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M. S. GLASS
PHOTOELECTRIC TUBE
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2,178,227

FIG. 1

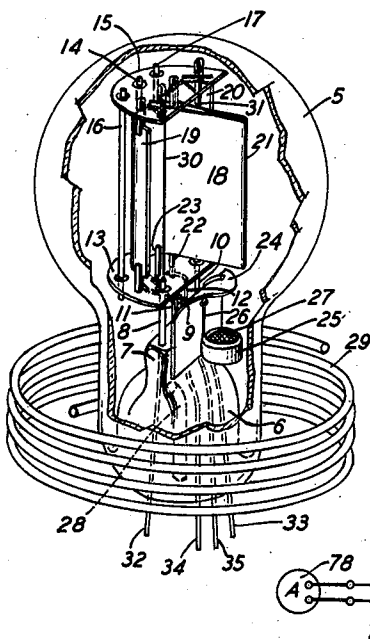


FIG. 4

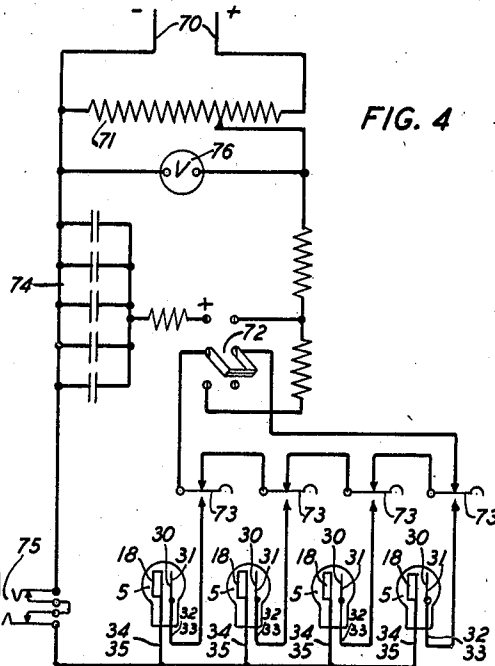


FIG. 2

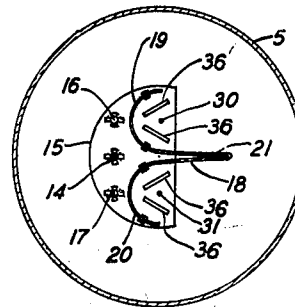
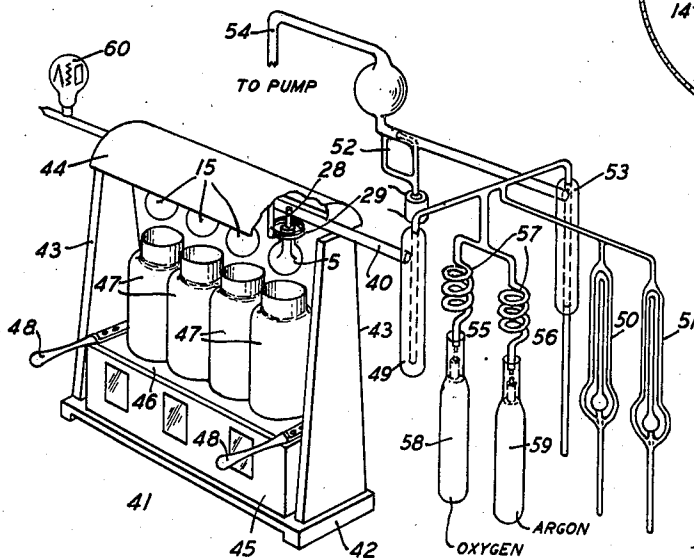


FIG. 3



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PHOTOELECTRIC TUBE

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10 Claims. (Cl. 250—166)

This invention relates to photoelectric tubes and more particularly to the electrode structure of such tubes.

An object of the invention is to provide an improved type of double anode photoelectric tube.

