March 17, 1959 G. BERGSON 2,878,406

PHOTOELECTRIC TUBE

Filed July 23, 1954

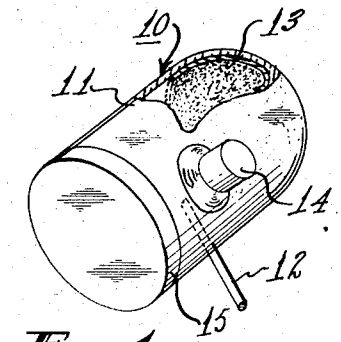


FIG. 1a.

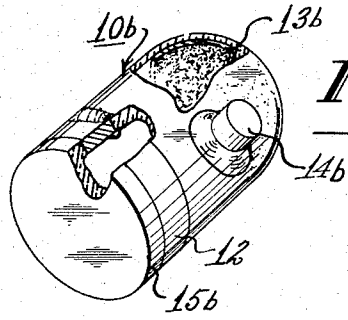


FIG. 1b.

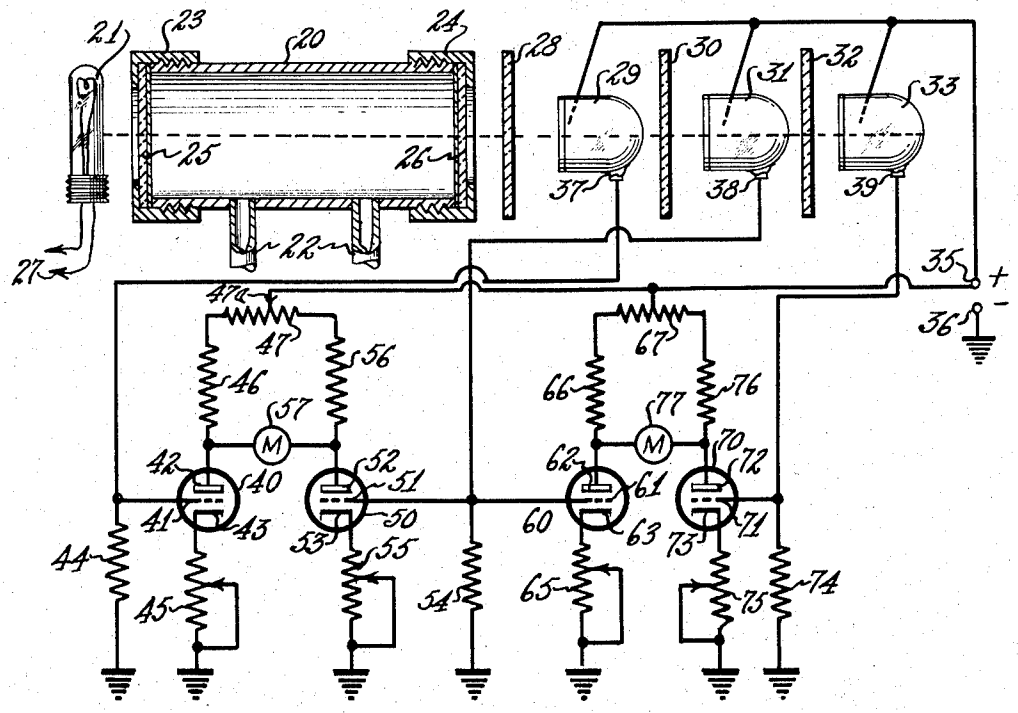


FIG. 2.

INVENTOR.
GUSTAV BERGSON

BY Eugene M. Whitacre
ATTORNEY

United States Patent Office 2,878,406 Patented Mar. 17, 1959

2,878,406

PHOTOELECTRIC TUBE

Gustav Bergson, Philadelphia, Pa.

Application July 23, 1954, Serial No. 445,233

5 Claims. (Cl. 313—102)

This invention relates to photo-sensitive detectors, and more particularly to photoelectric cells of the type having photoemissive cathodes.

The primary object of this invention is to provide a photoelectric tube which may be energized by radiant energy passing completely through the tube. To accomplish this object, the photoelectric tube cathode is formed as a semi-transparent surface through which the radiant energy may pass.

Another object of this invention is to provide a photo-sensitive tube which is characterized by its simplicity of construction and its economy of manufacture.

A still further object of this invention is to provide a photoelectric tube which is responsive to predetermined wavelengths within the ultra violet range.

A further object of this invention is to provide a photoelectric tube for use in a system wherein radiant energy is passed through successive tubes, each tube being responsive to different components of the composite spectra of radiant energy passed therethrough.

