ELECTRON DISCHARGE DEVICE WITH APERTURED GRID ELECTRODE OF SPHERICAL SHAPE
Filed May 17, 1961 2 Sheets-Sheet 1

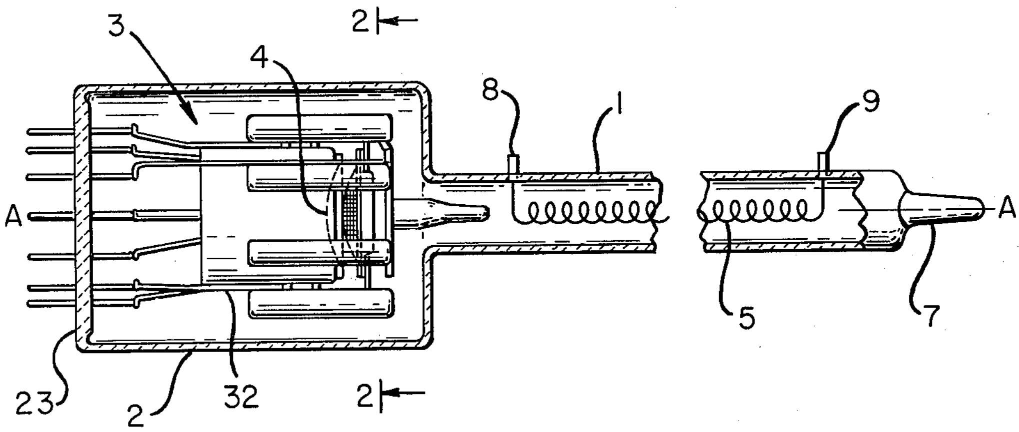

FIG-1

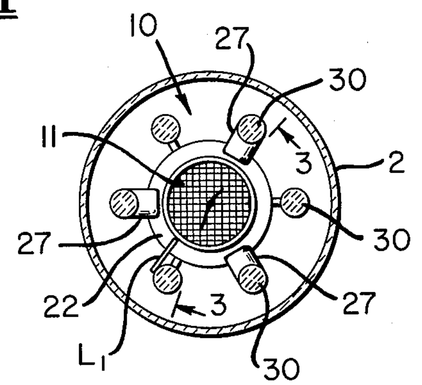

FIG-2

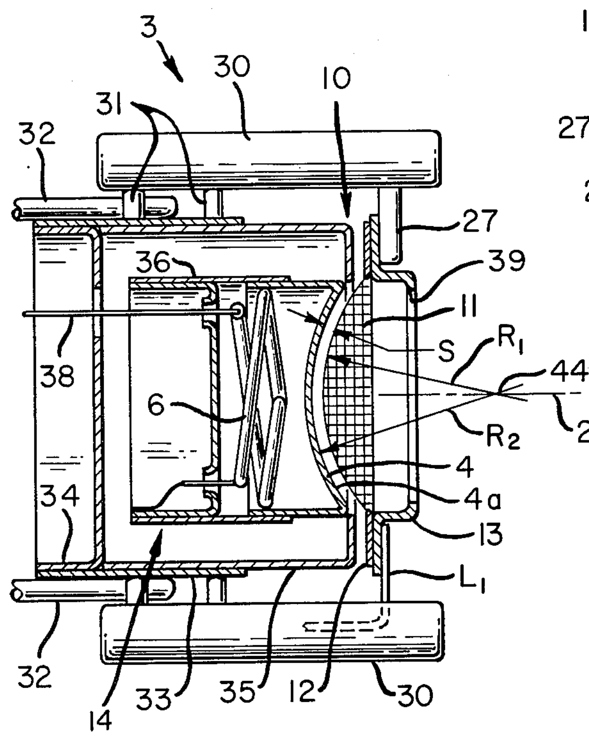

FIG-3

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ELECTRON DISCHARGE DEVICE WITH APERTURED GRID ELECTRODE OF SPHERICAL SHAPE

