these and various other features thereof may be gained from consideration of the following detailed description and the accompanying drawing in which:

Fig. 1 depicts a side view of a gas discharge device illustrative of one specific embodiment of this invention, the envelope of the device being shown in section;

Fig. 2 is a cutaway of the tube envelope of a gas discharge device in accordance with another specific illustrative embodiment of this invention;

Fig. 3 is a cutaway of a gas discharge device envelope in accordance with another embodiment of this invention;

Fig. 4 depicts a curve of the relationship between the spacing of the wires and the radio frequency voltage applied to these wires to produce ionization within a certain gas tube; and

Fig. 5 depicts curves of switching time-overvoltage characteristics for certain gas tubes employing this invention.

Referring now to Fig. 1, there is depicted, in accordance with one specific embodiment of this invention, a gas discharge device having an envelope 10, main gap defining electrodes 11 and 12, a pair of wires or probes 14 adjacent to the envelope at a point remote from the main gap defining electrode and a source 15 of radio frequency potential connected to wires 14. While this radio frequency discharge may be employed in combination with any of the gas discharge devices well known in the art, this invention is particularly advantageous when employed in combination with a gas diode having a negative resistance characteristic and adapted for use in a switching network. One example of such diode is disclosed in M. A. Townsend application Serial No. 169,121, filed June 20, 1950, now Patent No. 2,804,565, issued August 27, 1957. For optimum results in the reduction of the statistical delay time, this radio frequency source applies a balanced radio frequency voltage to probes or wires 14. This may be achieved by employing a transformer to couple the wires to the source of radio frequency energy. Also, a push-pull type oscillator may be used to supply this balanced radio frequency energy to wires 14. The total delay time may be reduced by applying an overvoltage to the electrodes, which overvoltage effectively reduces the formative delay time as described above. Connected to the main gap defining electrodes 11 and 12 is a source 16 of ionization and sustain voltages. These voltages may be applied in any convenient form, such as direct current voltages or as pulses applied to one or both of these electrodes.

The application of radio frequency voltage to wires 14 causes a localized discharge to take place within the

gas discharge device envelope at a point remote from the main gap defining electrodes, which point may advantageously be near the base of the envelope as depicted in Fig. 1. Since this discharge is maintained on a low power basis in a localized region remote from the main gap defining electrodes 11 and 12, the ionization is insufficient to substantially modify the value of the ionization potential required by the main gap defining electrodes. By utilizing this radio frequency discharge to maintain a localized ionization within the envelope, the statistical probability of the occurrence of the previously mentioned random event is greatly increased. In one specific embodiment of this invention employing a gas diode, the ionization potential is only modified in the order of 1 to 2 volts by the presence of the radio frequency discharge. This represents a modification of less than 1 percent of the voltage required in the absence of a localized radio frequency discharge.

Referring now to Fig. 2, there is depicted another specific illustrative embodiment, in accordance with this invention, in which only a small portion of tube envelope 10 is shown. Points 18 represent high resistance glass spots in the wall of the tube envelope. These points effectively capacitively couple the radio frequency energy from wires 14 to a predetermined region within the tube envelope. The application of this energy causes a discharge between spots 18 within the envelope.

Fig. 3 depicts another specific illustrative embodiment in accordance with this invention showing a small portion of the tube envelope in which a pair of high resistance glass spots 18 on the envelope 10 have superimposed on them metallic spots 20. On the application of radio frequency energy to wires or probes 14 from source 15, a localized discharge takes place on the inner wall of the envelope in a region between metallic spots 20.

Fig. 4 depicts a graphical relationship between the separation of the probes or wires 14 as employed in Fig. 1 and the root mean square value of radio frequency voltage applied to these wires to produce the localized discharge. From this graph it is seen that the optimum separation of wires 14 is in the range of .33 to .36 centimeter and the optimum voltage is in the order of 550 to 650 volts root mean square. However, it is apparent from the graph that other radio frequency voltages and other spacing of wires may be employed.

Referring now to Fig. 5, there is depicted a graphical representation of the relationship between the overvoltage applied to the main gap defining electrodes and the switching time required to establish a predetermined stable discharge through each of several gas diodes. In the absence of any means for reducing the delay time, these diodes would have substantially uniform delay times. Curve 1 represents the response characteristics of a particular gas diode having a low radium content. Curve 2 represents the response of another diode having a high radium content. Curve 3 represents the response of still another diode containing no radium and having an applied radio frequency localized discharge in accordance with this invention.

