

Oct. 24, 1950

R. S. GORMLEY ET AL
ELECTRONIC DISCHARGE DEVICE

2,527,127

Filed Dec. 24, 1948

2 Sheets-Sheet 1

FIG. 1

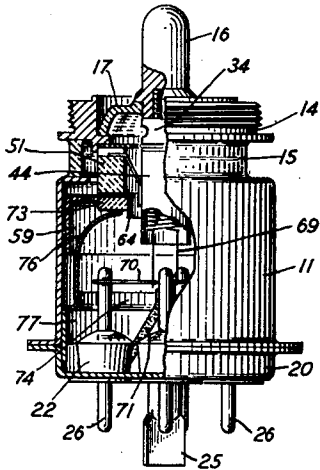


FIG. 2

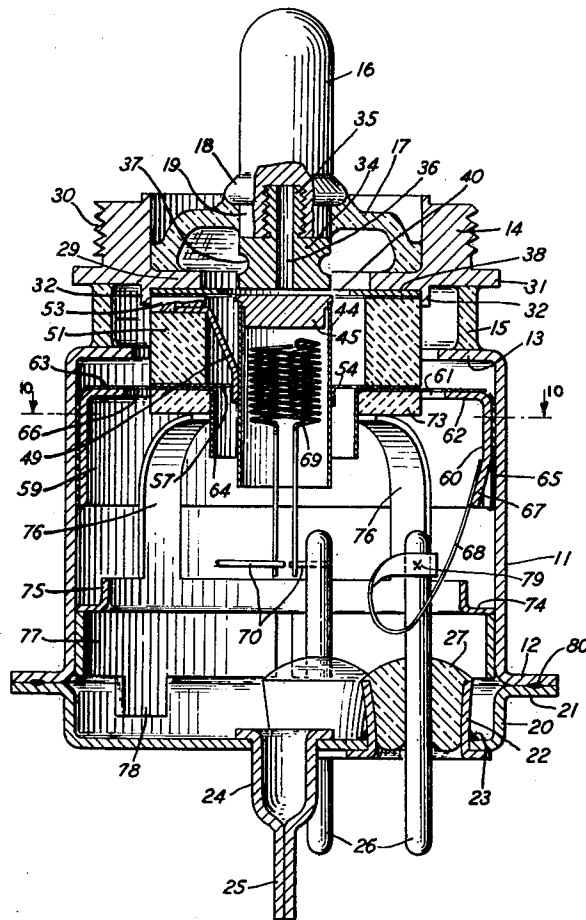


FIG. 5

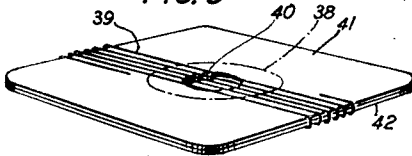
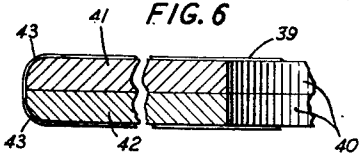


FIG. 6



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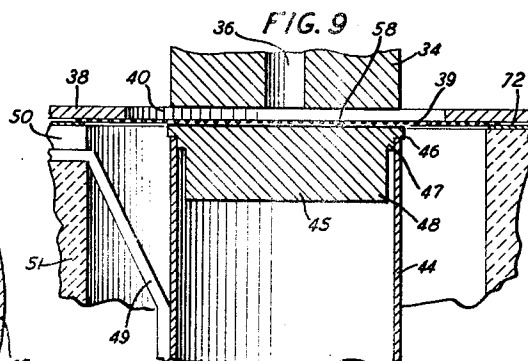
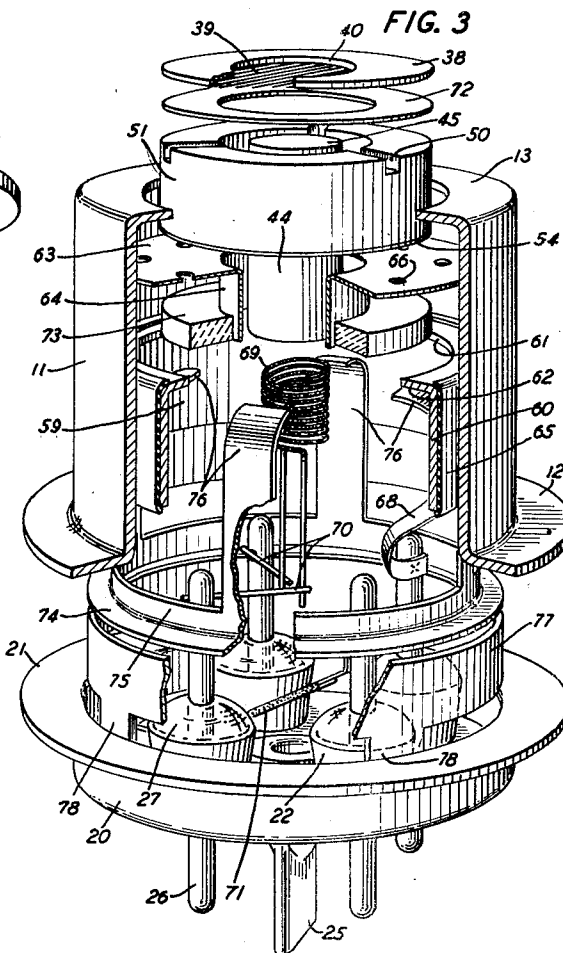
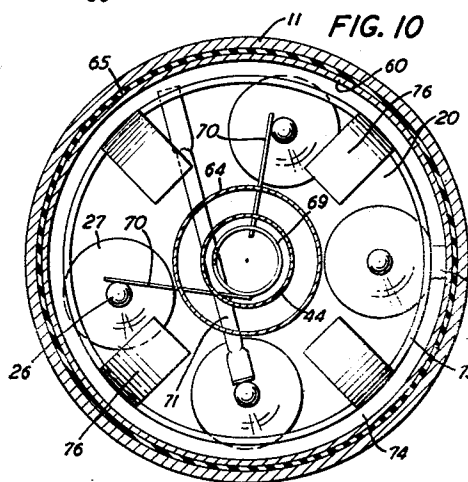
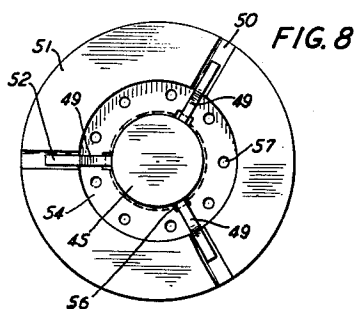
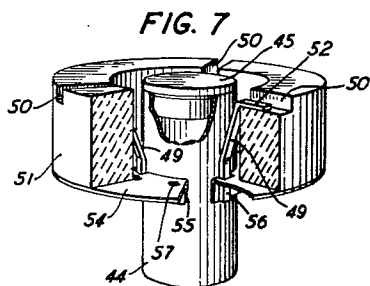
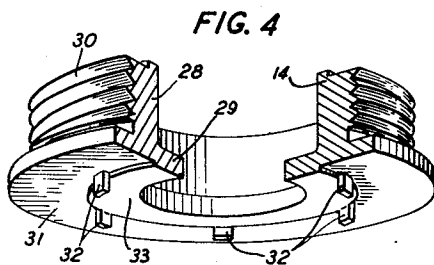
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UNITED STATES PATENT OFFICE