The novel features that are considered characteristic of this invention are set forth with more particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

Figure 1*a* is a perspective view of a photoelectric tube constructed in accordance with the invention;

Figure 1*b* is a perspective view of a photoelectric tube similar to that shown in Figure 1*a*, but having a modified anode structure; and

Figure 2 is a diagrammatic longitudinal sectional view of a gas analyzing apparatus including a schematic circuit diagram of an electrical indicating circuit, illustrating one form of equipment with which the photoelectric tubes of the invention may be used.

Referring now to the drawings and particularly to Figure 1*a*, the photoelectric tube **10** of the invention is provided with an envelope **11**. A rod-shaped anode **12** projects through the side of the envelope **11** to provide an external connection point and is preferably of a material which lends itself satisfactorily to a glass to metal seal. A semi-transparent cathode **13** of suitable photo-sensitive material is deposited on the inner rear window of the envelope **11** and is provided with an external terminal connection point **14** which has a conductive connection through the wall of the envelope **11**. The term photo-sensitive cathode, as used herein, refers to a cathode which is sensitive to wavelengths in at least a portion of the spectra of radiant energy including infra-red, ultra violet, and visible wavelengths. The open end of the envelope is sealed by a front window **15** which renders the tube airtight so as to maintain a vacuum. The front window and envelope are made of a material which does not unreasonably attenuate wavelengths of the radiant energy which it is desired to detect.

The tube is generally cylindrical in shape so as to admit the radiant energy which is to energize the tube through the front window **15**, and allow the energy to pass through the cathode **13** and out of the tube to a second tube or the like, while at the same time energizing the cathode **13**.

One method of forming the cathode on the inner surface of the tube is by evaporation of the cathode material to be deposited. In this process, the cathode material is placed on a filament structure which is then placed near the surface to be coated and then heated to boil off the material. The process is continued until the desired degree of opacity is reached whereupon the evaporation is stopped. If desired, the filament structure may be left in the envelope to provide an anode element for the tube.

In one embodiment of the invention a platinum cathode is formed by coating a tungsten filament with platinum and evaporating the platinum onto the surface of the envelope of the tube. Those portions of the envelope which should not have a metallic coating such as those adjacent the anode element, are masked. After the evaporation process the masking material may be removed to provide a clean surface not having leakage paths formed by the evaporated material. The evaporation of the platinum onto the envelope is halted after the desired degree of transparency of the cathode was reached. The process may be carried out in a vacuum to prevent contamination of the platinum since the platinum itself without further activation is to serve as the cathode material of the tube. Since this tube as described is designed for use in the ultra violet region of the spectrum, the envelope and the front window are constructed of good quality quartz or some other material which is easily permeable by wavelengths in the ultra violet region.

The cathode material for a photoelectric tube constructed in accordance with the invention is primarily a matter of design. For the detection of radiant energy having wavelengths in the ultra violet region, the platinum cathode described above would be sensitive to wavelengths shorter than 196 millimicrons. That is, electrons would be released from the platinum cathode by wavelengths of the ultra violet spectrum shorter than 196 millimicrons, which electrons would be attracted to the anode of the tube. A cathode of tungsten would be responsive to wavelengths of substantially 260 millimicrons or shorter. The wavelengths at which various metals become responsive is a property of the work function of the metal, and the formulas for computing the response of various metals together with the physical characteristics of the metals are set forth in the text "Photoelectric Phenomena" by Hughes and Du Bridge, first edition 1932.

If desired, the cathode of the phototubes may be made sensitive to the visible spectra or to the infra-red spectra by sensitizing with a caesium or some other sensitizing material. The sensitizing material may be enclosed in a pill and placed within the envelope of the tube, and after the tube is evacuated and baked, the sensitizing material is released from the pill and deposited on the cathode to render it photo-sensitive. If after the application of the sensitizing material, the cathode becomes too opaque, heat may be applied to the cathode to drive off the excess caesium.

In Figure 1*b*, a modification of the photoelectric tube **10** of Figure 1*a* is shown in which the anode structure is modified. An annular anode **12***b* is provided as part of the envelope structure. The anode should be of a material which lends itself to the making of a glass to metal seal. If desired, the anode could be located entirely within the envelope **11***b*, however, an external connection to such an anode would be required.

It is not intended that the invention be limited to a particular process of constructing the photoelectric tube or to particular cathode materials therefor, the above being described by way of example to enable a clear understanding of this invention.

