

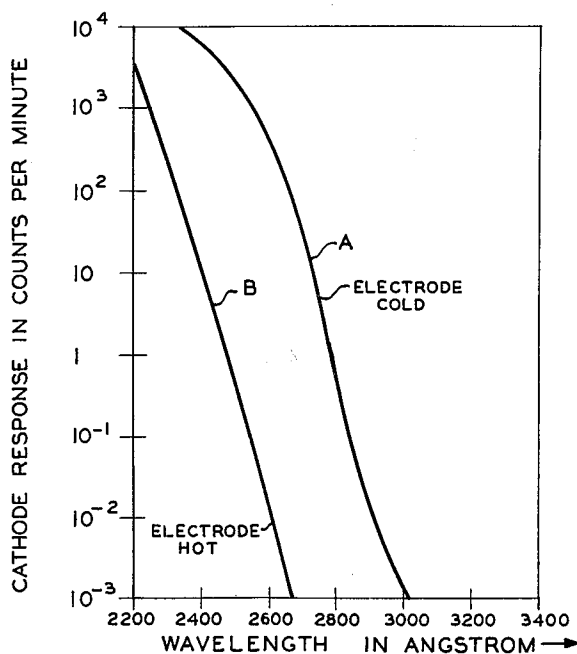
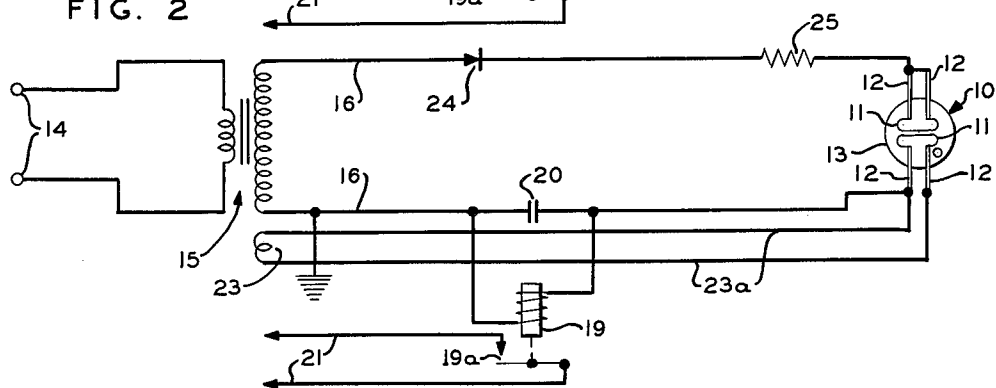
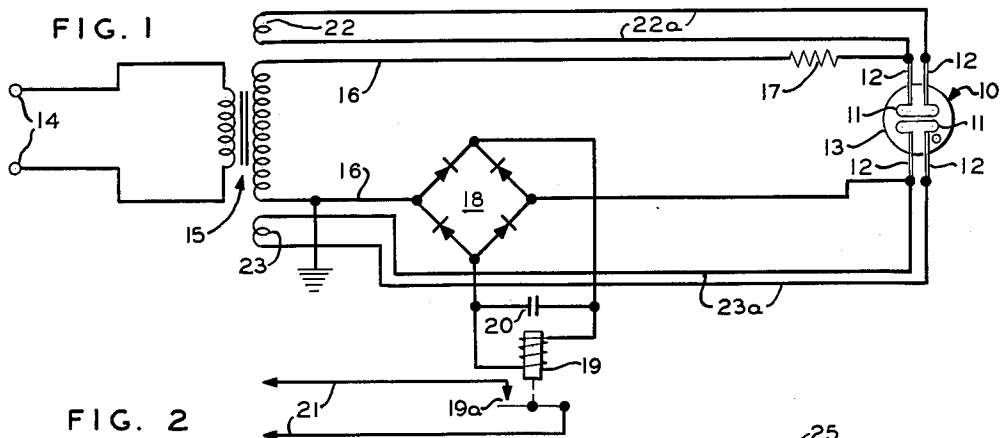
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U-V DETECTOR TUBE WITH HEATED ELECTRODES

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3,103,589 U-V DETECTOR TUBE WITH HEATED ELECTRODES

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This invention relates to U-V detector systems utilizing detector tubes of the type described in my pending application Serial No. 801,625, filed March 24, 1959, now U.S. Patent No. 3,047,761 granted July 31, 1962. More particularly, the invention relates to improvements in such systems which are adapted to shift the spectral response of the U-V tubes to shorter wave lengths and to maintain the spectral response within a fixed band throughout the life of the tubes.