2,527,127

ELECTRONIC DISCHARGE DEVICE

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Application December 24, 1948, Serial No. 67,106

16 Claims. (Cl. 250—27.5)

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This invention relates to electron discharge devices and more particularly to such devices capable of operating in broad band ultra-high frequency systems with high gain and without substantial distortion.

The primary object of this invention is to maintain high transconductance values in the operation of discharge devices, especially devices operable at ultra-high frequencies, for example in the 4000-megacycle range.

Another object of the invention is to facilitate mass production of such devices while still attaining relatively close critical space relations between the electrodes.

A further object of the invention is to obviate the need for specialized technical skill in the assembly of the device so that manufacturing costs may be reduced.

Another object of the invention is to coordinate productivity with stability in the fabrication of the electrode assembly of the device so that loss by inspection rejects is held to a minimum.

A still further object of the invention is to increase efficiency of production by expediting the assembly of the combined electrodes of the device to insure stability in the spacing and operating relations of the electrodes.

Another object of the invention is to achieve precision in planar electrode relations in such devices within close tolerances, which are maintained constant throughout the operating life of the devices.

A further object of the invention is to increase the emission density of the cathode and more nearly approach the theoretical transconductance limit so that high gain is realized at high power output levels.

Another object of the invention is to maintain accurate parallelism between the cathode and grid in such devices at constant close spacing, thereby to insure permanence of performance even at relatively high temperatures and high voltage operation.

These objects are realized in accordance with the various aspects of this invention by an integrated assembly of electrodes in a casing of the device which insures accurate collateral and concentric relation of the electrodes and definite space relation therebetween. This construction involves a metallic shell casing having an annular metallic portion at one end of and insulated from the body of the casing and a central anode mounted therefrom and similarly insulated from the casing. The annular portion is provided with an internal guide ring which de-

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finer a means for indexing the grid and cathode assemblies concentrically within the casing. This arrangement facilitates the fabrication of electrodes and the spacing thereof by straightforward mechanical methods in which high cost assembly labor is eliminated and precision spacing to close tolerances is attained.

In a specific embodiment of the invention, the device embodies a multisection housing or casing comprising a main sleeve or shell portion, an external collar or ring portion, which serves as the grid terminal of the device, sealed by a vitreous circular wall to one end of the shell, and a central anode terminal supporting an anode disc coaxial with the ring portion and hermetically sealed thereto by a vitreous dome portion. The external collar is provided with an internal registering guide coaxial with the periphery and preferably of castellated formation projecting toward the open end of the casing. A planar grid ring together with a shim spacer and a flat tubular cathode-insulator mounting assembly are introduced into the casing and fit within the guide to insure concentricity between the electrodes in superimposed relation. A pressure spring bears against the cathode assembly and a locking ring secured to the casing holds the spring under the desired compression to prevent variations between the various electrodes. The locking ring also registers with a closure base or stem, supporting a central heater element, on the end of the casing to position the heater coaxially within the tubular cathode.

A particular feature of this construction relates to the formation of an integral guiding ring portion concentrically within the grid terminal collar portion of the casing for correlating the electrode assemblies cooperating with the flat anode disc projecting from the central terminal closure. This is accomplished by forming an annulus on one surface of the grid terminal collar projecting toward the open end of the casing, the annulus being castellated in one form to present a plurality of guide prongs concentrically related to the periphery of the collar and arranged in circular closed series relationship to form an indexing guide or bearing portion for accommodating the cooperating electrodes of the device. This arrangement insures accurate concentricity in the mounting of the electrode assemblies of the device and eliminates the effect of shielding of the electrodes within the indexing boundary by high frequency heating during manufacture of the device.

Another feature of the invention relates to the provision of coupling means on the casing to facilitate the installation and quick replacement of the device in associated equipment. This is accomplished by forming an integral threaded sleeve portion on the grid terminal ring of the device to provide a mechanical coupling to a coaxial line which will expedite the connection of the device in the operating circuit.

Another feature of the invention relates to the cathode assembly for unitary insertion in the device. This assembly comprises a tubular cathode suspended coaxially within a ceramic ring spacer by a plurality of arms which retain the cathode emissive surface coplanar with the spacer surface to insure constant relation of the cathode surface with respect to the adjacent grid winding interposed between the anode and cathode of the device. The construction permits expansion of the cathode without axial movement so that the critical spacing of the cathode with respect to the grid winding is not altered in service or even during the high temperature processing cycle during manufacture.

A further feature of this construction relates to the provision of a stable temperature absorption surface for the emissive coating of the cathode. This involves a heavy metal disc surface of step-like construction to eliminate warping and to avoid heat dissipation whereby the emission coating is maintained at the desired temperature for efficient operation. The step-like construction of the disc permits mounting in relation to the sleeve portion of the cathode wherein the larger diameter of the disc supports the active coating, the intermediate step is attached to the sleeve and the smaller diameter portion is within and spaced from the sleeve to act as a heat storing mass to maintain the cathode emissive surface at a uniform operating temperature.

Another feature of this cathode assembly relates to the formation of the active surface to insure an emission commensurate with the power output figure of merit desired in the operation of the device in service. This requires a cathode emission density three or four times greater than commercial devices of comparable size. The density of the emissive coating is accurately produced by a special spraying technique employing very fine particles of the emissive oxide material which are applied in a thin film of the order of one-half mil thickness under controlled conditions.

A further feature of the cathode unit assembly relates to the provision of a radio-frequency connector for coupling the cathode to the main shell of the casing. This connector includes a flexible sheet metal disc attached to the cathode sleeve adjacent the supporting arms and provided with recesses to clear the arms. In addition, the connector is provided with a circular series of apertures adjacent the boundary of the cathode sleeve to permit evacuation of the confined space surrounding the cathode structure.

