ULTRAVIOLET DETECTOR SYSTEM WITH MEANS TO KEEP ELECTRODES CONTAMINATION FREE

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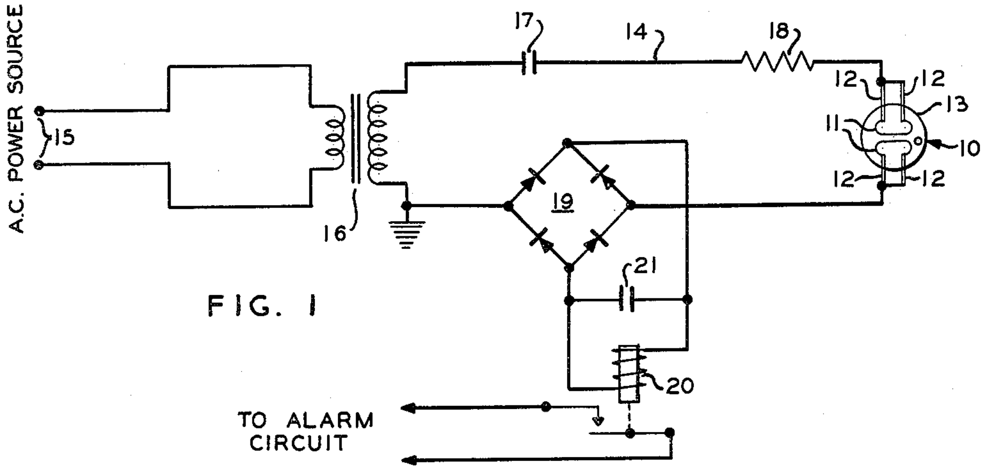

FIG. 1

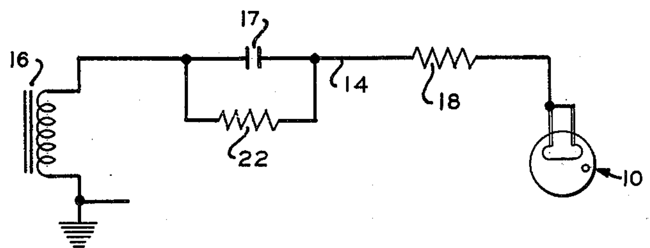

FIG. 1a

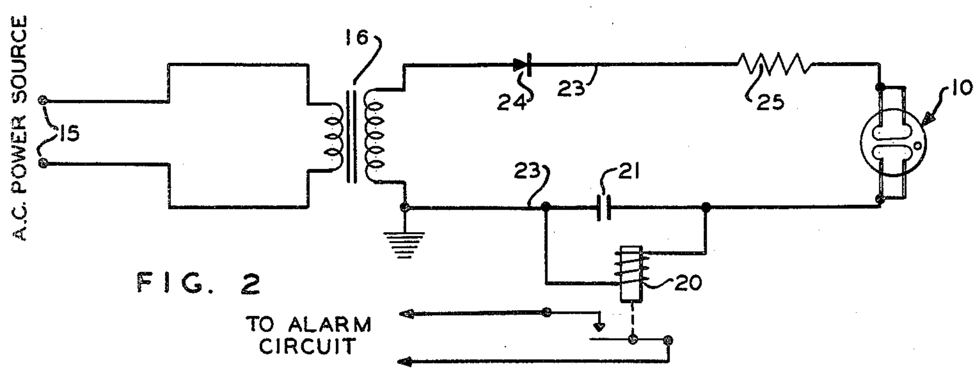

FIG. 2

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ULTRAVIOLET DETECTOR SYSTEM WITH MEANS TO KEEP ELECTRODES CONTAMINATION-FREE

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6 Claims. (Cl. 250—83.6)

This application is a continuation of our application Serial No. 83,755, filed January 19, 1961, and being abandoned upon the filing of this application.

This invention relates to ultraviolet detector systems utilizing detector tubes of the type described in the pending Howling application Serial No. 801,625, filed March 24, 1959 (now Patent No. 3,047,761, dated July 31, 1962). More particularly, the invention relates to a novel combination of such detector tube with an electrical operating circuit which causes the tube to have a more stable response.

An object of the invention is to provide improvements in ultraviolet detector systems of the character mentioned which are adapted to maintain the systems stable in their operation especially as to their spectral response.

A further object is to provide special operating circuits for the detector tube abovementioned, which are designed to subject the tube to operating conditions effective to cause the tube to have a uniform and stable response.

A further object is to provide improved means and methods of maintaining the electrodes of the aforesaid tube clean of low work function contaminants such as would alter the spectral response of the tube.