In the preferred form of the above detector tubes the same are provided with symmetrical electrodes rendering the tubes capable of passing alternating current when the tubes are subjected to an A.C. firing voltage and to incident photon radiation, the term "firing voltage" being herein used to mean a voltage sufficient to cause a tube to undergo a glow discharge and pass current when the tube is excited by incident photons. The electrodes of this type of U-V tube 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 in the tube wherein an emitted electron responsive to an incident photon is capable of triggering a glow discharge between the electrodes. The effect of these refinements in the tube structure is to cause the electrodes to have a uniformly high work function throughout the working region with the result that the tubes respond with high sensitivity to U-V radiation but are essentially solar blind in the normal atmosphere.

It has been found however that if a contaminant lodges on the electrode surface within the working region it lowers the work function at that point to render the tube responsive to photon radiation of longer wave length, even wave lengths in the solar spectrum. Such point becomes therefore a controlling one in the operation of the tube since it will emit electrons preferentially to other surface portions of the electrodes located within the working region. The lodging of contaminants in the working region therefore gives rise to a shifting and unpredictable spectral response.

A source of these contaminants are alkali metal ions released from the glass envelope when the envelope is made of the commercial U-V transmitting glasses instead of the costly fused quartz glass. These commercial glasses contain alkali metals which are believed to reside as ions in the interstices of the open lattice structure of silica, boron, oxygen and other elements of which the glass is composed. The alkali metal ions of the glass are mobile and are released into the gaseous atmosphere within the glass envelope of the tube under influence of the energy of ion bombardment and of the electric fields occurring during a counting discharge. Even if the more costly fused quartz glass were used for the envelope, there would still be a source of contaminants from the alkali metal containing graded glass seals whereby the supporting pins are brought into the envelope.

In accordance with the invention it has been found that the deleterious effect of these contaminants on the operation of the U-V tube can be eliminated by heating the cathode electrode or electrodes, depending on whether the tube is operated from unidirectional voltage pulses or from an A.C. voltage source, to an elevated temperature. This elevated temperature is however not to exceed about 300° C. to 400° C. at which electrons would begin to be emitted

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thermionically because thermionic emission would produce lock-on—i.e., a condition in which the tube would spontaneously and repeatedly reignite the discharge during each applied successive voltage pulse. In this respect, it is to be noted that the term "voltage pulses" is herein employed with reference to both A.C. operation wherein the successive pulses occur with alternate polarity and rectified A.C. operation wherein the successive pulses occur with the same polarity. The effect of so heating the cathode electrode is believed to be one of causing any positive ion contaminant to re-evaporate the instant it strikes the electrode thus leaving the electrode surface essentially free from contaminants even though it is exposed to an ambient of positive ion contamination.

An object of the invention is to provide novel and simple means for controllably shifting the spectral response of U-V detecting systems to radiation of shorter wave length and for rigidly maintaining the spectral response in a definite chosen band.

Another object is to provide a U-V detector system with a stable spectral response by electrically heating the electrode or electrodes serving as the cathode or cathodes of the U-V tube.

Another object is to provide novel utilization circuits for the abovementioned U-V detector tube which are adapted to heat the cathode electrode or electrodes by a heating current obtained from the power source.

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 the accompanying drawings, of which:

FIGURE 1 is a schematic circuit diagram of a U-V detector system illustrating one form of the invention;

FIGURE 2 is a schematic circuit diagram of a U-V detector system illustrating another form of the invention; and

FIGURE 3 is a graph showing the spectral shift in the response of the U-V tube when the cathode electrode is heated in accordance with the invention.

