

June 8, 1954

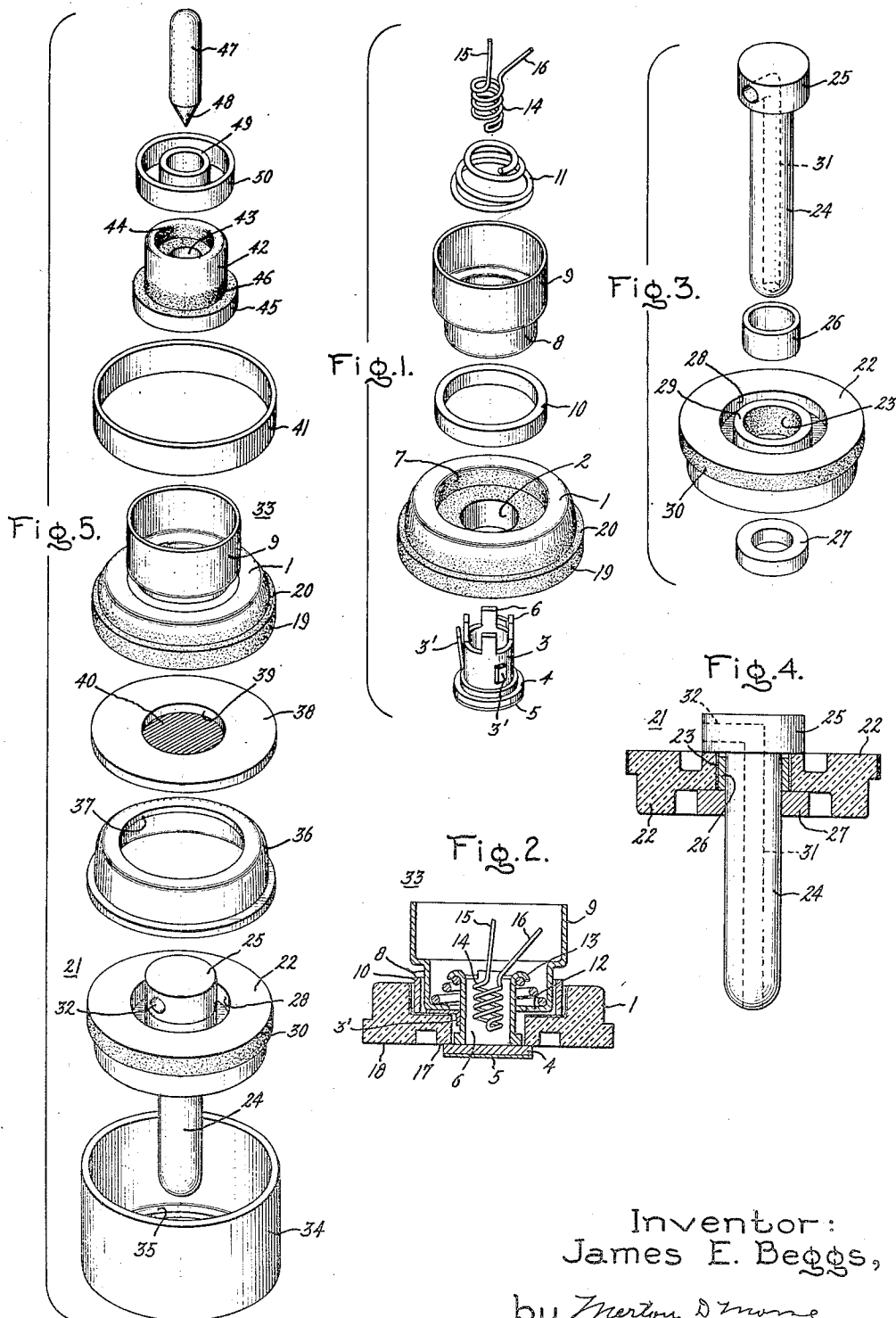
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2,680,824

ELECTRIC DISCHARGE DEVICE

Filed Aug. 16, 1950

2 Sheets-Sheet 1



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Fig. 6.

