

May 10, 1938.

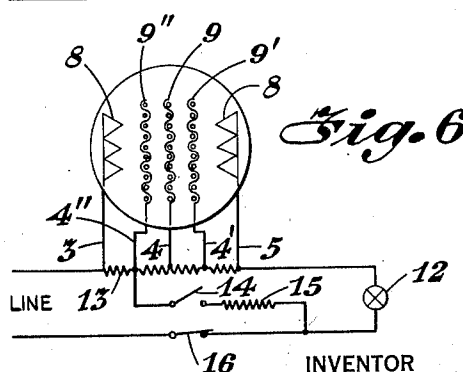
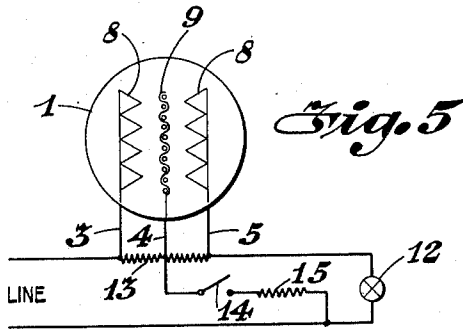
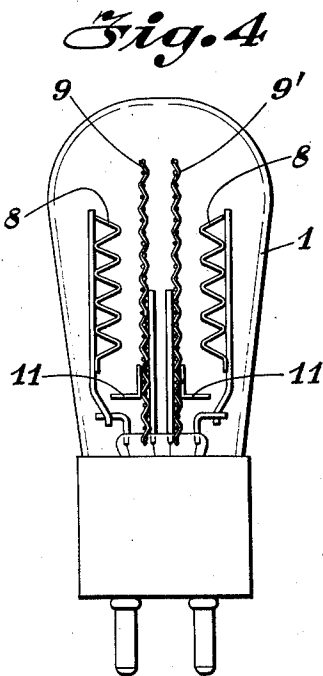
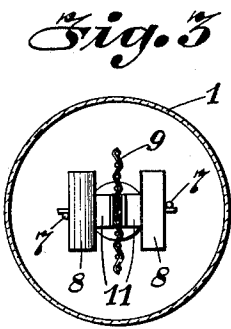
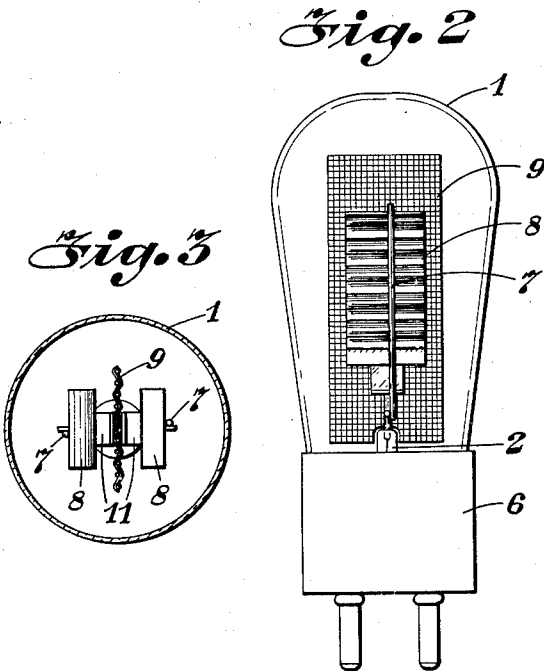
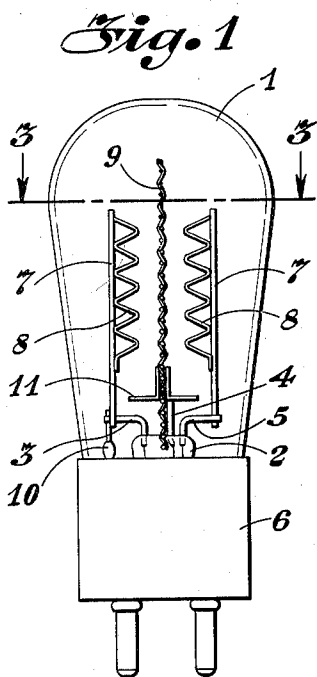
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2,116,677