The above tube is operated in either an A.C. circuit or in a D.C. pulsing circuit so that the tube is quenched by the drop of the voltage at the end of each voltage pulse, thereby enabling the tube to be operated in a low impedance circuit for maximum power efficiency. Preferably, the tube is provided with symmetrical electrodes and is operated in an A.C. circuit so that it will be triggered and conduct current during some or all half cycles so long as the tube is subjected to incident photons sufficient to trigger a discharge of the tube. The tube electrodes are characterized as being free of sharp edges, projections or other discontinuities as well as of any contaminants throughout the working region, this being the entire region wherein an emitted electron responsive to an incident photon is capable of triggering an avalanche discharge between the electrodes. However, it has been found that during use of the tubes contaminants such as alkali metal atoms are released from the glass envelopes when commercial glass materials are used, and that these contaminants will lodge on the electrodes within the working region and there lower the work function and cause the tubes to respond randomly to ultraviolet radiation of longer wave length than was intended. This random response is particularly objectionable as to tubes which are designed to be solar blind.

It has been found in accordance with the invention that if each glow discharge covers the electrodes throughout the entire working region the contaminants are removed by ion bombardment and the spectral response remains stable throughout the life of the tubes without the tubes becoming responsive to radiation in the solar spectrum. However, if the glow discharge covers the entire working region for the duration of each voltage pulse of the supply circuit, the electrodes will overheat and emit electrons thermionically to cause the tubes to lock-on—i.e., fail to quench at the end of the voltage pulses after the incident photon radiation has ceased. This difficulty has however been coped with successfully in

accordance with the present invention by using an operating circuit which causes the glow to cover the entire working region for at least an instant of each discharge without the R.M.S. current reaching such value that would overheat the electrodes to the point of producing thermionic emission. As will appear, these conditions have been met by suitably operating circuits according to the invention to provide a stable operation throughout the life of the tube.

These and other objects and features of the invention will be apparent from the following description and the appended claims.

In the description of the invention, reference is had to accompanying drawings of which:

FIGURE 1 is a schematic circuit diagram of an illustrative operating circuit for the above detector tube wherein the tube is operated from an A.C. voltage source;

FIGURE 1*a* is a fractional drawing of the circuit of FIGURE 1 showing a modification thereof; and

FIGURE 2 is a schematic circuit diagram of an illustrative operating circuit for the above detector tube wherein the tube is operated by D.C. pulses.

The ultraviolet detector tube **10** shown in the figures comprises preferably two tungsten-wire electrodes **11** having semicircular end portions directed away from each other and welded to supporting pins **12** and having rectilinear intermediate portions parallel to each other. As an example, the supporting pins and tungsten wires may be .050″ and .017″ respectively in diameter and the spacing between the rectilinear portions of the tungsten wires may be .040″. The tungsten wires, supporting pins and weld joints are electropolished and refined as described in the aforesaid Howling patent so that they have ultra-smooth surfaces free of edges, projections or other discontinuities as well as of any contaminants. It is particularly important that the weld joints to the supporting pins be smooth, round and free of contaminants in order to confine the working region to a space encompassing only the parallel portions and portions of the half-circle end formations of the tungsten-wire electrodes.

The tube is provided with a commercial ultraviolet transmitting glass such as of the borosilicate family, for example, Corning glass No. 9741. The supporting pins **12** are extended through graded glass seals in the base of the envelope. The envelope **10** is pumped to a high vacuum while the tungsten wire electrodes are heated, the envelope is filled with a substantially pure hydrogen to a pressure typically of about 10 cm. Hg to obtain a striking voltage of about 700 volts under ultraviolet excitation and, finally, the tungsten-wire electrodes are subjected to positive ion bombardment to remove any trace of impurity.

A result of the refining operations carried out in the construction of the above ultraviolet tube is that all elemental surface areas of the electrodes within the working region are made to have a uniformly high work function causing the tube to have a spectral response sensitive only to radiations of wave lengths below about 2800 to 3000 Angstrom units. Thus, the tube is inherently highly responsive to ultraviolet radiation but unresponsive to sunlight in the normal atmosphere.

It is found however that the commercial ultraviolet transmitting glasses contain alkali metals as a fundamental ingredient which appear to reside as ions in the interstices of the open lattice strucure of the silica, boron, oxygen and other ingredients of the glasses. These alkali metal ions are released into the gas space under influence of the heat of ion bombardment and of the electric fields occurring during the discharge. Some of these alkali metal ions will lodge on the electrode surfaces in the working region and there reduce the work function to provide incremental surface areas responsive to ultraviolet radiation of longer wave length within the solar spectrum—i.e., to wave lengths above 2800 to 3000 Angstrom units. Although these contaminants can be largely avoided by using an alkali-free glass for the envelope such as a pure fused quartz, such procedure is not an economical one and would leave still a source of contaminants from the graded glass seals where the supporting pins are brought into the envelope.