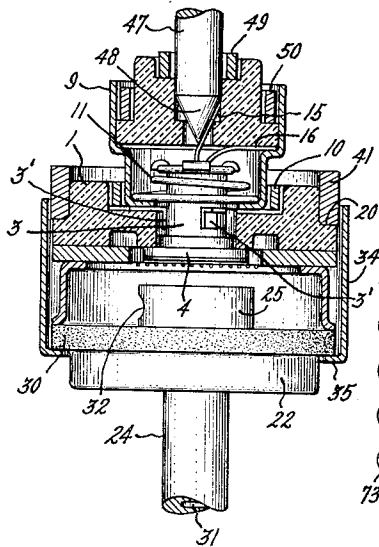


Fig. 8.

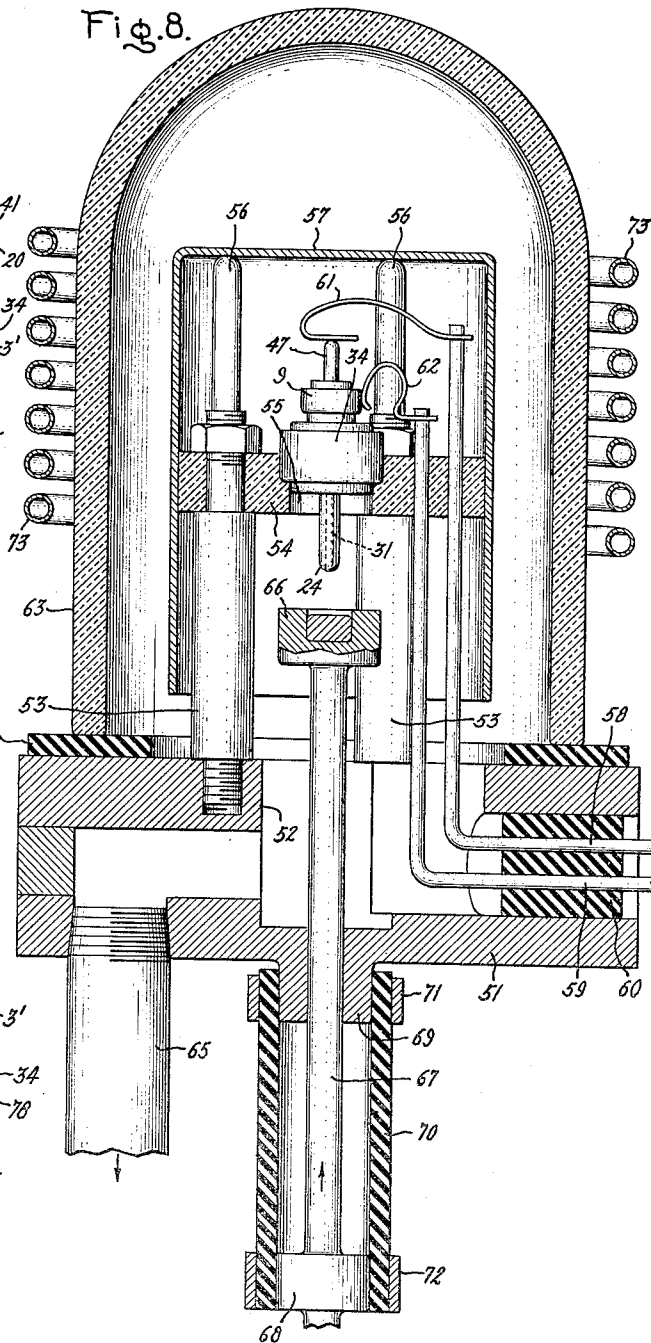
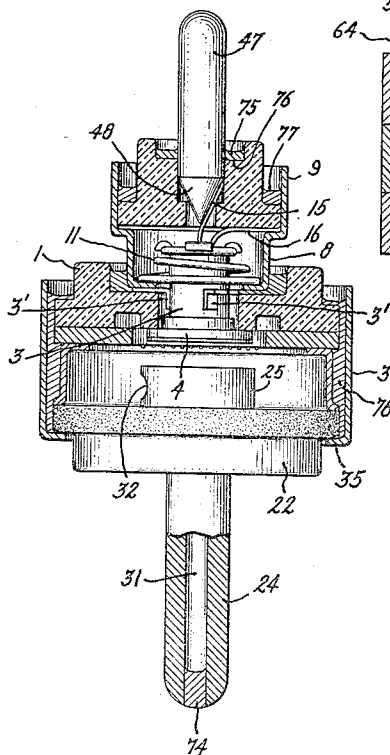


Fig. 7.



