July 29, 1958 J. LEMPERT 2,845,559

STRUCTURE FOR HIGH VOLTAGE TUBE

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Fig.1.

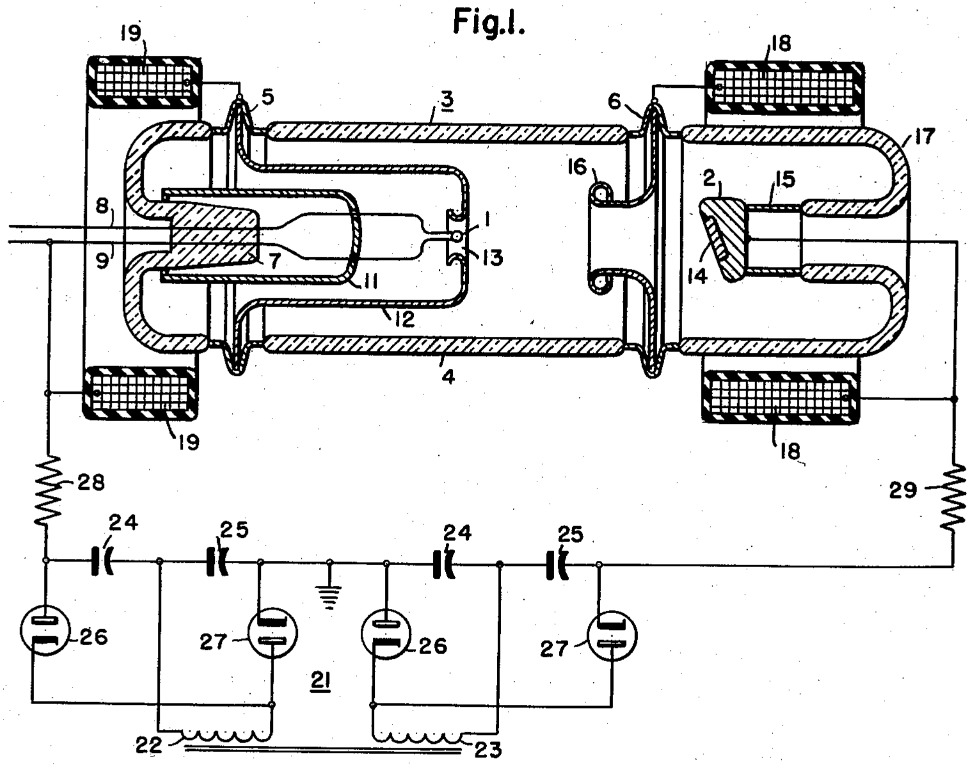

Fig.2.

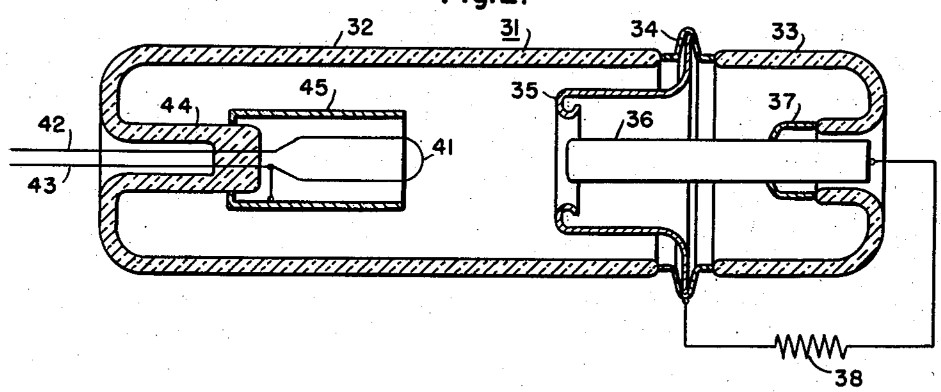

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Fig. 3.

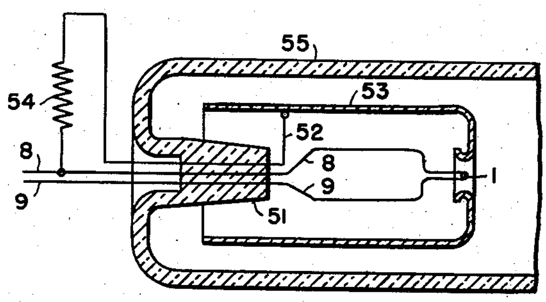


Fig. 4.

