Oct. 25, 1955 D. E. KENYON 2,721,952

GRID STRUCTURE AND THE PROCESS OF MAKING

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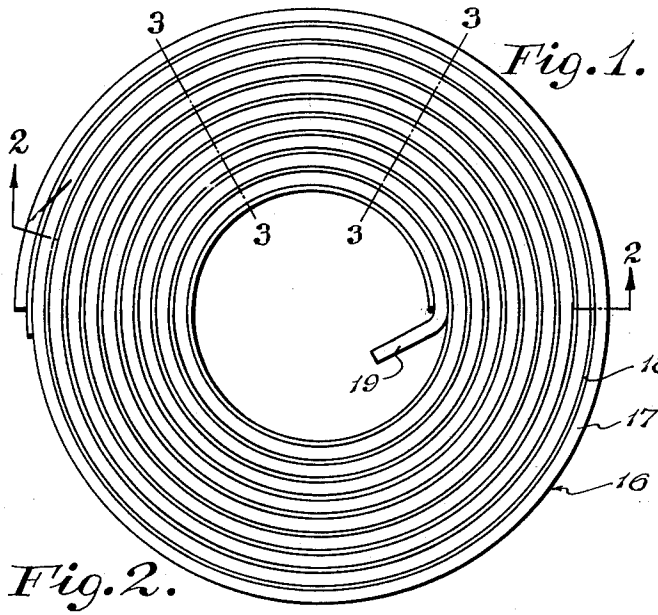


Fig. 1.

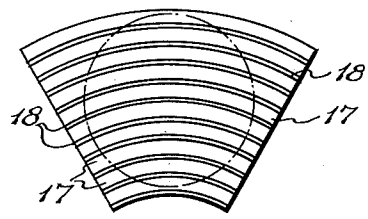


Fig. 3

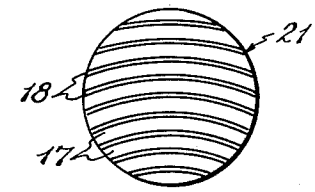


Fig. 4.

Fig. 2.

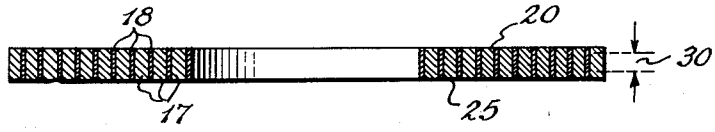


Fig. 5.

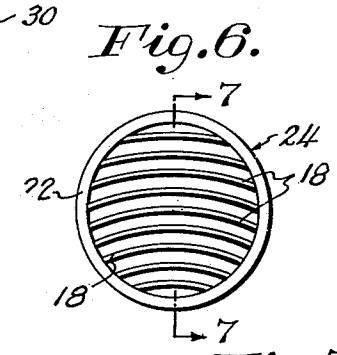
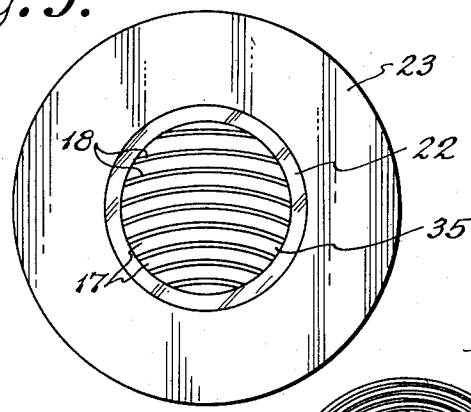


Fig. 6.

Fig. 7.



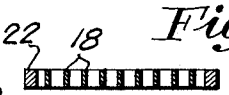


Fig. 9.