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UNITED STATES PATENT OFFICE

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ELECTRIC DISCHARGE DEVICE

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11 Claims. (Cl. 313-250)

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The present invention relates to improved electric discharge devices and methods of fabrication and exhaust.

The art of manufacturing electric discharge devices is, in general, highly developed. In spite of this the art has experienced great difficulty in producing tubes having satisfactory performance characteristics particularly as the demand for higher and higher operating frequencies has increased. Modifications of conventional tube structures have been employed, for example, in the present television broadcast frequency bands which lie in the ranges of 54 to 88 megacycles and 174 to 216 megacycles. These tubes however require some sacrifice in performance characteristics. Other tubes, such as the disk seal tubes widely used in high frequency applications in radar and similar equipment are expensive and difficult to manufacture so that they have not offered, from a cost standpoint, a satisfactory tube for mass production for such applications as television. With the proposed television band of 475 to 890 megacycles there is a real need for electric discharge devices possessing much better electrical characteristics at these frequencies and which may be manufactured in large quantities at a reasonable low cost.

While not limited thereto, the present invention is directed to novel structural features and the departure from known manufacturing methods which may be combined to produce electric discharge devices possessing superior electrical characteristics with respect to gain, noise factor and transconductance. The performance of tubes manufactured in accordance with the present invention is superior in the proposed television band of 475 to 890 megacycles as compared with known varieties of disk seal tubes, for example, in the present television band.

The present invention involves the use of materials for the tube envelope which are selected for their desired electrical and mechanical characteristics without regard for their thermal expansions and they are joined together by the use of lead solders, the ductility of which accommodates the differences in expansion. Such solders have hitherto been considered unsatisfactory for use in electric discharge devices because of the vaporization of the solder within device during bake-out or use. The present invention also involves novel structural features which essentially eliminate such vapors from the interior of the device. It is a feature of the present invention that the bonds or seals between the electrically conductive and insulating parts of the envelope are in a liquid state during the outgassing and evacuation of the device so that a high temperature bake-out is possible without subjecting the parts to high mechanical stresses which would result from cooling a previously bonded composite structure through such

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a large temperature range. The parts are also designed so that the soldered joints are not relied upon for mechanical strength after the device is evacuated.

In accordance with an important aspect of the present invention the component parts are shaped so that the complete tube may be assembled and supported from a single element of the envelope prior to the bonding together of any of the conductive and insulating parts which make up the envelope. The spacings between the electrodes is entirely controlled by the dimensions of the component parts which may readily be formed to accurate dimensions. Contributing to this feature of the invention is the positioning of the seals between radially spaced surfaces so that solder or sealing material does not in any way affect the inter-electrode spacing. The terminals and electrodes are also electrically connected by the same solder which bonds the components of the envelope together so that no separate welds between the parts are required during assembly.

While many of the features of the present invention are usable separately for discharge devices generally, they may be combined to produce a greatly improved electric discharge device particularly for high frequency applications.

The present invention will be better understood by reference to the following description of a preferred embodiment thereof considered in connection with the accompanying drawing and its scope will be pointed out in the appended claims. In the drawing Fig. 1 is an exploded view of the components of the cathode sub-assembly shown in Fig. 2 in an elevational view in section; Fig. 3 is an exploded view of the anode sub-assembly shown in Fig. 4 in an elevational view in section; Fig. 5 is an exploded view of the entire electric discharge device including the sub-assemblies of Figs. 2 and 4; Fig. 6 is an elevational view in section of the assembled device prior to completion of the device by exhausting and formation of the bonds between the component parts; Fig. 7 is an elevational view in section of the completed device; and Fig. 8 is a schematic representation of exhaust and bake-out equipment suitable for manufacturing an electric discharge device of the present invention in accordance with the methods of the present invention.

Before describing the embodiment of the invention with reference to the drawing, it should be pointed out that the discharge device illustrated in Figs. 1-7, inclusive, is about five and one-half times the size of an actual embodiment of the invention which has been successfully operated at frequencies up to 4000 megacycles and with a power gain of ten decibels or more.