GASEOUS ELECTRIC DISCHARGE DEVICE AND METHOD OF OPERATING THE SAME

Filed Feb. 19, 1934

2 Sheets-Sheet 1



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GASEOUS ELECTRIC DISCHARGE DEVICE AND METHOD OF OPERATING THE SAME

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2 Sheets-Sheet 2

Fig. 7

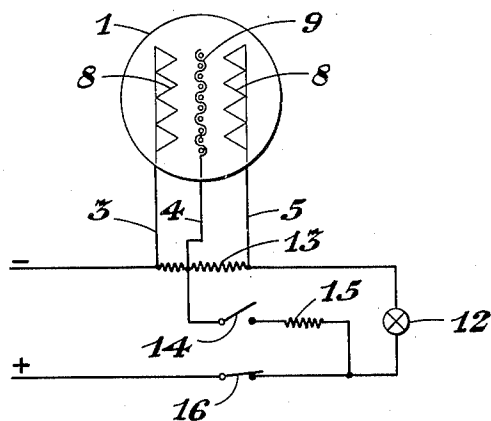
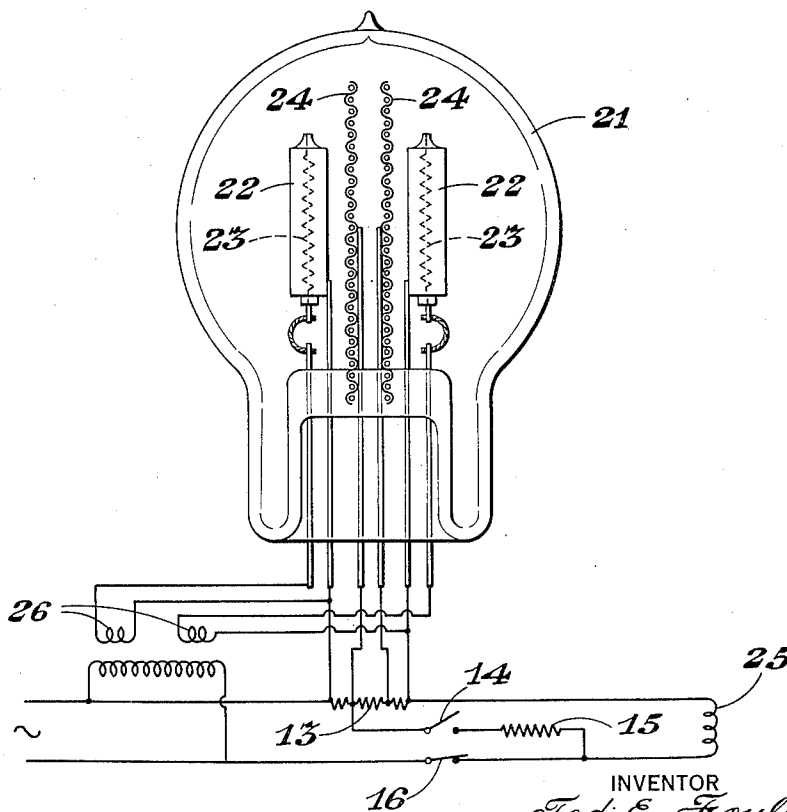


Fig. 8



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GASEOUS ELECTRIC DISCHARGE DEVICE
AND METHOD OF OPERATING THE SAMETed E. Foulke, Nutley, N. J., assignor to General
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Application February 19, 1934, Serial No. 712,031

3 Claims. (Cl. 250—27.5)

The present invention relates to electric gaseous discharge devices generally, and more particularly to devices of this type which can be used as a relay.

5 A particular object of the invention is to provide a gaseous electric discharge device capable of passing a relatively large current in response to flow of an extremely small current there-through. Another object of my invention is to
10 provide a gaseous electric discharge device which normally interposes an extremely high resistance to the passage of current therethrough at a predetermined voltage before current flow starts, but only a low resistance once the discharge is
15 initiated. A further object of my invention is to provide a device which will function on either direct or alternating current. Another object of my invention is to provide a novel method of operation whereby a discharge can be re-started at a comparatively low voltage after relatively long intervals. Still other objects and advantages of my invention will appear from the following detailed specification or from an inspection of the accompanying drawings.

25 The invention consists in the new and novel structure and combination of elements which is hereinafter set forth and claimed.