Another feature of the cathode assembly relates to the coupling of an internal by-pass capacitance thereto to provide a low impedance path to an external circuit during operation. This arrangement involves an inverted cup-shaped member abutting against the cathode connector disc and closely fitting within the interior wall of the main shell casing with an interposed dielectric layer thereon to combine with the shell and form a capacity element in the

device. The cup-shaped member is also provided with a circular series of apertures to permit escape of gases within the enclosed space of the electrodes, these apertures being staggered in relation to the apertures in the connector disc.

A further feature of the invention relates to a pressure spring mounting of considerable force bearing against the cathode assembly to insure positive and permanent location of the respective electrodes in pressure relation in the device. This construction comprises a ring member having a plurality of arcuate fingers extending inwardly and upwardly toward an insulating collar which presses against the inner surface of the capacitance element within the shell, the ring member fitting closely within the shell casing. The forcible engagement of the electrodes in compact juxtaposed relation against the base of the indexing portion of the grid terminal ring provides a static fixation of the critical spacing of the grid-cathode surfaces and eliminates variations thereof even at temperatures encountered while the device is in operation. Furthermore, the strong force of the spring insures uniform axial pressure so that no distortional stresses are present to change the prescribed relationship of the electrode assembly in the device.

Another feature of the invention relates to the locking and stem indexing ring engaging the inner wall of the casing to maintain the pressure spring and align the closure stem on the open end of the casing. The locking ring is of suitable diameter to fit closely within the open end of the shell and its upper end bears against the flange of the pressure spring, the ring being welded to the shell after the required pressure is applied to the spring. The lower end of the retainer ring is provided with index projections extending outwardly from the shell to engage the inner surface of a dished stem adapted to be welded to a flange portion of the shell to complete the assembly of the device prior to processing. This arrangement insures positive concentricity of the stem in relation to the shell and accurate coaxiality of the heater element supported on the stem in relation to the tubular body of the cathode assembly.

A further feature of the invention relates to the methods of assembly of the various electrodes within the casing which insure positive alignment, definite laterality of adjacent electrodes and accurate critical space relation, for example of the order of one-half mil distance between the active surface of the cathode and the grid wires. One method of assembly involves, literally, dropping the grid disc, spacer shim, and cathode unit assembly, successively, in that order, into the shell to be automatically centered within the register ring on the surface of the grid terminal ring. Since the grid, shim and cathode ceramic spacer are positively enclosed within the circular index projections on the grid terminal portion of the device, the electrodes are accurately mounted in layer or sandwich fashion concentrically associated and spaced in their desired relation.

The cathode assembly includes also the radio-frequency connector disc and the capacitance element which are concentric with the cathode proper and jointly slip into the shell casing of the device to lie adjacent to the inner wall. The pressure spring is inserted to bear against an insulating ceramic ring engaging the inner surface of the capacitance element and coaxial with the cathode sleeve and the retainer ring is placed

within the shell to engage the spring. When the desired pressure is applied to the ring, while the shell is held rigidly, the spring and retainer ring are forced further into the shell and finally the ring is welded to the wall of the casing. The stem, with a central helical heater element supported by certain terminal prongs in the stem, is applied to the shell and automatically centered therewith by the index projections on the retainer ring within the casing. While the stem is slightly spaced from and at an angle with respect to the shell, a flexible connector strap carried by the capacitance element is affixed to another terminal prong on the stem to provide a low frequency coupling for the cathode. When this operation is completed the stem is ring-welded to the shell flange to complete the assembly process. This method of assembly facilitates the mounting of the electrodes in the device, insures absolute alignment of the several electrode assemblies, avoids precision adjustment to accurately space the electrodes yet attains precise relation without highly skilled technicians. Furthermore, it eliminates the use of high temperature adjacent the cathode surface which was necessary in prior integrated unit assemblies involving fusing operation on vitreous connecting posts. Also, since the thickness of the cathode is known and the surfaces of the cathode prior to coating and of the ceramic spacer are accurately coplanar, it will be appreciated that the critical distance of the coated cathode surface from the grid wires is readily secured by the use of the spacer shim of known thickness. The "drop method" of assembly of the device increases production capacity, reduces costs, facilitates assembly by low cost labor, decreases distortion of the elements in the casing, permits quality control of activation of the cathode and quick pumping time of the device, automatically aligns the electrodes in the assembly, reduces rejection loss in the inspection of completed units, and affords a high salvage value of the components of the device when defective units are processed.

These and other features and advantages of this invention will be readily apparent from the following detailed description when considered in connection with the accompanying drawings in which:

Fig. 1 is a view in elevation of a complete assembly of the electronic discharge device with portions of the vessel and the internal elements broken away to show the structural relation of the electrodes;

Fig. 2 is an enlarged cross-section view of the device, showing the detailed assembly;

Fig. 3 is an enlarged perspective view, in exploded fashion, of the components of the device, partly in section and partly broken away, to show the positions of the various internal elements within the casing of the device;

Fig. 4 shows the grid terminal ring of the device in enlarged perspective view with a portion in cross-section to emphasize the detailed construction thereof;

Fig. 5 is a perspective view of the winding assembly of a pair of grids, one of which is employed in each device;

Fig. 6 shows in greatly enlarged cross-section a portion of the grid frames shown in Fig. 5;

Fig. 7 is a perspective view, partly broken away, of the cathode-insulator assembly of the device;

Fig. 8 is a plan view of the structure shown in Fig. 7;

Fig. 9 illustrates in a grossly enlarged sectional view the critical spacial relation of the main planar electrodes as attained in the fabrication of the device, in accordance with this invention; and

Fig. 10 is a sectional view of the device taken on the line 10—10 of Fig. 2 showing the relationship of some internal components with respect to the stem closure of the device.

This invention and the constructions described hereinafter represent an improved assembly structure for ultra-high frequency discharge devices of the type disclosed in copending application Serial No. 572,596 filed January 13, 1945 by J. A. Morton and R. L. Vance, which is now Patent No. 2,502,530, issued April 4, 1950. While the basic electrode relations are similar, this invention enables a simpler assembly technique which materially enhances the attainment of the critical spacial constants of the electrodes, considerably reduces manufacturing cost, avoids parasitic leakage losses, reduces high resistance coupling, obviates need for highly skilled labor and increases unit production with low shrinkage loss.