Referring now to the drawing, the cathode assembly shown in Fig. 2 is made up of the com-

ponents shown in the exploded view of Fig. 1. The support for the cathode subassembly is provided by an insulating member or washer 1 having a central aperture 2 for receiving a generally cylindrical cathode eyelet 3. Preferably the washer is of a suitable ceramic but it may also be quartz or even of glass in some instances. It will be understood that ordinary glass will not withstand sufficiently high temperature to permit the high temperatures employed in accordance with some features of the invention. As illustrated, the eyelet supports at one end a disk-like member 4 which provides the support for the emissive coating 5 of the active cathode. The other end of the eyelet is provided with projections or fingers 6 which are used to retain the eyelet in the ceramic support 1, as will be described at a later point. The side of the washer 1 opposite the cathode disk 4 is recessed, as illustrated at 7, to receive the reduced end portion 8 of a cathode terminal shell 9 which forms a part of the tube envelope and the electrical terminal of the cathode. A solder ring 10 is placed in the recess 7 and lies between the cylindrical wall of the recess and the portion 8 of the cathode shell 9. The shell 9 and the cathode eyelet 3 are retained in the ceramic washer 1 by means of a spring member 11 which in the embodiment illustrated is in the form of a spiral having its larger end engaging the inwardly directed flange 12 of the cathode shell 9 and its smaller end engaging the tabs 6 which are bent outwardly and over the upper turn of the spring 11, as illustrated at 13 in Fig. 2. As will be readily appreciated, other forms of spring members may be employed for retaining the cathode and cathode terminal in position. In order to reduce the inductance of the cathode circuit it is preferable to provide metal fingers 3' secured to cathode eyelet 3 and having the free ends thereof recessed between the ceramic ring 1 and the flange 12 of the cathode terminal 9. Three equally spaced fingers may be used and if they are formed of spring material it is possible to omit the coil spring 11. The illustrated construction is preferred, however. The cathode heater 14 is in the form of a double spiral suitably insulated by a material such as aluminum oxide in a manner well understood in the art. The heater is positioned within the cathode eyelet and the heater leads 15 and 16 extend from the eyelet within the confines of cathode shell 9.

The cathode disk 4 rests upon an annular surface 17 of the ring 1 and this surface is accurately formed or lapped to dimensions. As will be described later, the grid cathode spacing is determined by this surface 17 and a concentrically arranged annular surface 18 on the ring 1 from which the grid washer is supported.

At a suitable time in the assembly of the discharge device and preferably before assembly of the insulating and conducting parts, the surfaces of the members, such as the member 1, that are to be bonded to the metal parts of the envelope are painted with a material which assists in the bonding operation. In accordance with one method, known in the prior art to be suitable for bonding ceramics or similar refractory materials and metals, a slurry of titanium hydride formed by mixing the hydride in a suitable carrier such as acetone, amyl acetate or the like, is painted on the surfaces. Accordingly, the surface of the recess 7 of the ceramic ring 1 and the outer surface 19 of the flange 20 of the ceramic ring 1 are painted with a thin coating of titanium hydride.

In a similar manner the electric discharge device includes an anode sub-assembly illustrated in Fig. 4 and designated generally by the numeral 21. This sub-assembly, as illustrated in Figs. 3 and 4, includes a ceramic ring 22 having a central cylindrical aperture 23 for the reception of an elongated cylindrical anode member 24 which terminates in an enlarged disk-like portion 25 the end of which provides the active anode surface. The part 24 extends through the aperture 23 and provides the external anode connection. As illustrated, the surface 23 is painted with a titanium hydride slurry and a ring 26 of solder is interposed between the anode conductor 24 and the wall of the recess 23. The anode is held assembled on the ring 22 during the fabrication of the electric discharge device by a small ring 27 which is readily deformed into firm engagement with part 24 of the anode and in contact with the lower surface of the ring 22 as viewed in Fig. 4. The upper surface of the ring 22 is recessed, as shown at 28, to provide an annular boss 29 on which the anode 25 rests and to increase the surface resistance of the ring between the anode and the outer flange 30 which is also painted with titanium hydride for purposes of bonding to other parts of the device. The anode conductor 24 is provided with a longitudinal passage 31 which terminates in a radially extending passage 32 opening on the side wall of the anode 25. This passage provides for the exhaust of the discharge device, as will be described in more detail at a later point in the specification.