For many purposes there is need of a relay which will respond to a momentary current of
30 a few microamperes to permit the continued flow of a much larger current, of the order of milliamperes or even amperes. It has been proposed heretofore to use gaseous electric discharge devices of the cathode glow type for this purpose,
35 but the field of usefulness of these devices of the prior art has been greatly restricted by several inherent limitations thereof. Perhaps the most important of these limitations is the relatively low voltage which can be made available for use
40 in the load circuit, due to the fact that there is only a small difference between the breakdown potential and the discharge maintaining potential of these prior art devices. Secondly, the current which can be safely controlled by any
45 of these devices of the prior art is very definitely limited to a few milliamperes. As a result of these two factors the energy available for a load circuit is severely limited. Thirdly, these devices have all been limited to operation on direct current, due to the fact that on alternating current
50 the discharge is extinguished at the end of the first half cycle after any starting impulse, whereas in virtually all cases it is essential that this discharge should continue once it has been initiated. Thus it has been impossible to use these

gaseous electric discharge devices in many applications where they would otherwise be extremely desirable not only because of their relatively small cost but also because of the complete absence of moving parts and the small actuating current
5 required.

I have now discovered that all of these limitations of the prior art devices are avoided by a novel electric gaseous discharge device of my invention. In my novel structure the breakdown
10 potential is greatly increased without any appreciable increase in the discharge maintaining potential through the novel use of a grid of fairly fine mesh, between the main electrodes of the
15 discharge device. With this novel construction the breakdown potential between these main electrodes is approximately the sum of the individual breakdown potentials between the various
20 pairs of adjacent elements, whereas the discharge maintaining potential is virtually the same as if the grids were not present. For example, in a cathode glow device having a normal breakdown
25 potential of the order of 55 volts A. C., and a discharge maintaining potential of the order of 45 volts the insertion of a single grid will raise the breakdown potential to approximately 110
30 volts without any appreciable increase in the discharge maintaining potential, while the addition of more grids has the further effect of increasing this breakdown potential by at least 55
35 volts per grid. This is due to the fact that so long as there is no appreciable ionization within the gaseous discharge device the wires of the grids are all surrounded by an electron sheath of such thickness that they merge and form an impenetrable barrier to the passage of a discharge
40 current. Thus it is impossible for the so-called "dark current", by which the necessary ionization for a glow discharge is ordinarily produced, to flow between the main electrodes at the usual
45 potential. As soon, however, as the potential is increased, as between any pair of adjacent electrodes, for example, to the point where a glow discharge occurs therebetween, the resulting increase in ion density causes the electron sheaths
50 about the grids to shrink, with the result that a discharge occurs between the main electrodes at the applied potential. Thus in the device previously referred to, for example, 105 volts A. C. may be safely impressed between the main electrodes, provided there is a single grid therebetween, without producing a discharge so long as
55 the potential of the grid is maintained half way between that of the main electrodes. As soon, however, as the potential of the grid is altered

sufficiently to initiate a discharge of a few microamperes between this grid and either electrode the main discharge, of the order of many milliamperes, starts to flow, with some 60 volts available for use in an external load circuit. Thus this novel structure of my invention permits for the first time the efficient use of relatively high voltages in a load circuit which is controlled by a relay of the gaseous discharge type.

In addition to this very great increase in potential, which may obviously be even further increased by the use of additional grids, this novel structure provides a means for handling currents which are of the order of a hundred fold those heretofore controlled by this type of device. The current which may be safely carried by a cold type cathode is relatively small, of the order of 15-20 milliamperes per square inch of cathode under the most favorable conditions. It is thus impossible to carry larger currents, of the order of amperes, in a device of practical size using this type of cathode. These larger currents can, of course, be carried by thermionic cathodes, but thermionic cathodes can not be successfully employed in the gaseous relay devices of the prior art, due to the fact that there is so little difference between breakdown and operating potential that no satisfactory relay action can be gained therewith. With my novel structure, however, the intervening grids, being cold, very materially increase the breakdown potential, by 75 volts or so per grid, without increasing the operating potential of the device, and without reducing the current capacity thereof. Hence it is apparent that currents of the order of amperes and at a relatively large voltage may now be successfully controlled by a gaseous discharge relay for the first time.

