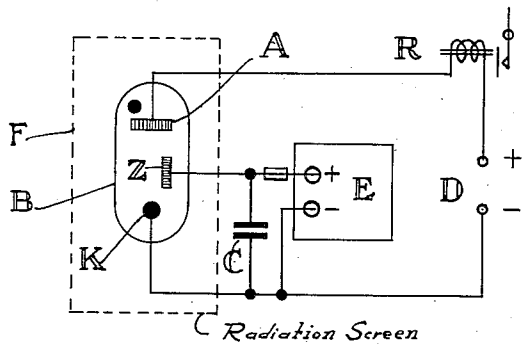
Oct. 8, 1957 E. MEILI 2,809,317

DEVICE FOR INTENSIFYING AN ELECTRIC CURRENT

Filed Feb. 16, 1950 2 Sheets-Sheet 1

Fig. 1.



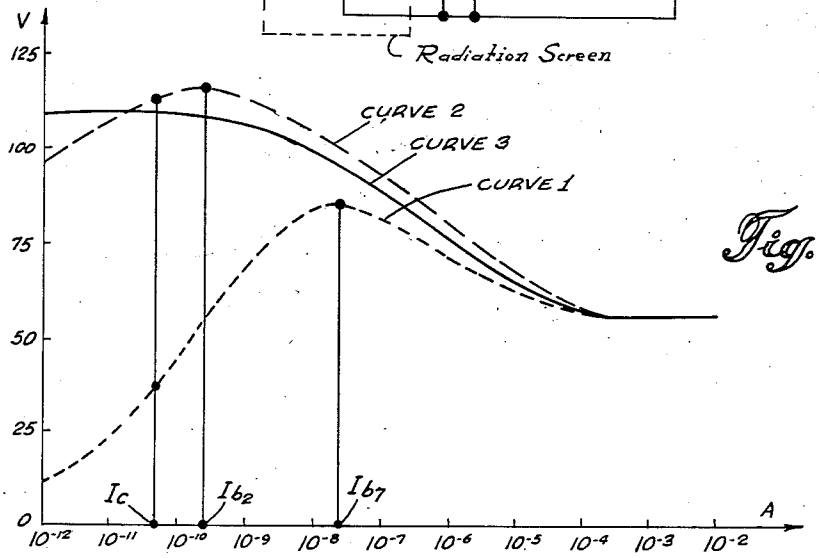


Fig. 2.

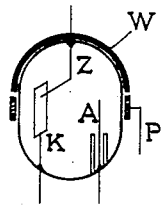


Fig. 3.

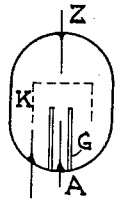


Fig. 4.

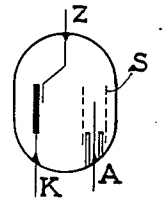


Fig. 5.

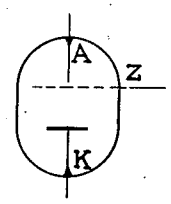


Fig. 6.

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DEVICE FOR INTENSIFYING AN ELECTRIC CURRENT

Filed Feb. 16, 1950 2 Sheets-Sheet 2

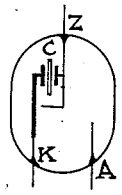


Fig. 7.

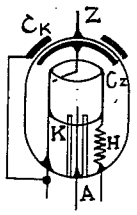


Fig. 8.

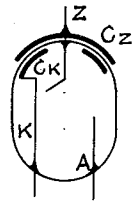


Fig. 9.

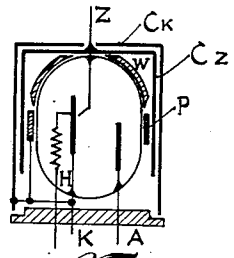


Fig. 10.

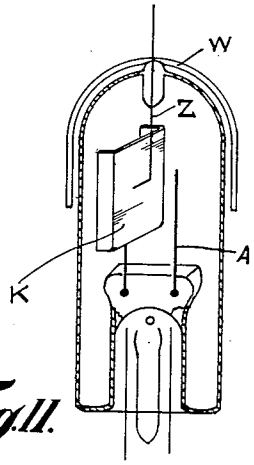


Fig. 11.