Filed May 17, 1961 2 Sheets-Sheet 2

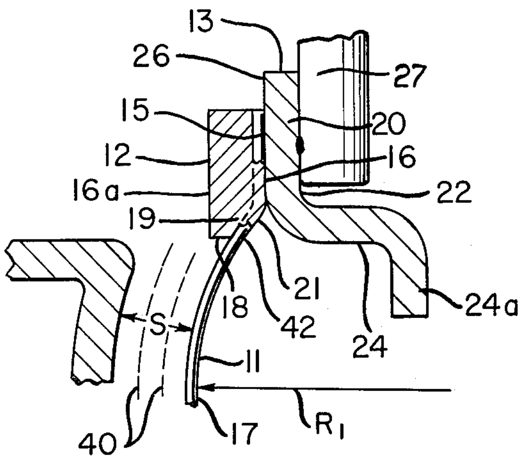

FIG-4

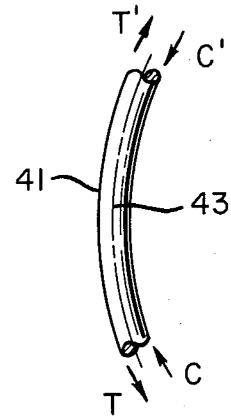

FIG-5

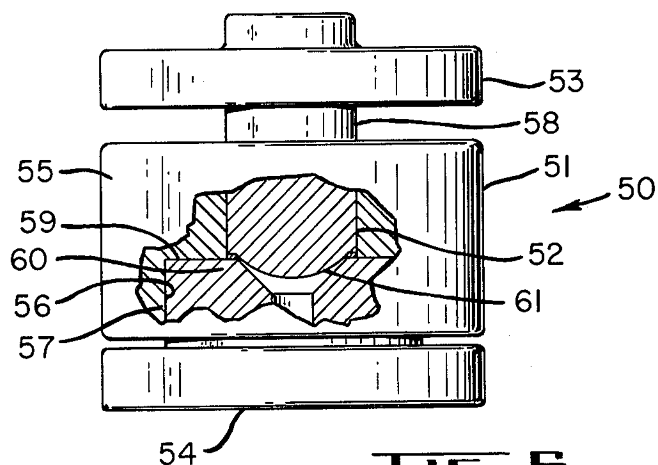

FIG-6

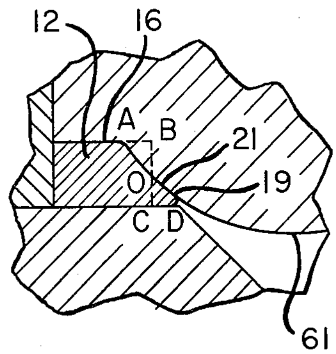

FIG-7

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United States Patent Office

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3,255,374
ELECTRON DISCHARGE DEVICE WITH APERTURED GRID ELECTRODE OF SPHERICAL SHAPE

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1 Claim. (Cl. 313—308)

This invention relates to electron discharge devices employing cathodes having spherically shaped electron emitting surfaces, and more particularly to electrically biased, fine mesh screens (grids) for controlling the axial travel of an electron beam generated from such cathodes.

An object of this invention is the provision of an efficient spherically shaped beam control electrode to allow pulsed operation of electron discharge devices.

Another object of the invention is the provision of a grid electrode such that axial spacing between adjacent surfaces of the electron emitting surface of the cathode and electrode is constant.

A further object of the invention is to simplify the grid electrodes of such devices, thereby enabling them to be produced in greater quantities and at less cost.

A still further object is to provide a method of fabricating a grid electrode in which a spherically shaped surface is achieved rapidly and with increased accuracy.

In accordance with the invention, a fine mesh screen, e.g., 80 strands of tungsten per lineal inch, is formed into a segment of a sphere having a constant radius of curvature and is attached by its outer peripheral surface to a grid ring. A portion of the engaged surface of the grid ring is concavely formed with respect to its axis of symmetry, the radius of curvature of which is constant and equal to that of the screen. This results in the individual wires comprising the screen being subject only to bending stresses at their points of attachment to the grid ring.