In an example of practice illustrative of this invention, a cathode plate and two anodes are mounted on a stem within an evacuated container. The cathode comprises a silver plate formed with two concave semi-cylindrical portions of semi-circular cross-section located edge to edge and joined by a folded portion extending tangentially from adjacent edges, the concave surfaces being sensitized by oxidation and treatment with caesium vapor. The two anodes are fine metal wires supported coaxially with the semi-cylindrical surfaces.

The continuously curved surfaces provided by the concave portions of the semi-cylinders facilitate the oxidation thereof and treatment with caesium vapor. The folded tangential portion prevents electrons emitted from one concave surface from passing to the anode located at the axis of the other concave surface when the anodes are used separately. However, if the anodes are connected together in use, the whole cathode surface may function as a continuous cathode because the folded portion is light sensitive as well as the concave portions.

Photoelectric tubes according to this invention are particularly useful in the projection of sound from the so-called push-pull sound records. When used for this purpose, the anodes are connected separately to the sound circuit. If it is desired to project sound from ordinary sound records, the anodes may be connected together. The light beam can then be projected on the whole surface of the cathode without loss of efficiency because there is no separation between the two portions of the cathode.

The invention will now be described more in detail having reference to the accompanying drawing.

Fig. 1 shows the structure of a completed photoelectric tube according to this invention;

Fig. 2 is a cross-section of the tube of Fig. 1 perpendicular to the axes of the electrodes and looking away from the stem;

Fig. 3 illustrates a pumping station suitable for processing four tubes concurrently; and

Fig. 4 is a schematic electric circuit used in processing such tubes.

Like reference characters are used to refer to identical elements in the various figures.

The photoelectric tube illustrated in Fig. 1 com-

prises a glass bulb 5 having a reentrant stem 6 sealed therein. The stem 6 is provided with a press 7 in which are sealed support wires 8, 9, 10, 11 and 12. To the upper ends of wires 8 and 10 a mica disc 13 is secured, the wires passing through eyelets in the disc and being welded thereto. A bent support wire 14 is welded intermediate its ends to wire 9, and after passing through an eyelet in mica disc 13, to which it is welded to give added support to disc 13, partially supports mica disc 15, being secured thereto by being welded to an eyelet in a hole in disc 15. Disc 15 is further supported by wires 16 and 17 extending between discs 13 and 15, the ends of which wires pass through and are welded to eyelets in the discs. The cathode 18 consists of a sheet of silver formed into two hollow semi-cylinders 19 and 20 and a folded portion 21 extending tangentially from the adjacent edges of portions 19 and 20. Cathode 18 is mounted between the mica discs 13 and 15 by means of U-shaped clips, the open ends of which clips are slipped over the edge of the cathode and welded together while the bent ends are passed through holes in the discs. The lower ends of clips 22 and 23 are also welded to support wires 11 and 12, respectively. The anode wires 30 and 31 are secured to the ends of wires 8 and 10, respectively, which extend through the eyelets in mica disc 13 and are held in place at their other ends by passing through holes in mica disc 15. These anode wires 30 and 31 are positioned coaxially of the semi-cylindrical portions 19 and 20, respectively, of cathode 18. These anodes are molybdenum wires, 10 mils in diameter. A nickel shield 24 is supported from the other end of bent wire 14. To this shield 24 is secured a metallic cup 25 by means of wire 26. Within the cup 25 is a mixture for producing caesium vapor when heated, the mixture being held in place by a piece of metal gauze 27. The stem 6 is provided with an exhaust tube 28.

A coil 29 is arranged to induce high frequency current in the metal cup 25 for heating the mixture within the cup to its reaction temperature. This coil 29 is used only during the processing of the tube.

Sealed to the press 7 are lead-in wires 32, 33, 34 and 35, connected respectively to support wires 8, 10, 11 and 12. Consequently, lead-in wires 32 and 33 are conductively connected respectively to anodes 30 and 31 while lead-in wires 34 and 35 are conductively connected respectively to portions 19 and 20 of cathode 18.

A portion of the glass bulb 5 is shown broken away for clearness of illustration.