I have further discovered that the use of a novel mixture of gases of my invention enables my novel gaseous discharge relay to be employed in alternating current circuits of any usual frequency, as contrasted with the devices of the prior art, which have been useful only in direct current circuits. I have furthermore found that this same novel mixture of gases permits the use of smaller control currents, and the use of more grids than would be possible with a pure gas. Both of these novel results are attained by adding to any gas a very limited amount of another gas whose ionizing potential is less than a metastable potential of the principal gas. For example, argon may be added to neon or helium, or mercury vapor may be added to argon. Likewise helium-krypton, xenon-caesium, and mercury-caesium mixtures are also effective, the first gas in each case being the principal one. By experiment I have found that any one of these mixtures, in proper proportions, gives a novel result, due to the fact that ionization is more widely distributed and persists therein for much longer periods than in a pure gas. The percentage of the added gas of lower ionizing potential is quite critical, however. Thus in the case of neon at a pressure of 40 m. m. of mercury a concentration of from a trace to approximately 3% of argon may be employed, although I prefer to use a concentration of the order of .05% argon, since this has been found to give the best results. With lower pressures somewhat lower concentrations of the argon produce the desired result. With other combinations of gases, such as outlined above, substantially the same proportions are used as in the neon-argon case, which is given by way of example.

The unique persistence of ionization which is obtained with this novel gas mixture manifests itself in two different, but related, ways. At the instant any gaseous discharge is discontinued there is, of course, sufficient ionization of the gas to permit instantaneous restarting of the discharge at the normal discharge maintaining potential. As the ions are destroyed, however, by recombination and by collisions with the wall the concentration of the ions rapidly decreases, with the observed result that the voltage required to restart the discharge increases gradually for an interval and then rapidly increases to the normal breakdown potential. With pure gas this transition is so rapid that at sixty cycles virtually the full breakdown potential is necessary to reinitiate the discharge on each half cycle. When a trace of a gas which can be ionized by collision with a metastable atom of the main gas is added two effects are produced. First the initial increase in potential per unit of time is materially decreased, and secondly the abrupt upswing to the normal breakdown potential occurs at a much later time. With neon both of these effects increase until approximately .05% of argon has been added, after which further increases in the argon content cause both of these effects to again decrease. This novel result is due to the fact that where a pure gas is employed the concentration of ions outside of the immediate path of the discharge is relatively small, since it is entirely dependent upon diffusion. There are, however, large numbers of metastable atoms throughout the bulb, due to the penetration of resonance radiations throughout the gas space. As soon as a trace of another gas which can be ionized by these metastable atoms is added, these metastable atoms collide therewith and thus produce additional ionization throughout the bulb. This ion concentration, which has been found to be increased under these conditions by more than a thousand fold, not only greatly assists the control current to eliminate the effect of the grids, permitting an extremely small current to shrink the electron sheaths about said grids, even though they are some distance from the initial discharge, but also results in a higher concentration at any given instant after the discharge has stopped, with a consequent decrease in the voltage required to restart at that instant, and an increase in the time interval until the ionization has fallen to the critical value at which the voltage required to restart rises abruptly to the normal breakdown potential. This is of decided importance in many cases. For example, on sixty cycles A. C. the discharge must be reinitiated each half cycle after a lapse of the order of 2 or 3 mil-seconds during which there has been no current flow. With pure neon, the voltage necessary to restart the discharge is practically the full normal breakdown potential, whereas with the addition of .05% of argon only a few volts more than the normal discharge maintaining potential is required. Furthermore with pure gas the critical time at which there is an abrupt rise in voltage occurs after only a few mil-seconds, whereas with .05% of argon it is found that the restarting voltage is still only a few volts above the discharge maintaining potential after 20 mil-seconds, and that the abrupt rise in the voltage required to restart does not occur until after more than 100 mil-seconds. As more argon is added, however, it begins to take an important part in the discharge and thus cuts down the neon resonance radiations. This in turn decreases the number of metastable neon atoms, and the ion concentration throughout the

envelope. As a result the voltage required to re-start the discharge after any given interval again increases. The maximum interval before the abrupt rise in potential occurs is likewise much less with these higher concentrations of argon as compared to that where a concentration of .05% of argon is used. This desired persistence of ionization is also assisted where these mixed gases are used due to the fact that some ionization is produced even after the discharge has stopped by collisions between metastable neon atoms and argon atoms, this factor also tending to maintain a high ion concentration.

From the foregoing it will be apparent that my invention contemplates the addition of effective amounts of a particular impurity as set forth above, this in the case of neon at 40 m. m. of mercury being from a trace up to approximately 3% of argon, for example, although from .01 to .1% of argon is preferred since this range gives by far the best results. My invention further contemplates the control, in some cases, of the interval during which a discharge can be restarted at a given voltage through variation in the gaseous content of the device.