The U-V detector tube 10 shown in the figures comprises preferably two tungsten wire electrodes 11 having parallel intermediate portions and semicircular end portions directed away from each other and welded to supporting pins 12 at their outer ends. As an example, the supporting pins and tungsten wires may be .050" and .017" respectively in diameter and the spacing between the rectilinear parallel portions may be .040". The electrodes, supporting pins and weld joints are electropolished and refined as described in my aforesaid application so that they have ultra-smooth surfaces free of edges, projections or other discontinuities as well as of any contaminants.

An envelope 13 of the tube 10 is made preferably of a commercial U-V transmitting glass such as of lime glass, soda glass or Corning glass, No. 9741 of the borosilicate family. The supporting pins are extended through graded glass seals in the base of the envelope. The envelope is pumped to a high vacuum while the tungsten wire electrodes are heated approximately to their melting temperature, and is then filled with pure hydrogen to a pressure of from three to ten cms. Hg to provide a striking voltage under U-V excitation typically about 700 volts D.C. Finally, the tungsten wire electrodes are subjected to ion bombardment with positive hydrogen ions to remove any last trace of impurity.

To assure a stable operation of the tube, it is important that there be no combination of sharp edges, projections and contaminants at any outlying point of the internal structure of the tube together with such spacing between the electrodes at that point as would give rise to a sufficiently intense electric field and a sufficiently low work

function to cause there a discharge to occur responsive to incident photons in preference to a discharge in the intended working region encompassing only the adjacent smooth uniform portions of the tungsten wire electrodes. A result of the refining operations carried out in the construction of the above U-V tube as abovedescribed is to confine all discharges to a single working region and to provide all electrode surface areas within that working region with 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 made inherently highly responsive to ultraviolet radiation but substantially unresponsive to sunlight in the normal atmosphere.

As before noted, the commercial U-V transmitting glasses contain alkali metal ions which are released into the gas space during use of the tube and which tend to lodge on the electrode surfaces within the working region and there reduce the work function. This causes the U-V tube to respond erratically to radiation of longer wave lengths extending into the solar spectrum. By the present invention the deleterious effect of these contaminants is overcome by heating the cathode electrode or electrodes to an elevated temperature short of that which would produce thermionic emission of electrons.

In the illustrative schematic diagram of one embodiment of the invention shown in FIGURE 1 an A.C. voltage is applied to the U-V tube 10 as from a 110 volt power line indicated at 14 through a voltage step-up transformer 15 designed to produce a firing voltage across the secondary winding of the order of 700 volts r.m.s. A circuit 16 is connected to the secondary winding and serially includes a current limiting resistor 17 typically of the order of 15,000 ohms, the tube 10 and a full wave rectifier 18. The output of the rectifier is connected to a D.C. relay 19 paralleled by a time delay and filter condenser 20. The relay 19 has a pair of contacts 19a connected in a load or control circuit 21.

Each tungsten wire electrode 11 of the tube 10 has two lead-out terminals formed by the supporting pins 12, as shown. These terminals enable the electrodes to be heated electrically to drive out occluded gases and contaminants in the processing of the tube, and are utilized in the present invention to heat the electrodes during the use of the tube. Since the tube is operated on an A.C. basis in the embodiment shown in FIGURE 1, causing the electrodes to operate alternately as a cathode, both electrodes are required to be heated in this embodiment. For this purpose the transformer 15 is provided with two heater windings 22 and 23 connected respectively by circuits 22a and 23a across the two electrodes. The heater circuit connections are preferably made directly to the pins or terminals 12, and the operating circuit 16 is made directly to one of each of the two pairs of terminals, as shown, so as to divorce the heater and operating circuits as much as possible.

In the embodiment of the invention in FIGURE 2 a unidirectional pulsing voltage is applied across the U-V tube 10 by connecting it through a rectifier 24 to the secondary winding of the transformer 15. This rectifier may be either of the half-wave or full-wave type, the former being shown by way of example. Included in the circuit 16 is a current limiting resistor 25, and the D.C. relay 19 paralleled by the filter condenser 20. Since only one of the electrodes serves in this embodiment as cathode only that electrode is electrically heated in accordance with the invention as from the heater winding 23 through the circuit 23a.