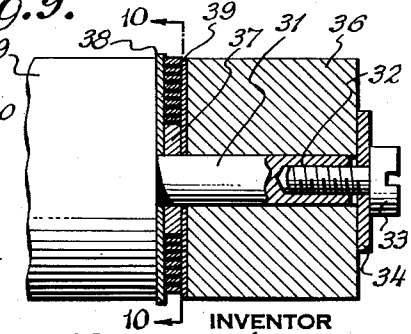
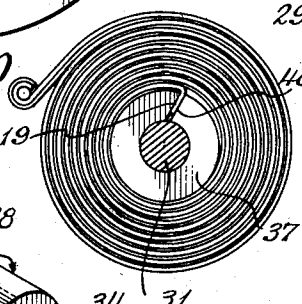


Fig. 10



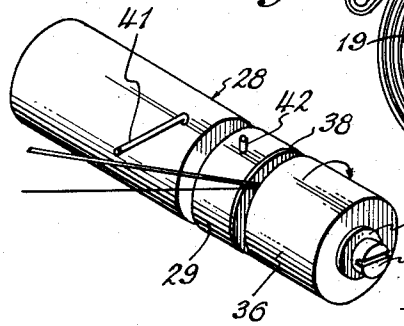


Fig. 8.

INVENTOR
DAVID E. KENYON
BY
Paul B. Hunter
ATTORNEY

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GRID STRUCTURE AND THE PROCESS OF MAKING

David E. Kenyon, Huntington, N. Y., assignor to Sperry Rand Corporation, a corporation of Delaware

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11 Claims. (Cl. 313—348)

The present invention relates to minute grid electrodes for extremely high frequency electron tubes such as microwave klystrons and triodes, for example. This application is a continuation-in-part of application Serial No. 155,432, filed April 12, 1950, now abandoned, by the same inventor, and assigned to the same assignee.

It is customary to design grids for klystrons and related microwave tubes in such a way as to provide for minimum electron interception, maximum mechanical stability, and relative insensitivity to high operating temperatures. For klystron tubes operating in the range of frequency of 3000 to 6000 megacycles, a variety of grid designs have been successfully used, prominent among which are "vane" type grids. These usually comprise cantilever-type "vanes" attached to the cylindrical interior surface of a grid mounting ring and projecting inwardly part way toward the center thereof. In one prior grid construction suitable for grids of the order of one-half inch in diameter, for use in microwave tubes operating in frequency ranges such as set forth above, grids have been jig-assembled with arched vanes extending across the grid ring interior. Each vane is attached at both ends to the ring interior surface by solder junctions of bent tabs at the vane ends.

The present invention is concerned with grids of a much fined order of size, viz., of the order of one-tenth inch diameter and smaller. Grids of such small size are required in klystrons, for instance, operating at wavelengths of the order of one centimeter (frequencies of the order of 30,000 megacycles per second). In grids of this order of size, the vane elements are so fine as to be hardly visible to the naked eye, strongly militating against attempts at jig assembly of individual grid pieces.

In accordance with the present invention, minute grids possessing the aforementioned attributes of a good electrode are produced by winding a pair of unlike metal strips into a spiraloid form, bonding the strips together into a rigid disc, cutting from sectors thereof, a plurality of discs each having a diameter which is a fraction of the diameter of the original rigid disc, mounting each of these discs in a conformal ring, bonding the disc and ring together, and removing, by etching, the material of one of the two original metal strips, to leave thin correspondingly curved arcuate vanes of the desired material. Each vane element extends across the interior of the grid ring, free from any bent tabs, and is bonded directly at its transverse end surfaces to the inner surface of the ring.

An object of the present invention, therefore, is to provide a minute grid of the arched-vane type which may be constructed in extremely small sizes, i. e., wherein no linear dimension between any two points on the inner surface of the structure supporting the grid elements is greater than the order of 0.1 inch.

A further object of this invention is to provide such a minute arched-vane grid which is of uniform construction, has relatively high mechanical stability and ruggedness, and very low electron interception.

Still another object of the invention is to provide a workable process for fabricating grids of the above-mentioned type.

Other objects and advantages of this invention will become apparent from the following specification, taken in connection with the accompanying drawings wherein the invention is embodied in concrete form.

