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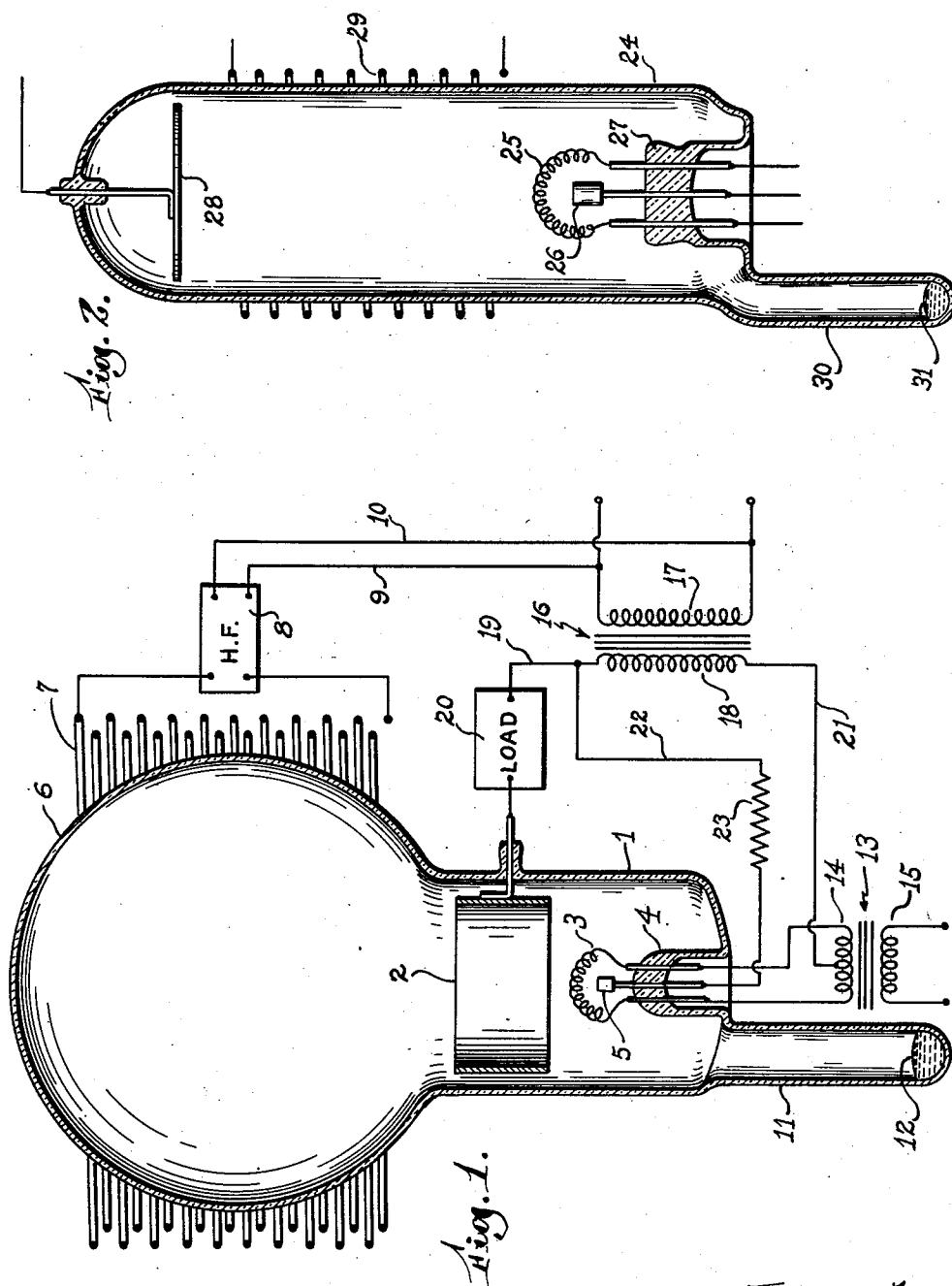
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ELECTRICAL GASEOUS DISCHARGE DEVICE