An elevational view in section of the discharge device prior to the exhaust of the device and the bonding of the parts together is shown in Fig. 6 and in Fig. 5 is shown an exploded view of these parts including the anode sub-assembly 21 of Fig. 4 and the cathode sub-assembly of Fig. 2, the latter being designated generally by the numeral 33. In accordance with a feature of the invention the discharge device is designed so that it may be supported from a single component of the envelope. In the particular embodiment illustrated, this part is the grid shell or terminal designated by the number 34. The member 34 is provided with an inwardly directed flange 35 which engages the outwardly directed flange of the anode supporting ring 22. After assembly of the anode sub-assembly 21 into the shell 34, a grid spacer ring 36 is inserted. This ring engages the surface of the anode supporting ring 22 and is provided on its upper end with an inwardly directed flange 37 which supports the grid ring 38. As illustrated, the opening 39 of the grid ring is covered by a plurality of parallel and very fine grid wires 40 which are suitably bonded to the lower surface (surface toward the anode) of the ring 38. Next, the cathode sub-assembly 33 is inserted and as will be apparent from an inspection of Fig. 6 the grid cathode spacing is determined by the surfaces 17 and 18 of the cathode supporting ring 1, the flange 4 of the cathode and the thickness of the grid washer 38. This unique arrangement provides for the very accurate spacing of the cathode and the easy control of this spacing in manufacture. Next, a solder ring 41 is inserted and this ring lies between the shell 34 and a concentric outer surface of the supporting ring 1. If desired, an additional solder ring may be inserted prior to the assembly of the grid and cathode sub-assembly in the area between the grid ring 36 and the shell 34. However, a single ring such as 41 has been found to be adequate.

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The envelope is completed and the heater connections provided by cylindrical insulator 42 having a central cylindrical opening 43, a recess 44 and a shoulder 45. The surface of the recess 44 and the area 46 just above the flange 45 are coated with titanium hydride. The insulator 42 is inserted in the cathode shell 9 and wire 15 of the heater is threaded through the small central opening of the ring 42. The other heater terminal 16 is positioned between the ring 42 and the flange provided between the portions 8 and 9 of the cathode shell. In this manner, one heater lead is connected to the cathode shell 9 and the other is connected to a centrally located cathode terminal 47 which is inserted in the opening 43 and provided with a tapered portion 48 which engages the heater terminal 15. The lead wire 15 of the heater is wedged against the edge of the aperture 43 of the insulating ring 42, as clearly visible in Fig. 6. Solder rings 49 and 50 are placed in the recess 44 and in the space between the body of insulator 42 and the cathode shell 9.

With discharge device assembled as described thus far in the specification it is ready for evacuation, bake-out and sealing off. In Fig. 8 is illustrated equipment suitable for accomplishing these operations in accordance with the present invention. Referring now to Fig. 8, there is illustrated what is commonly termed a bell jar exhaust system which includes a support or table 51 having a generally planar upper surface including an exhaust port 52. Surrounding the port are three vertically extending supports 53 on which is carried a suitable refractory member 54 which is apertured at 55 to receive and support an electric discharge device of the present invention. As illustrated, the device is supported from the grid terminal shell 34 from which the remainder of the assembled tube is entirely self-supporting. Suitable extensions 56 of the supports 53 provide means for supporting on inverted cup-shaped metal shield 57 which is adapted to be heated by high frequency induction and to radiate heat to the electric discharge device.

Suitable lead-in conductors and terminals are provided for energizing the heater of the electric discharge device while it is being exhausted. To this end conductors 58 and 59 are brought in through the support 51 through a suitable rubber plug or gasket 60 and the conductors are supported from the insulating member 54. These conductors terminate respectively in spring terminals 61 and 62 which engage respectively the terminal 47 and the cathode terminal shell 9 which as may be seen from Fig. 6 are connected with the heater terminals.

The support for the electric discharge device and the radiating shield 57 are enclosed by a bell jar 63 the lower edge of which rests upon and is sealed to the upper surface of the support 51 in vacuumtight relation by a suitable rubber gasket 64. The exhaust port 52 communicates with a suitable vacuum system (not shown) through a conduit 65.