Referring to the drawings, and particularly to Figs. 1 and 2, one embodiment of the invention is shown completely fabricated to illustrate the correlation of the various components of the internal electrode system and the cooperating casing assembly. The device shown is particularly suitable for use in ultra-high frequency applications, such as in the 4000-megacycle range, in which high transconductance, high gain, low capacitance losses and high power output are of paramount importance.

In these figures the container of the device includes a composite, multisection cylindrical casing and a stem or closure. The casing includes a cylindrical metallic shell 11, preferably formed of Kovar alloy, provided with a circular outer flange 12 at one end and an inner flange 13 at the other end to form an inverted cup portion with a concentric opening at the upper end. An external cup-shaped grid terminal ring 14, also of Kovar alloy, is concentrically mounted on the smaller apertured end of the shell by a vitreous spacer sleeve 15, of borosilicate glass, and hermetically sealed between the parallel facing surfaces of the ring 14 and the flange 13 of the shell. A central solid terminal post 16, of Kovar alloy, is mounted in the cup portion of the ring by a domed glass cap 17 which is hermetically sealed to the inner base and wall of the ring and the shoulder 18 and internal extension 19 of the terminal post. This arrangement forms a symmetrical casing in which the main shell, grid terminal ring and central terminal post are accurately spaced to insure adequate insulation resistance against leakage currents and in coaxial relation to facilitate coupling of the device in associate transmission equipment. Also, the sealed joints with the glass sections provide efficient strain-free coupling of the major metallic parts due to similar thermal coefficients of the glass and metal parts entering into the fabrication of the casing. The stem closure is a dished metallic member 20, advantageously of drawn steel, having a plurality of apertures in the base portion and a peripheral flange 21 corresponding to flange 12 on the shell 11. A plurality of Kovar eyelets 22 are welded externally to the stem in a circular row of apertures and project within the stem. The internal joints of the eyelets and dish are additionally hermeti-

ally sealed by copper brazed rings 23 at the junction of the eyelets with the stem. An outwardly extending metallic tubulation 24 is internally welded within a central aperture of the stem and is pinch-sealed at 25 after complete processing of the interior to produce a high degree of vacuum in the device. The eyelets are slightly flared within the stem and support coaxial rigid Kovar terminal pins 26 by means of glass beads 27 hermetically sealed to the pins and eyelets. The flanges 12 and 21 are ring-sealed by percussion welding to form a strong tight joint between the shell and stem.

The grid terminal ring 14, shown more clearly in Fig. 4, is made of solid Kovar metal with a central and coaxial deep recess or cup portion 28 to form an internal annulus or basal portion 29. The ring 14 is provided also with an external threaded portion 30 on the perimeter of the cup portion, to facilitate the coupling of the device to associate apparatus, particularly a coaxial line, in the operation of the device and to permit expeditious removal and replacement of the device in various circuit applications. An external flange portion 31 projects from the base of the threaded portion and is slightly undercut with respect to the lower surface of the internal flange portion 29 to compensate for differences in the electrode assembly pile-up and the surrounding resonant chamber between the grid terminal ring and the shell bounded by the glass sleeve portion 15.

The grid terminal ring is provided further with internal projections 32 in a circular boundary intermediate the flange portion 31 and the internal plane face or datum surface 33, to form an indexing or registering guide portion on the rigid and accurately fixed portion of the casing to positively align the cooperating electrodes within the casing of the device. These projections may be formed by milling a protruding ring of solid metal on the lower surface of the grid terminal, to provide spaced guide prongs or castellations in accurate concentric relation to the diameters of the flange and central aperture. The inner diameter of the castellated guide portion is preferably coextensive with the diameter of the cup portion 28 of the grid ring 14. The indexing guide portion may be formed as a complete annulus to facilitate fabrication and reduce the cost of assembly.

In the fabrication of the casing of the device, the shell 11 is sealed to the ring 14 by fusing the glass sleeve intermediate the flanges 31 and 13 with both the ring and shell held in definite spacial and concentric relation in a jig or fixture. Then the terminal 16 is concentrically sealed in the glass cap 17 which is fused in sealing engagement with the wall and flange of the grid ring. The extension 19 of the terminal is accurately gauged with respect to index surface 33 of the ring 14, to provide substantially exact spacial relation for the insertion of an anode button 34, preferably of copper, which is threaded into a socket of the terminal by a sleeve extension 35 so that the face of the anode button is precisely coplanar with the index surface of the ring 14. Since the shell 11, ring 14 and terminal post 16 are made of Kovar alloy, these parts of the casing have expansion characteristics closely similar to the glass sleeve and cap so that strain-free seals are produced at the junctions to preserve the hermetic condition of the casing.

After the sealing operations are performed on the casing and prior to mounting the anode button 34 in the terminal post, all surfaces of the metal parts except the flange 12 are gold-plated internally and externally to reduce high frequency loss due to current conduction along the high resistance Kovar metal surfaces, to avoid excessive oxidation and improve the cleanliness of the steel alloy parts. The copper anode also is gold-plated and the threaded shank or extension 35 is provided with a thread pitch slightly dissimilar to the threaded opening of the terminal post to insure a tight or binding fit of the shank in the terminal post. The anode button is provided also with a central bore which extends completely through the button and shank and the peripheral surface of the button is provided with parallel notches 37 on opposite sides, to facilitate gripping the button with suitable tongs to adjust the face of the button coplanar with the index surface 33 of the grid ring 14.

The planar grid of the device is formed of a molybdenum disc 38, shown in Fig. 3, of 10 mils thickness, which is goldplated, and a plurality of fine tungsten wire strands 39, of .00031 to .00034 inch diameter, extend across a concentric opening 40 in the disc, the wires being brazed to the disc by heating the disc to flow the gold-plating over the wires. The method of forming the grid is shown in Figs. 5 and 6 wherein two molybdenum plates 41 and 42 are polished and plated to the required thickness and placed back to back with opposite edges rounded at 43, as shown in Fig. 6, and the fine tungsten wire wound over the pair of plates at the rate of 1000 turns per inch with a winding tension of 15 grams ± 1 gram weight by winding methods disclosed in a co-pending application Serial No. 775,733, filed September 23, 1947 of J. A. Morton. The tension applied to the wire is about 60 per cent of the breaking strength of the wire and the mean deviation of lateral wire spacing is less than 10 per cent so that the grid laterals are regular and fine enough to employ the grid as a diffraction grating. The rounded edges of the plates prevent sharp bending of the wire and avoid cutting or scraping of the wire during the winding process. When the dual grids are completely wound the assembly is placed in a hydrogen filled oven and heated to 1070° C. for thirty seconds to braze the wire to the plates. Then the plates are separated and each plate is punched by a suitable die to a disc diameter, for example of .531 inch, this diameter being concentric with the central aperture 40 of say .250 inch within $\pm .001$ inch. After the punching operation, the individual grids must be truly flat and the periphery is processed to remove burrs. Then the grid is heated in vacuum at 800° C. to remove occluded gases and finally stored in a low pressure container evacuated to about 1×10^{-3} millimeters of mercury maximum.