Much greater flexibility results from the fact that my new device is operable on alternating current, especially since very considerable voltages are made available for the load circuit by means of my novel structure, due to the fact that the relatively small current output of a cold cathode type device can be easily transformed, when desired, to a much larger current at a somewhat lower voltage. Where lamps comprise the load this is often an important feature, since it permits the use of heavier and hence more durable filaments.

For the purpose of illustrating my invention I have shown several embodiments thereof, together with schematic diagrams showing their use in the accompanying drawings, in which

Fig. 1 is a side elevation of a simple form of my new structure,

Fig. 2 is a front elevation of the same device,

Fig. 3 is a sectional view of the same device, taken on the line 3-3 of Fig. 1,

Fig. 4 is a side elevation of a modification of the device of Fig. 1,

Fig. 5 is a schematic diagram of a circuit utilizing the device of Fig. 1 to control the operation of a lamp,

Fig. 6 is a schematic diagram of a circuit utilizing a modification of the device of Fig. 1,

Fig. 7 is a schematic diagram showing a modification of the circuit of Fig. 5 which may be used on direct current, and

Fig. 8 is a side elevation of another modification of the device of Fig. 1, together with a schematic diagram of an operating circuit therefor.

In these drawings, with particular reference to Figs. 1 to 3, my novel discharge device has a sealed envelope 1 which is conveniently made of glass. At one end of said envelope there is a reentrant pinch seal 2 through which extend a plurality of inleads 3, 4 and 5. Said inleads are connected externally of said envelope with three different prongs of a conventional base 6 which is affixed to said envelope 1. The outside inleads 3 and 5 each carry a wire 7 which extends along the envelope 1. Each wire 7 in turn has an electrode 8 welded thereto, each of said electrodes preferably being corrugated, as shown, in order to increase the surface area which can be disposed within the available space.

Said electrodes are preferably parallel and are separated by a few millimeters. A grid 9 which is welded to the inlead 4 extends between said electrodes 8 and is approximately equidistant therefrom. Said grid may be made of nickel, iron, tungsten, or any other suitable material. The size of the mesh, which depends to some extent upon the pressure of the gas, is so chosen that the electron sheath which forms thereabout will completely close the openings therein until there is a cathode glow discharge in the device. For example, in a device containing neon at about 30 m. m. of mercury I find that a gauze of 7 mil nickel wire having 60 wires per inch in one direction and 40 in the other gives extremely good results. As the mesh is enlarged to about $\frac{1}{8}$ inch squares the effect thereof is almost entirely lost, and if the mesh is made much smaller the discharge maintaining potential is unduly raised. This grid 9 extends downwardly on either side of the pinch seal 2, and likewise extends above and beyond the sides of the electrodes 8, so as to make the path from electrode to electrode, or from lead 3 to 5 materially longer than the direct path through said grid. In some cases it may be desirable to enlarge said grid sufficiently to completely divide the envelope 1, but in general I find the foregoing construction satisfactory for all practical needs. The surface of the electrodes 8 are preferably coated with a substance having a low work function, in order to reduce the discharge maintaining potential of the device. In practice I coat these electrodes with a mixture of barium and strontium together with the oxides thereof bonded in place by oxygen, according to the method disclosed in my co-pending application Serial Number 637,310, filed October 11, 1932. As there set forth such a coating, which is produced by partially reducing the oxides of the alkaline earth metals in situ by means of a steep wave front discharge, not only has an exceptionally low work function of the order of 1.3 volts, but also has an extremely long useful life. This method of producing the activated coating requires the presence of a substance which will clean up, chemically or by absorption or adsorption, the excess oxygen which is evolved. As shown in Fig. 1 this is conveniently provided by means of a pellet 10 which contains magnesium. After the lamp has been carefully evacuated this magnesium is distilled onto the inner surface of the envelope 1, preferably around the base of the reentrant stem. In some cases, however, where the opposing faces of the electrodes 8 have ample current carrying capacity for the purpose to which the relay is to be put, the back of said electrodes may be coated with finely divided aluminum after the manner disclosed in the aforesaid application. This aluminum will clean up the necessary oxygen, and at the same time confine the glow discharge to the face of the electrodes where the radiations therefrom will be effective to maintain a minimum anode fall. Where the electrodes are thus coated the getter pellet 10 may be omitted, of course, since the aluminum powder serves the same purpose as the magnesium. In some cases the grid 9 is also coated with aluminum powder in any suitable manner, since an additional advantage is gained thereby, in that this coating prevents the adherence thereto of any alkaline metal particles which are sputtered from either electrode 8 during operation of the device. As a result the work function of the grid

9 remains relatively high and thus maintains a higher breakdown potential between said grid as a cathode and either electrode 8 than would be possible if the grid were not so coated. This may obviously be availed of, if the device is used in a direct current circuit, to permit the application of an even higher voltage between the main electrodes 8 without initiation of a discharge therebetween.