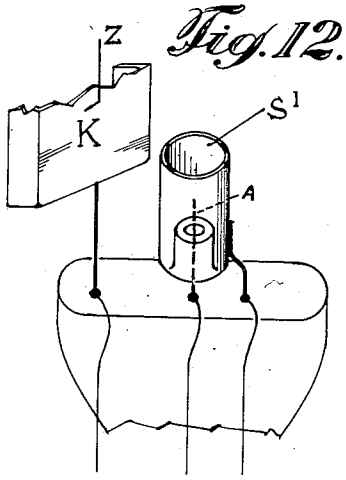


Fig. 12.

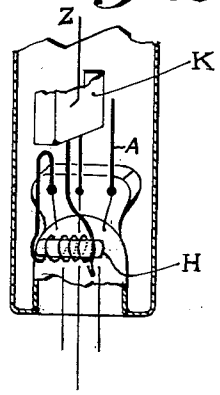


Fig. 13.

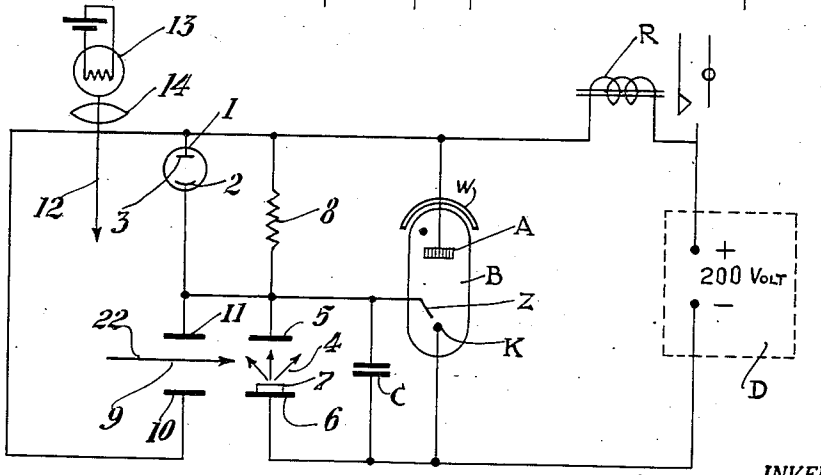


Fig. 14.

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DEVICE FOR INTENSIFYING AN ELECTRIC CURRENT

Ernst Meili, Bad Ragaz, Switzerland, assignor to Electro-Watt Electrical and Industrial Management Co., Ltd., Zurich, Switzerland

Application February 16, 1950, Serial No. 144,570

Claims priority, application Switzerland February 21, 1949

13 Claims. (Cl. 313—226)

The present invention relates to a current amplifying device embodying a gas discharge tube or glow relay, and more particularly to a device capable of effecting operation of ordinary electro-magnetic relays with control currents of the order of about 10^{-7} A. or less.

More specifically, the present invention relates to an improved gas discharge tube and its associated circuit which are of simple construction and are capable of initiating, with an extremely small control current, a relatively large operating current which may be employed, for example, to actuate an electro-mechanical relay.

The use of cold cathode tubes having a starter gap and a control gap as relay-like elements for initiating the flow of a larger current with the aid of a smaller current is known. It is also known in the art to use the control current for charging a condenser, and to operate the tube with a short pulse of current obtained by the sudden discharge of the condenser through the starter gap of the tube. Such an arrangement provides in most cases a considerably higher sensitivity of the device with respect to the control current than other known arrangements.

In the known discharge tube relays, however, the control current is at least of the order of 10^{-6} A. and no difficulty is experienced in charging the condenser to a predeterminable gap break-down voltage. Nor is there any difficulty in effecting the flow across the starter gap of a trigger pulse of current of adequate magnitude to bring about discharge across the main gap.

However, the known gas discharge tubes cannot be operated reliably with extremely feeble currents, such as currents of the order of 10^{-7} A. or less, as low as 10^{-12} A. At these low current strengths, factors come into play which are of no significance where the control currents are of considerable size, but which interfere with the operation of the tube at the very low current values.

It is accordingly the general object of the present invention to provide a gas discharge tube of the cold cathode type which is capable of reliable operation with steady currents of the order of 10^{-7} A. or less.

It is a further object of the invention to combine a cold cathode gas tube, according to the aforesaid object, with a radiation screen and a trigger capacitor, these elements forming a compact unit affording effective protection and enabling a proper build-up of a charge on the condenser.

It is a further object of the invention to provide a cold cathode tube which is effectively shielded against leakages which will interfere with the proper build-up of a charge on the condenser.

A still further object of the invention is to construct a cold cathode tube of such characteristics as to insure rapid build-up of ionization when the discharge across the starter gap occurs.

Other objects and advantages of the invention will appear from the following more detailed description thereof.