The cathode assembly of the device is precision fabricated to insure positive parallelism with the wires of the grid and maintain close spacing thereto, of the order of $\frac{1}{2}$ mil. The cathode assembly must be fabricated under precision control conditions to attain the desired critical spacial relation with reference to the grid surface in the device, to insure high transconductance values and minimum variation in spacing with temperature changes in the operation of the device. Since the spacing, of the order of $\frac{1}{2}$ mil, can be radically changed by aggregative

or cumulative variations in the several components entering into the cathode structure, all operations in the development of the cathode assembly must be precisely governed to compensate for thermal and mechanical differences occurring under operating temperature conditions.

The components of the cathode assembly are shown in Figs. 7 and 8 and an illustrative exposition of the close relationship of the cathode to the grid and anode is represented, on an enlarged scale, in Fig. 9. The cathode proper includes a molybdenum sleeve member or supporting housing 44 to enclose the heater element for energizing the cathode to emission temperature, and a rigid metallic disc portion 45, to provide a stable flat surface for the emissive coating applied thereto. The disc is formed of a solid nickel mass having a maximum diameter of .185 inch, in the particular application of the device set forth as an example in this description, to eliminate buckling of the emissive surface during high temperature operation. The sleeve is formed of material of .005 inch thickness while the disc is formed of nickel having a thickness of .060 inch. The disc 45 has a definite configuration, in accordance with this invention, to eliminate mechanical distortion, allow radial expansion and increase residual heating effect to maintain the emissive surface at a uniform emission temperature effective to secure high efficiency. The disc is formed in steps of decreasing diameters and includes a free outer diameter or immediate emission surface portion 46 extending beyond the sleeve 44, as shown in Fig. 10, an intermediate lesser diameter portion 47 spot-welded within the confines of one end of the sleeve, and a large mass portion 48 of smaller diameter enclosed wholly within the sleeve and circumferentially spaced therefrom. The large mass portion increases the heat storing properties of the cathode disc and materially strengthens the disc against buckling which would be detrimental in operation due to the close critical spacing of the active cathode surface with respect to the grid wires. The elemental cathode structure is mounted in juxtaposition to the grid surface by arms 49, advantageously of molybdenum strips having a thickness of .010 inch to .020 inch. These arms are attached to the periphery of the cathode sleeve 44 intermediate the ends and equally distributed at points 120 degrees apart, and extend angularly and divergently toward corresponding slots 50 in an annular ceramic spacer ring 51. The latter is of dense "steatite" material having a coefficient of expansion close to that of molybdenum so that the major components of the cathode assembly will expand in unison, i. e., as the sleeve elongates in one direction the arms compensate the movement by expansion in the opposite direction and the insulator expansion will coincide with that of the sleeve. Therefore, longitudinal displacement of the cathode is substantially prevented. The flexible arms permit radial expansion so that the location of the cathode surface is constant with respect to the grid surface. The dense ceramic spacer is of such composition as to eliminate gas absorption and provide the desired characteristics of thermal expansion to harmonize with the cathode sleeve structure. This material is more clearly disclosed in Patent 2,332,343 dated October 19, 1943 of M. D. Rigterink.

The supporting arms are provided with bent portions 52 which are located in the slots 50 on the upper surface of the insulator ring and are

secured therein by a glaze cement 53. The cathode sleeve is also attached to a radio frequency connector disc 54 which has an inner collar portion 55 embracing and attached to the sleeve 44, preferably by welding, substantially in covering relation to the lower ends of the arms attached to the sleeve. The collar portion, however, is provided with rectangular-shaped grooves 56 where the collar encounters the arms to allow freedom of movement of the disc 54. In the relation, as shown in Fig. 7, the disc 54, which may be of .001 inch nickel, has its major surface in abutting relation to the lower face of the ceramic insulator 51 and the periphery coincides with the outer wall of the insulator. The connector disc is provided also with a circular series of apertures 57 which lie in a boundary intermediate the cathode sleeve 44 and the ceramic spacer 51, to permit evacuation of the space or area confined by these elements.

The cathode assembly, as described in connection with Figs. 7 and 8 is placed in a jig or fixture and the top surfaces of the disc 45 and the surrounding insulator are ground by a suitable silicon carbide disc, to substantial coplanar relation without imposing stress on the arms 49 and the connector 54. Since the grinding is applied to dissimilar materials, namely the ceramic 51 and the nickel disc 45, the parallelism of these surfaces is achieved within three or four hundredths of a mil so that for practical purposes the surfaces are coplanar, the difference being negligible between these surfaces.

When the above operation is completed, the insulator 51 and the supporting assembly of the cathode disc 45 are masked with only the disc exposed and a thin dense coating of barium and strontium carbonates in a suitable vehicle, such as amyl acetate and nitrocellulose, is sprayed on the cathode disc to a thickness of about $\frac{1}{2}$ mil to provide a relatively smooth layer or dense coating. The emissive coating is shown as a solid line 58 in Fig. 9, since even to this enlarged scale it is difficult to show the actual thickness of coating attained on the cathode. A high density for the coating is accomplished by thorough ball milling of the coating mixture in which the particle size of the carbonates is reduced to uniform dimensions of 1 to 1.5 microns and also by the method of spraying to form a controllable thickness on the surface of the cathode disc. The thin dense coating provides an emission density of 180 milliamperes per square centimeter to develop an emission current five to six times greater than former cathodes of comparable size and voltage rating. The applied thickness of coating is substantially the same after activation treatment since practically no shrinkage results therefrom as to the density of the coating material.