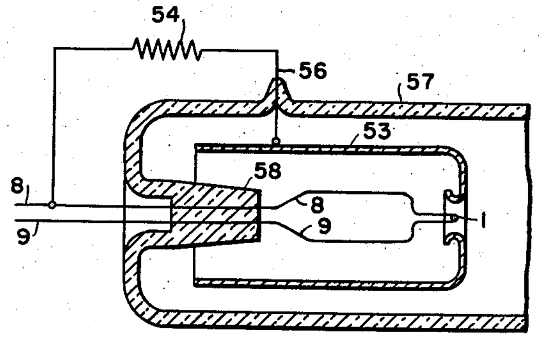
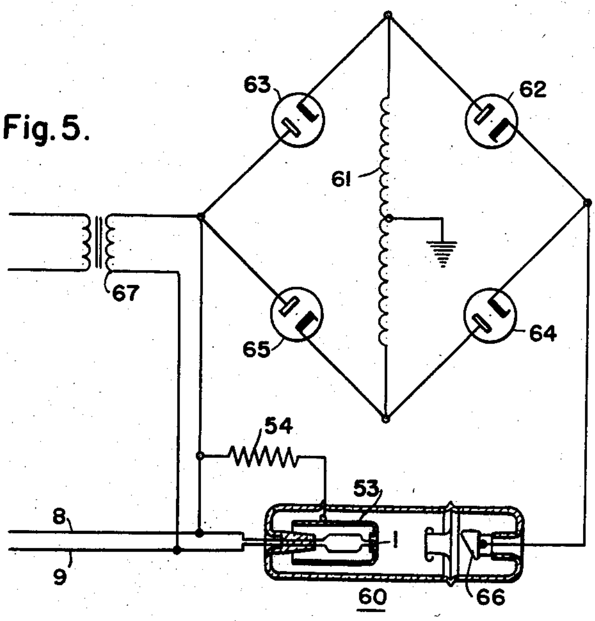


Fig. 5.



United States Patent Office

2,845,559

Patented July 29, 1958

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STRUCTURE FOR HIGH VOLTAGE TUBE

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Application October 9, 1953, Serial No. 385,069

5 Claims. (Cl. 313—58)

My invention relates to high voltage electron tubes and in particular relates to tubes so designed as to prevent breakdown across the gaps between the electrodes inside the tube. Typical of the tubes to which my invention is applicable are high voltage rectifiers and high voltage X-ray tubes operating with potentials in the order of thousands of volts between their electrodes.

In prior art tubes of the foregoing types, voltage breakdown between the electrodes frequently manifests itself as high current pulses of short duration, the magnitude of the current depending on the amount of impedance in the tube circuit. In those cases where a high impedance in series with the tube electrodes is tolerable, the current pulse may be limited to values which are not too injurious, but in certain modern uses like X-ray tubes for taking radiographic exposures from the order of 0.1 second to exposures as short as 0.1 microsecond or less duration an impedance of size sufficient to adequately protect the tube is out of the question because for the short period of time in which current flows, extremely high current values are needed to produce the pictures desired.

In accordance with the principles of my invention, I subdivide one or more electrodes in the tube into sections, one of which may be looked at as forming a kind of shield, in case of arc-over for the other section which it partly surrounds. In normal operation, the discharge between the electrodes passes through the main or shielded sections of the electrodes and traverses the low impedance path desired for normal operation of the tube. Impedances of sufficiently high value are interposed between each shielding section and the electrode which it protects, and when voltage breakdown between the tube electrodes starts, the current transfers to the shielding electrodes and has to traverse the high impedances which are then in series with them. In this way, energy supply to the arc-over has to pass over high-impedance paths which prevent its rise to values destructive to the tube and its electrodes.

One object of my invention is, accordingly, to provide a novel type of structure for electrical discharge tubes which shall render them immune to injurious effects of breakdown between their electrodes.

Another object is to provide a novel type of structure for electrodes of electron discharge devices.

Another object is to provide a new and improved type of high voltage electron tube which shall be capable of connection to supply channels of relatively low impedance for normal operation but in which arc-over currents are forced to traverse high impedance circuits.

Another object is to provide an improved type of X-ray tube capable of conducting large instantaneous currents between its electrodes, yet in which breakdown discharges between the electrodes are limited to nondestructive values.

Other objects of my invention will become apparent upon reading the following description taken in connection with the drawings, in which:

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Figure 1 is a schematic diagram and a view partly in longitudinal section of a high voltage X-ray tube and supply circuit therefor which embody the principles of my invention;

Fig. 2 is a longitudinal sectional view of a high voltage rectifier tube designed to employ my invention.

Fig. 3 and Fig. 4 are schematic views in longitudinal section of a less expensive form in which my invention may be applied to tube electrodes; and

Fig. 5 is a schematic diagram showing my invention applied to an X-ray tube of type standard with roentgenologists and operating at 60 to 125 kilovolts.