In the foregoing embodiments of the invention the heater windings 22 and 23 are set to provide a heater current sufficient to heat the electrodes to a temperature of 300° C. to 400° C. since this is the maximum temperature which tungsten electrodes may be heated in a hydrogen ambient without producing thermionic emission and a resultant self counting of the tube.

When the cathode electrode or electrodes, as the case may be, are heated as abovedescribed the spectral response is shifted from curve A to curve B as shown in FIGURE 3. This shift in the spectral response renders the tube totally unresponsive to radiations of wave lengths above about 2700 Angstrom units making the tube totally solar blind in the normal atmosphere. This shift in the spectral response enhances the reliability of the tube especially in aircraft fire-detection applications since an absolute solar blindness is an essentiality in such application. Still further, it is found that the spectral shift is accompanied by a very marked improvement in the stability of operation of the tube causing the tube to respond only to a definite spectral range throughout its entire life. This enhanced stability is an important factor in nearly all practical applications of the tube since it means that the tube is well-nigh totally free of the random and spurious counting which has been such a common defect of U-V detecting tubes as heretofore produced.

It is believed that the spectral shift which results from the heat biasing of the cathode electrode is probably due to a modification of the charge transfer characteristics existing at the electrode-gas surface. It appears, for instance, that the additional thermal energy dissipated in the electrodes increases the effective concentration of absorbed negative gas dipoles on the surface and raises the work function of the gas-electrode surface.

It is also believed the stabilizing influence on the work function produced by the invention arises, at least in great measure, from the fact that when the cathode electrode is so heated the contaminants from the glass envelope are prevented from lodging on the electrode surfaces. Tests have shown that when alkali metal ions dissociated from the glass envelope by the mechanisms herein described deposit on the electrodes they produce an unstable variation in the work function. When a tube is operated over a continuous period without heating the electrodes there is a continuous growth of contaminant rising to an equilibrated value which may maximize at a level of 0.3 monolayer impurity absorbed positive ions or sodium and/or potassium. Such level of contamination can shift the spectral response in an indeterminate and uncontrollable way into the visible spectrum. Tests have shown that the higher the temperature of the electrode per cycle—i.e., the higher the power dissipation—the less the amount of deposited contaminant. The limit is reached when the thermal lock-on occurs—i.e., when self re-ignition of the discharge occurs by the thermally emitted electrons on the next voltage cycle. However, it is found that when an electrode is heated only to approximately 300° C. to 400° C. it will not emit electrons and will yet remain substantially clean of contaminants and maintain its originally assigned work function.

The means by which this cleaning action takes place is believed to arise from the probability that the heat supplied to the cathode electrode changes the ability of an impinging positive ion to adhere to the electrode surface. In other words, when a positive ion contaminant strikes the heated cathode surface it is effectively re-evaporated from the surface at once to leave the cathode surface clean even though the cathode is immersed in an ambient of positive ion contamination. An alternative hypothesis is that the surface sites of the electrode available for absorption of positive ion contaminants are drastically reduced by a modification in the charge transfer characteristics of the absorbed filling gas when the electrode is subjected to a heat bias in accordance with the invention. It is to be understood however that the explanations herein given of the operation of the invention are intended only to provide a more fundamental understanding of the invention without giving rise to any unnecessary limitation of the invention.

The embodiments of my invention herein particularly shown and described are intended to be illustrative and

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not necessarily limitative of the invention since the same is subject to changes and modifications without departure from the scope of the invention, which I endeavor to express according to the following claims:

I claim:

1. A U-V detecting system comprising a U-V detector tube having an envelope of a U-V transmitting glass and electrodes in said envelope with portions in an adjacent relationship providing a desired working region wherein the emission of an electron responsive to an incident photon is capable of triggering a glow discharge between the electrodes when a firing voltage is applied across the electrodes, an electrical circuit for applying successive voltage pulses across said electrodes each having at least momentarily a value capable of striking a discharge between the electrodes when the electrodes are excited by incident photons, and heating means applied to said U-V tube to cause the electrode serving as cathode during each discharge to be heated to an elevated temperature.