The shape of the cathode 18 and location of the anode wires 30 and 31 are clearly shown in Fig. 2, which is a cross-section through the bulb 5 at its largest diameter perpendicular to the axes of the semi-cylindrical portions 19 and 20 looking toward the mica disc 15. Due to the configuration of the cathode 18 and location of the anodes 30 and 31 substantially all of the electrons emitted from either portion of the cathode 18 will be collected by the corresponding anode. In view of this fact, the efficiency of this tube, when used in the so-called push-pull projection circuit, is very high.

In order to lengthen the leakage paths along the mica surface between the anodes and cathode, slots 36 are cut in disc 15 and similar slots are cut in disc 13.

The electrodes and accessory structure carried by the stem 6 are fabricated before the stem is sealed into the glass bulb 5. The cathode 18 is formed from a polished silver sheet of a high degree of purity which has a clean mirror finish. The formed cathode is washed and reduced in hydrogen. The concave surfaces of the cathode have a diameter of approximately one-half inch, the folded portion extends approximately nine-sixteenths of an inch, and the length of the cathode is approximately one and three-eighths inches.

The caesium producing mixture within the cup 25 is in the form of a compressed pellet which is composed of approximately 3.5 milligrams of caesium chromate Cs_2CrO_4 , 22.5 milligrams of chromic oxide Cr_2O_3 , and 9 milligrams of powdered aluminum Al. These ingredients are carefully prepared, finely pulverized and thoroughly mixed in the proper proportions before being formed into pellets.

The pumping station illustrated in Fig. 3 is adapted for the processing of four tubes concurrently. The tubes 5 are sealed to a glass header 40 by exhaust tubes 26. This header 40 runs through an oven 41 which comprises a base 42 carrying end supports 43 on the upper ends of which is a metallic cap 44. An electric heater 45 between the supports 43 is surmounted by a removable cover 46 carrying four chimneys 47. This cover is provided with handles 48. The heater 45, cover 46 and chimneys 47 may be raised as a unit so that the chimneys surround the bulbs 5. Each chimney is provided with a slidable baffle (not shown) to control the convection air currents flowing therethrough. With the cover 46 and chimneys 47 removed, the heater 45 may be raised up against the cap 44 to completely surround the bulbs 5.

The header 40 is connected to a pumping apparatus comprising a liquid air trap 49, two McLeod gauges 50 and 51, mercury vapor pump 52 and mercury cut-off 53, and a vacuum pump (not shown) connected to tube 54.

Between the mercury cut-off 53 and the liquid air trap 49, two gas supply units 55 and 56 are connected to the pumping apparatus. These units comprise flexible coiled glass tubes 57 associated with gas containers 58 and 59 through mercury seals surrounding a pair of porous plugs 70 of "Lavite", which plugs when brought together permit gas to pass from the respective containers 58 and 59 to the bulbs 5 through the glass coil 57. An ionization manometer 60 is connected to the other end of the header 40.

An electrical circuit used during the process-

ing of four tubes while they are sealed on a pumping station is illustrated in Fig. 4. This circuit comprises conductors 70 adapted to be connected to a direct current source (not shown) and a potentiometer 71 for determining the potentials to be applied between cathodes 18 and anodes 30 and 31 in parallel of tubes 5. With the switch 72 in its lower position and jack 75 closed, a potential may be impressed on any one of tubes 5 by closing the lower contacts of switch 73 which is individual to such tube. With the switch 72 in its upper position the potential determined by potentiometer 71 is impressed through the upper contacts of all of switches 73 in series on condenser 74 which have a total capacitance of 5 microfarads. Condenser 74 can then be discharged through any of tubes 5 by closing the lower contacts of the corresponding switch 73. The voltage determined by potentiometer 71 is indicated by voltmeter 76. The current flowing through tubes 5 during a later stage of the processing is indicated by an ammeter 78 which may be connected into the circuit by inserting plug 77 into jack 75.

The processing of four tubes after the untreated assemblies have been sealed onto the header 40 will now be described.

The tubes 5 are sealed onto the header 40 with the concave sides of the cathode plates 18 facing directly forward with the bulbs 5 centered with respect to the high frequency coils 29 and at such a height that the cup 25 is approximately midway of the coil 29 longitudinally.