A comparison of the switching times of these three tubes for a given overvoltage indicates the relative effectiveness of the localized radio frequency discharge as compared with the addition of a radioactive metal to the gas discharge device. For example, for an overvoltage of 5 volts the low radium content tube requires approximately 5 milliseconds to establish a stable discharge, the high radium content tube requires approximately 1 millisecond while the gas tube having a radio frequency discharge requires only 200 microseconds. For an increase in the overvoltage, each of the switching times is decreased. This decrease is more pronounced in the gas tube having a localized radio frequency discharge as indicated by the relative slopes of the curves. For example, with a 10 volt overvoltage applied to each

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of these tubes, the low radium content tube requires approximately $2\frac{1}{2}$ milliseconds to establish a stable discharge, the high radium content tube requires approximately 500 microseconds while the tube having the localized radio frequency discharge requires only about 53 microseconds. Curve 3 of Fig. 5 further indicates that with 20 volts overvoltage applied, a stable current is established in approximately 14 microseconds, and with an overvoltage of 80 volts, the delay time is only $2\frac{1}{2}$ microseconds.

Advantageously, in accordance with this invention, gas discharge devices having quite low switching time may be manufactured and used without incurring the hazards of radiation from radioactive metals. Also, the switching time of any gas discharge devices may be decreased without modifying the internal structure of the tube by placing the radio frequency wires at any convenient place adjacent to the gas discharge device envelope. Further, the application of this radio frequency discharge may be controlled by additional logic circuits thus making delay time subject to easy external control. This radio frequency energy may be in pulse form and may be applied sequentially to groups of gas discharge devices employed in a crosspoint switching network, such as disclosed in the previously mentioned patent to E. Bruce and H. M. Straube, to facilitate the establishment of a single path through the crosspoint network. Thus, the switching time of gas discharge devices may be readily controlled and easily applied to all types of gas discharge devices and may be achieved with relatively low power. For example, the power required to produce the localized discharge in connection with the response curve 3 of Fig. 5 is of the order of 2 to 10 milliwatts.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A gaseous discharge device having an envelope, a gaseous atmosphere within said envelope, a pair of electrodes defining a main discharge gap having a predetermined breakdown voltage, and means for reducing the breakdown time of said gap while maintaining the voltage necessary to effect the breakdown of said gap at substantially said predetermined breakdown voltage, said means comprising means for maintaining a localized low power radio frequency discharge in said envelope at a point removed from said gap.

2. A gaseous discharge device comprising an insulating envelope, a gaseous atmosphere within said envelope, a pair of electrodes defining a main gap, a source of radio frequency power external to said envelope, and a pair of probe wires electrically connected to said source and extending adjacent said envelope at a point remote

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from said gap, said wires each being capacitively coupled through said envelope to a distinct area of the inner surface of said envelope whereby a localized low power radio frequency discharge occurs within said envelope between said distinct areas.

3. A gaseous discharge device in accordance with claim 2 further comprising metallic spots on the inner surface of said envelope at said distinct areas.

4. A gaseous discharge device having an envelope; a gaseous atmosphere within said envelope; a pair of electrodes defining a discharge gap having a predetermined ionization voltage; and means for reducing the ionization time of said gap without substantially reducing said ionization voltage necessary to effect ionization across said gap, said means comprising means for maintaining a localized low-power radio-frequency discharge within said envelope at a point removed from said gap, said last-mentioned means including a pair of probe wires lying side by side and positioned external to said envelope and adjacent thereto, said radio-frequency discharge being within said envelope only directly adjacent said wires.

5. A gaseous discharge device in accordance with claim 4 wherein the separation of said wires is of the order of .33 to .36 centimeter.

6. A gaseous discharge device as in claim 4 wherein said means for maintaining a localized low-power radio-frequency discharge in said envelope at a point removed from said gap includes a pair of high resistance glass spots in said envelope adjacent said probe wires for accurately positioning said discharge in said envelope.

7. A gaseous discharge device having an envelope; a gaseous atmosphere within said envelope; a pair of electrodes defining a discharge gap having a predetermined ionization voltage; and means for reducing the ionization time of said gap without substantially reducing said ionization voltage necessary to effect ionization across said gap, said means comprising means for maintaining a localized low-power radio-frequency discharge in said envelope at a point removed from said gap, said last-mentioned means including a pair of probe wires lying side by side and positioned external to said envelope and adjacent thereto, and a pair of spots of metallic material on the inner wall of said envelope adjacent said wires and capacitively coupled thereto, the discharge being within said envelope only directly adjacent said metallic spots.

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