During the course of making numerous tests on the above ultraviolet detector tube it was observed that under certain operating conditions the tubes had a more stable response with less tendency to be sensitive to the longer wave length radiation. For example, tubes which had been operated so that the glow of ionized gas covered the entire working region of the electrodes, or which were operated under relatively intense unidirectional current pulses were found to remain relatively insensitive to the longer wave length radiation. However, tubes which were operated under such relatively intense A.C. current would lock-on. These observations led to the realization that a glow discharge has the effect of cleaning the electrode surface by ionic bombardment and that upon extending the glow discharge throughout the working region the tubes will have a stable response but that the R.M.S. value of the current flow through the tube must be limited so that the electrodes will not overheat and emit electrons causing lock-on by thermionic emission. Further tests have shown that high level instantaneous spikes of current sufficient to extend the glow discharge throughout the entire working region are sufficient to keep the electrodes clean of low work function contaminants collected during the previous pulse and/or during the quenched condition, and that such instantaneous high level spikes of current will not overheat the electrodes and cause thermionic emission so long as the R.M.S. value of the current is below the critical threshold value.

A preferred operating circuit for maintaining the ultraviolet tube **10** during its operation with a stabilized response is the A.C. circuit **14** shown in FIGURE 1. This circuit is connected to a potential source **15** through a step-up transformer **16** so that the circuit will receive an R.M.S. voltage of the order of 700 volts. Connected serially in the operating circuit is a condenser **17**, resistor **18**, the ultraviolet detector tube **10** and a full-wave rectifier **19**. The output of the rectifier is connected to a relay **20** shunted by a condenser **21**. Typical component values are as follows: condenser **17**, .075 mfd.; resistor **18**, 3600 ohms; and condenser **21**, 50 mfd. Preferably the resistor **18** is connected in the circuit in close physical relationship to the ultraviolet tube **10** so as to prevent a flow of stray capacity current which may quench the discharge in the ultraviolet tube and prevent operation of the relay.

Upon the application of a voltage pulse across the circuit **14** from the source **15** and the simultaneous triggering of the ultraviolet tube by incident photons, an initial current spike will flow due to the sudden collapse of the voltage across the detector tube from 700 or more volts to 330 volts. This current spike has a value determined by the resistor **18** since the condenser **17** does not at the outset support any voltage. The resistor **18** is chosen so that the initial current spike will produce a glow discharge in the tube **10** throughout the entire working region, and the RC time constant of the condenser **17** and resistor **18** is chosen so that each current pulse will decay rapidly enough to prevent overheating of the electrodes over a continued period of ultraviolet excitation of the tube. Although the time interval of each half cycle of applied voltage is 8.3 milliseconds for a 60 c.p.s. source of voltage, a series RC time constant of only .27 millisecond is found highly satisfactory in preserving the stability of the spectral response of the tube while providing still an ample output current of the order of 10 milliamps R.M.S. at saturation. The bridge rectifier **19** provides full wave rectification of the discharge pulses for the D.C. relay **20**, and the condenser **21** smooths out the succesive pulses into a steady current.

In a more specific sense it may be noted that as the supply voltage rises in the circuit **14** from zero a nearly equal counter voltage builds up across the ultraviolet tube **10** because until the tube is fired it is the highest impedance element in the circuit. When the counter voltage across the tube **10** reaches the firing voltage of approximately 700 volts, the tube discharges if there is incident photon radiation to trigger it. The instant a discharge occurs in the ultraviolet tube **10** the voltage across the tube falls to approximately 330 volts. The initial current is determined by the resistor **18** and the net voltage in the circuit across this resistor. The instant the current begins to flow a charge begins to build up on the condenser **17** causing a potential to build up across the condenser and causing the current to begin to decay. When the source potential falls below 330 volts the tube is quenched. At this instant there is a potential across the condenser **17** in a direction to aid the discharge in the next half cycle. For the values of the circuit components given above, the peak value of the current spikes in the succeeding half cycles reach a value of the order of 1.85 ampere.

Because of the increasing voltage which becomes applied across the ultraviolet tube **10** after the first pulse as described above, there is a possibility of multiple counts—a condition wherein the probability of a pulse on the next half cycle is greater than that on the first half cycle for the same radiation excitation. A means of reducing this tendency towards multiple counting while still retaining the advantage of the condenser **17** in maintaining a stable spectral response of the tube without incurring overheating of the electrodes, is in connecting a resistor **22** of appropriate value in parallel with the condenser **17** as shown in FIGURE 1*a*. This resistor bleeds off some of the charge on the condenser during the period between pulses to mitigate the possibility of multiple counts. A suitable time constant for the RC parallel circuit is about half of the time of each half cycle of the applied voltage. For example, for a voltage source of 60 c.p.s., with a time duration of 8.3 milliseconds for each half cycle, a time constant of 4.5 milliseconds giving a decay to about 30% in the condenser charge during each half cycle is found to produce very satisfactory results. To this end the resistor **22** may have a value of the order of 60,000 ohms. Since the series RC time constant of the condenser **17** and the resistor **18** is only of the order of .27 millisecond as a typical value, a representative value for the parallel RC time constant is of the order of sixteen times that of the series RC time constant.