The vacuum pump is turned on. Liquid air trap 49 is cooled with liquid air. When the pressure has fallen sufficiently the manometer 50 is turned on. The heater 45 without the cover 46 and chimneys 47 is raised to engage the cap 44. Current is turned on to bring the oven temperature up to 400° C. and maintained until the manometer shows a pressure of 5×10^{-5} mm. of Hg (millimeters of mercury), or lower, when the current is shut off and the oven allowed to cool. Slow leaks anywhere in the system are indicated if the pressure is not less than 2×10^{-5} mm. of Hg when the tubes are cooled to room temperature. If leaks are indicated they should be eliminated before the processing proceeds. This treatment removes occluded gases from the bulbs but does not cause any chemical reaction in the caesium pellet. The pumping station is then flushed with oxygen from gas supply unit 55 until a clear green haze is obtained in the manometer 60 which indicates sufficient purity of the oxygen.

Mercury cut-off 53 is now closed to cut off the vacuum pumps and the manometer 60 turned off. Additional oxygen is admitted to a pressure of 2.2 mm. of Hg as indicated by McLeod gauge 50. Switch 72 of the electrical circuit of Fig. 4 is set in its lower position and the potentiometer 71 adjusted so that the voltmeter 76 shows a voltage of 700 volts. Switches 73 are then operated in succession to close their lower contacts so that each cathode 18 in succession is subjected to positive ion bombardment. The first effect of such bombardment is to produce a heavy layer of silver oxide on the concave surfaces and tangential extensions of cathode 18, followed by a heating-up of the silver plate and reduction of the layer of silver oxide. The cathodes are allowed to cool, the oxygen pressure again adjusted to 2.2 mm. of Hg and the oxidation, reduction and cooling repeated. The mercury cut-off 53 is then opened and the oxygen pumped out. This treatment leaves the concave surfaces and tan-

gential extension of each cathode 18 clean and slightly rough so that it has a uniform matte finish.

After a good vacuum has again been obtained as indicated by manometer 60, the mercury cut-off 53 is again closed and the manometer turned off. A fresh charge of oxygen through gas supply unit 55 is admitted to a pressure of 0.75 mm. of Hg. Switch 72 is thrown to its upper position after potentiometer 71 has been adjusted so that the voltmeter 76 shows a voltage of 650 volts. Each tube 5 is then subjected to a series of discharges from condenser 74 by the operation of closing switches 73 on their lower contacts. This operation is hereinafter called "tapping". Switch 72 in its upper position is therefore said to be in the "tapping" position. Each switch 73 is tapped sixty times in three groups of twenty taps each. The first group of taps is applied to the four tubes in succession, then the second group and so on until each tube has received the required number of taps or discharges. The mercury cut-off 53 is again opened and the oxygen pumped out. The manometer 60 is again turned on and the pumping continued until the pressure is down to 3×10^{-5} mm. of Hg or less.

This treatment with oxygen by tapping produces a thin layer of silver oxide on the concave surfaces and tangential extensions of each cathode 18. At each tapping of a switch 73 a glow discharge occurs in the associated tube 5 and the cathode 18 of that tube is bombarded with a definite number of positive ions. The amount of silver oxide which is formed is therefore closely controlled.

The cathodes 18 are now in condition to be treated with caesium vapor under suitable temperature conditions. A source of high frequency current (not shown) is connected to coils 29 in succession to "flash" the caesium pellets, that is, to induce sufficient current in the cups 25 to start a chemical reaction of the ingredients of the caesium pellet. The exothermic reaction which follows develops a large amount of heat and causes the immediate and complete expulsion of all of the caesium. The high frequency source is disconnected as soon as the reaction starts. The caesium, as it travels from the open end of cup 25 through metal gauze 27, is deflected by shield 24 and is condensed on the glass walls of the bulb 5 in front of the oxidized surface of the cathode 18. The shield 24 prevents the hot caesium vapor from impinging directly on the cathode surface. This shield 24 is so shaped that it lies substantially parallel to the magnetic lines of force produced by the high frequency current in coil 29 and therefore is not heated to any great extent by eddy-currents induced therein.