As will be described in more detail at a later point in the specification, the electric discharge device is sealed off while within the exhausted bell jar. In order to accomplish this sealing, I provide a recessed member 66 for receiving a quantity of solder which will be in a molten condition during the exhausting process and this recessed member is movable relative to the electric discharge device so that the exhaust passage 31 in the conductor 24 may be immersed within

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the molten solder carried by the member 66. The member 66 is supported in vacuum tight relation with respect to the support 51 and for relative movement with respect thereto by an elongated rod 67 provided with a flange 68 spaced somewhat from the point where the rod 67 emerges from the lower wall of the support 51. The flange 68 is connected to a suitable boss 69 on the lower surface of the support 51 by an elongated resilient tube 70. The tube may be in the form of a rubber hose which is clamped to the boss 69 and to the flange 68 by suitable clamping rings 71 and 72.

A suitable source of high frequency for heating the shield or oven 57 is illustrated schematically by the coil 73; as will be readily understood, this coil may be arranged to be moved into and out of operative position with respect to the bell jar and the shield 57.

In a typical exhaust schedule for the discharge device described in detail in the foregoing part of this specification, the bell jar is placed over the assembly and the vacuum system placed in operation. As soon as the pressure has been reduced to about 1 micron, which takes a very short time, in the order of 15 seconds with the system used, the high frequency coil 73 is energized and the shield 57 rapidly heated to a high temperature. The energy of the coil is adjusted so that the entire tube assembly reaches approximately 800° C. in a period of four minutes. After about a minute and a half of heating, the titanium hydride which, as previously described, has been painted on all of the ceramic surfaces which are to be soldered to metal surfaces begins to decompose and by about three minutes the solder flows over the surfaces to which the hydride has been applied. This period depends, of course, upon the particular solder employed and in accordance with an important feature of the present invention a very ductile solder such as lead or a lead silver or lead copper alloy is used. If a pure lead alloy is used the melting point is 327° C. and for the alloy solders it is slightly lower. For example, a 2½% silver solder melts at 305° C. After about 3½ minutes the entire discharge device is up to a temperature of approximately 800° C. and at this time the heater is energized by applying voltage to the conductors 58 and 59. As is well understood, it is common practice to apply a higher than normal voltage to the heater during activation of the cathode and this is usually done by increasing the voltage in steps. For a 6 volt heater, for example, the voltage applied may be in steps of 5, 7 and 10 with each voltage applied for a period of 15 seconds. This leaves the cathode energized at a voltage of 10 volts for 15 seconds after the high frequency energy is turned off. This voltage supplies essentially double normal wattage to the cathode heater. As the assembly has cooled slightly after de-energization the high frequency coil and the heater, the solder pot provided by the member 66 is raised to immerse the lower end of conductor 24 and a solder seal is retained in the lower end of the exhaust passage 31, as shown at 74 in Fig. 7. The solder pot may be lowered at once since the solder is retained in the passage 31 by capillary action. After the device has cooled below 300° and all of the solder joints are in a solid condition, the device may be removed from the bell jar. At this time the device appears as shown in Fig. 7 and the solder rings are all melted to solder the metal and ceramic parts of the en-

velope in hermetically sealed relationship. The ring 49 has melted and flowed around the conductor 47 to seal member 47 to the ceramic ring 42 and to bond the heater terminal 15 to the conductor 47. The solder of the joint is illustrated at 75 and 76. In like manner the solder ring 50 bonds the outer surface of the ceramic ring 42 to the cathode shell 9, as illustrated at 77. Since the outer surface of the member 42 and the very outer edge of the lower surface of this member are coated with a hydride, the solder flows along the edge of the ring and bonds the heater terminal 16. Similarly, the other solder rings bond the various ceramic members to the metal members. The solder ring 41 completes a bond between the grid terminal shell 34 and both of the ceramic rings 1 and 22 as illustrated at 78 and also completes the connection from the grid to the grid terminal shell 34.

From the foregoing it is apparent that the present invention provides not only for the simultaneous exhaust and bonding together of the envelope parts but also the making of the electrical connection by soldering with the titanium hydride method used in accordance with the preferred embodiment of the invention this amount essentially to completing the circuits between the various electrodes and the corresponding terminals by a circuit printing. By this method all separate welding operations, usually required for making these connections are eliminated.