In the drawings,

Fig. 1 is an enlarged plan view of a disc structure comprised of interleaved spiraloid members, formed according to the present invention at an early stage of fabrication of the grid;

Fig. 2 is a vertical sectional view taken along lines 2—2 of Fig. 1;

Fig. 3 shows a sector cut from the structure of Fig. 1 on the lines 3—3 thereof, and indicates where a circular portion is derived therefrom;

Fig. 4 is a plan view of a circular section of Fig. 3 after a grinding operation;

Fig. 5 is a plan view of the structure of Fig. 4 supported in a mounting means;

Fig. 6 is a plan view of a completed grid structure according to the present invention;

Fig. 7 is a vertical section of Fig. 6 taken along lines 7—7 thereof;

Fig. 8 is a perspective view of a form of apparatus suitable for use in carrying out a part of the method of the instant invention;

Fig. 9 is an elevational view, partly in longitudinal section, of the apparatus of Fig. 8; and

Fig. 10 is a cross sectional view of the structure of Fig. 9 taken along lines 10—10 thereof.

Referring to Figs. 1 and 2, disc 16 is shown, which is formed by winding two ribbon-like members 17 and 18 together to provide a flat disc structure comprised of spiraloid or convoluted interleaved members. Members 17 and 18 are constituted of continuous strips of ribbon of different metals, ribbon 17 being of iron, for example, and ribbon 18 being of tungsten, molybdenum, or other suitable grid material. In order to provide a mechanically rigid disc 16, adjacent portions of members 17 and 18 may be joined together by brazing with a suitable brazing material such as copper, cupro-nickel or manganese.

Referring to Fig. 2, the upper and lower faces 20 and 25, respectively, of the disc 16 may be ground to a finished or desired grid thickness or axial depth, such as indicated at 30. Instead of grinding to a finished dimension at this stage, the faces 20 and 25 may be ground merely to insure that each face is perfectly flat and planar. The ground surfaces preferably are immediately provided with a protective plating, such as chromium. The plated disc is then heated, if desired, in wet hydrogen at low heat, approximately 800° C., in order to oxidize the chromium.

The disc 16, after grinding and plating, is cut into sectors, one of which is shown in Fig. 3, by employing an abrasive wheel or other suitable cutting apparatus. It has been found that as many as 10 usable sectors may be cut from a single disc such as 16, depending upon its perfection and size.

The sector, such as shown in Fig. 3, is then mounted between two collinear pins (not shown) which frictionally support the sector at the faces thereof. Both pins are synchronously rotated, thereby rotating the sector. A grinding mechanism (not shown) is employed to edge grind the rotating sector until a disc is formed as is

shown in Fig. 4. During this operation care should be taken to insure that the oxidized chromium surface is not damaged by abrasion. The resulting grid blank **21** has both faces protected by oxidized chromium, with the edge a bright, ground surface.

Referring to Fig. 5, the grid blank **21** is surrounded by a tightly fitting ring **22** and apertured disc **23**. Ring **22** may be composed for instance, of gold, copper or nickel. Apertured disc **23** is comprised of iron, steel, or other suitable material.

If a gold ring is employed, the assembly is brazed at a temperature suitable for fusing the ring **22** to the periphery of grid blank **21** without destroying the ring. If ring **22** is of copper, it is preferable to employ a very thin layer of gold solder between the periphery of grid blank **21** and the ring **22** preparatory for the brazing operation. The gold solder, which is a gold alloy, has a lower melting point than the copper. If ring **22** is of nickel, copper powder is utilized to braze the ring **22** to the grid blank **21**. In lieu of copper powder, the inner surface of the ring of nickel could be copper plated. The oxidized chromium plating prevents any of the brazing material from flowing onto either face of the grid blank **21**.