I have found that to enable the weak control current to charge the storage condenser to the minimum voltage necessary to break down the starter gap, it is important to avoid any leak currents such as might result from insufficient insulation or any kind of preliminary formation of ions or electrons within the tube. I have found further that if an adequate trigger pulse is to occur within the cold cathode tube, the tube must have a starter gap with a negative slope of its current-voltage characteristic even at very low currents and with a short enough ionization time.

According to the present invention there is provided a cold cathode discharge tube having at least three electrodes, namely, a cathode, an anode, and a starter electrode or anode, there being disposed between the starter electrode and the cathode a capacitor of less than 100 $\mu\mu$f. which is charged by the control current, the starter gap being screened to reduce pre-ionization or the release of electrons as a result of outside radiation. The necessary characteristics of the tube are further provided by making the starter electrode small in area in comparison with the cathode and by suitably selecting the gas pressure and the composition of the gas to the end that the current-voltage characteristic of the starter gap has a steep and negative slope even at very low currents, so that with a condenser of the size indicated, charged by a feeble current which is supplied at only fractions of a volt above the breakdown voltage of the starter gap, a voltage breakdown of at least a number of volts, preferably at least 20 volts, occurs on discharge.

The invention will be further described with the aid of the accompanying drawings which illustrate the operation of the tube of the present invention and also various constructional embodiments of the tube. In said drawing:

Fig. 1 shows a circuit diagram of a cold cathode tube of the present invention acting as a trigger device operated with a very small current;

Fig. 2 is a diagram showing the current-voltage characteristics of different gas discharge tubes at very low currents;

Fig. 3 to 10 show diagrammatically various embodiments of discharge tubes constructed in accordance with the invention;

Fig. 11 shows a tube similar to Fig. 3 but with the parts arranged as in a tube of commercial design, the tubes being provided with a transparent wax or similar coating in contradistinction to Fig. 3, wherein the tube has an opaque coating;

Fig. 12 is a fragmentary view of a tube of modified construction wherein the main anode is surrounded by a metal tube;

Fig. 13 shows a modified arrangement of a heater disposed inside the glass tube;

Fig. 14 shows diagrammatically a fire and smoke detecting apparatus embodying the present invention.

The trigger tube B in Fig. 1 has two main electrodes consisting of a cold cathode K, and a main anode A, and has also a starter anode Z, the cathode and starter anode forming, in the illustrated embodiment, a starter gap and the cathode and main anode forming a main gap. Usually the breakdown voltage of the starter gap will be considerably smaller than the breakdown voltage of the main gap. The cathode is connected directly with the negative side of a voltage supply D, while the connection from the main anode goes through the coil of an electromechanical relay R to the positive side of this same supply. A control device E, which may contain a photocell or an ionization chamber, and which is able to supply a sufficient voltage to break down the starter gap of the cold cathode tube, but which is able to produce only a very small current, is connected with its negative output to the cathode and with its positive output to the starter anode of the glow tube. A small storage condenser C of, for example, 30 $\mu\mu$f. is also provided between the starter anode and the cathode. The anode voltage, applied be-

tween anode and cathode for example 200 volts, is chosen in such a manner as to be substantially higher than the sustaining voltage of the main gap, but insufficient to initiate a discharge by itself, that is, without an auxiliary discharge of sufficient strength in the starter gap.

The circuit operates in the following manner: After applying only the anode voltage, nothing happens, as it is unable to break down the tube. If, however, the control device delivers a small signal or output current, the condenser will gradually be charged and eventually the voltage across the starter gap will reach the breakdown value. At this moment, a current will start across the starter gap and, being supplied by the charge stored in the storage condenser, it will increase momentarily to a value which is much larger than the available control current. This short, but relatively strong pulse of current in the starter gap, is sufficient to lower substantially the breakdown voltage of the main gap and to enable the previously insufficient anode voltage to initiate a discharge between cathode and main anode. This current will energize the coil of the relay and operate its contacts, and thereby operate any desired alarm or other circuit.

The peak current through the starter gap, which controls this control operation, has to be much larger than the average control current as available from the controlling device E. The function of the described circuit is, therefore, dependent on an unstable breakdown in the starter gap together with a pulse of high current. Such a pulse, however, is not sure to occur, except under the conditions provided by the present invention, since it is very dependent on the tube characteristics and operating conditions. In tubes of known construction there will be no observable definite breakdown of the starter gap, but rather a more or less steady discharge at very low current and near the breakdown voltage of the starter gap.