Filed Nov. 4, 1936

2 Sheets-Sheet 1



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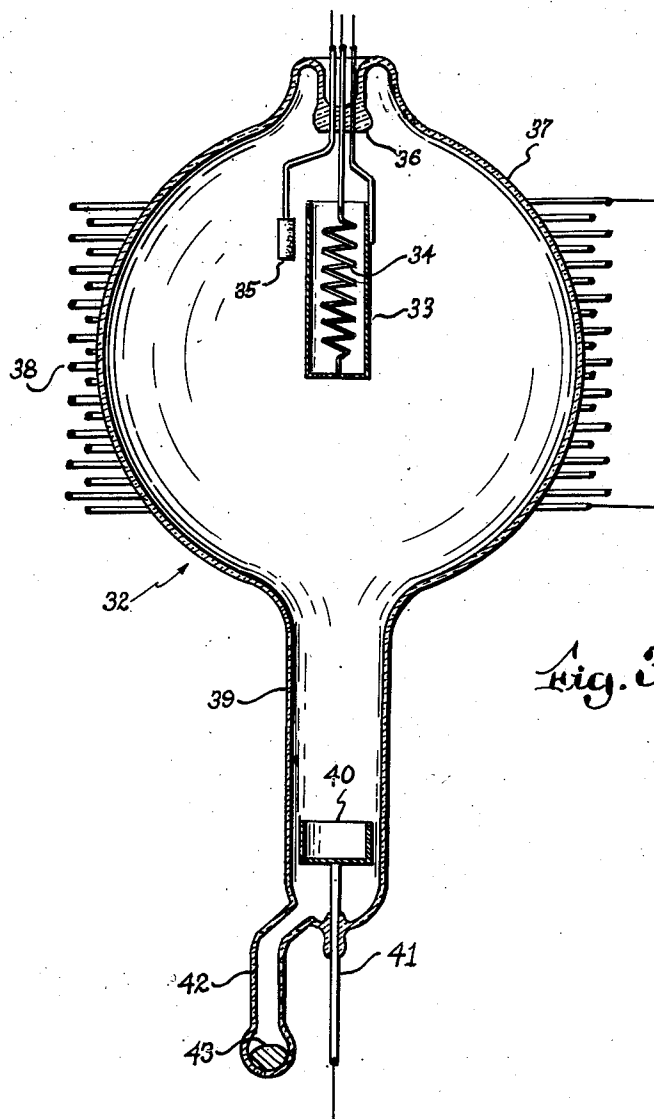


Fig. 3.

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UNITED STATES PATENT OFFICE

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ELECTRICAL GASEOUS DISCHARGE DEVICE

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18 Claims. (Cl. 250—27.5)

This invention relates to an electrical gaseous discharge device, and more particularly to such a device which is adapted to operate as a rectifier.

An object of this invention is to produce such a device which has an abnormally low voltage drop during the conducting phase during which large currents can be carried.

Another object is to produce such a device which can withstand high or low reverse voltage without any substantial chance of flashback.

A still further object is to produce such a device in which the conduction of current can be controlled in both the forward and in the reverse direction.

The foregoing and other objects of my invention will be best understood from the following description of exemplifications thereof, reference being had to the accompanying drawings, wherein:

Fig. 1 is a diagrammatic view showing a tube in section constituting one embodiment of my invention, together with an associated circuit with which it may be used;

Fig. 2 is a diagrammatic view showing a tube in section constituting another embodiment of my invention; and

Fig. 3 is a diagrammatic view showing a tube in section constituting another embodiment of my invention in which the conduction of current can be more easily controlled.

The present invention is based upon certain observations of mine dealing with mercury vapor in the pressure region of the order of .001 mm. of mercury and lower. I have discovered that a ring or electrodeless discharge of considerable current (measured in some cases in hundreds of amperes) can be passed through mercury vapor with small voltage drop (5 volts more or less) when the vapor pressure is in the region mentioned. The requirements for passing such current are a region of considerable volume and a few electrons for initiating the discharge to make a supply of ions for a current between a filament and a cool anode. The supply of ions near the cathode needs, in some cases, to be only enough to neutralize the electronic space charge. Near the anode enough ionization should be produced to give a random electronic current shower upon the anode equal to the current carried by the rectifier. For this reason and for purposes of heat radiation, the anode is of considerable area and is preferably placed in a region of great ionization.