In the foregoing description, a particular process of bonding or soldering ceramic to metal parts has been described. This titanium hydride method is described and claimed in the copending applications, Serial No. 36,289—Kelly, filed June 30, 1948, and Serial No. 36,244—Bondley, filed June 30, 1948, both assigned to the assignee of the present invention. It is to be understood that the present invention is not limited to this particular method of bonding and that in its broader aspect the invention may be applied to any method in which the soldering operation may be carried out in a vacuum. It is also possible that the ceramics be metalized prior to the assembly of the tube so that only the soldering operation is completed during the fabrication and exhausting of the tube within the bell jar.

In the foregoing description, the insulating parts have been described as ceramic. There are a large number of ceramics which are suitable for electric discharge devices and they may be selected in accordance with their electrical and mechanical characteristics. The high alumina bodies and the silicate bodies are particularly suitable. The invention is not limited to materials strictly classified as ceramics since quartz, for example, may be used. It is of particular advantage to use high melting or softening point insulating materials which will stand the high temperature bake-out which the present process makes possible. It is also not necessary to many aspects of the present invention that lead solders be employed. It is a particular advantage, however, to use a soft solder so that the parts are not required to have matching thermal expansion characteristics. This permits the metal parts and the ceramic parts to be selected for their other desired characteristics. In the particular embodiment illustrated, the metal parts of the envelope have been formed of a copper or copper coated steel. In an extreme case the part 1 has been made of quartz and parts 9 and 34 of copper. It is necessary to give some attention to the amount of solder available in

the joint and its relation to the amount of mismatch between the expansion characteristics of the component parts to be joined. It is also important to note that the present technique of making electric discharge devices permits a very high temperature of bake-out during exhaust, and that during this time all of the joints between the insulating and conducting members of envelope are in a fluid state. This means that the bonds themselves are not required to withstand a temperature change from the high temperature of 800° C., in the example given down to the point where the solder solidifies, namely at about 327° C. for pure lead.

From the foregoing description it will be apparent that adjacent parts of the envelope bear directly against one another so that the solder joints are not called upon to withstand any appreciable mechanical force after the device is evacuated. The anode assembly is the one exception and as previously described the ring 27 has a press fit with the anode part 24 so that the load is removed from the joint between the ring 22 and the anode part 24. This permits operation of the device at temperatures approaching the softening part of the soft solder.

It is also significant that the bonds or solder joints are in general made between circumferentially spaced surfaces so that the joints themselves do not enter into the electrode spacing which is determined by the mechanical dimensions of the members in the stack. The cathode to grid spacing particularly is very accurately controlled by the dimensions of the ceramic ring 1, particularly the surfaces 17 and 18 thereof, the thickness of the cathode disk 4 and the thickness of the grid washer or disk 33. The resilient support for the cathode takes care of any expansions encountered during operation of the device. This construction also eliminates direct communication between the solder of the bonds and the inter-electrode space so that detrimental vapor from the soft solders does not enter into this region and contaminate the interior of the device.

While I have described a particular embodiment of my invention, it will be apparent to those skilled in the art that changes and modifications may be made without departing from my invention in its broader aspects and I aim in the appended claims to cover all such changes and modifications as fall within the true scope and spirit of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A cathode subassembly for an electric discharge device comprising a disk-like insulator having a central aperture therethrough, a bearing surface surrounding said aperture on one surface of said insulator, a generally cylindrical cathode structure positioned in said aperture and including an outwardly extending bearing surface engaging the bearing surface of said insulator, a hollow generally cylindrical cathode terminal having an inwardly directed flange engaging the opposite side of said insulator and spring means interposed between said inwardly directed flange and said cathode structure for urging said cathode structure into engagement with the bearing surface of said insulator and electrically connecting said cathode and said cathode terminal.

2. A cathode subassembly for an electric discharge device comprising an insulating member forming a part of the envelope of the device and having an aperture therethrough, a bearing sur-

face surrounding said aperture on one surface of said insulator, a cathode structure positioned in said aperture and including an outwardly extending bearing surface engaging the bearing surface of said insulator, a cathode terminal shell bonded to said insulating member, means electrically connecting said cathode with said terminal shell and spring means interposed between an opposed surface of said insulator and said cathode structure for urging said cathode structure into engagement with the bearing surface of said insulator.