The first condition for a reasonably strong starting pulse across the starter gap is a sufficient difference between the breakdown voltage and the sustaining voltage of such gap, so that a sufficient amount of energy can be taken out of the storage condenser during development of the pulse. But in spite of such a sufficient difference, a more or less steady "Townsend" discharge at the value of the available control current is to be expected, if the current-voltage characteristic of the gap does not show a negative resistance slope from the beginning on, that is, if the breakdown voltage of the starter gap is reached only on a certain minimum current, and if the control current is lower than this breakdown current.

This is illustrated by the diagram of Fig. 2. Curve **1** shows the current-voltage characteristic in the case of known tubes which are subjected to outside radiation which ionizes the gas or liberates electrons from surfaces inside the tube, as by the photoeffect on the cathode K: curve **2** shows the characteristics of a tube which is filled with neon with only traces of argon. In both of curves **1** and **2** the current-voltage characteristic rises to and goes through a maximum before entering a region of negative resistance. The diagram shows that in both cases the breakdown voltage is reached only at a certain breakdown current I_{b1} and I_{b2}, and the starter gap discharge will stabilize itself at the value of I_c of the available control current, if I_c is smaller than I_{b1} or I_{b2}. As already indicated, the shape of curve **1** is determined by the formation of ions or electrons within the tube by some accidental outside radiation, such as light, which may liberate electrons at one of the inner surfaces of the tube, or radioactive radiations, which form ions and electrons within the gas space. Even a very small number of charge carriers resulting from outside radiation may have a very large influence on the shape of the current-voltage characteristic at very low currents. This arises from the fact that with increasing voltage, these charge carriers cause gas amplification within the gas space of the tube as well as emission of new charge carriers from the electrode surfaces which are struck by the accelerated ions and electrons.

As is known in the art, the sensitivity of tubes of this general type can be improved if means and measures are provided for eliminating or at least greatly reducing the effects of such outside radiations by appropriate shielding of the tube in order to obtain a desirable current-voltage characteristic of the starter gap. However, such shielding alone is not sufficient to provide a characteristic of continuously negative slope. My investigations have shown that it is necessary also to select a proper gas filling for the tube and to take account of the geometry within the tube. Thus I have found that even in the absence of outside radiation a characteristic such as is represented by curve **2** of Fig. 2 which, while more favorable than curve **1**, is still not satisfactory, will be obtained where the tube is filled with a mixture of neon and argon wherein the argon content is too low. A neon-argon mixture with an argon-content of at least 2%, the pressure being more than 60 mm. of Hg for an argon content of 2% and decreasing gradually as the argon content increases, in combination with certain geometrical relationships which will be described below, has shown good performance. These specific gas fillings are presented only by way of example; other gases and mixtures thereof as known in the art and at various pressures may be employed with good results. It will be understood that the different variables, such as character of the gas filling, its pressure, the size and spacing of the electrodes, etc., are functionally interrelated, so that a change in one will generally be accompanied by changes in the other variables for best results, and it is therefore impossible to set out the various gas compositions and pressures and sizes and distances of electrodes for all possible conditions. However, by taking into account the several variables discussed herein, optimum discharge conditions can be ensured for any particular size or type of tube by simple preliminary experimentation. With adequate shielding and geometry and/or proper choice of gas filling and pressure, the characteristic of the starter gap should show a negative resistance slope from the very beginning as is indicated by curve **3** of Fig. 2, which represents a desirable form of characteristic curve.

There will now be considered the further conditions that must be met if the starter gap is to be broken down with the charge of a small condenser. In many arrangements of a condenser in parallel with the starter gap a steady discharge may be observed in a wide region of low currents and despite a negative current-voltage characteristic. This is due to the very slow build-up of ionization which will occur if the applied voltage is very little above the breakdown voltage. It will be evident that as soon as the discharge current in the starter gap increases above the value at which the current is supplied by the control device E (Fig. 1), any further increase has to go on at the expense of the energy stored in the condenser C. If the build-up of ionization is too slow on discharge through the starter gap, the condenser will be discharged before a sufficiently high peak current has been reached, and the starter pulse will be relatively long but too weak to trigger the tube. A fast build-up of ionization, on the other hand, will discharge the condenser in much shorter time and to a larger extent, and will, therefore, provide the desirable strong trigger pulse which is needed to operate the tube within reasonable margins.