Referring to Figure 2, which shows a gas analyzing or testing equipment illustrating one form of apparatus in which the photoelectric tubes of the invention may be used, a sample of the gas to be tested is admitted into an absorption chamber **20** through a pair of inlet and outlet pipes **22**. If desired, the gas under test may be continuously passed through the absorption chamber **20**. The absorption chamber **20** has a cylindrical body portion with opposite ends thereof closed by the windows **25** and **26**. The windows **25** and **26** are tightly sealed with appropriate gaskets to the cylindrical body portion by any suitable fastening device such as a pair of screw-on caps **23** and **24**.

A source of radiations **21**, which by way of example, may be a source of ultra violet radiations such as a G4S11 lamp, which is connected with a pair of terminals **27** for supplying an energizing potential, is positioned adjacent to the window **25** for directing radiant energy into the absorption chamber **20**. The windows **25** and **26** are made of a material such as quartz or other material which is easily permeable by the radiant energy from the source **21**.

The beam emerging from the window **26** is directed successively through a series of photoelectric tubes **29**, **31** and **33** constructed in accordance with the invention, which have semi-transparent cathodes or cathodes which allow a portion of the beam to pass through and responsive to a wide range of ultra violet frequencies. A first optical filter **28** is interposed between the absorption chamber **20** and the photoelectric tube **29**. A second optical filter element **30** is interposed between the first photoelectric tube **29** and the second photoelectric tube **31**, and a third optical filter **32** is positioned between the second photoelectric tube **31** and the third photoelectric tube **33**.

In describing the operation of the gas analyzing system, it will be assumed that the gas under test contains two components which it is desired to measure. One of the components will be assumed, by way of example, to have a strong absorptive spectra at wavelengths around 185 millimicrons, and the other to have a strong absorptive spectra around 254 millimicrons. The beam emanating from the source **21** has a relatively wide band of ultra violet wavelengths including the wavelengths at 185 and 254 millimicrons. The beam is passed through the absorption chamber **20** which contains the gas sample having the two components mentioned above, and wavelengths at 254 and 185 millimicrons are at least partially absorbed by these components. The optical filter **28** attenuates wavelengths below 185 millimicrons so that any minor absorptive spectras of the components below 185 millimicrons will not affect the energization of the cathodes of the photoelectric tubes in the system. The filter **28** is optional equipment and is not necessary to the effective operation of the gas analyzing system.

It may be assumed that the photoelectric tubes **29**, **31** and **33** are of similar construction, and are responsive generally to all the wavelengths of interest in the ultra violet range. The cathode of the photoelectric tube **29** is therefore responsive to the wavelengths at both 185 and 254 millimicrons and will give a relative indication of the radiant energy at 185 and 254 millimicrons which is incident thereon as well as miscellaneous changes in absorption. The filter **30** attenuates the wavelengths of the radiant energy of 185 millimicrons or less, so that the second photoelectric tube **31** will only be affected by the relative absorption at 254 millimicrons as well as incidental changes in absorption by the windows in the absorption chamber **20**, the filters **28** and **30**, and the windows of the photoelectric tubes. The third photoelectric tube **33**, which is a comparison or standard cell, is connected in circuit with the second photoelectric tube to provide a differential indication of the relative absorption of the particular component at 254 millimicrons are sensitive. The filter **32**, which is located between the photoelectric tubes **32** and **33**, attenuates the wavelengths equal or less than 254 millimicrons so that the response of the cathode of the third photoelectric tube is essentially outside the range of any of the wavelengths absorbed by the components of the gas under test and serves as a standard comparison photocell whose current measures the changes in lamp intensity, window absorption of the absorption cell and the phototubes and filters, and the like.

The system could be continued upward in wavelengths for several cells so that several components contained in the gas mixture under test could be detected and measured. It is recognized that the filters could be incorporated as the front surface of the phototube thus eliminating an extra part. If desired, phototubes having cathodes which respond only at certain wavelengths could be used as well, as will be hereinafter described.

The photoelectric tubes **29**, **31** and **33** are each provided with an anode element and a cathode element. The anodes of the photoelectric tubes **29**, **31**, and **33** are connected with a terminal **35** which supplies a polarizing potential from a power source, not shown. A second power supply terminal **36** is connected with a point of fixed reference potential or ground.

The cathodes **37**, **38** and **39** of the photoelectric tubes **29**, **31** and **33**, respectively, are connected with the electrical indicating circuit. The cathode **37** is connected with a control electrode **41** of an amplifier tube **40** which also has an anode **42** and a cathode **43**. A resistor **44** is connected between the control electrode **41** and ground to provide a direct current grid return circuit for the tube **40**, and also to complete the direct current path of the photoelectric tube **29**. A variable cathode bias resistor **45** is connected between the cathode **43** and ground to provide an operating bias potential for the amplifier tube **40**. The anode **42** is connected through the resistor **46** and a point of the variable resistor **47** to the terminal **35**, which supplies the polarizing potential for the amplifier.