Before describing the construction shown, a

few remarks concerning the nature of the discharge used are in order.

It is commonly observed that space current between a thermionic cathode and an anode in a mercury vapor device will pass readily at a pressure of say .01 mm. in ordinary cases, which may be termed a "relaxed gaseous discharge". If the pressure is reduced, a point is reached where the current begins to be limited. This may occur at a pressure as high as .001 mm. in some cases. When the pressure is decreased to zero, the voltage drop for conduction is that required by space charge limitations, and the practical current is measured usually in milliamperes. While the present tube is not limited to operation in this transition pressure region between a high vacuum and a relaxed gaseous device, it is adapted for such operation.

The device shown in Fig. 1 comprises a sealed envelope 1 of some suitable material, such as glass, containing a cylindrical anode 2 having open ends, whereby current carriers can pass from one side of the anode to the other. This anode is of considerable area as specified above. The envelope also contains a thermionic cathode 3 which is supported on a stem 4. A small auxiliary anode 5 may also be supported on the stem 4. The auxiliary anode 5 is used mainly for starting purposes. The gas pressure is low and preferably of the order specified above. In each case, however, the gas pressure is so related to the spacing between the cathode and anode and the rest of the geometry of the device that in absence of any outside supply of ions, a high voltage drop would exist between the cathode 3 and anode 2 which would tend to prevent any appreciable passage of current between them. Thus a separate source of ions, as described below, is used.

The envelope 1 is provided with a bulbous enlargement 6 in which a ring discharge of the type described above may be produced. In order to produce such a discharge, a coil 7 surrounds the enlargement 6. The coil 7 is energized from some suitable source of high frequency current which may be an oscillator 8 supplied with power through conductors 9 and 10 from a suitable source of alternating current. The anode 2 is preferably slotted in order to prevent the inducing of a large high frequency current therein.

In order to maintain the desired low pressure, the envelope 1 is provided with a tubular extension 11 projecting away from the envelope 1 and in which the vapor filling of the tube may condense. Such vapor may be, for example, mercury vapor supplied from a drop of mercury 12

placed in the extension 11. The pressure in the envelope 1 may be controlled by controlling the temperature of the extension 11 which may be artificially cooled if desired. It is to be understood that other vapors or gases at the desired low pressures may be utilized. The pressure, as indicated above, should be low and preferably of the order of .001 mm. of mercury or lower.

The cathode 3 may be heated from a heating transformer 13 whose secondary 14 is connected to the terminals of the cathode and whose primary 15 is connected to a source of alternating current. The current to be rectified may be derived from an input transformer 16 whose primary winding 17 is connected to a source of alternating current. One end of the secondary 18 of the transformer 16 has connected thereto a conductor 19 which extends to one terminal of a load device 20 whose other terminal is connected to the anode 2. The other end of the secondary 16 is connected by a conductor 21 to an intermediate point on the secondary winding 14.

A discharge may be maintained between the cathode 3 and the auxiliary anode 5 by having a conductor 22 extend from the conductor 19 and through a current-limiting resistor 23 to the auxiliary anode 5. In this way the secondary 18 impresses a potential between the cathode 3 and the auxiliary anode 5, and a few electrons flow between these electrodes to produce a few ions between them.

When the device is connected and energized as described above, in addition to the discharge between the cathode 3 and the auxiliary anode 5, a small current of electrons flows from the cathode 3 to the anode 2, also producing some ions. Some of the ions created by these discharges wander into the enlargement 6 and initiate an electrodeless discharge under the action of the field of the coil 7. The current carriers in this discharge are caused to travel in circular paths of considerable length, and considerable amperage flows in such a discharge. This intense discharge creates large numbers of positive ions and electrons, many of which travel down into the region of the anode 2 and the cathode 3. Thereupon large currents can be drawn between 2 and 3 at voltage drops which in many cases may even approach zero or less. Since the voltage is so low, it is to be noted that the gas pressure is high enough, under the conditions described, to completely neutralize space charge, and the discharge can properly be termed "arc-like".

