Nov. 23, 1937. E. F. LOWRY 2,100,196

ELECTRON DISCHARGE DEVICE

Filed Jan. 4, 1936

Fig. 1.

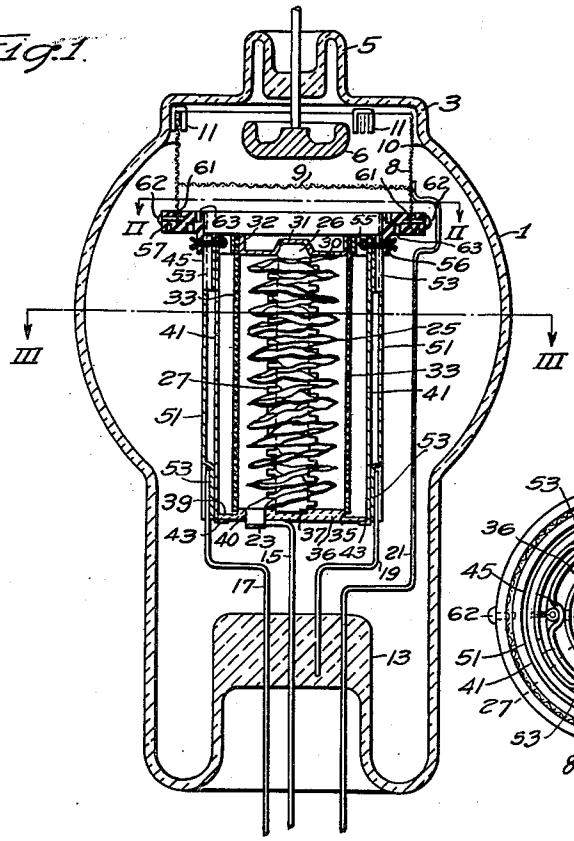


Fig. 2.

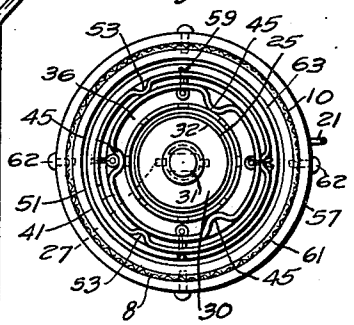


Fig. 3.

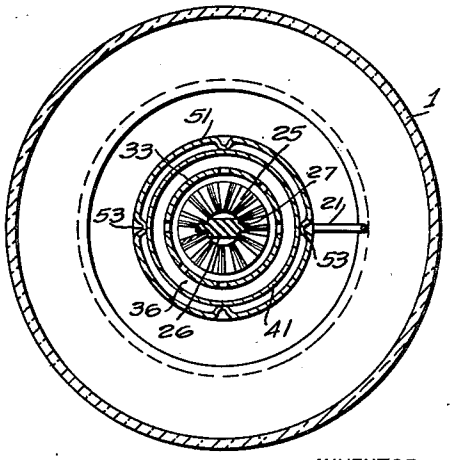
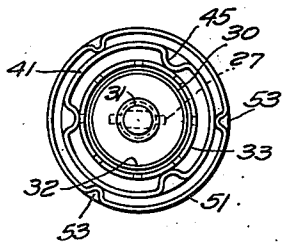


Fig. 4.



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ELECTRON DISCHARGE DEVICE

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Application January 4, 1936, Serial No. 57,536

15 Claims. (Cl. 250—27.5)

This invention relates to electron discharge devices, and is particularly adapted to such devices containing a gas or vapor and intended to carry heavy currents.

It is an object of my invention to produce a device which may carry peak currents much greater than the average current.

It is a further object of my invention to produce a gas-filled space-current device in which the peak current from anode to cathode shall bear a greater ratio to the heating current than heretofore has been obtained.

This invention is an improvement over the invention disclosed in my application Serial No. 43,347, filed October 3, 1935, and the cathode structure disclosed herein has the property of the cathode structure, described in said application, of delaying the discharge constituting the anode current until the cathode is well heated and can carry such current without damage.

One respect in which the tube here disclosed is an improvement over that disclosed in said application is the better protection of the space around the directly heated part of the cathode from the field of the anode. This better protection has many important results among which is that surges do not injure the tube and the tube may even cut down the surge current.