The present invention accordingly contemplates a cold cathode discharge tube in which a very small control current is capable of producing a strong pulse of current in the starter gap and is characterized in addition to the shielding and selection of the proper gas filling and pressure for attaining a continuously negative current-voltage characteristic, also by the provision of a sufficient difference between the breakdown and sustaining voltage

in the starter gap, and of correlated geometrical relationships of the starter gap which will tend to bring about a fast build-up of the ionization.

To the above might be added a further condition, the creation of even a very slight excess voltage above the static point of breakdown. With a finite charge rate of the condenser, such an excess voltage is achieved during the first period of build-up of ionization when the discharge current in the starter gap is still even smaller than the control current. This time is still relatively long (for example, 10 milliseconds) and it is even increased by the so called statistical ignition lag, i. e., the time which elapses before a first electron formed by outside radiation starts the formation of a discharge, the ignition lag being the larger the better the screening of the tube from such radiation. At the same time, it will be seen that the breakdown current cannot be reduced to indiscriminately small values.

With reference to the geometrical relationships of the starter gap, at least one of the electrodes of the starter gap, in accordance with the invention, is made of relatively small area. Where only one electrode is of small area, it is preferably the anode, which may be in the form of a thin wire which is preferably spaced at a rather small distance from the cathode. This makes it possible to utilize control currents which under suitable circumstances may be as low as 10^{-12} A. A small surface anode tends to increase the breakdown voltage of the gap, while it has little influence on its sustaining voltage. I have found also that a small anode surface will increase the negative slope of the current-voltage characteristic at very low currents. This is due to the fact that in the case of a very small electrode a small current will provide a relatively large current density with corresponding space-charge effects. A narrow electrode spacing, in combination with a sufficient gas pressure, will shorten the period for the build-up of ionization, and thereby insure a high-current trigger pulse across the starter gap.

I have also found that it is desirable to avoid the presence of insulating components, for example, glass or porcelain, at the edge or in the vicinity of the starter gap, as they have an unfavorable effect on the development of the condenser discharge. This can be attributed to two causes; first, the insulating components may become charged, this resulting in interference with the field, and secondly, interfering secondary discharges may develop by way of these insulating components since the insulation is never infinitely efficient. The result is in both cases a field distortion with an effect similar to that which would be obtained if the starter anode had too large a surface.

Figs. 3 to 13 show examples of tubes incorporating in various ways the features of the invention described hereinabove. In Figs. 3, 4, 7, 8, 9, 10 and 11 the starter anodes are in the form of anode tips or wire ends Z which are opposed to a cathode K of relatively large superficial area. The cathode of the starter gap is at the same time the cathode of the main discharge gap, the anode of the main gap being shown at A. In Fig. 5, the starter anode takes the form, not of a tip or point, but of a thin wire parallel to the cathode.

The cathode may consist of a nickel or molybdenum plate and may be coated with a layer of barium or other material with a low work function, as is well known in the art; if desired, the cathode may be left uncoated. The starter anode Z may be formed by a platinum wire having a diameter of about 0.010" and spaced about 0.025" from the cathode. The cathode itself may be of rectangular form, of about ⅜" by ½", but it may be of any other desired shape. The cathode area is determined by tube size and desired output current. It may have a thickness of about 0.010".

The main anode A may be a nickel wire of 0.020" diameter and placed about ¼" from the cathode. If desired the main anode may be surrounded by a further electrode in the form of a section of nickel tubing of about ⅛" diameter which extends for about 1/16 of an inch above the upper edge of the main anode, in order to obtain further increase in the breakdown voltage of the main gap. In Fig. 5 this further electrode is in the form of a grid S and is insulatedly supported within the tube, while in Fig. 12 the additional electrode is shown at S' with its surface imperforate. The electrode S of Fig. 5 is not connected to an outside source of potential but acquires a potential within the tube which can freely adjust itself. In the structure of Fig. 12, which shows a satisfactory commercial embodiment of the internal structure according to Fig. 5, the additional or intermediate electrode S' may be given a fixed potential from an outside source in any suitable manner.

In the tube of Fig. 6 the ignition does not take place towards the cathode of the main gap, but between the pointed or wire anode of the main gap and a grid-type starter cathode Z of large superficial area. Both in this tube as well as in all of the other illustrated tubes the arrangement is such that the starter gap is not influenced or interfered with by insulating components located in the vicinity thereof.

It is not necessary for the starter electrode and the main anode to be arranged on the same side of the cathode. Thus the cathode may be of grid-like design, the starter electrode and the main anode being disposed on opposite sides of such grid, as shown in Fig. 4.