2. A U-V detecting system comprising a U-V detector tube having an envelope of a U-V transmitting glass, a substantially pure hydrogen gas in said envelope, a pair of tungsten wire electrodes in said envelope having intermediate portions in an adjacent relationship providing a desired working region wherein the emission of an electron from an incident photon is capable of triggering a glow discharge between the electrodes when a voltage of predetermined value is applied thereacross, each of said electrodes having a pair of end terminals leading out of said envelope in sealed relation thereto, said U-V transmitting glass being characterized as containing alkali metal ions which are released into the gas space during glow discharge and which tend to lodge on the electrode surfaces and shift the spectral response of the tube, and means for maintaining the electrodes free of said released alkali metal ions to maintain the spectral response of the tube at a stable value comprising current supply means connected to said end terminals for electrically heating the electrode serving as cathode during each discharge.

3. The U-V detecting system set forth in claim 2 wherein said heating means is adapted to heat the cathode electrode to a temperature in the range from about 300° C. to 400° C.

4. A U-V detecting system comprising a U-V detector tube having a glass envelope capable of transmitting ultra-violet light, a substantially pure hydrogen gas in said envelope, a pair of identical electrodes in said envelope having portions in an adjacent relationship to provide a desired working region wherein the emission of an electron from an incident photon is capable of triggering a glow discharge in either direction depending upon the polarity of the applied voltage, means for applying an A.C. potential across said electrodes of a firing magnitude capable of producing a glow discharge when the tube is excited by incident photons, and means for electrically heating both of said electrodes to an elevated temperature sufficient to shift the spectral response of the tube to shorter wave lengths but insufficient to heat the electrodes to the point of causing thermionic emission therefrom.

5. A U-V detecting system comprising a U-V detector tube having a glass envelope capable of transmitting ultra-violet light, a substantially pure hydrogen gas in said envelope, a pair of tungsten wire electrodes in said envelope having intermediate portions in an adjacent relationship providing a desired working region wherein the

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emission of an electron responsive to an incident photon is capable of triggering a glow discharge between the electrodes when a voltage of predetermined value is applied across the electrodes, each of said electrodes having a pair of end terminals leading out of said envelope in sealed relation thereto, circuit means connected to said end terminals for applying successive unidirectional voltage pulses across said electrodes each having at least said predetermined firing value whereby to cause a current pulse through the tube responsive to each applied voltage pulse while the tube is excited by incident photons, and circuit means connected across the terminals of the cathode electrode of said tube for passing a current therethrough to electrically heat the same to an elevated temperature sufficient to reduce the spectral response of said tube to ultra-violet radiation of wave lengths below about 2700 Angstrom units but insufficient to cause thermionic emission from the cathode electrode.

6. A U-V detecting system comprising a U-V detector tube having a glass envelope capable of transmitting ultra-violet light, a pair of electrodes in said envelope with portions in an adjacent relationship providing a desired working region wherein the emission of an electron responsive to an incident photon is capable of triggering a glow discharge between the electrodes when a voltage of predetermined value is applied across the electrodes, a voltage step-up transformer having a primary winding adapted to be connected to an A.C. source of potential and a secondary winding for providing a firing voltage capable of striking a discharge between the electrodes of said tube when the tube is excited by incident photons, a secondary circuit connected across said secondary winding and serially including a U-V tube and a load device, and heater windings in said transformer connected respectively across said electrodes whereby the electrodes are heated to an above-normal temperature sufficient to stabilize the spectral response of said tube but insufficient to cause thermionic emission from the electrodes.

7. A U-V detecting system comprising a U-V detector tube having a glass envelope capable of transmitting ultra-violet light and a pair of electrodes in said envelope with portions in an adjacent relationship providing a desired working region wherein the emission of an electron responsive to an incident photon is capable of triggering a glow discharge between the electrodes when a voltage of predetermined value is applied across the electrodes, a voltage step-up transformer having a primary winding adapted to be connected to an A.C. power line and a secondary winding for providing a firing voltage capable of striking a glow discharge between the electrodes of said tube when the electrodes are excited by incident photons, a secondary circuit connected across said secondary winding and serially including a rectifying means and said U-V tube and a load device, and a heater winding in said transformer serially connected with the cathode electrode of said tube to heat said electrode to a temperature capable of stabilizing the spectral response of said tube but insufficient to cause thermionic emission from the cathode electrode.

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