During the above-described mounting operation of grid blank **21**, the assembly is preferably fired in a hydrogen atmosphere, as with a hydrogen bell jar (not shown). The use of a hydrogen atmosphere is found beneficial to insure that the molten metal wets the end surfaces of the members comprising the grid blank **21**, particularly the transverse or cross-cut ends of members **18**. If such a procedure is not followed when dealing with extremely closely spaced surfaces, such as the cylindrical outer surface of grid blank **21** and the cylindrical inner surface of the ring **22**, the surface tension of the molten metal customarily prevents it from flowing sufficiently to form a suitable bond. The oxidized chromium coating protects the faces of the grid blank **21** and prevents the molten brazing material from wetting either face of the grid blank **21**.

After brazing ring **22** to the periphery of grid blank **21**, the faces of the assembly comprising grid blank **21**, ring **22**, and apertured disc **23** may be ground to a finished grid thickness, if the grinding process described in referring to dimension **30** in Fig. 2 was not carried out.

After the mounting and grinding operations above, the apertured disc **23** is removed from the rest of the structure. This can be done by a cutting operation, after which the ring **22** is polished to remove any peripheral burrs that may exist after the cutting. The structure is then etched in a suitable bath of hydrochloric or sulphuric acid, for example, to remove the iron vane elements. If hydrochloric acid is employed for etching, it will also remove any chromium on the faces of grid blank **21**, if the face grinding process supra was not undertaken. The structure may also be electro-etched in a bath of sodium hydroxide, if desired, to remove burrs which remain after any of the face grinding processes.

Instead of cutting the apertured disc **23** from the grid blank **21** and ring **22**, it may be removed by the same etching process as is employed to remove the iron vanes. In the case where a nickel grid ring is employed the structure may also be etched in a bath of ammonium hydroxide and hydrogen peroxide to remove any remnants of the copper brazing material which may exist on the faces of the grid blank **21** and ring **22**.

The result of the foregoing procedure is an electron-permeable structure or grid **24**, as shown in Fig. 6, which has a plurality of arcuate members or vanes **18**, the transverse or cross-cut ends of which abut and are supported by a mounting means, such as ring **22**.

Grids of the above-described type are capable of fabrication in extremely small sizes. Examples of the minute dimensions of a few of the highly successful grids of the present invention made according to the novel method disclosed herein are set forth below:

O. D. Grid Ring, inch	I. D. Grid Ring, inch	Axial Depth of Grid, inch	Vane Spacing, inch	Vane Thickness, inch
.120	.105	.010	.010	.001
.060	.051	.005	.005	.0005
.052	.045	.007	.005	.0005
.030	.025	.003	.003	.0003
.055	.045	.003	.003	.0003

This method allows independent control of any and all of the above dimensions. For example, it is possible to make the following grid:

O. D. inch	I. D. inch	Axial Depth, inch	Vane Spacing, inch	Vane Thickness, inch
.120	.105	.005	.003	.0003

Referring to Fig. 6, it will be noted that grid **24** comprises curved vanes **18** which form a section of a flat spiraloid structure. Each vane has its transverse or cross-cut ends supported by ring member **22**. There is uniform spacing between vanes. Each of the vanes **18** has a width greatly in excess of its thickness, with the width dimension of each vane oriented in a direction parallel to the axis of the ring **22**. Accordingly, the orientation of the vanes **18** is such as to provide ample mechanical rigidity and strength for the minute size thereof, and at the same time provide a grid structure **24** which presents a minimum electron beam intercepting area.

If desired, the thickness of the vanes **18** may be reduced by a suitable etching fluid, such as by treating the grid **24** with molten potassium nitrate. However, the action with this treatment is quite rapid. In such operations designed to reduce the thickness of the vanes **18**, care must be taken to ensure that the structure of the vanes **18** is not impaired. If the action is permitted to progress too far the vanes **18** may neck down at a point and break. It has been found possible and practical to reduce the vanes **18** to one-half their original thickness.