A further manner of providing between cathode and main anode a breakdown voltage substantially above the sustaining voltage so as to insure the availability of sufficient power to operate normal electromagnetic relays in the main circuit with relatively small current intensity when breakdown of the main gap takes place, other than the measures shown in Figs. 5 and 12, consists in disposing insulating elements in the main gap so as to hinder discharge across such gap. This can, for example, be accomplished by arranging a concentric glass, porcelain or other insulating tube G about the main anode A, as shown in Fig. 4.

As shown in Figs. 3 to 11, the lead-in of the starter electrode is disposed as far as practicably possible from the lead-ins of the cathode and main anode, the lead-in of the starter anode entering the tube at a point which is preferably at the opposite end or side of the tube from those of other electrodes. With the extremely low control current values contemplated, the superficial insulation of glass will usually be found to be insufficient and in accordance with the invention the glass is expediently coated with a layer of wax, resin or silicon. This insulating coat is shown at W and can simultaneously function also as a light-excluding screen as shown in Fig. 3, and so may be composed of non-transparent wax or resin, however, the insulating coat W may also be transparent, as indicated in Fig. 11. In certain cases it may be desirable to separate the lead-in of the starter electrode from the other lead-ins by a conductive potential ring. The advantages of this precaution are, on the one hand, that it creates definite conditions and, on the other hand, that it affords the possibility of reducing the voltage across the insulation point, and with it the undesirable leakage currents, when a suitable voltage is applied to the potential ring. The ring is shown at P in Figs. 3 and 10 along with the insulating and screening coating W. It may be biased to a potential near the breakdown potential of the starter electrode Z.

A further measure for improving the surface insulation consists in preventing deposit of moisture by warming the surface slightly above the temperature of the ambient atmosphere. This is conveniently achieved by arranging a heating resistance H inside the tube, as shown in Figs. 8, 10 and 13, the resistance being heated by the application of a suitable auxiliary voltage.

Fig. 11 shows a construction embodying a number of

preferred features, in that the starter electrode Z is in the form of a thin wire having its end portion bent toward the cathode K of the main discharge gap, the area of the cathode being large in comparison with that of the starter electrode which functions as an anode. The tube is also provided with a radiation-excluding screen W of non-transparent material, as described hereinabove.

In Fig. 12, the starter electrode Z functions as a cathode in relation to the anode A disposed within the tubular additional electrode S' which, as already indicated, may be given a fixed potential from an outside source.

Fig. 13 shows a further modification in which the cathode K is disposed between the main anode A and the starter electrode Z. In this construction there is provided a heater H, as indicated above.

The tube may be filled with either of the gas fillings indicated above (such as argon or a mixture of neon and about three percent argon) at the pressures disclosed above. The applied voltages will be determined by the specific requirements of the tube, and the optimum relationships can be determined by simple experiment. In a typical case, the sustaining voltages of both gaps may be 70 volts, the breakdown voltage of the starter gap 100 volts, and the breakdown voltage of the main gap, without starting trigger pulse, about 300 volts. The trigger pulse coming from a 30 $\mu\mu$f. condenser can diminish the breakdown voltage of the main gap sufficiently so as to break it down with 200 volts. Arrangement of the control discharge in a path with the main discharge is desirable for obtaining easy transfer of the flash from one to the other.

It is important to provide a high degree of insulation not only in the leads into the tube but also in the connections to the starter electrode; in particular, the insulation of the condenser C must meet the same high requirements. The several figures illustrate various arrangements by which this can be achieved in a simple manner. In Fig. 7, the condenser is arranged completely inside the tube. In Fig. 8, the condenser consists of a conductive coat *Ck* with the cathode potential on the outside of the glow-discharge tube, and the conductive coat *Cz* with the starter electrode potential on the inner wall of the tube. In Fig. 9, the outside coat *Cz* is connected to the starter electrode and the inside coat *Ck* to the cathode. Fig. 10 shows an arrangement with an air condenser without any additional surface insulation point, one of the electrodes *Cz* of the condenser being secured directly to the starter electrode Z while the electrode *Ck* of the condenser surrounds the first electrode concentrically and is connected to the cathode.

The device of the present invention is utilizable wherever it is desired to amplify feeble currents for control purposes in the manner of a relay. It is particularly suitable in conjunction with photo-cells or ionization chambers. It is not necessary, however, to effect ignition by actual charging up of the condenser; ignition can, for instance, be initiated by a subsequent reduction in the capacitance of a charged condenser (as by increasing the distance between the plates), so that the voltage rise associated therewith effects breakdown of the starter gap.