It is a further object of my invention to provide an electron device with a controlling grid in which the path of the electrons is restricted so that the grid does not need to surround the whole of the cathode.

It is a further object of my invention to support the grid from the cathode structure in a way which will be rigid and economically manufactured and which will afford abundant insulation.

It is a further object of my invention to protect the directly heated part of the cathode from the anode potential more completely than has been done heretofore.

It is a further object of my invention to afford a better support for the filament, whereby a longer filament or ribbon than heretofore, when heated to the point where it has little tensile strength, may be supported with sufficient rigidity to avoid movements that might produce shorts or perceptible changes of the tube characteristics.

It is a further object of this invention to produce a cathode structure in which a cathode spot is unlikely to occur and very unlikely to be where it can do injury.

It is a further object of my invention to provide a tube with certain portions of the cathode structure coated with emissive materials in which the coated surfaces are protected from the formation of a cathode spot thereon even when an arc is formed to some part of the cathode structure.

It is a further object of my invention to provide a tube of the class described in which the cathode structure may be more rigid than heretofore.

Other objects of the invention, details of the construction and functions of the several parts will be apparent from the following description and the accompanying drawing in which:

Figure 1 is a vertical central sectional view of the tube;

Fig. 2 is a sectional view taken upon the line II—II of Fig. 1;

Fig. 3 is a sectional view taken upon the line III—III of Fig. 1; and,

Fig. 4 is a top plan view of the cathode structure, apart from the tube and with the surmounting ring of insulation removed.

The tube is provided with the usual envelope 1, enclosing a vapor such as mercury vapor or a gas. The vapor may be provided by a little of mercury within the tube which is evaporated when the tube is hot. The envelope 1 is provided with a dome 3, which carries a press 5 through which a lead extends to the anode 6. Surrounding the anode is a grid 8 consisting of a flat portion 9 and a skirt 10. The skirt extends into close proximity to the walls of the dome 3 and is separated therefrom by mica clip-like devices 11. The other end of the tube has a conventional press 13 through which extends a conductor 15 and a return conductor 17 for the cathode-heating current. A standard 19 and a lead 21 seated in the press support parts of the structure, which will be presently described.

The lead 15 is joined at 23 to one terminal of a ribbon 25 which is corrugated, as described more fully in my Patent No. 1,968,608, granted July 31, 1934.

This ribbon is preferably of a suitable alloy of nickel and various other metals and is coated with a mixture of barium and strontium oxides which will readily emit electrons when the ribbon is heated. The ribbon 25 is supported upon a body of insulation 26, which is accompanied with staggered teeth 27 for supporting the individual whorls of the helically wound ribbon. The support 26 may have other forms. A screw thread in a cylindrical body of insulation may

be used, for example; the inner edge of the ribbon 25 fitting into such a thread.

The upper end of the ribbon 25 is welded to a nickel cap 30, which is raised at the center as indicated at 31, to provide a recess into which the upper end of the insulation member 26 fits.

The cap 30 is provided with an annular flange 32 which fits the inner face of a cylindrical guard 33. At its bottom end the guard fits a shoulder 35 in a plate 36 of lavite or other refractory insulation which is at the bottom of the ribbon. This plate is equipped with a recess 37 which receives the lower end of the body 26 of insulation. The plate 36 also has a radial slot 40 to receive the tab 23 which is formed by the end of the ribbon 25. The plate of lavite has a shoulder from which an annular flange 39 extends beyond the shoulder 35 to a shield 41 concentric with the guard 33. The lower edge of the shield 41 is provided with tabs 43 which are bent under the lavite plate and thus support the same.