Referring in detail to Fig. 1, an X-ray tube comprises an electron-emissive cathode **1**, which may be of tungsten, and an anticathode **2** supported from opposite ends of a tube **3**. The latter comprises a mid-portion **4** of cylindrical glass sealed at its opposite ends to rings **5** and **6**, which may comprise the sealing cobalt-nickel-iron alloy well known under the trade-name Kovar. The ring **5** is also sealed to a stem **7** through which are sealed two leads **8**, **9** which support and supply heating current to the cathode **1**. A shield **11** is supported on the lead **9** and extends downward over the stem **7** to shield the latter from any electric gradient between the cathode **1** and the anticathode **2** or the ground. A shielding-section **12** of cylindrical contour is connected at one end to the ring **5** and has an opening or window **13** in its other end looking toward the anticathode **2**. The margin of window **13** is rolled over as indicated so that no sharp edges are presented toward either anticathode **2**, cathode **1** or the ground. Other portions of shielding-section **12** are likewise curved for the same reason.

The anticathode **2** may comprise a copper block having an inclined end-face in which is set a plate **14** of tungsten, and supported at its other end by a cylinder **15** which may have a Kovar edge sealed to a re-entrant glass cup **17**, the other edge of which is sealed to ring **6**. The edges of anticathode **2** are all rounded for the reason pointed out in describing shield-section **12**.

A shield-section **16** for the anticathode is supported from seal-ring **6** and has all its corners rounded like shield-section **12**. The anticathode **2** is electrically connected to its shield-section **16** through a high impedance of, for example, 500,000 ohms which may be in the form of a sleeve **18** of high resistance material surrounding the cup **17**. The shield-section **12** for cathode **1** is connected to the latter through a high impedance which may likewise have the form of a sleeve **19** surrounding stem **7**.

The X-ray tube **3** is supplied by a conventional direct-current voltage source **21** which may comprise two similar transformer secondaries **22**, **23** delivering each a voltage of the order of 60,000 and powered by a primary winding (not shown). The opposite ends of windings **22** and **23** are interconnected by a pair of like capacitors respectively connected in series with rectifiers **26** and **27** which are oppositely poled. These networks are well known in the art as means to charge the capacitors **24**, **25** each to approximately the voltage of windings **22** and **23**, with their voltages additive to around 125,000 volts. The negative end of one set of condensers **24**, **25** is connected to cathode **1** through a resistor **28** of say 150,000 ohms and its positive end is grounded, while the negative end of the other set of condensers **24**, **25** is grounded and its positive end is connected to the anticathode **2** through a resistor **29** of around 200,000 ohms.

As long as the space within the tube **3** maintains its insulating properties unimpaired, current from the direct-current source comprising condensers **24**, **25** traverses the direct path from hot cathode **1** to anticathode **2** through the center of shield-section **16** within tube **3** which passes through resistors **28**, **29** but avoids high resistors **18**, **19**. All elements of the cathode except for hot filament are shielded from high electric field by shield electrode **12**, which is at cathode potential until a high voltage breakdown occurs. Similarly the shield **16** on the anode side of the tube shields anode **2** from high electric fields. High voltage breakdown, which is produced by the high electric fields must then occur between these electrodes. Thus, should the space within tube **3** break down, because of a field emission from the cathode shield, the discharge will naturally go to the shield of opposite potential, thus relieving cathode **1** of any destructive effect incident to subsequent arc-over. However, the arc-over current can reach shield-sections **12** and **16** only by flowing through high impedances **18** and **19**; hence it will be limited by them to a much smaller value than that it could attain if it traversed only resistors **28**, **29**, cathode **1** and anticathode **2**. The presence of shield-sections **12**, **16** thus protects the cathode **1** and other elements of tube **3** from injury due to electrical breakdown in interior of tube **3** and greatly minimizes the probability of destruction of the tube by puncture of the tube envelope.

Fig. 2 shows a high voltage electron-discharge rectifier to which the principles of my invention have been applied. This comprises a glass-walled container **31** having two sections **32**, **33** sealed together by a metal ring **34** which supports a shield-section **35** for the anode **36**. The latter is a metallic tube or rod closed at its inner end and having an annular collar **37** sealed to the container section **33**. The anode **36** is connected to the shield-section **35** through a high impedance **38**.

The cathode **41** comprises a filament of tungsten or thoriated tungsten supported on in-leads **42**, **43** sealed through a re-entrant stem which is continuous with the container section **32**. The cathode **41** is surrounded by a cylindrical shield **45** supported on the stem **44** and connected to inlead **43**.

The tube of Fig. 2 applies the shielding principles of my invention to only one electrode, although those principles might, of course, also be applied to its cathode in the same way as they were applied to the cathode in Fig. 1. The application of shielding to one electrode only is, of course, simpler and less costly than its application to two or more electrodes, and yet it obtains much of the advantage of the more expensive structure.