Fig. 14 shows my above described tube and circuit embodied in a fire and smoke detecting device similar to the one disclosed in my application, Serial No. 384,478, now Patent No. 2,702,898, dated February 22, 1955, filed October 6, 1953, as a continuation of my prior application Ser. No. 108,015, filed August 1, 1949, now abandoned. The controlling elements may be a photoelectric cell **1** and an ionization chamber **4**, connected in series. The cathode **2** of the photoelectric cell **1** and the anode **5** of the open ionization chamber **4** are connected with each other, with one plate of the capacitance C, and with the starter anode Z of the cold cathode tube B. The cathode K of the tube, the other plate of capacitance C and the cathode **6** of the ionization chamber **4** are directly connected with the negative side of supply D, which provides a D. C. voltage of 200 volts. The positive side of this supply goes through the coil of relay R to the anode **3** of the photoelectric cell **1** and to the main anode A of the tube B. A light beam **12**, coming from a source of light **13** and passing through a lens **14**, passes through the neighborhood of the photosensitive layer of cell **1** without striking it directly. A resistance element **8** is connected in parallel with cell **1**. The air in ionization chamber **4** is made slightly conductive by radiation coming from the radioactive preparation **7**. The function of the two electrodes **10** and **11** will be explained later.

The operation of the device is as follows: The conductivities of the ionization chamber **4**, the resistance element **8** and the photoelectric cell **1** are chosen so as to provide normally a potential on the starter anode Z which is somewhat too low to trigger tube B. In the presence of smoke or other visible matter suspended in the air, some of the light of beam **12** is diffracted in a diffuse manner and part of it will strike the photosensitive layer **2**, thus increasing the conductivity of the cell **1**. In addition, the presence of smoke or invisible combustion gases interferes with the ionizing action of the radiation in chamber **4**, as explained in Patent No. 2,465,377, dated March 29, 1949, to Walter C. Jaeger. In this manner, the conductivity of the ionization chamber **4** is reduced. Either of the effects on photoelectric cell and ionization chamber alone, or the combination of both, will increase the potential on the starter anode Z and may therefore trigger the tube B. It will be evident that it is not necessary to employ both the photoelectric cell **1** and the ionization chamber **4** in the circuit; either one can operate to trigger the tube B, but greater sensitivity and reliability will be secured if both are used in the manner shown.

The resistance element may be another ionization chamber, as disclosed in my above-mentioned application, whereby compensation of the influence of changes in gas density on the potential of the starter anode Z is effected. However, this compensation can be obtained in other ways, and the resistance element **8** can then be dispensed with. The potential of the starter anode Z may then be adjusted by a bias voltage or by controlling the conductivity of the photoelectric cell **1**, for example, by some small standard illumination.

Instead of a photoelectric cell **1**, or in parallel with it, there may be connected the pair of electrodes **10** and **11**, which form a chamber **9**. Chamber **9** controls the conductivity of the air to be tested and adds to the rise of potential at the starter anode Z in case of the presence of ions such as are known to be formed in a flame. In a preferred arrangement the air might first be deionized in such a chamber before being allowed to enter the ionization chamber **4**, where ions coming from the outside would have an undesirable effect. An arrangement of a deionizing chamber in series with an ionization chamber is described in U. S. Patent No. 2,408,051 to Donelian, issued September 24, 1946. In Fig. 14 the arrow **22** indicates the stream of the gas to be tested; Donelian realizes this stream by the use of concentric chambers. Many other combinations of such elements as ionization chambers, conductivity chambers and photo or thermosensitive devices could easily be designed by those skilled in the art, but their usefulness as reliable alarm devices depends largely on a sufficiently simple and reliable way of amplifying the often extremely small available currents. The tube and circuit, which are the main object of this invention, lend themselves readily as a suitable amplifier, which, without use of additional stages, permits of the operation of a large variety of electromechanical devices. As the tube is of the cold cathode type, which draws no current in the state of readiness, it offers the additional and very important advantages of using no standby power and of not being subjected to wear over indefinitely long periods of readiness.

The shielding of the tube against external radiation can

be effected, as already indicated, with the aid of the coating W. However, the tube may, if desired, be shielded by a metallic sheath or screen F, as is shown diagrammatically in Fig. 1.