The cylindrical shield 41 has its upper margin inwardly offset at peripherally spaced points 45 to provide inwardly extending braces. These contact with and preferably are welded to the exterior surface of the guard 33. A cylindrical shield 51 surrounds the shield 41 and is equipped at both top and bottom with inwardly offset portions 53, peripherally spaced around the shield and contacting with the exterior surface of the shield 41. These are preferably welded to the shield 41 where they contact it. As shown, in Fig. 4, there are three offset portions 45 and three of the upper offset portions 53. There are, however, four offset portions 53 at the bottom of the shield 51, as may be seen in Fig. 3. If it is desired to use a different number of them, that may be done but there should be two of the lower offsets diametrically opposite one another to receive the wires 17 and 19. The upper end of the standard 19 is secured in one of the lower offset portions of the shield 51, preferably by welding. In the diametrically opposite offset portion 53, the upper end of the conductor 17 is similarly secured. The lower offsets 53 being different in number will not align with the upper ones but for clearness the lower ones have been omitted in Fig. 4. The guard 33 differs from the shields 41 and 51 by having numerous perforations. These foramina preferably are uniformly spaced throughout the lateral surface of the guard, but do not exist in the cap 30, nor in the lavite disc at the lower end of the shield. The guard 33 is coated with emissive material, preferably the same as the material on the ribbon 25. The coating may be on either the inner face alone, the outer face alone or both faces of the guard. The guard differs in function from the cylinders concentric therewith as will be pointed out below.

The top of the shield 51 is pinned as shown at 55 to a flange 56 of a lavite ring or collar 57. The collar is provided with concentric grooves 63 in both the upper and the lower face thereof. One of these, 61, in the upper face of the collar, receives the lower edge of the skirt of the grid 10 which is secured therein by pins 62. The other grooves 63 which do not serve for mechanically securing any parts, but add to the length of the creepage path between the cylinders and the grid. The conductor 21 extends from the press into contact with the grid 8 and is preferably welded thereto. The grid 8 thus surrounds the anode 6, but extends merely across one end of the cathode structure.

In assembling the cathode structure, the ribbon is first corrugated and wound into its helical shape. The ribbon is then threaded upon the refractory body 26. It is then coated with the emissive material, the ends being kept clean and each end flattened and the lower end bent into its tab-like shape. The cap 30 is placed on the upper end of the body 26. The central elevated part of the cap fits snugly on the end of the refractory 26. The upper end of the ribbon is then welded to the cap 30. The guard 33 is coated on the inner face before being put in place, or if desired on the outer face or on both faces. It is put in place by being slipped up over the ribbon and its upper end is then welded to the cap throughout the circumference. The refractory disk 37 is next fitted onto the lower end of the guard 33 and the flange 35 fitting into this end. In order to put the refractory in this position, the end 23 of the ribbon must be made to project through the radial slit in the refractory plate, and the notch 37 must be seated over the lower end of the body 26.

The shield 41 is then slipped down outside guard 33 and the off-sets 45 are welded to the exterior of the top of the guard 33. The conductors 17 and 19 are welded onto the shield 51 in their appropriate off-sets 53. The collar 57 is pinned to the top of shield 51 and then the assembled structure consisting of ribbon 25, guard 33 and shield 41 is then inserted upward into the shield 51 and the tab 23 is welded to the lead 15. Then the outer ends of the pins 55 are bent into retaining shape. The offsets 53 at the top of shield 51 are welded to the shield 41 but those at the bottom are left unwelded, merely contacting shield 41. The tabs at the bottom of shield 41 are next bent under the plate 36. If preferred, the whole bottom edge of the shield 41 may extend below the plate 36 and be bent under it by peening.

The recess 37 and the recess in the cap 30 fit the ends of the insulating body 26 closely, making a rigid structure therewith. The welded connection of the cap 30 to the guard 33 and the fitting of the guard 33 against the shoulder 35 makes the structure including guard 33 rigid except for the permissible expansion lengthwise of the guard. The outer cylinders 41 and 51 are welded at the top to each other and to guard 33. Thus, the whole cathode structure is rigidly connected together. This rigidity permits closer spacing which has a beneficial effect on the characteristics of the tube.

In the operation of the device, when the tube is first connected to power, heating current enters through the conductor 15, traverses the ribbon 25 and the cap 30. From thence it passes through the upper edge of radiation shield 41 to the radiation shield 51 through which it passes and emerges to the conductor 17. The current does not pass through the guard 33 because, although the guard is connected to the shields at the top, it is insulated at the bottom. Very little heating current traverses the shield 41 because, although connected through a weld at the top to shield 51, at the bottom it merely contacts the offset 53 and a good connection is not afforded there.

The heating current in traversing this path, heats the ribbon 25 and causes it to emit electrons. It does not heat the shield 51 much, directly, because its conducting cross-section is large compared to that of the ribbon, and its length is short compared to that of the ribbon. The shield 41 carries but little heating current and thus is not substantially heated thereby.