The high frequency source 8 may be modulated by the potential supplied from the conductors 9 and 10 so that a high frequency current is delivered to the coil 7 only during the conducting half of the voltage cycle between the cathode 3 and the anode 2. In absence of the ionizing action of the high frequency coil, it is extremely difficult to cause any conduction of current through the discharge space. Thus, at the low pressures specified and particularly under the conditions specified above, the practical voltage that can be rectified is extremely high, and in some cases may approach those voltages which can be rectified by a high vacuum device. For example, voltages of the order of a thousand volts or more can be rectified.

Instead of an electrodeless discharge, large circulating currents may be produced in the enlargement 6 in other ways as, for example, by a thermionic cathode and an anode, the circulation of current being produced by a constant

magnetic field at right angles to the path between the electrodes.

The supply of positive ions and electrons may be created by a discharge located in the region between the main cathode and anode, as shown, for example, in Fig. 2. In this figure is shown a tube comprising a sealed envelope 24 containing a cathode 25 and an auxiliary anode 26 supported on a stem 27, and analogous to the cathode 3, an auxiliary anode 5 of Fig. 1. A main anode 28 is located at the opposite end of the envelope from the cathode 25. The anode 28 should preferably extend substantially across the envelope 24 in order to have the desired area. The envelope 24 has a relatively large cross-sectional area so that under the pressure conditions specified, large circulating currents can be produced therein. For this purpose a coil 29 surrounds the envelope 24 in the region between the cathode 25 and the anode 28. This coil 29 may be energized as is coil 7 of Fig. 1. The envelope 24 is also provided with a tubular extension 30 containing a source of vapor, such as a mercury drop 31. The device of Fig. 2, when operated under the conditions and in the manner as indicated for Fig. 1, produces substantially the same type of operation and results as described in connection with Fig. 1.

The facility with which the high frequency field may control the conduction of current can be increased by such an arrangement as is shown in Fig. 3. In this figure is shown a tube comprising a sealed envelope 32 containing a thermionic cathode 33 which may be of the indirectly-heated type having an interior heater 34. Adjacent the cathode 33 is supported an auxiliary anode 35. The cathode 33, the heater 34, and the anode 35 may be conveniently supported on a stem 36 through which lead-in wires for the respective elements are sealed. The cathode 33 is placed in a relatively large bulbous portion 37 which is surrounded by a high frequency coil 38, whereupon the ionizing circulating discharge referred to above may be produced. The pressure conditions within the tube are those also as specified above.

The bulbous portion 37 is provided with a restricted side arm 39 at the outer end of which is supported an anode 40. The anode is supplied with a lead-in conductor 41 sealed through the end of the side arm 39. The outer end of the side arm may be provided with an appendix 42 in which a drop of mercury 43 may be placed. The temperature of the appendix 42 may be controlled in any suitable manner to produce the desired low vapor pressure within the envelope 32. The diameter of the side arm 39 is so restricted that a self-sustaining discharge cannot be maintained to the anode 40 without some additional supply of ions other than the discharge between the cathode 33 and the anode 40. The restriction of the side arm 39 produces a greater loss of ions on the walls of said side arm so that the discharge itself between the cathode 33 and the anode 40 does not create a sufficient number of ions within the side arm 39 to compensate for the rate at which these ions are lost. However, the ionizing circulating discharge which is produced by the high frequency coil 38 within the bulbous portion 37 creates a large number of ions which are showered down upon the open end of the side arm 39, and at the low pressure specified penetrate into the side arm in sufficiently great numbers so that the loss of ions on the side walls of said side arm is compensated.

sated for and relatively great discharges at low voltages may easily be maintained under these conditions. Of course it is to be understood that instead of providing a side arm, such as 39, other means of restricting the discharge path intermediate the anode 40 and the cathode 33 may be utilized.