The cathode **38** of the photoelectric tube **31** is connected to the grids **51** and **61** of the amplifier tubes **50** and **60**, respectively. A resistor **54** provides a common grid return for the amplifier tubes **50** and **60**, and also serves to complete the direct current path of the photoelectric tube **31** to ground. The amplifier tube **50** includes, together with the grid **51**, an anode **52** and a cathode **53**. The cathode **53** is connected through a variable cathode bias resistor **54** to ground while the anode is connected through a resistor **56** and part of the variable resistor **47** to the terminal **35** which supplies the polarizing potential for the tube. A meter **57** is connected between the anodes **42** and **52** to indicate the differential anode potential of the tubes **40** and **50**, which is a function of the absorption of the wavelengths at 185 millimicrons as will hereinafter be explained.

As mentioned above, the cathode **58** of the photoelectric tube **31** is connected with the control electrode **61** of the amplifier tube **60**. The amplifier tube **60** also has an anode **61** and a cathode **63**. A variable cathode bias resistor **65** is connected between the cathode **63** and ground. The anode **62** is connected through an anode loading resistor **66** and a portion of a variable resistor **67** to the terminal **35** which supplies the polarizing potential for the amplifier tubes.

The cathode **39** of the photoelectric tube **33** is connected with a control electrode **71** of the amplifier tube **70**. A resistor **74** provides a grid return for the tube **70** and also serves to complete the direct current path of the photoelectric tube **33** to ground. The tube **70** has a cathode **73** which is connected to ground through a variable bias resistor **75**, and also has an anode **72** which is connected through an anode loading resistor **76** and a

portion of the variable resistor 67 to the polarizing potential terminal 35. A meter 77 is connected between the anodes 62 and 72 to provide means for indicating the differential anode potential which is a function of the absorption of the wavelengths at 254 millimicrons in the present example.

To adjust the system for operation, the tubes 40 and 50 should have equal anode potentials when none of the components of the gas to be detected are present, or in other words, when none of the radiant energy is absorbed. This may be done by evacuating the absorption chamber 20 or supplying a reference gas therein, and adjusting the tap 47*a* of the resistor 47 to increase the load resistance in the anode circuit of one of the tubes and reduce it in the anode circuit of the other tube. A sample of gas containing a component which absorbs ultra violet energy at 254 millimicrons and no components which absorb 185 millimicrons is then admitted to the absorption chamber and the cathode resistors 45 and 55 are adjusted so that the tubes 40 and 50 will operate on a predetermined portion of their operational curves whereby they will have equal response at the anodes thereof to the input signal from the tubes 29 and 31.

If a gas is introduced into the absorption chamber 20, which contains components that absorb wavelengths of 185 and 254 millimicrons respectively, the energization of the photoelectric tube 29 will be changed as a function of the absorption of the radiant energy by both components, in addition to the changes in absorption of radiant energy due to the filters, phototube windows, absorption chamber windows, etc. Since the filter 30 absorbs 185 millimicrons, the photoelectric tube 31 is responsive to changes in absorption of the radiant energy by the component which absorbs 254 millimicrons in addition to the other changes in absorption due to the filters, phototube windows, and absorption chamber windows, etc.

Thus the signals fed to the control electrodes 41 and 51, tubes 40 and 50 by the photoelectric tubes 29 and 31, are equal except to the extent of the changes in energization of the phototube 29 due to absorption of the 185 millimicrons wavelengths. Accordingly, this differential input voltage on the grids is amplified and appears between the anodes 42 and 52 of the tubes 40 and 50. The potential difference between the anodes 42 and 52, which is a function of the quantity of gas present which absorbs wavelengths at 185 millimicrons, is indicated on the meter 57.

In like manner, the reading on the meter 77 gives an indication of the relative quantity of the component of gas present in the sample which absorbs 254 millimicrons. The photoelectric tube 31 is responsive to change in absorption due to the presence of a component which absorbs 254 millimicrons in addition to the other miscellaneous absorptions. Since the filter 32 stops the 254 millimicrons, the energization of the phototube 33 is only due to the miscellaneous changes in absorption of the radiant energy. The outputs of the photoelectric tubes 31 and 33 are fed to the tubes 60 and 70 respectively, the only difference between the two being due to the absorption of the components of the gas at 254 millimicrons. The differential input voltage is amplified and appears between the anodes 62 and 72 which difference in potential is indicated by the meter 77. The readings of the meter 77 is thus a function of the absorption of radiant energy at 254 millimicrons and gives a relative indication of the quantity of a component of gas present in the absorption chamber 20 which has an absorption spectra at 254 millimicrons.