In order to prevent sputtered particles forming a film across the seal 2 between the inleads 3, 4 and 5, and thus possibly affecting the voltage distribution therebetween, a pair of shields 11 of nickel or the like are carried by the grid 9 in such a manner as to intercept any particles sputtered in the direction of said seal. These shields are a refinement which may be omitted, however, especially if the leads are connected to a potentiometer in the manner hereinafter described.

The device of Fig. 4 is similar to that of Fig. 1. In this structure, however, two grids 9 and 9' are provided between the electrodes 8. These grids are each preferably coated with aluminum powder, which resists activation of the grids by particles sputtered from the electrodes 8. The back of each electrode 8 is also coated with aluminum which serves to clean up any undesired gas, the getter pellet 10 of Fig. 1 thus being omitted. In this case the breakdown potential between the grids 9 and 9' is greater than that between either electrode 8, as a cathode, and the adjacent grid, so that on either alternating or direct current the breakdown potential between the electrodes 8 is more than three times what it would be without the intervention of the grids.

For use in direct current circuits the envelope 1 of the devices of either Figs. 1 or 4 may be filled with any desired gaseous atmosphere such as neon or argon at a pressure of the order of 30 m. m. of mercury. Where the relay is to be operated on alternating current, however, or in any case where the grids are more widely separated or more grids used, it is essential that a particular mixture of gases should be employed. This mixture must consist of any desired gas, such as helium, neon, argon or the like as the principal gas, together with a small quantity of another gas having an ionizing potential which is lower than a metastable potential of the principal gas. This second gas must be present in such a limited quantity, however, as not to play any important part in the ordinary current conduction between the electrodes 8. For example, when either neon or the neon-helium mixture which is obtained by fractionating air is employed at a pressure of the order of 30 m. m. of mercury I find that the discharge can be restarted at a low voltage for a much longer period if from a trace to approximately 3% of argon is added thereto, although I prefer to use percentages of from .01 to .1% argon, since the latter concentrations are particularly effective. As a result of the longer period during which the discharge can thus be restarted at substantially the discharge maintaining potential I find that a gaseous discharge relay using such a gas mixture can be successfully used on alternating current despite the inherent momentary interruptions at the end of each half cycle. I likewise find that when this novel gas mixture is used an extremely small control current, of the order of a few microamperes, produces ample ionization about even relatively remote grids to shrink the electron sheaths thereabout, due to the novel production of ionization throughout the

device by radiations from the discharge, as described hereinbefore.

A use of the device of Fig. 1 is schematically indicated in Fig. 5. As shown in this figure one side of a suitable source of potential either alternating or direct current, is connected to the inlead 3, while the other side of said source is connected to the inlead 5 through a lamp 12 or any other desired load, such as a magnet or the like. A potentiometer 13 having a resistance considerably lower than that of any leakage path between the inleads 3, 4 and 5, this being of the order of 100,000 to 1,000,000 ohms, is preferably connected therebetween, the midpoint of said potentiometer being connected to the inlead 4. This potentiometer may be omitted if desired, especially where the shields 11 avoid the production of a leakage path, the grid 9 being allowed in this case to float at space potential. I prefer, however, to use the potentiometer since it assures the correct voltage distribution at all times and thus positively precludes improper operation of the relay. A connection is likewise made from the inlead 4 through a switch 14 and a high resistance 15, of the order of a sixth of the resistance of the potentiometer 13, to one side of the line, preferably the positive in case direct current is used.