When the cathode 33 is heated to temperature of thermionic emission by the heater 34, a small discharge will flow to the auxiliary anode 35, creating a few ions which enable the high frequency coil 38 to set up the intensely ionizing circulating discharge within the bulbous portion 37. Thus when the proper potential is applied between the cathode 33 and the anode 40, a large discharge current will flow at a relatively low voltage. By shutting off the high frequency in the coil 38 when the voltage between the cathode 33 and the anode 40 reverses, the device can be made to withstand very high voltages, and thus rectification of such high voltages may be produced without danger of flashback. Under these conditions the inability of a self-sustaining discharge to be maintained in the side arm 39 assists in the ability of the discharge to withstand such high reverse voltages.

Under proper conditions, the cutting off of the high frequency from the coil 38 will also prevent the device from conducting current in the forward direction; that is, when the cathode 33 is negative and the anode 40 is positive. Thus, by impressing a direct current potential between the cathode 33 and the anode 40 and by starting and stopping the high frequency current in the coil 38, the tube can be made to periodically interrupt the direct current and thus cause the device to act as an inverter.

This invention is not limited to the particular details of construction or operation as described above, as many equivalents will suggest themselves to those skilled in the art. For example, instead of mercury vapor, such as I have specified above, other vapors at low pressures may be utilized. Also inert gases at sufficiently low pressures may be useful in such a device. The exact pressure which is to be used in each case may vary somewhat with the type of the tube and the type of gas or vapor. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. A gaseous discharge device comprising a sealed envelope containing a cathode of the type from which substantial electron emission occurs independently of a discharge, an anode, and an ionizable medium at a pressure at which the current flow between said cathode and anode would normally tend to be limited by the space charge created by said electron emission, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein, and means for producing an intense ionizing discharge flowing in a circular path through said medium in said envelope and for introducing the ions so generated into the space between said cathode and anode, whereby a discharge at low voltage may take place between said cathode and anode.

2. A gaseous discharge device comprising a sealed envelope containing a cathode of the type from which substantially electron emission occurs independently of a discharge, an anode, and an ionizable medium at a pressure at which the

current flow between said cathode and anode would normally tend to be limited by the space charge created by said electron emission, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein, and means for producing a periodically varying field in said medium in said envelope for producing an electrodeless discharge therein and for introducing the ions so generated into the space between said cathode and anode, whereby a discharge at low voltage may take place between said cathode and anode.

3. A gaseous discharge device comprising a sealed envelope containing a cathode of the type from which substantial electron emission occurs independently of a discharge, an anode, and an ionizable medium at a pressure at which the current flow between said cathode and anode would normally tend to be limited by the space charge created by said electron emission, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein, means for producing a periodically varying field in said medium in said envelope for producing an electrodeless discharge therein and for introducing the ions so generated into the space between said cathode and anode, whereby a discharge at low voltage may take place between said cathode and anode, and means for producing a few initial ions and for introducing them into said high frequency field for starting said electrodeless discharge.

4. A gaseous discharge device comprising a sealed envelope containing a cathode of the type from which substantial electron emission occurs independently of a discharge, an anode, and an ionizable medium at a pressure at which the current flow between said cathode and anode would normally tend to be limited by the space charge created by said electron emission, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein, an enlargement formed on said envelope, and means for producing a periodically varying field in said medium in said enlargement for producing an electrodeless discharge therein and for introducing the ions so generated into the space between said cathode and anode, whereby a discharge at low voltage may take place between said cathode and anode.

5. A gaseous discharge device comprising a sealed envelope containing a cathode of the type from which substantial electron emission occurs independently of a discharge, an anode, and an ionizable medium at a pressure of the order of .001 mm. or less whereby the current flow between said cathode and anode would tend to be limited by space charge in absence of additional means, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein, and additional means for producing an intense ionizing discharge through said medium in said envelope and for introducing the ions so generated into the space between said cathode and anode, whereby a discharge at low voltage may take place between said cathode and anode.