Moreover, the ribbon is coated with emissive material and these shields are not. The shields 41 and 51 therefore do not emit electrons but the ribbon 25 does. The guard 33 does not emit electrons until there has elapsed sufficient time for it to become hot by radiation from ribbon 25.

As the ribbon heats the cylinders by radiation, thermal expansion elongates them. The elongation upward is simultaneous because the cylinders are united at the top by the welds at the offsets 45 and 53. The guard 33 being nearest the ribbon is, especially at first, elongated more than the shields. This may be provided for by locating the flange 39 a little below the bottom edge of guard 33. The shoulder on the plate 36 holds the shield from lateral movement and the expansion is accommodated by the creeping along the height of the shoulder. When the shield 41 expands more than the shield 51, motion at the unwelded lower offsets 53 cares for the inequality.

A difference of potential is applied between the anode 6 and the cathode structure. The connection from the source of this potential difference to the cathode structure may be made to the wire 17 which is then assumed to be the negative terminal of the heating circuit. This potential may be applied without waiting for the guard 33 to reach the temperature at which its inner surface begins to emit electrons. Before such temperature is reached, the guard acts as a grid. Being under the assumed condition negative with respect to all parts of the ribbon 25, it does not attract any electrons which are emitted from said ribbon but, at least slightly, repels them. The holes in the guard 33 are small enough not to interfere much with its electrostatic effect, and it therefore confines the electrons from the ribbon 25 nearly as effectively as if it were imperforate. The cap 30 prevents any electrons from going from the ribbon 25 directly to the anode 6 and the plate 36 prevents any electrons from emerging from the interior of the guard 33 at this end.

Even if the potential drop along the ribbon 25 were not applied to the guard 33, it could still be made to confine the electrons. By insulating the guard from the cap 30, it would be an insulated conductor on which the electrons from the ribbon 25 would produce a negative charge which would then repel other electrons.

If the guard 33 be slightly positive with respect to the ribbon 25, as, for example, when the conductor 17 were the positive terminal of the heating circuit, the guard will still prevent the emerging of electrons from within it before it becomes itself hot enough to emit. This is because the potential drop between the ribbon and the guard is not enough to give to electrons sufficient velocity to cause them to ionize the gas there. The field from the anode 6 will not reach the interior of the guard 33 to sufficient extent to accelerate the electrons there enough to cause ionization even when supplemented by the conditions last described.

This shutting out of the field is the principal function of the guard, although it also acts to some extent to retain radiant heat from ribbon 25 in its interior. The shields 41 and 51 on the other hand act principally to retain radiant heat although they also guard the space around the ribbon 25 to some extent from the anode field.

The cap 30 and to some extent the shields 41 and 51 cooperate with the guard 33 in preventing nearly all of the field from anode 6 reaching the interior of the guard. Therefore any field from the anode 6 inside the guard 33 is too small to produce any great velocity of electrons and for this reason the electrons do not ionize the gas inside of the guard. The gas outside of the guard is not ionized under these circumstances because no electrons reach this region where the anode field is stronger.

When the guard 33 becomes hot, electrons emerge from the coated face or faces. If the inner face alone be coated, the following explanation applies. If the outer face is coated a simpler explanation can be given.

With the inner coating alone, there will be some oxide coating close to the edges of the holes in the guard and the electrons which emerge therefrom with small thermionic velocity may be attracted into the space between guard 33 and shield 41, even by the feeble field from the anode 6 which exists at the hole. Also there may be some oxide on the surface of the edges of the holes, or a speck or two on the outer surface of the guard 33 by accident.

If the guard be coated on the outer surface, as soon as it is hot enough to emit, the electrons are delivered at once into the space between the guard 33 and shield 41.

When, from any of these causes, or from causes not here mentioned, electrons get into the space exterior to the guard 33, they are acted upon by the field of the anode 6 and acquire a very considerable velocity. Consequently, they ionize the gas in this region and positive ions are produced in the space between guard 33 and shield 41, as well as in the space above the top of the cathode structure. These positive ions are attracted inward through the holes in the guard 33 and neutralize, to a greater or less extent, the space charge therein, produced by the electrons emitted by the ribbon 25 and to some extent by those from the inner surface of the shield.