Although certain specific values have been suggested hereinabove for the several variables, it will be understood that many other combinations are possible which will lead to similar results and that the inter-relationship of these variables is such that upon change in one of them, a compensating change may have to be made in one or more of the other variables. As will be evident from the foregoing, the several variables such as electrode sizes and distances, gas pressure and gas composition are interrelated and can be varied within reasonable limits, if care is taken to maintain the important characteristics of the tube, as explained hereinabove. Thus the capacity of the condenser may vary between about 10 and 100 $\mu\mu$f. depending upon the size of the control current, the available voltage, etc., but with any particular magnitude of the capacitance there will be an optimum relationship among the various physical magnitudes within the tube, such as the sizes, the distances of the electrodes and the gas pressure, and also the specific gas composition. While therefore all of these factors can be varied within reasonable limits, it will be understood that such variation may depend upon compensating variations in the other variables within the tube and the impressed voltages.

I claim:

1. A device for amplifying an electric current of the order of 10^{-7} to 10^{-12} A., comprising a cold cathode gas-filled discharge tube having a sub-atmospheric internal pressure and having a pair of main electrodes consisting of a main cathode and a main anode forming a main gap, a starter electrode forming with one of the main electrodes a starter gap, and a condenser of less than 100 $\mu\mu$f. connected between said one main electrode and the starter electrode and adapted to be connected with the source of low current to be amplified so as to be charged thereby, the geometrical dimensions of the starter gap being small in comparison with the main gap, so as to provide a high current density on breakdown of the starter gap, the said starter gap being characterised by a continuously negative slope of its current-voltage characteristic on discharge of the condenser between at least a current of the order of the current to be amplified, i. e., 10^{-12} to 10^{-7} A. and up to the current at which the characteristic reaches the sustaining voltage of the glow discharge, the breakdown voltage of the starter gap on discharge being of the order of at least 20 volts, whereby there is produced a short pulse of current in the starter gap with rapid build-up of ionization as soon as the voltage across such gap reaches a value near its breakdown voltage to initiate discharge across the main gap.

2. A device according to claim 1 provided with means for shielding the tube against external radiation.

3. A device according to claim 1, wherein the starter electrode is the anode of the starter gap, said starter anode being small in comparison to the cathode.

4. A device according to claim 1, wherein the starter electrode is an anode and is in the form of a thin wire.

5. A device according to claim 1, wherein the filling gas is argon or a mixture of neon and argon, containing about 3% of argon.

6. A device according to claim 1, wherein the electrodes are so disposed that the control discharge takes place between the starter electrode, acting as a cathode and a main anode.

7. A device according to claim 1, wherein an insulating element is disposed in the main gap to raise the breakdown voltage of such gap.

8. A device according to claim 1, including a fourth electrode disposed in the main gap to raise the breakdown voltage of such gap.

9. A device according to claim 1, wherein the condenser is in the form of an air condenser, one of whose terminals is secured directly to the lead-in of the starter electrode, whereby no supplementary surface insulation areas arise.

10. A device according to claim 1, including a metallic screen between the main anode and cathode and acting to raise the main gap breakdown voltage, said screen being connected to the outside of the tube for the application of a fixed potential thereto.

11. A device for amplifying an electric current of the order of 10^{-7} to 10^{-12} A., comprising a cold cathode gas-filled discharge tube having a pair of main electrodes consisting of a main cathode and a main anode forming a main gap, a starter anode forming a starter gap with the main cathode, a condenser of less than 100 $\mu\mu$f. connected between said starter anode and main cathode and connected with the source of low current to be amplified so as to be charged thereby, said tube being filled with rare gas of sub-atmospheric pressure, and means for shielding the tube against outside radiation, the starter anode being in the form of a wire having a diameter of about 0.010" and spaced about 0.025" from the cathode when the latter has an area of about $\frac{3}{16}$ sq. in. and the main anode is spaced about $\frac{1}{4}$" from the cathode, the breakdown voltage of the starter gap being about 100 volts and that of the main gap without the starting trigger pulse being about 300 volts, the sustaining voltages of both gaps being about 70 volts, the starter gap being characterized by a continuously negative slope of its current-voltage characteristic on discharge of the condenser between at least a current of the order of the current to be amplified, i. e. 10^{-12} to 10^{-7} A., and up to the current at which the characteristic reaches the sustaining voltage of the glow discharge, the breakdown voltage of the starter gap on discharge being of the order of at least 20 volts, whereby there is produced a short pulse of current in the starter gap with rapid build-up of ionization as soon as the voltage across such gap reaches a value near its breakdown voltage to initiate discharge across the main gap.

12. A device according to claim 1, wherein the filling gas is argon.

13. A device according to claim 1, wherein the filling gas is a mixture containing neon and about 3% of argon.

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