3. An electric discharge device comprising a hollow generally cylindrical conductive grid terminal, a cathode assembly joined to one end of said terminal and including an insulating support having two positioning surfaces occupying accurately determined relative positions, a cathode surface positioned from one of said bearing surfaces, a grid member electrically connected to said grid terminal and spaced from said cathode from the other of said bearing surfaces, an anode assembly sealed to the other end of said grid terminal and including an insulating support on which the anode is supported in accurate positional relationship and a spacer member within said grid terminal interposed between said grid and the insulating support of said anode assembly for determining the grid anode spacing.

4. An electric discharge device comprising a cathode assembly including an insulating support having two positioning surfaces occupying accurately determined relative positions, a cathode surface positioned from one of said bearing surfaces, a grid member spaced from said cathode from the other of said bearing surfaces, an anode assembly including an insulating support on which the anode is supported in accurate positional relationship and conductive means connected with said grid and providing a terminal therefor, and a cylindrical grid terminal of conducting material surrounding both said insulating supports and bonded thereto to join said anode and cathode subassemblies together.

5. An electric discharge device comprising a hollow generally cylindrical conductive grid terminal, a cathode assembly joined to one end of said terminal and including an insulating support having two positioning surfaces occupying accurately determined relative positions, a cathode surface positioned from one of said bearing surfaces, a grid member electrically connected to said grid terminal and spaced from said cathode from the other of said bearing surfaces, an anode assembly sealed to the other end of said grid terminal and including an insulating support on which the anode is supported in accurate positional relationship and a spacer member within said grid terminal determining the spacing between said anode assembly and said cathode assembly.

6. An electric discharge device comprising an envelope including electrically insulating and conducting members positioned in alternate relation in the wall of the envelope and providing mutually insulated externally accessible terminals of the device, a filamentary member within the device having terminal portions received respectively between different adjacent insulating and conducting members and solder joints connecting the terminal portions to said conducting members and bonding said conducting members to the adjacent insulating members.

7. An electric discharge device comprising an envelope including a plurality of insulating and conducting members having generally circular

symmetry, said members being positioned in a stack with the relative positions determined by opposed bearing surfaces in an axial direction to determine the spacing between the elements, a plurality of electrodes within said envelope and positioned respectively from certain of said insulating members and connected with different ones of said conducting members, adjacent ones of said members having closely spaced radial surfaces, and a body of solder between the closely spaced radial surfaces for hermetically sealing the members together without affecting the inter-electrode spacing.

8. An evacuated envelope comprising a plurality of metal members and a plurality of insulating members having mismatching thermal expansion characteristics with respect to said metal members, said members being stacked to provide the envelope wall with the metal members providing mutually insulated terminals, and ductile bonds between continuous surfaces of adjacent members, said bonds each comprising a layer of a lead solder.

9. An evacuated envelope comprising a plurality of metal members and a plurality of insulating members having mismatching thermal expansion characteristics with respect to said metal members, said members being stacked to provide the envelope wall with the metal members providing mutually insulated terminals, ductile bonds between contiguous surfaces of adjacent members, said bonds each comprising a layer of a lead solder, and means including abutting surfaces on adjacent members for relieving the ductile bonds of mechanical force due to atmospheric pressure on the exterior of said envelope.

10. An evacuated envelope including an insulating member and a pair of conducting members spaced apart and mutually insulated by said insulating member, said members having mismatching thermal expansion characteristics over the temperature range to which the envelope is to be subjected in use, said members having abutting surfaces determining the spacing between said metal members and absorbing the compressive force due to atmospheric pressure on the exterior of said envelope, and ductile bonds between other surfaces of said members hermetically sealing said members together, said bonds including a lead solder.

11. An evacuated envelope including an insulating member and a pair of conducting members spaced apart and mutually insulated by said insulating member, said members having mismatching thermal expansion characteristics over the temperature range to which the envelope is to be subjected in use, said members having abutting surfaces determining the spacing between said metal members and absorbing the compressive force due to atmospheric pressure on the exterior of said envelope, said members also having closely spaced circumferentially opposed surfaces and ductile lead solder bonds between said latter surfaces hermetically sealing said members together.

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