In combination with the cathode assembly, another unit element incorporated in the device and prefabricated before insertion into the casing is the capacitance element generally designated by numeral 59 in Fig. 1, and shown more in detail in Figs. 2 and 3. This element includes a flanged cylinder 60 of Kovar alloy having a thickness of 0.15 inch and a central concentric opening 61 of .625 inch at the top adjacent the internal flange portion 62, the outside diameter of the cylinder being .809 inch. The flange portion is welded to a thin steel disc 63 of .005 inch thickness having a depending shield sleeve portion 64 reentrant and concentric with the cylinder 60 and coaxial with the cathode sleeve 44 which it surrounds. The cylinder 60 is provided with a

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dielectric coating on the outer surface in the form of a fused glass layer 65. This is applied by spraying powdered boro-silicate glass in a suitable binder to a thickness of about .005 inch and then firing to intimately seal the glaze coating to the surface of the cylinder. The steel disc 63 is provided also with a circular series of apertures 66 adjacent the flange portion of the capacitance element to communicate with the space in the casing between the insulator ring 51 and the casing portions bounding this area, such as the grid ring 14, glass wall 15 and shell adjacent the flange portion 13. The lower end of the cylinder 60 is slotted longitudinally at an appropriate location to form a bent tab 67 and a flexible nickel strip 68 is attached to the tab, preferably by welding.

The stem 20 is prepared for assembly to the shell by mounting a double helix heater 69 of .005 inch tungsten wire concentrically in relation to the stem periphery by a pair of stub wires 70 between the legs of the heater element and a pair of terminal pins 26 in the stem. The heater is wound on a mandrel of .114 inch diameter and after removal the wire is coated by spraying an insulation layer thereon of aluminum oxide in a suitable binder material. A getter strip 71 is welded at one end to the base of the stem and extends at an angle to another terminal pin in the stem, the vaporizable substance being directed downwardly towards the base to avoid diffusion on the insulated leads in the stem.

After the main internal components of the device are assembled, such as the grid, cathode assembly, condenser element and stem, the fabrication of these units in the casing of the device may proceed in an expeditious manner without the need for highly technical skill, to attain the desired critical spacing of the elements in the device. Since the mounting of the anode button 34 on the terminal post of the device was described heretofore, description of this operation need not be repeated. To be noted, however, is the coplanar relation of the face of the anode button with the datum surface 33 of the grid terminal ring 14. The casing of the device is inverted in a holding fixture so that the open end of the shell is uppermost in position. The grid disc 38 with the wires 39 on the outermost surface is placed in contact with the index or datum surface 33 of the grid terminal ring 14 within the confines of the milled projections 32, to accurately center the grid with respect to the anode button 34 and positively gauge the spacial relation of the face of the anode button to the wires of the grid by the thickness of the grid disc, which, as noted heretofore, is 10 mils. The grid disc outer diameter is .531 inch which substantially corresponds to the inner diameter of the register boundary within the confines of the projections 32 which is .535 inch. The minute difference between these dimensions allows for radial expansion so that buckling is prevented during high temperature operation.

The next operation is to insert the cathode assembly, including the spacer ring 51, arms 49, sleeve 44, cathode disc 45, and connector disc 54, into the casing with the cathode disc 45 having the $\frac{1}{2}$ mil thick coating thereon facing the anode button 34. To secure the accurate parallel relation between the $\frac{1}{16}$ mil wires 39 of the grid and the active coating on the cathode disc 45 by a definite spacing of approximately $\frac{1}{2}$ mil, it is necessary to insert a spacer shim 72, shown more clearly in Figs. 3 and 9, preferably of thin copper material, between the grid disc 38 and the ceramic

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spacer ring 51 of the cathode assembly. The shim is a ring-like wafer having a diameter of .530 inch similar to that of the grid, and a central aperture of .320 inch diameter.

The close space relation between the grid wires and the cathode surface is achieved by selection of a shim of requisite thickness, to compensate for minor dimensional differences between the grid and cathode surfaces. As indicated previously, the surfaces of the spacer 51 and the bare cathode disc 45 are ground as nearly coplanar as possible, taking into consideration the effect of the grinding disc on the dissimilar materials of the spacer and cathode disc. The difference between the cathode disc and the surface of the spacer may be, for example, .00014 inch. The expansion difference between the ceramic spacer, molybdenum arms, sleeve and cathode disc may introduce a variation of approximately .00046 inch. The cathode coating thickness is known to be substantially .0005 inch so that these variations and coating dimensions must be taken into account in arriving at the thickness of the shim to secure the necessary critical spacing of the grid and cathode in the device. Assuming, for example, that the measurements specified above, are the actual requirements to be met and compensated then the shim thickness should be .00170 inch.

A satisfactory method of obtaining a variety of shims of various thicknesses differing by .0001 inch is to punch the wafers 72 from a single sheet of .001 inch copper, then apply a heavy pressure to each shim in a lever press of 2-ton capacity to cold flow the copper to a uniform dimension. The pressed shims are finally gauged individually and placed in containers suitably marked with their exact thickness which will vary by $\frac{1}{16}$ mil. By selecting the desired shim from the accurately measured supply the proper thickness of shim may be matched to the dimensional requirements and inserted into the casing of the device within the confines of the guiding projections 32 on the grid ring to abut against the grid wires 39 on opposite portions of the grid disc 38. This is shown in Fig. 9 wherein the shim 72 is spaced from the grid disc by the dimension of the wires.

After the shim 72 is placed in juxtaposed relation to the grid, the cathode assembly is dropped into the shell with the ceramic spacer 51 entering the index portion of the grid ring provided by the automatic centering projections 32. The cathode disc 45 with its coating will be axially centered with respect to the anode button 34 and definitely spaced from the grid wires by the required $\frac{1}{2}$ mil distance. The condenser can and shield assembly is inserted in the shell and since the outer diameter of the can is slightly smaller than the inner diameter of the shell 11 accurate concentricity is secured when the assembly is placed in position against the radio frequency connector 54 of the cathode assembly. Since the shield disc 63 is coaxial with and welded to the condenser 59, it will assume a position concentric with the cathode sleeve 44 and project toward the open end of the shell on a slightly smaller diameter than the ceramic spacer 51. It will be noted from Fig. 2 that the connector disc 54, shield disc 63 and condenser can 59 form a closure partition to the space or area in the active zone of the casing. However, the concentric series of apertures 57 in the connector disc 54 and 66 in the shield disc 63 permit the adjacent spaces to be highly evacuated during the pumping and

processing of the device. Similarly, the threaded coupling of the anode structure is completely evacuated through the central bore in the button to remove occluded gases.

A dense "steatite" ceramic collar 73 fits snugly around the shield cylinder 64 and rests against the lower surface of the shield disc 63, the outer diameter of the collar being the same as that of the spacer 51 so that a uniform bearing contact is secured to hold the abutting surfaces of the connector ring 54 and shield ring 63 in intimate engagement. This construction provides a low resistance radio frequency input coupling for the active cathode surface through the condenser and shell to an external circuit, and a low voltage, low frequency coupling connection from the cathode to a terminal pin of the device through the metallic circuit formed by the condenser can and the flexible strip 68.