Immediately after the caesium pellet has been flashed stem heaters (not shown) are inserted around the stems of the tubes 5. Thermocouples are placed against each bulb 5 at the surface opposite the stem to indicate temperatures. The cover 46 with the chimneys 47 are placed on the heater 45 and the whole raised until a chimney 47 surrounds each bulb 5. The stem heaters are turned on first and after two minutes the heater 45 is turned on to quickly bring up the temperature of the convection air currents flowing past the bulbs 5. When the hottest bulb reaches a temperature of 150° C. the heater 45 is regulated to hold this temperature for five minutes. At the end of this five-minute period the heater 45 is again regulated to raise the temperature of the air currents to quickly bring the temperature of

the hottest bulb 5 up to 225° C. The heater 45 is then regulated to hold this temperature until the cathode surface of each tube has reached the proper sensitivity.

The sensitivity may be indicated by the ammeter 78 when connected into the circuit of Fig. 4 by the insertion of plug 77 into jack 75. Each cathode 18 may be illuminated by a source of light (not shown). The potentiometer 71 is adjusted to give a voltage of 50 volts, as shown on voltmeter 76. Switch 72 is closed in its lower position. The sensitivity of each tube 5 will be indicated by the ammeter 78 if the corresponding switch 73 is closed in its lower position. The tubes 5 are tested from time to time while illuminated and the hot air treatment is continued until the photoelectric current tends to decrease. As each tube reaches its proper sensitivity the air current for that tube is cut off. When all of the tubes have reached the proper sensitivity the chimneys 47 are lowered and the bulbs allowed to cool to room temperature with the pumping apparatus still on.

When the bulbs 5 are cooled and the pressure is down to 2×10^{-5} mm. of Hg, mercury cut-off 53 is closed and argon is admitted from the gas supply unit 56. The argon is admitted until the pressure assumes a steady state at the desired value, when the tube is sealed off from the header 40 by sealing off the exhaust tube 28. The pressure of argon is dependent upon the amount of gas amplification desired in the completed tube. A suitable pressure is 5×10^{-2} mm. of Hg.

The cathode 18 may comprise a nickel or copper sheet having a surface layer of silver which is processed in the manner hereinbefore described to render it photoemissive. The preliminary roughening of the silver surface may be accomplished in other ways than by oxidation and reduction of the silver oxide, as, for example, by sandblasting, etching with acid, or even by applying a coating of silver oxide and a binder with a brush or air spray and reducing the silver oxide to metallic silver by heat.

The cathodes may also be sensitized by subjecting the oxidized silver surface to the vapor of other of the alkali metals, rubidium, lithium, potassium and sodium. The temperature conditions would be varied somewhat depending upon the materials being used.

What is claimed is:

1. A photoelectric tube comprising an evacuated container, a metallic cathode plate comprising two portions joined along one edge and each having a concave cylindrical surface, said surfaces being curved away from each other, means supporting said cathode within said container, two anodes also supported within said container and located in front of the concave sectors of said curved cathode surfaces respectively parallel thereto and in a plane which intersects both portions of said cathode intermediate said anodes, and a light sensitive electric layer on both said concave surfaces.

2. A photoelectric tube comprising an evacuated container, a metallic cathode plate having two concave semi-cylindrical surfaces mounted side by side within said container and joined by a folded portion extending tangentially from the adjacent edges of said semi-cylinders, two anodes also supported within said container and located in front of said concave surfaces respectively parallel to the axes thereof and in a plane which intersects both surfaces intermediate said anodes,

and a light sensitive electric layer on both said concave surfaces and folded portion.

3. A photoelectric tube comprising an evacuated container, a stem with a press within said container, a silver cathode plate in the form of two hollow parallel semi-cylinders joined by a folded portion extending tangentially from the adjacent edges of said semi-cylinders supported from said press, an anode on each side of said folded portion coincident with the axes of said semi-cylindrical portions respectively also supported from said press, said axes being located in a plane which intersects said cathode plate in two parallel lines between said axes, and a light sensitive electron emitting layer over said semi-cylindrical surfaces and the outside surfaces of said folded portion.