An observance of the current pulses through the ultraviolet tube **10** shows that they decay exponentially in the manner of discharge currents through RC circuits. The point in each half voltage cycle at which the ultraviolet tube fires depends upon the intensity of the radiation excitation. If the excitation is high the current pulses start during the early part of each voltage wave and the peak amplitude of the current is low. If the excitation is low the current pulses tend to start when the voltage is at its peak value and the peak value of the current is therefore relatively high.

A function of the condenser **21** in parallel with the relay **20** is not only to smooth out the current pulses into a steady current but also to act as an integrating means so that a series of successive pulses is required to operate the relay. The condenser **21** therefore serves to prevent occasional single pulses from operating the relay.

In FIGURE 2 there is shown an operating circuit for the ultraviolet tube **10** wherein the operation is from unidirectional voltage pulses instead of from an A.C. voltage source. This embodiment of the invention is now covered by our divisional application Serial No. 274,272, filed April 19, 1963. Connected in this case across the secondary winding of the transformer **16** is a circuit 23 serially including a half-way rectifier 24, resistor 25, the ultraviolet tube 10 and the relay 20 and condenser 21 in parallel. The resistor 25 is chosen to provide a current flow which will extend the glow discharge throughout the working region of the ultraviolet tube when the tube is triggered by incident ultraviolet radiation. There being no condenser in the circuit 23 the triggered discharge current flows at a rate dependent upon the applied potential on the circuit 23 and the resistance 25, the current flow continuing until the voltage supplied to the ultraviolet tube has fallen below about 330 volts. A typical value for the resistor 25 is of the order of 6,000 ohms. Preferably, the resistor 25 is connected in the circuit in close physical relationship to the ultraviolet tube 10 so as to prevent a flow of stray capacity currents which may quench the ultraviolet tube prematurely and prevent operation of the relay 20. Although the current flow during each discharge pulse does not drop greatly from its initial value, and may even pass through a peak value, before the tube 10 is quenched the greater duration of the current at or near its peak valve does not produce overheating of the electrodes because the current flows only during alternate half cycles.

The embodiments of our invention herein particularly described are intended to be illustrative and not limitative of our invention since the same is subject to other changes and modifications without departure from the scope of our invention, which we endeavor to set forth in the following claims.

We claim:

1. An ultraviolet detector system comprising an ultraviolet detector tube having a sealed glass envelope, an ionizing gas and a pair of electrodes having intermediate portions in an adjacent relationship and diverging portions supported at their ends to provide a working region not embracing the supported end portions and wherein the emission of an electron from incident ultraviolet radiation is capable of triggering the tube into a glow discharge when a striking potential is applied across the electrodes, said tube being characterized in that an applied voltage of a predetermined value will extend the glow discharge throughout said working region to clean the electrodes of contaminants from said glass envelope tending to change the spectral response of the tube, and an

operating circuit for said detector tube including a utilization device responsive to flow of discharge current in said tube when the tube is triggered by ultraviolet radiation and a source of voltage providing successive voltage pulses across said tube of which each pulse reaches at least said predetermined value to cause the glow discharge to extend throughout the working region.

2. The ultraviolet detector system set forth in claim 1 wherein said voltage source is A.C. and wherein said opertaing circuit includes a condenser connected effectively in series with said voltage source, detector tube and utilization device.

3. The ultraviolet detector system set forth in claim 2 wherein said operating circuit includes a resistor and condenser connected in series with said detector tube and having an RC time constant adapted to limit the R.M.S. value of the successive current pulses to a level insufficient to cause overheating of said electrodes when the detector tube is subjected to utraviolet radiation of a saturation level.

4. The ultraviolet detector system set forth in claim 3 wherein said RC time constant is of the order of 1/30 of the time period of each pulse of applied voltage of said source.

5. The ultraviolet detector system set forth in claim 3 including a resistor connected in parallel with said condenser for bleeding off a portion of the charge on said condenser between successive current discharge pulses in said detector tube.

6. The ultraviolet detector system set forth in claim 5 wherein the RC time constant of said condenser and parallel resistor is of the order of one-half the time period of each half-cycle of said A.C. source of voltage.

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