The circuit shown in Fig. 6 indicates the arrangement used with a device having a plurality of grids, such as 9, 9' and 9''. This circuit is similar to that of Fig. 5, except that the inleads 4' and 4'' are connected to intermediate points on the potentiometer 13 so as to definitely fix the potential of the associated grids. This resistance is ordinarily divided into equal portions between the various pairs of leads, although in those cases where the grids are coated with aluminum somewhat more resistance can be connected between each pair of leads 4''—4, and 4—4' than is connected between the leads 3 and 4'', or 4' and 5, if desired. A switch 16 which is normally closed is connected in one of the leads between the device 1 and the source of potential.

A slight modification of the circuit of Fig. 5 is shown in Fig. 7. In this case, the inlead 4 is connected to a point on the potentiometer 13 which is somewhat off center toward the negative end, so that the voltages between the electrodes 8 and the grid 9 are unequal.

The use and operation of the device of Fig. 1 can best be illustrated by reference to Fig. 5. The minimum A. C. breakdown potential between each electrode 8 and the grid 9 is of the order of 55 volts (it being noted that where the grid 9 is aluminum coated each of these breakdown potentials may be higher on one half cycle), the breakdown potential between said electrodes 8 thus being at least 110 volts, since the electron sheath about said grid 9 prevents any direct gaseous conduction between said electrodes. Hence if a potential of as much as 105 volts is impressed between the electrodes 8 no discharge will ensue, so long as this voltage is equally divided between the gaps, either by the potentiometer 13, or as a result of the grid floating in space. As soon as a higher potential is impressed across that gap, however, a discharge will occur across that gap. Thus by closing the switch 14 more than half the line potential is impressed between the left hand electrode 8 and the grid 9 and a discharge occurs therebetween, this discharge being limited to a few microamperes by the resistance 15. This discharge ionizes the gas and causes the electron sheath about the grid 9 to shrink, with the result that it is now

possible for a discharge to take place through said grid 9 directly between the electrodes 8 at the existing potential difference therebetween. This discharge current flows through the lamp 12 or other load back to the line, and is of the order of 15-20 milliamperes per square inch of active cathode surface in the preferred case. The discharge maintaining potential between the electrodes 8 under these conditions is only about 45 volts A. C., so that it is obvious that approximately 60 volts are available for the lamp 12. The switch 14 need be closed only momentarily, since once the main discharge is initiated it is self sustaining, on either A. C. or D. C., especially where the aforesaid gas mixture is used, and will continue until the line potential is interrupted by the operator.

The operation of the device of Fig. 4 is exemplified in Fig. 6, although Fig. 6 shows the use of one additional grid. In the device of Fig. 6 there is a minimum A. C. breakdown potential of the order of 55 volts between each pair of elements, or a total for the device of approximately 220 volts between the electrodes 8. At least 200 volts may thus be safely impressed between these electrodes without initiating a discharge therebetween, so long as the voltage is properly divided between the gaps. As soon as the switch 14 is closed, however, the potential between the grid 9' and the adjacent electrode 8 is sufficient to produce a discharge therebetween. This discharge causes the electron sheaths about each of the grids to so shrink that these grids no longer afford any obstacle to a discharge between the electrodes 8. The potential difference between these electrodes is thus far more than enough to initiate a discharge therebetween. The grids do not very greatly affect this discharge, and hence a potential of the order of 50-55 volts is sufficient to maintain it, leaving a potential of at least 145 volts available for the load. This discharge will continue until the switch 16 is opened for an interval which is long enough to allow the ion concentration within the envelope 1 to decrease to a value at which the electron sheaths again close the passages through the grids.

When the device of Fig. 1 is used on direct current advantage may be taken of the fact that the grid 9 has a higher cathode fall, if coated with aluminum as hereinbefore proposed, than that of either electrode 8. Thus the breakdown potential between one electrode 8 as a cathode and the grid 9 is considerably less than that between said grid as a cathode and the other electrode 8. For example, these breakdown potentials are of the order of 75 and 130 volts, D. C. respectively. Thus by adjusting the voltage impressed across each of these gaps to this ratio by means of the potentiometer 13 it is possible to obtain an even greater relay effect. In the present case the breakdown potential between the electrodes 8 is approximately 205 volts D. C., whereas if the grid 9 were connected so as to impress equal voltage on each gap this breakdown potential would be but 150 volts. Since the voltage necessary to maintain the discharge is the same in either case, being approximately 60 volts, D. C., this difference results in making an additional 65 volts available for the load circuit.