The nature of the invention can be better understood with reference to the attached drawings in which:

FIGURE 1 is a partially schematic diagram of a traveling wave tube embodying the invention;

FIGURE 2 is a transverse section taken along lines 2—2 of FIGURE 1 illustrating a radial position of the screen and its supports;

FIGURE 3 is an enlarged longitudinal section of the gun part taken along lines 3—3 of FIGURE 2 showing the relative axial positions of the cathode and the grid assembly;

FIGURE 4 is a greatly enlarged view of part of FIGURE 3 at the point of attachment of the grid to the ring;

FIGURE 5 is an enlarged view of the part of a grid wire at the point of attachment to the grid ring, bar diagramming the forces acting upon the grid;

FIGURE 6 is a side-elevation, partially cut away, of a swaging fixture used to form the grid electrode (the latter being omitted for clarity); and

FIGURE 7 is a greatly enlarged view of the part of FIGURE 6 at the edge of the grid ring within the fixture.

A preferred embodiment of the invention is illustrated in FIGURE 1 as a traveling wave tube comprising an elongated glass envelope **1** having enlarged end portion **2** enclosing the gun structure **3** of the tube. Cathode **4** in the gun structure produces an electron beam which is focused and accelerated along tube axis A through helix **5** to collector **7** at the opposite end of the tube.

The electrons of the beam interact in a well known manner with electromagnetic waves on the helix so that a signal applied to the input **8** is amplified when it appears at the output **9**. Inasmuch as the amplification of the signal is directly related to the number of electrons

adjacent a finite length of the helix, the electron emitting surface **4***a* of cathode **4** (FIGURE 3) is usually spherically shaped in such devices (as shown) to achieve the high beam density required for efficient tube performance.

However, in order that the high power beam thus formed not unduly overheat the tube parts adjacent the beam path, a grid assembly **10**, as shown in FIGURE 3, is located adjacent the emitting surface to turn on and turn off the beam by alternately biasing the grid assembly positive and negative with respect to the cathode. This allows the tube parts to be cooled during the off cycle of the pulse train. That is, when the beam is interrupted and electrons are prevented from traveling axially beyond the fine mesh screen or grid **11** (hereinafter called "grid").

To achieve this pulsed or interrupted mode of tube operation the uniformity of spacing between the adjacent surfaces of the grid and the cathode emitting surface is extremely critical and a dominant factor in achieving this spacing is a precisely formed and assembled grid assembly. This invention concerns such a grid assembly and its method of manufacture.

Grid assembly **10** is mounted coaxially of the axis A of the tube and comprises grid **11** pressed into grid ring **12** (FIGURE 4) adjacent to grid frame support **13**. Grid **11** is mounted at its peripheral end portion **15** integral with the forward surface of grid ring **12** and has central region **17** formed into a segment of a sphere, the radius of curvature of which is referenced as R_1. For purposes of this description, the term "forward" is used hereinafter to describe the end of the assembly from which electrons are emitted, and "rearward" means the opposite or left end of the assembly, as viewed.

The inner forward edge portion **18** of ring **12**, adjacent to rear surface **16***a*, is formed with a concave annular step **19** which the grid **11** firmly engages. As explained hereinafter, forward surface **21** of step **19** has a radius of curvature equal to R_1 to facilitate uniform support of the grid **11** relative to the cathode **4**.

Ring **12** is supported concentrically of axis **25** of the assembly (FIGURE 3), which axis is coincident with axis A, by engagement of the outer forward surface **16** with rearward surface **26** of outwardly extending lip **20** of grid frame support **13**. Lead L_1 attaches to forward surface **22** of lip **20** to electrically bias the grid assembly, the opposite end of which extends to and is supported on base **23** of glass envelope **1** (FIGURE 1) for connection with outside energizing sources (not shown).

Grid support frame **13** also has an annular forwardly extending side wall **24** integral with frame lip **20** and bent radially inwardly to form forward lip **24***a*. The inner edge **39** of lip **24***a* defines an aperture (FIGURE 3) which is coaxially located with respect to gun axis **25** remote from the central portion **17** of grid **11**. When electrically biased above cathode potential, i.e., as an accelerating electrode, the side wall **24** forms an electric field pattern (equipotential lines) which causes the electrons to form into a smooth cylindrical beam for interaction with a signal on helix **5** of the tube, as explained above.