6. A gaseous discharge device comprising a

sealed envelope containing a thermionic cathode, an anode, and an ionizable medium at a pressure of the order of .001 mm. or less, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein, and additional means for producing an intense ionizing discharge through said medium in said envelope and for introducing the ions so generated into the space between said cathode and anode, whereby a discharge at low voltage may take place between said cathode and anode.

7. A gaseous discharge device comprising a sealed envelope containing a cathode of the type from which substantial electron emission occurs independently of a discharge, an anode, and an ionizable medium, means for restricting the discharge path intermediate the anode and the cathode to such an extent that cathode and anode would tend to be limited by the space charge created by said electron emission under the normal pressure conditions in the envelope, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein, and additional means for producing an intense ionizing discharge through said medium and for introducing said ions into said restricted path, whereby a discharge at low voltage may take place between said cathode and anode.

8. A gaseous discharge rectifier comprising a sealed envelope containing a cathode, an anode, and an ionizable medium, the pressure of said medium being of the order of .001 mm. or less, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein, and additional means for producing an intense ionizing discharge through said medium in said envelope and for introducing the ions so generated into the space between said cathode and anode, whereby a discharge at low voltage may take place between said cathode and anode, said additional means being energized during the period when said cathode is positive with respect to said anode and deenergized during the period when said cathode is negative with respect to said anode, whereby said rectifier is enabled to withstand high reverse voltages.

9. A gaseous discharge device comprising a sealed envelope containing a cathode of the type from which substantial electron emission occurs independently of a discharge, an anode, and an ionizable medium, the pressure of said medium being of the order of .001 mm. or less, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein, and additional means for producing an intense ionizing discharge through said medium in said envelope and for introducing the ions so generated into the space between said cathode and anode, whereby a discharge at low voltage may take place between said cathode and anode, said additional means being deenergized periodically during the operation of said device to prevent conduction of current between cathode and anode during said deenergized period.

10. A gaseous discharge device comprising a sealed envelope containing a cathode of the type from which substantial electron emission occurs

independently of a discharge, an anode, and an ionizable medium at a pressure of the order of .001 mm. or less, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein, and additional means for producing an intense ionizing discharge through said medium in said envelope and for introducing the ions so generated into the space between said cathode and anode sufficiently to produce a discharge between said cathode and anode at a voltage drop of the order of the ionization voltage of said medium or less.

11. A gaseous discharge device comprising a sealed envelope containing a cathode of the type from which substantial electron emission occurs independently of a discharge, an anode, and an ionizable medium at a pressure at which the current flow between said cathode and anode would normally tend to be limited by the space charge created by said electron emission, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein, and means for producing in said medium an electrodeless discharge and for introducing the ions so generated into the space between said cathode and anode, whereby a discharge at low voltage may take place between said cathode and anode.

12. The method of operation of a gaseous discharge device comprising a sealed envelope containing a cathode of the type from which substantial electron emission occurs independently of a discharge, an anode, and an ionizable medium at a pressure at which current flow between said cathode and anode would normally tend to be limited by the space charge created by said electron emission, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein which comprises impressing the voltage between said cathode and anode tending to cause a discharge to pass between said electrodes, producing an intense ionizing discharge through said medium by additional means, and introducing the ions so generated into the space between said cathode and anode to such an extent as to produce a low voltage discharge between said cathode and anode.

13. The method of operation of a gaseous discharge device comprising a sealed envelope containing a cathode of the type from which substantial electron emission occurs independently of a discharge, an anode, and an ionizable medium at a pressure at which current flow between said cathode and anode would normally tend to be limited by the space charge created by said electron emission, said pressure being sufficiently high to substantially entirely neutralize the space charge between said cathode and anode upon the occurrence of an intense ionizing discharge therein which comprises impressing the voltage between said cathode and anode tending to cause a discharge to pass between said electrodes, producing an intense ionizing electrodeless discharge through said medium by additional means, and introducing the ions so generated into the space between said cathode and anode to such an extent as to produce a low voltage discharge between said cathode and anode.