As shown in Fig. 8 my invention is also applicable to devices using thermionic cathodes and controlling several amperes at a relatively high voltage. The device illustrated in this figure has

a sealed envelope 21 of glass or other suitable material having a reentrant stem through which are sealed six leads. Two of these leads each support a conventional thermionic cathode 22 of the indirectly heated type, said cathode being preferably coated with a mixture of barium and strontium oxides or other suitable thermionically active substance. The two outside inleads are each connected to one end of the heaters 23, of the respective cathodes, the other end of each heater being connected to its cathode. The two inside inleads each support a grid 24 similar to that used in the devices previously described. Said envelope 21 contains a suitable gaseous atmosphere which is preferably a mixture of gases such as neon-argon mixture disclosed hereinbefore, in order to make the device operate satisfactorily on alternating current. A somewhat lower pressure is preferably used, however, in order to have a low discharge maintaining potential.

The inleads which support the electrodes 22 are connected, one directly to one side of a suitable alternating current source and the other to the other side of said source through the coil 25 which represents the load circuit. A potentiometer 13 is likewise connected between these inleads. The inleads which support the grids 24 are likewise connected to said potentiometer in such a fashion as to divide the potential applied across the various gaps in proportion to the minimum breakdown potential thereof. One of these grids is likewise connected through the switch 14 and resistance 15 to one side of the line. A switch 16 which is normally closed is also connected in the return lead to the line. The secondary coils 26 which are energized by said line are each connected between a cathode 22 and a heater 23 and serve to energize said heaters.

In the use and operation of this device, the minimum breakdown potential between each cathode 22 and the adjacent grid 24 is of the order of 25-30 volts, while that between the grids is at least 75 volts, and may range as high as 150 volts, depending on pressure and the nature of the surface of the grids. Thus a voltage which is only slightly less than 100 volts may be applied between the cathodes 22 without initiating a discharge therebetween under the most unfavorable circumstance. As soon as the switch 14 is closed, however, a discharge is produced between a cathode 22 and a grid 24 which increases the concentration of ions throughout the device and thus results in the shrinkage of the electron sheaths about said grids, and thus permits the flow of the main discharge directly between the cathodes 22. Since the grids do not materially affect this discharge, once it is started, only 17 volts is required to maintain it, with the result that a current of several amperes at a potential of the order of 93 volts is made available for the load. If a higher potential is desired it can be easily provided by the addition of one or more grids, each of which will make available an additional 75 volts, at the very least.

The operation of the hot cathode relay device of Fig. 8 has been described in connection with the use of alternating current, since this is the most difficult field for such a relay. It is to be understood, however, that it is also useful in direct current circuits, where the relay action is even more pronounced, due to the higher breakdown potentials on direct current. Suitable sources of potential would, of course, be provided for the heaters 23 in this case.

From the foregoing it will be apparent that my novel structure affords a unique means by which the breakdown potential of a gaseous discharge device may be varied through a wide range without materially affecting the discharge maintaining potential, so that the field of use of this type of relay is now greatly extended. Furthermore, this field of use is even further extended by the novel gas mixture herein disclosed, since this gas mixture now makes possible the use of these devices on alternating current.

While I have described my invention by reference to certain structures and circuits it is to be understood that it is not limited thereto, but that various changes, substitutions and omissions, within the scope of the appended claims, may be made therein without departing from the spirit of my invention.

I claim as my invention:—

1. An electric gaseous discharge device comprising a sealed envelope, a pair of electrodes sealed into said envelope, a grid extending between said electrodes, and a gaseous atmosphere within said envelope, said atmosphere comprising a principal gas which sustains gaseous conduc-

tion in said device and a minor gas whose ionizing potential is less than a metastable potential of the principal gas, said minor gas comprising at least .001% and less than .5% of the volume of said atmosphere.

2. An electric gaseous discharge device comprising a sealed envelope, a pair of electrodes sealed into said envelope, a grid extending between said electrodes, and a gaseous atmosphere of which the principal component is neon, said atmosphere containing from .01% to .1% of argon.

3. An electric gaseous discharge device comprising a sealed envelope, a pair of electrodes sealed into said envelope, at least one of said electrodes comprising a thermionic cathode, a grid extending between said electrodes, and a gaseous atmosphere within said envelope, said atmosphere comprising a principal gas which sustains gaseous conduction in said device and a minor gas whose ionizing potential is less than a metastable potential of the principal gas, said minor gas comprising at least .001% and less than .5% of the volume of said atmosphere.

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