It should be noted that the shape of the grid ring **12** can be varied to fit the electric field pattern necessary to sustain the correct beam profile and in practice it has been found for a traveling wave tube having the characteristics and dimensions hereinafter described, an aperture diameter of .224 inch, a wall diameter and height of .294 and .058 inch, respectively, correctly focus a beam of electrons emitted from a spherical cathode having a radius of curvature of .206 inch, a chord length of .038 inch, a diameter of .037 inch and a peak current density of 1.76 amperes per square centimeter.

Supported on the forward surface **22** of lip **20** equally spaced about axis **25** are outwardly extending tabs **27** which support the grid assembly relative to the cathode assembly 14. As illustrated in FIGURES 2 and 3 each tab, preferably made of an alloy comprising nickel, cobalt, iron and manganese, has opposite ends attached to lip 20 and to longitudinally extending insulator 30, respectively. Insulators 30, the axes of which are parallel with axis 25 of the assembly, are preferably made of glass and are in turn supported at their rearward ends by pairs of radial posts 31 and elongated input leads 32. Tabs 27 are secured to insulators 30 when the latter are in a heat-softened state and the entire grid assembly is axially and radially adjusted relative to these insulators in order to properly space grid 11 and cathode 4 so that the centers of formation of spherical emission surface 4*a* and grid 11 are coincident at 44 and spacing S between the emission and surfaces is constant. The radii of curvature R_1 and R_2 for the grid 11 and emission surface 4*a*, respectively, are measured from the same point 44 on the gun axis 25 and R_2 is longer than R_1 by the distance S.

Mounted on posts 31 coaxially of the gun assembly is a tubular support member 33 having a doubled wall rear portion 34 and a thin walled forward portion 35 which serves as a heat shield and as a support for cathode assembly 14. Another tubular support 36 fits coaxially within member 33 and houses the spherically shaped cathode 4 and heater 6, the latter having leads 38 which pass through base 23 of glass envelope 1.

In order to correctly focus and accelerate the beam of electrons along axis A of the tube, two conditions with respect to mechanical alignment and spacing of the respective adjacent surfaces of cathode 4 and grid 11 must be met. These are: (1) the centers of formation of the spherical emission and grid surfaces must be coincident, and (2) the spacing of these two surfaces must be held constant within ±.001 inch. The reason for these requirements is explained by considering the relationship of the axial spacing of these parts and the electron beam.

Assume that the spacing between adjacent surfaces of the grid and cathode is not uniform or constant. The "lines" of equal field potential, i.e., imaginary surfaces indicated at 40 in FIGURE 4, which denote spacial points of equal potential as a result of static charge on grid 11, do not have constant curvatures. This results in a non-homogeneous beam profile caused by uneven distribution of electrostatic forces which nonuniformly influence the beam. This coupled with space charge effects, causes the diameter of the beam to vary with time ("scallop") which has the effect of decreasing the efficiency of the interaction between this beam and the signal on the helix 5.

In order to obtain grids having constant radii of curvature, two conditions must be met: (1) a greater proportion of individual wires comprising the screen grid must be subject only to bending stress at the plane of attachment 42 (FIGURE 4) (for a discussion of bending stress, see "Elements of Strength of Materials," by S. Timoshenka and G. H. MacCullough, D. Van Nostrand Company, Inc., New York, 3rd edition, 1954, pp. 119–120); (2) the transition curvature at the point of attachment must be uniform from wire-to-wire, notwithstanding the change in magnitude of the bending stresses of each.

These two conditions are met as illustrated in FIGURE 4, at the forward edge of grid ring 12, by the formation of concavely shaped step 19, the surface 21 of which has a radius of curvature equal to radius R_1 for grid 11. The probability of attaching each wire tangent to the mating surface of a grid (thus creating negligible shearing stress in the wire) is greatly increased by the extension of this transition region in a finite distance conforming with the shape of the grid, i.e., surface 21 of step 19.