In another way of regarding this action, when electrons ionize the gas in the space outside the guard 33, the electrons produced by the ionization move rapidly toward the anode 6, leaving the slower ions producing a positive space charge in the space around the guard. Between this positive space charge and the negative space charge inside the guard an attraction will exist which will cause positive ions to go inwardly and electrons to go outwardly through the holes in the guard.

As rapidly as the space charge in the interior of guard 33 is neutralized, the electrons there are not retarded by such space charge and emerge more readily through the holes in the guard 33. This produces a greater supply of electrons in the space outside of the guard 33 and thus a greater degree of ionization there. This increases the effect first described and so results in still greater ionization, and this action continues until the space outside of the guard 33 has become a good conductor and the full current is established between the cathode structure and the anode 6. The time occupied by this process is much shorter than would seem from this description, and, as a practical result, the tube, which is non-conducting until the guard reaches the critical temperature, and then abruptly becomes conducting.

When the electrons can emerge readily through the holes in the guard 33 there is an abundance of them. If a strong potential is applied momentarily to the anode 6, a very heavy current can be drawn without being limited by a meager

supply of electrons. The same result can be obtained with the strong potential on the anode enduring longer or even being permanent if the grid is negative enough to prevent the anode current except for a moment. If the grid under these circumstances becomes, during said moment, positive or at least not negative enough to prevent the tube from conducting there will be a heavy current during said moment. Being only momentary, the heavy current does not heat any part of any of the electrodes enough to cause damage.

On the other hand, if a surge occurs subjecting the anode to a much greater potential than will yield the intending peak current, the current through the tube will be limited by the number of electrons the cathode structure can yield. If the surge potential establishes an arc the guarding effect of guard **33** and shields **41** and **51** will prevent much field getting to the coated surfaces and so prevent a cathode spot there with attendant damage.

The anode current is upward from the space between the guard **33** and the shield **41** and cannot be otherwise because the bottom of this space is closed by the insulating plate **36** and the top of the interior of the guard **33** is closed by the cap **30**. For this reason it is unnecessary to supply a grid completely enclosing the cathode structure and the grid **8** can completely control the current.

The grid **8** extends across the cathode structure and completely covers the end of the space between guard **33** and shield **41**. The skirt **10** of the grid extends into a groove in the lavite annulus **57** thus making complete the closure of the top of the cathode structure. The skirt extends from the flat portion **9** into close proximity with the envelope **1**. The distance between the skirt **10** and the wall of the dome **3** is less than the free mean path of electrons within the vapor, and consequently, electrons do not pass and no ionization is set up outside of the grid. Current from the anode **6** around the grid to the exterior of shield **51** is, therefore, prevented.

If under certain circumstances, the potential between the cathode structure and the anode rises to a maximum while the grid **8** is not sufficiently negative to prevent, there may be an arc formed through the meshes of the grid from the anode **6** to the exterior of the cathode structure. Such an arc will be accompanied by a cathode spot on the exterior of shield **51**. This shield being bright nickel and clean, not coated with emissive material, such a hot spot will not injure it and such an arc will not reach the ribbon **25** of the interior of the shield **33**, so that all danger of injury of the coating of these elements is eliminated.

The ability of the tube to deliver heavy currents, although for only short periods, fits it for use with welding machines or in many-phase rectifiers. Other situations where this property will be advantageous will readily occur to those skilled in the art.

Various modifications will occur to those skilled in the art and can be embodied in the structure without departing from the spirit of this invention. For example, the cathode structure instead of being supported by two standards in the press, one of which is a conductor, may be supported by a ring clamped around the press **13**. The standards will then be well separated from all conductors and influence of the field thereof upon them will be negligible. Again, instead of a corrugated ribbon, a flat ribbon or even a filament, may be used.

Many other modifications will be obvious to those skilled in the art and I do not intend the specific description and illustration herein to operate as a limitation. The only intended limitations are those expressed in the accompanying claims or required by the prior art.

I claim as my invention:

1. In an electronic device, a cathode structure comprising a central portion and a plurality of metallic cylinders concentric therewith, and connections whereby the full heating current is conducted through said central portion and the main portion of the heating current is conducted through one of said cylinders, the central portion being of a cross section which causes the heating current to heat it above emitting temperature and said cylinder being of a thickness that causes it to carry the heating current without being brought to emitting temperature, the central portion and the innermost of said cylinders being coated with emissive material and said coated cylinder being foraminated.