When the main components are deposited in their assigned relation in the casing, a heavy pressure spring member is inserted into the shell to press against the collar 73 and thereby force all the components toward the datum surface 33 of the grid terminal ring so that all the elements will be accurately held in constant relation during the operating life of the device. This spring may be formed of .010 inch molybdenum having a ring portion 74 with an outer diameter coinciding with the inner dimension of the shell 11 and an upstanding flange 75 of smaller diameter. A plurality of inwardly curved leaf spring portions 76 extend upwardly from and integral with the flange portion, the curved ends bearing equally against the collar 73, as shown in Fig. 2. A split retainer ring 77, of steel of .015 inch thickness and a diameter the same as the inner dimension of the shell, is introduced into the shell to bear against the flat surface of the spring element 74. When the spring and retainer or locking ring are in position in the shell a pressure force of about 8 pounds is imposed on the spring and ring to force them further into the shell and then the locking ring 77 is welded to the shell 11.

The retainer ring is provided with spaced downwardly projecting ears 78 formed integral with the ring and these ears extend beyond the edge of the flange 12 of the shell, to form concentric guide portions for positioning the stem 20 on the end of the casing and accurately centering the heater element 69 within the cathode sleeve 44. Prior to attaching the stem to the shell the stem is brought into engagement with one edge of the flange 12 and tilted to permit the insertion of a welding electrode into the shell to rigidly affix the strip 68 to the remaining terminal pin, as shown at 79 in Fig. 2. After this welding operation is completed, the stem 20 is applied concentrically to the open end of the shell and the ears 78 fit into the dish stem and guide the stem into engagement until the flange 21 is in abutting contact with the flange 12 of the shell. These flanges are then ring welded at 80 to hermetically join the stem to the shell and complete the assembly of the device.

The construction and fabrication of the device in accordance with this invention provides an efficient assembly technique and structure which result in expeditious production of delicate and critically spaced components in a compact unit.

The "drop-in" method of inserting the cooperating elements in the device and the concentric centering of the grid and cathode assembly by

automatic guiding means formed on the grid terminal ring of the casing insure accurate alignment of the several elements in the device. Furthermore, the specific arrangement of the cathode structure and mounting assembly contributes to the facility with which the prefabricated unit is accurately fitted into the casing and cooperates with other equally accurate assemblies to form a cooperative combination of electrodes having close critical planar relation and exact concentricity so that high transconductance and gain characteristics may be realized in the operation of the device. The assembly technique also eliminates the use of fusing fires adjacent the active coating material of the cathode so that no poisoning effects occur when the cathode surface is activated during the pumping processing of the device.

The positive pressure exerted against the electrode assemblies by the crown-shaped spring insures constant maintenance of the critical spacial relation between the grid and cathode so that distortion due to temperature changes will not affect the spacing nor cause internal stresses to alter the close spacing and parallelism between these electrodes. Furthermore, the uniform contacts of the spring arms against a solid ring insulating collar bearing positively against the abutting metal discs coupled to the cathode and the alignment of the collar with the cathode ceramic spacer afford a broad base pressure contact against the datum surface of the grid terminal ring to realize constant and permanent location of the components in the device during the whole life thereof without danger of displacement.

The locking of the spring member in the casing and the added provision of aligning the stem accurately with the casing facilitates rapid fabrication without gauges or assembly tools and represents a combination of elements which requires no highly skilled technician to complete the final mounting of the parts in the device.

It may be noted that the preparation of the components entering into the assembly of the device of this invention requires the utmost care in fabrication, heat treatment to remove occluded gases and normalize the parts, storage of the elements prior to assembly and the environment in which assembly takes place. Generally, it is found that clean, dust-free and air-conditioned locations are conducive to reducing difficulties in leakage along the surfaces of the parts, high resistance to radio frequency currents and absorption hazards. In connection with the grid, cathode and condenser assemblies, it is desirable to seal these elements under vacuum after heat treatment so that pumping time of the device is held to a minimum after complete assembly in the casing of the present invention.

While the invention has been disclosed in a particular embodiment and cooperative relation of the several components of a high frequency triode device, it is, of course, understood that various modifications may be made in the detailed assembly of the elements in other types of devices to secure the high transconductance, gain and broad band frequency range characteristics as exemplified in the particular structure set forth as an illustrative example of the features of this invention. Therefore, it is to be understood that the present disclosure represents only a specific example of the invention and that various modifications may be made therein with-

out departing from the scope and spirit of this invention.

What is claimed is:

1. An electron discharge device comprising a metallic shell, a metallic portion insulatingly mounted on one end of said shell, a plurality of flat surface electrode units located within said shell, and cylindrical means integral with said metallic portion peripherally engaging said electrode units to align said electrode units in a single boundary in layer relation.

2. An electron discharge device comprising a metallic shell, a metallic portion insulatingly mounted on one end of said shell, a plurality of flat surface electrode assemblies located within said shell, and integral projections on and coaxial with said metallic portion peripherally engaging said electrode assemblies to align said electrodes concentrically within said shell.

3. An electron discharge device comprising a metallic shell, a metallic portion insulatingly mounted on one end of said shell, a plurality of flat surface electrode units located within said shell, said portion having a castellated inner boundary in engagement with said electrode units, and pressure means forcing said units toward said metallic portion.

4. An electron discharge device comprising a metallic shell, a metallic portion insulatingly mounted on one end of said shell, a plurality of flat surface electrode units located within said shell, said portion having an annular inner boundary in engagement with said electrode units, pressure means forcing said units toward said metallic portion, and a retainer ring bearing against said pressure means and secured to the inner wall of said shell.

5. An electron discharge device comprising a metallic shell, a metallic ring portion insulatingly sealed to one end of said shell, a planar grid electrode within said shell, a disc type cathode assembly adjacent said grid electrode and including an annular insulating spacer member, and integral projections on said ring portion engaging the periphery of said grid electrode and said spacer member to centrally align them within said ring portion.

6. An electron discharge device comprising a metallic shell, a metallic ring portion insulatingly sealed to one end of said shell, a planar grid electrode within said shell, a disc type cathode assembly adjacent said grid electrode and including an annular insulating spacer member, integral projections on said ring portion engaging the periphery of said grid electrode and said spacer member to centrally mount them within said ring portion, a spider spring within said shell, an annular spacer interposed between said spring and cathode assembly, and a locking ring attached to said shell and bearing against said spring.