Referring now to FIGURE 5, the relationship between a single grid wire 41 under such a condition is illustrated with reference to the force diagram of the portion of the wire at the surface of attachment 42 between the surfaces of the grid and grid ring in FIGURE 4. Neglecting

gravity forces and recognizing the uniformity of compressive stress C and tensile stress T about neutral fiber 43 of the wire, it can be concluded that the neutral fiber is stable (thus defining constant radius of curvature R_1 of the grid), maintained by and equal to opposite couples C′T′ and CT, respectively, acting in the plane of each wire, i.e., such that there are no shearing forces parallel with this line.

By way of example, a method by which a grid assembly having the aforementioned advantages has been fabricated, is illustrated with reference to FIGURES 6 and 7, wherein fixture 50 comprises a die 51 having an opening 52 to accommodate punch 53, preferably made of heat-treated steel, to swage the grid 11 integral with the grid ring 12.

The die comprises a break-away construction having a base 54 upon which is mounted a guide 55. The parts, preferably made also of heat-treated steel, are mechanically secured relative to one another by means of recess 56 and wall 57 in guide 55, the latter snugly engaging with the reduced outer surface of base 54.

In the upper portion of guide 55, centrally located opening 52 facilitates the confined travel of the cylindrical barrel portion 58 of punch 53 which terminates at the upper surface 59 of annular lip 60 of base 54 upon which the grid ring 12 is mounted. When the punch is inserted in the opening and is allowed to travel its full extent, contact is made between the spherically shaped end 61 of the punch having a radius of curvature equal to that to be achieved in grid 11 and upper surface 16 of the ring 12.

The outline of the grid ring at this instant is shown best in FIGURE 7 and has a rectangular cross section, the inner corners of which are referenced by dotted line B–O–C. As additional pressure is applied to the punch, the metal in the inner edge of the ring "flows" to conform with the surface of end 61 forming a step 19, the surface 21 of which is outlined by the solid line labeled A–O–D having a radius of curvature equal to that of the punch.

The punch is then removed and a circular, tungsten screen placed on the upper surface 16 of the ring. Forces normal to the surfaces 21 of the step 19 and surface 16 are simultaneously applied by the punch such that the outer portion of the grid becomes embedded (swaged) within the grid ring, i.e., within surface 21 of step 19 and surface 16 or ring 12 while the central portion of the screen conforms to the spherical shape of the punch end.

The fixture is thereafter disassembled and grid assembly 10 is removed for further processing.

By way of example, a grid assembly having the characteristics described hereinabove has been successfully fabricated and tested and has the following dimensions:

Grid Assembly 10

	Inches
Grid 11	
Chord height	.048
Radius of curvature R_1	.186
Material, tungsten.	
Mesh, 80 strands per inch.	
Action width	3/8
Wire diameter	.0012
Diameter of blank	.440
Grid ring 12	
Outside diameter	.435
Thickness before swaging	.010
Edge 18, height	.004
Upper surface 16, width	.087
Lower surface 16*a*, width	.094
Grid frame support 13	
Thickness	.010
Lip 20—	
Outside diameter	.44
Inside diameter	.274
Side wall 24—	

Height	.058
Diameter	.294
Aperture—	
Diameter	.224

We claim:

In an electron discharge device having an axis, an electron emitter supported within and coaxially of said device and having a spherically shaped electron emitting surface, a ring supported within and coaxially of said device and being axially spaced from said emitting surface, said ring having a transversely extending flat surface remote from said cathode and an adjoining inwardly extending spherically shaped surface with a center of formation coincident with that of said emitting surface, a screen type electrode adjacent to and axially spaced from said emitting surface, said electrode having a plane transversely extending peripheral portion and an inwardly extending spherically shaped portion with a center of formation coincident with the center of formation of said emitting surface, the radius of formation of the spherical ring surface being equal to the radius of formation of the electrode and being shorter than the radius of formation of the emitting surface by an amount equal to

the axial spacing between said electrode and said emitting surface, said peripheral electrode portion and the spherical electrode portion extending uniformly into the flat and spherical surfaces, respectively, of said ring to a depth no greater than the thickness of said electrode whereby the electrode is thereby mechanically gripped and permanently locked to the body of the ring and the spherical portion of the electrode is coincident with the spherical surface of the ring.

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