2. In an electronic device, a directly heated emissive conductor and a plurality of metallic cylinders concentric therewith, one of said cylinders being emissive.

3. In an electronic device, a directly heated conductor coated with emissive material and an electrostatic foraminated guard surrounding the same and having a coating of emissive material and a radiation shield surrounding said guard.

4. An electron tube comprising an anode and an electron source comprising a conductor coated with emissive material, a foraminated guard surrounding said conductor and having electron emissive material on its surface, said guard enclosing said electron source and further guarding means adapted to direct electrons toward the anode.

5. An electron tube comprising an anode, an electron source comprising a conductor coated with emissive material, a foraminated guard surrounding said conductor and having electron emissive material on its inner surface, and further guarding means enclosing said electron source and open only toward the anode, and a grid adjacent said opening.

6. In an electron tube, a source of electrons, a foraminated guard surrounding said source and coated on its inner face with electron emissive material, said guard being connected to said source whereby while cold, it prevents the electron from said source emerging, but when hot, it becomes part of the electron emitting source.

7. In a cathode structure, a conductor adapted to be heated to electron emitting temperature by current therethrough, a series of concentric cylindrical conductors surrounding said conductor, the innermost conductor being foraminated, and thermionically active.

8. In a cathode structure, a conductor coated with electron emissive material, a guard surrounding said conductor and coated with electron emissive material, a conductive cap securing the conductor to the guard and closing its end of said guard, a non-conductive plate at the opposite end of said guard closing the interior of the shield at that end, said guard having foramina which afford the only exit for electrons from the interior of said guard.

9. In a cathode structure, a conductor coated with electron emissive material, a guard surrounding said conductor and coated with elec-

tron emissive material, a conductive cap securing the conductor to the guard and closing its end of said guard, a non-conductive plate at the opposite end of said guard closing the interior of the guard at that end, said guard having foramina which afford the only exit for electrons from the interior of said guard, and uncoated shields surrounding the foraminate guard and electrically connected thereto.

10. In a discharge device a cathode structure, a conductor coated with electron emissive material, an electrostatic guard surrounding said conductor and coated with electron emissive material, a conductive cap securing the conductor to the guard and closing its end of said guard, a non-conductive plate at the opposite end of said guard closing the interior of the guard at that end, said guard having foramina which afford the only exit for electrons from the interior of said guard, and an anode longitudinally spaced from said guard.

11. In a discharge device, a conductor coated with electron emissive material, an electrostatic guard surrounding said conductor and coated on the inside with electron emissive material, a conductive cap securing the conductor to the guard and closing its end of said guard, a non-conductive plate at the opposite end of said guard closing the interior of the guard at that end, said guard having foramina which afford the only exit for electrons from the interior of said guard, an anode longitudinally spaced from said guard, and a grid interposed between the end of said guard and said anode.

12. In an electron discharge device, a cathode structure including a plurality of concentric shields, a source of electrons within the innermost shield, an electrostatic guard within said shields and surrounding said source, an anode beyond the ends of the shields, a grid between said anode and shields and means for supporting said grid from said shields including an annular body of insulating material contacting both grid and shields.

13. In an electron discharge device, a cathode including a plurality of concentric shields, a source of electrons within the innermost shield, a guard within said shields and surrounding said source, an anode beyond the ends of the shields, a grid between said anode and shields and means for supporting said grid from said shields including an annular body of insulating material having means for firmly securing the shield and the grid.

14. A cathode structure comprising a foraminated guard, a series of non-foraminated metallic cylinders, surrounding the same and electrically connected therewith, a directly heated conductor inside the guard, means for rigidly supporting said conductor in place and means for securing all said parts against relative bodily movement, said means including provision for thermal expansion, and means in said cathode structure producing electrons in response to heat in said conductor.

15. In an electron discharge device, a cathode structure including a plurality of concentric shields, a source of electrons within the innermost shield, an electrostatic guard within said shields and surrounding said source, said guard permitting electrons from said source to emerge only into the space between it and the shield, an anode spaced from the cathode structure in the direction of the length of said shields, a grid between said anode and said cathode structure and transverse of said direction, and means for supporting said grid from said shields including an annular body of insulating material contacting both grid and shields.

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