14. The method of operation of a gaseous discharge device comprising a sealed envelope con-

5 taining a cathode of the type from which sub-
 10 stantial electron emission occurs independently
 of a discharge, an anode, and an ionizable medi-
 15 um at a pressure at which current flow between
 said cathode and anode would normally tend to
 be limited by the space charge created by said
 electron emission, said pressure being sufficiently
 high to substantially entirely neutralize the
 20 space charge between said cathode and anode
 upon the occurrence of an intense ionizing dis-
 charge therein which comprises impressing the
 voltage between said cathode and anode tending
 to cause a discharge to pass between said elec-
 25 trodes, producing an intense ionizing electrode-
 less discharge through said medium by impress-
 ing a periodically-varying magnetic field on said
 medium, and introducing the ions so generated
 into the space between said cathode and anode
 to such an extent as to produce a low voltage
 30 discharge between said cathode and anode.

15. The method of operation of a gaseous dis-
 charge device comprising a sealed envelope con-
 25 taining a cathode of the type from which sub-
 stantial electron emission occurs independently
 of a discharge, an anode, and an ionizable medi-
 um at a pressure at which current flow between
 said cathode and anode would normally tend
 to be limited by the space charge created by said
 electron emission, said pressure being sufficiently
 30 high to substantially entirely neutralize the
 space charge between said cathode and anode
 upon the occurrence of an intense ionizing dis-
 charge therein which comprises impressing the
 voltage between said cathode and anode tending
 35 to cause a discharge to pass between said elec-
 trodes, producing an intense ionizing discharge
 through said medium by additional means, and
 introducing the ions so generated into the space
 between said cathode and anode to such an ex-
 40 tent as to produce a low voltage discharge be-
 tween said cathode and anode, and interrupting
 said intense ionizing discharge produced by said
 additional means to interrupt said discharge
 between said cathode and anode.

45 16. A gaseous discharge device comprising a
 sealed envelope containing a cathode of the type
 from which substantial electron emission occurs
 independently of a discharge, an anode, and an

ionizable medium at a pressure of the order of
 .001 mm. or less, whereby the current flow be-
 5 tween said cathode and anode would normally
 tend to be limited by space charge in absence of
 additional means, and additional means for pro-
 10 ducing an intense ionizing discharge flowing in a
 circular path through said medium in said en-
 velope and for introducing the ions so generated
 into the space between said cathode and anode,
 whereby a discharge at low voltage may take
 15 place between said cathode and anode.

17. A gaseous discharge device comprising a
 sealed envelope containing a cathode of the type
 from which substantial electron emission occurs
 independently of a discharge, an anode, and an
 15 ionizable medium at a pressure of the order of
 .001 mm. or less, whereby the current flow be-
 tween said cathode and anode would normally
 tend to be limited by space charge in absence of
 additional means, and additional means for pro-
 20 ducing a periodically varying field in said medi-
 um in said envelope for producing an electrode-
 less discharge therein and for introducing the
 ions so generated into the space between said
 cathode and anode, whereby a discharge at low
 25 voltage may take place between said cathode
 and anode.

18. A gaseous discharge device comprising a
 sealed envelope containing a cathode of the type
 from which substantial electron emission occurs
 30 independently of a discharge, an anode, and an
 ionizable medium at a pressure at which the
 current flow between said cathode and anode
 would normally tend to be limited by the space
 charge created by said electron emission, said
 35 pressure being sufficiently high to substantially
 entirely neutralize the space charge between said
 cathode and anode upon the occurrence of an
 intense ionizing discharge therein, and addi-
 40 tional means for producing an intense ionizing
 discharge through said medium in said envelope
 and for introducing the ions so generated into
 the space between said cathode and anode suf-
 45 ficiently to produce a discharge between said cath-
 ode and anode at a voltage drop of the order
 of the ionization voltage of said medium or less.

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