7. An electron discharge device comprising a metallic shell, a metallic ring portion insulatingly sealed to one end of said shell, a planar grid electrode within said shell, a disc type cathode assembly adjacent said grid electrode and including an annular insulating spacer member, integral projections on said ring portion engaging the periphery of said grid electrode and said spacer member to centrally mount them within said ring portion, a spider spring within said shell, an annular spacer interposed between said spring and cathode assembly, and a locking ring attached to said shell and bearing against said spring.

8. An electron discharge device comprising a

metallic shell, a metallic ring portion insulatingly sealed to one end of said shell, a planar grid electrode within said shell, a disc type cathode assembly adjacent said grid electrode and including an annular insulating spacer member, integral projections on said ring portion engaging the periphery of said grid electrode and said spacer member, a spider spring within said shell, an annular spacer interposed between said spring and cathode assembly, a locking ring attached to said shell and bearing against said spring, said locking ring having guide portions projecting beyond said shell, and a closure stem on said shell concentrically positioned with respect to said shell by said guide portions.

9. An electron discharge device comprising a metallic shell including a cylindrical ring portion and a central terminal at one end concentrically spaced from said shell by insulating portions in intermediate relation between said shell, ring portion and terminal, a metallic closure on the opposite end of said shell having terminal pins insulatingly sealed thereto, an anode button attached to said central terminal, a flat grid in contact with said ring portion, a cathode assembly including insulating rings projecting into said shell and spaced from said flat grid, an annular spring member forcing said cathode assembly toward said grid, and a locking ring engaging said spring member secured to said shell.

10. A cathode assembly for electron discharge devices including a thick metallic disc having plural aligned portions of decreasing transverse dimension, and a tubular metallic sleeve secured to and projecting from a portion of intermediate dimension.

11. A cathode assembly for electron discharge devices, comprising a thick metallic disc having three step-like portions of decreasing diameter, and a metallic sleeve having a diameter corresponding to the intermediate portion of said disc attached thereto, the larger diameter portion of said disc extending beyond said sleeve and the smaller diameter portion being enclosed by and spaced from said sleeve.

12. A cathode assembly comprising a cathode sleeve, a heavy disc mounted on the upper end thereof, an insulator ring surrounding said sleeve, a surface thereof being coplanar with said disc, a plurality of metallic arms angularly mounted in longitudinal and spaced relation about said sleeve, said arms being secured to said sleeve and the top of said ring, and a flexible disc secured to said sleeve and having cut-out portions clearing said arms and abutting against said insulator ring.

13. A cathode assembly comprising a cathode sleeve, a heavy disc mounted on the upper end thereof, an insulator ring surrounding said sleeve, one surface thereof being coplanar with said disc, a plurality of metallic arms angularly mounted in longitudinal and spaced relation about said sleeve, said arms being secured to said sleeve and the top of said ring, a flexible disc secured to said sleeve having cut-out portions clearing said arms and abutting against said insulator ring, and an inverted cup-shaped capacitance element coaxial with said sleeve secured to said flexible disc.

14. A cathode assembly comprising a cathode sleeve, a heavy disc mounted on the upper end thereof, an insulator ring surrounding said sleeve, one surface thereof being coplanar with said disc, a plurality of metallic arms angularly mounted in longitudinal and spaced relation about said sleeve, said arms being secured to said

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sleeve and the top of said ring, a flexible disc secured to said sleeve having cut-out portions clearing said arms, and abutting against said insulator ring, and an inverted cup-shaped capacitance element coaxial with said sleeve secured to and projecting from said flexible disc, said disc and capacitance element each having a circular series of apertures respectively in boundaries within and outside of said insulator ring.

15. An electron discharge device comprising a metallic shell, a cup-shaped ring spaced from one end of said shell, a vitreous sleeve hermetically sealed to said shell and ring, a dome-shaped vitreous cap sealed within said cup-shaped ring, a solid central terminal post projecting from said cap, an anode button supported by said post adjacent the opening in said ring, said ring having a circular series of integral projections extending therefrom away from said anode button and concentric with the peripheries of said ring, anode button and shell, a grid ring having lateral wires on one side facing away from said anode button and located within the boundary of said projections on said cup-shaped ring, an annular spacer shim abutting against said grid ring, a cathode assembly including a flat disc supported on a sleeve member, an annular insulating spacer surrounding said sleeve, and multiple arms supporting said sleeve from said spacer, said spacer being concentrically mounted in abutting relation to said shim within the confines of said projections, a flexible disc member secured to said sleeve, an inverted condenser cup carried by said disc, said cup being telescoped within said shell and coaxial therewith, an insulating spacer collar abutting against the surface of said flexible disc in alignment with said insulating spacer, a spring member slidably fitted into said shell having arcuate extensions bearing against said spacer collar, a locking ring mounted in juxtaposition to said spring member and rigidly affixed to said shell, and a terminal stem closure sealed to said shell.

16. An electron discharge device comprising a metallic shell, a cup-shaped ring spaced from one end of said shell, a vitreous sleeve hermetically sealed to said shell and ring, a dome-shaped vitreous cap sealed within said cup-shaped ring, a solid central terminal post projecting from said cap, an anode button supported by said post adjacent the opening in said ring, said ring having a circular series of integral projections extending therefrom away from said anode button and

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concentric with the peripheries of said ring, anode button and shell, a grid ring having lateral wires on one side facing away from said anode button and located within the boundary of said projections on said cup-shaped ring, an annular spacer shim abutting against said grid ring, a cathode assembly including a flat disc supported on a sleeve member, an annular ceramic spacer surrounding said sleeve, and diagonal yieldable arms supporting said sleeve from said spacer, said spacer being concentrically mounted in abutting relation to said shim within the confines of said projections, a flexible disc member secured to said sleeve, an inverted condenser cup carried by said disc, said cup being telescoped within said shell and coaxial therewith, an insulating spacer collar abutting against the surface of said flexible disc in alignment with said ceramic spacer, a spring member slidably fitted into said shell having arcuate extensions bearings against said spacer collar, a locking ring secured to said shell having a plurality of projections extending exterior to said shell in a circular boundary, a dish stem carrying terminals and supporting a central helical heater element thereon, and a flexible connection between said condenser cup and a terminal on said stem, said stem engaging said projections on said locking ring to accurately locate said heater element concentrically within said cathode sleeve.

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