In another embodiment of the gas analyzing equipment, phototubes may be used which have cathodes that are sensitive at different predetermined wavelengths. For example, as described hereinbefore, certain metals are responsive to different wavelengths, hence by fabricating the cathodes of the photoelectric tubes with the proper materials, the system described above can function without the use of filter elements. Platinum is sensitive to wavelengths of about 196 millimicrons and shorter. Tungsten, on the other hand, is responsive to wavelengths of about 260 millimicrons and shorter. To incorporate photoelectric tubes into the system shown in Figure 1, the tube 29 would have a cathode of tungsten, thus being responsive to changes in the absorption at both 185 and 254 millimicrons, while the photoelectric tube 33 would have a cathode of platinum and would be responsive to only 185 millimicrons. The standard cell 33 would preferably be fabricated of a material responsive to a relatively wider range of ultra violet wavelengths, and would be provided with a filter to remove the 185 and 254 millimicron components. The phototubes could be connected in the electrical measuring circuit in the same manner as described above in connection with Figure 2.

In accordance with the foregoing description, an improved photoelectric tube of simplified construction has been provided which has a semi-transparent cathode which enables the tube to be energized by a beam of radiant energy passing therethrough.

What is claimed is:

1. A photoelectric tube including a tubular body member with a pair of transparent windows affixed to opposite ends thereof to form an air tight envelope and to provide an unobstructed path for radiant energy successively through said windows, an anode supported by said envelope, a semi-transparent photosensitive cathode coated on one of said windows, and terminal connection means for said cathode and anode accessible exteriorly of said envelope.

2. A photoelectric tube as defined in claim 1 wherein the semi-transparent photo-sensitive cathode element comprises a thin film of platinum.

3. A photoelectric tube for use in a gas analyzing system of the type wherein radiant energy is passed successively through the gas and a plurality of photoelectric tubes to measure the relative absorption by the gas of the various spectral components passed therethrough comprising in combination, an envelope having a tubular body member and first and second transparent windows positioned generally in parallel planes transverse to the axis of said tubular member at opposite ends thereof so that a path for radiant energy is provided successively through said first and second windows, said first window comprising a radiation permeable window, means providing an anode in said envelope, external circuit connection means for said anode extending through a wall of said envelope, means providing a semi-transparent coating of a photosensitive material on the inner surface of said second window, said semi-transparent coating being responsive to radiant energy passing along the axis of said envelope to release electrons, and external circuit connection means conductively connected with said semi-transparent coating of photosensitive material extending through the wall of said envelope.

4. A photoelectric tube responsive to predetermined wave lengths of radiant energy and adapted to pass radiant energy therethrough to a further utilization device comprising in combination a cylindrical envelope having one end thereof closed by an integral transparent spherical section, a transparent circular disc secured to the free end of said envelope to provide an air tight cover therefor, and to provide a radiation admitting window for said photoelectric tube, means providing an anode electrode within said envelope having external circuit connection means extending through the wall of said envelope, means providing a semi-transparent coating of a photosensitive material on the inner surface of said spherical section, said semi-transparent coating being responsive to radiant energy passing along the axis of

said envelope to release electrons, and external circuit connection means conductively connected with said semi-transparent coating of photosensitive material extending through the wall of said envelope.

5. A photoelectric tube for use in a gas analyzing system of the type wherein radiant energy is passed successively through the gas and a plurality of photoelectric tubes each adapted to be responsive to different bands of wave lengths of said radiant energy to measure the relative absorption by the gas of the various spectral components passed therethrough comprising in combination, a cylindrical envelope having a first and second oppositely disposed transparent window positioned generally in parallel planes transverse to the axis of said cylindrical envelope, said first window comprising an optical filter for eliminating certain of said wave lengths of said radiant energy incident thereon, means providing an anode in said envelope, external circuit connection means for said anode extending through the wall of said envelope, means providing a semi-transparent coating of a photosensitive material on the inner surface of said second window, said semi-transparent coating being responsive to radiant energy admitted through said first window and passing along the axis of said envelope to release electrons, and external circuit connection means conductively connected with said semi-transparent coating of photosensitive material extending through the wall of said envelope.

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