4. A photoelectric tube comprising an evacuated container, a silver cathode plate having two concave semi-cylindrical surfaces mounted side by side within said container and joined by a folded portion extending tangentially from the adjacent edges of said semi-cylinders, two anodes also supported within said container and located in front of said concave surfaces respectively parallel to the axes thereof and in a plane which intersects both surfaces intermediate said anodes, and a light sensitive electron emitting layer on both said concave surfaces and folded portions comprising an intimate mixture of finely divided silver, caesium oxide and metallic caesium.

5. A photoelectric tube comprising an evacuated container, a stem with a press within said container, a mica disc at right angles to the axis of said stem supported by wires sealed into said press, a metallic cathode plate in the form of two hollow parallel semi-cylinders joined by a folded portion extending tangentially from the adjacent edges of said semi-cylinders supported in part from said disc, an anode on each side of said folded portions coincident with the axes of said semi-cylindrical portions respectively supported from said press, and a light sensitive electron emitting layer over said semi-cylindrical surfaces and the outside surfaces of said folded portions.

6. A photoelectric tube comprising an evacuated container, a stem with a press within said container, two parallel mica discs at right angles to the axis of said stem supported by wires sealed into said press, a metallic cathode plate in the form of two hollow parallel semi-cylinders joined by a folded portion extending tangentially from the adjacent edges of said semi-cylinders supported between said discs and in part at least from said discs, an anode on each side of said folded portions coincident with the axes of said semi-cylindrical portions respectively supported from said press, and a light sensitive electron emitting layer over said semi-cylindrical surfaces and the outside surfaces of said folded portions.

7. A photoelectric tube comprising an evacuated container, a metallic cathode plate comprising two concave cylindrical surfaces continuously curved in part, joined along one edge and curved away from each other, means supporting

said cathode within said container, two anodes also supported within said container and located in front of the concave sectors of said curved cathode surfaces respectively parallel thereto and in a plane which intersects both cylindrical surfaces intermediate said anodes, means supporting a caesium producing mixture in the vicinity of said concave surfaces, and a metallic shield supported between said surfaces and caesium mixture supporting means.

8. A photoelectric tube comprising an evacuated container, a metallic cathode plate comprising two portions joined along one edge and each having a concave cylindrical surface, said surfaces being curved away from each other, means supporting said cathode within said container, two anodes also supported within said container and located in front of the concave sectors of said curved cathode surfaces respectively parallel thereto and in a plane which intersects both portions of said cathode intermediate said anodes, and a light sensitive electric layer on both said concave surfaces, said means supporting said cathode comprising a stem with a press within said container and a mica disc at right angles to the axis of said stem supported by wires sealed into said press, said cathode being supported in part from said disc.

9. A photoelectric tube comprising an evacuated container, a metallic cathode plate comprising two portions joined along one edge and each having a concave cylindrical surface, said surfaces being curved away from each other, means supporting said cathode within said container, two anodes also supported within said container and located in front of the concave sectors of said curved cathode surfaces, respectively, parallel thereto and in a plane which intersects both portions of said cathode intermediate said anodes, and a light sensitive electric layer on both said concave surfaces comprising an intimate mixture of finely divided silver, caesium oxide and metallic caesium.

10. A photoelectric tube comprising an evacuated container, a metallic cathode plate comprising two portions joined along one edge and each having a concave cylindrical surface, said surfaces being curved away from each other, means supporting said cathode within said container, two anodes also supported within said container and located in front of the concave sectors of said curved cathode surfaces respectively parallel thereto and in a plane which intersects both portions of said cathode intermediate said anodes, and a light sensitive electric layer on both said concave surfaces, said means supporting said cathode comprising a stem with a press within said container and a mica disc at right angles to the axis of said stem supported by wires sealed into said press, said cathode being supported in part from said disc, said two anodes being supported in part from said press and in part from said mica disc and said light sensitive electric layer comprising an intimate mixture of finely divided silver, caesium oxide and metallic caesium.

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