Fig. 3 shows another form in which my invention may be applied to an electrode of a high voltage X-ray or other high voltage tube. In this figure the cathode **1** may be like that of Fig. 1 but the press **51** now encloses an inlead **52** in addition to the heating-current inleads **8** and **9**. The shielding section **53** may be like that in Fig. 1 except that its base is not flared and that it is supported at the end of inlead **52**. The shield **11** may be omitted in Fig. 1 and has been omitted in Fig. 3. The inlead **52** is connected through a resistor **54** to one inlead such as **8**. The vacuum-tight envelope **55** has a continuous glass wall at the point where Fig. 1 is provided with seal **5**.

Fig. 4 shows still another structure in which my invention may be embodied. Fig. 4 differs from Fig. 3 in that the shielding-section **53** is supported on an inlead **56** passing through the wall of container **57** instead of through the seal **58**.

Fig. 5 shows my invention applied to an X-ray tube **60** powered by a full-wave rectifier of a type frequently employed in roentgenology to supply voltages of 60 to 125 kilovolts. This power supply comprises a transformer secondary **61** having its mid-point grounded. One end of secondary **61** is connected to the anode of a rectifier **62** and to the cathode of a rectifier **63**. The other end of secondary **61** is connected to the anode of a rectifier **64** and to the cathode of a rectifier **65**. The free ends of rectifiers **62** and **64** are both connected to the anticathode **66** of X-ray tube **60** and the free terminals of rectifiers **63** and **65** are connected together to a cathode heater-lead for tube **60**. Tube **60** may have a cathode structure of the type described in Fig. 3, for example, and its cathode heater is supplied with current from the secondary **67** of a filament transformer of conventional type. The shielding section **53** is connected to one side of secondary **67** through a resistor **54** as previously described in connection with Fig. 3.

I claim as my invention:

1. In combination, a vacuum-tight envelope, a first electrode projecting inward from the wall of said envelope and supported therefrom, a cooperating electrode projecting inward from the wall of said envelope and supported therefrom toward said first electrode, a first shielding conductive wall about said first electrode and having a window facing said cooperating electrode, said first conductive wall supported from the wall of said envelope and the intervening wall of said envelope providing a high insulation between said first conductive wall and said first electrode, a second shielding conductive wall supported from said envelope wall and embracing the path through said window between said electrodes, the distance separating said shielding conductive walls being less than that separating said electrodes, and a pair of high impedances of about 500,000 ohms each positioned external of said envelope for respectively connecting said first shielding conductive wall with said first electrode and said second shielding conductive wall with said cooperative electrode to provide a high impedance shunt breakdown path for abnormal currents.

2. In combination, a vacuum-tight envelope, a first electrode projecting inward from the wall of said envelope and supported therefrom, a cooperating electrode projecting toward said first electrode and supported from said envelope wall, a shielding conductive wall about said first electrode and having a window facing said cooperating electrode, the distance separating said cooperating electrode from said shielding conductive wall being less than that separating it from said first electrode, the envelope wall providing high insulation between said electrodes and said shielding conductive wall and a high impedance of about 500,000 ohms positioned exterior of said envelope connecting said shielding conductive wall to said first electrode to form a high impedance shunt circuit between said coperating electrode and said shielding conductive wall for abnormal currents.

3. In combination, a vacuum-tight envelope, a first electrode having a thermionically-emissive surface thereon projecting inward from the wall thereof, a cooperating electrode projecting toward said first electrode, a shielding conductive wall about said cooperating electrode and having a window facing said first electrode, the distance separating said cooperating electrode from said shielding conductive wall being less than that separating it from said first electrode, and a resistance of about 500,000 ohms positioned exterior of said envelope and connecting said shielding conductive wall to said first electrode to provide a high impedance path for abnormal currents between said electrode and said conductive wall.

4. An X-ray tube comprising a vacuum-tight envelope, a first electrode having a thermionically-emissive surface thereon projecting inward from the wall thereof, a cooperating electrode projecting toward said first electrode, a first conductive wall about said first electrode and having a window facing said target electrode, a second conductive wall embracing the path through said window between said electrodes, the distance separating said conductive walls being less than that separating said electrodes, means for applying a voltage between said first electrode and said cooperating electrode, and a pair of impedances positioned exterior of said envelope of about 500,000 ohms each respectively connecting said first conductive wall with said first electrode and said second conductive wall with said cooperative electrode to provide a high impedance shunt circuit for abnormal currents.

5. In combination, a vacuum-tight envelope, a first electrode projecting inward from the wall thereof, a cooperating electrode projecting toward said first electrode, a first conductive wall about said first electrode and having a window facing said cooperating electrode, a second conductive wall embracing the path through said window between said electrodes, means for applying a voltage between said first electrode and said cooperating electrode, a pair of high impedances positioned exterior of said envelope of about 500,000 ohms each respectively connecting said first conductive wall with said first electrode and said second conductive wall with said cooperating electrode to provide high impedance external circuit between said conductive walls for abnormal currents.

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