Referring to Figs. 8 through 10, jig **28**, suitable for use in fabricating the disc **16** of Fig. 1, has a body portion **29** with a reduced-diameter continuation **31**. The continuation **31** is formed with an internally-threaded portion **32** for cooperation with screw **33**. The screw **33** together with washer **34** and continuation **31** is effective for maintaining the cap **36** of the jig **28** rigid against axial movement relative to the body portion **29**. Between the body portion **29** and the cap **36** is a circular slotted washer **37**, the slot **40** of which is provided for receiving the end **19** of the iron ribbon **17** in order to secure it during the winding operation. Although washer **37** is shown as circular it is obvious that the periphery thereof could have an oval shape, or even substantially flat portions. On one side of the slotted washer **37** is positioned an enlarged washer **38**, the diameter of which is preferably greater than that of body portion **29** to facilitate the removal of the disc **16** from the jig **28**. On the other side of the slotted washer **37** is placed a disc **39** of suitable brazing material, such as copper, cupro-nickel, or manganese.

The end **19** of the iron ribbon **17** may be inserted into the slotted portion **40** of washer **37**, with the tungsten ribbon **18** resting beneath the iron ribbon **17**. If desired, the end **19** of ribbon **17** may be initially bent to cooperate with the slot **40** in order to facilitate the start of the winding operation. By rotating the jig **28** about its longitudinal axis, the ribbons **17** and **18** may be wound to-

gether. After the space between the enlarged washer 38 and disc 39 is filled with the alternate, interleaved layers of iron and tungsten ribbons 17 and 18, the free end of one or both of the ribbons 17 and 18 may be wrapped around or pinched over a rotatable securing member 41, which member 41 is rotatable about an axis disposed at right angles to the longitudinal axis of the jig 28. Stop pin 42 limits the swing of the securing member 41, to prevent the member 41 from rotating therebeyond.

While the ribbon members 17 and 18 are mounted on the jig 28, as shown most clearly in Fig. 10, the assembly may be fired in a hydrogen atmosphere by use of a hydrogen bell jar. During such a process, the disc 39 melts to solidly braze together the iron and tungsten ribbons 17 and 18. At the same time, the heat involved in the fusing operation is effective for removing stresses from the iron and tungsten ribbons 17 and 18. After the formation of the solidly brazed disc 16, it may be removed from the jig 28 by disengaging the cap 36. The enlarged washer 38 facilitates this operation.

If desired, the removal of stresses and the joining together of the ribbon members 17 and 18 may be effected in separate operations. Under such circumstances, the disc 39, which constitutes the brazing material, may be omitted from the jig 28. After the winding operation, the ribbons 17 and 18 may be subjected initially to high temperature. A small piece of copper may be placed prior to the application of heat at the end of the iron ribbon 17 most remote from the center of the spiral configuration. Such a piece of copper, after melting and subsequent solidification, is effective for holding together the spiral of iron and tungsten ribbons 17 and 18, thereby facilitating its removal from the jig 28. Subsequently, the assembly may be fired with a suitable brazing material to solidly braze together the iron and tungsten ribbons 17 and 18.

The ribbons 17 and 18 of the disc 16 may be brazed or joined together in a somewhat different manner by employing, for instance, a copper-plated iron ribbon in place of the previously mentioned iron ribbon 17. Disc 39 may then be omitted. During the firing operation, the copper plating melts, acting as a brazing flux to join together the spiraloid members 17 and 18. However, the resulting structure may not be as solid as that provided by the other techniques discussed herein.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An electron permeable grid structure comprising a ring member having an inner diameter of less than approximately 0.1 inch, a plurality of spaced curved vane elements mounted within said ring member, said van elements being curved in the same direction within a plane containing said ring member, said plane being perpendicular to the axis of said ring member, the width dimension of each vane element extending in a direction substantially parallel to the axis of said ring member, the transverse ends of said vane elements directly abutting the inner surface of said ring member and being bonded thereto.

2. An electron permeable grid structure comprising a ring member having an inner diameter of less than approximately 0.1 inch, a plurality of arcuate vane elements mounted within said ring member, said vane elements being uniformly spaced and curved in the same direction within a plane containing said ring member, said plane being perpendicular to the axis of said ring member, each of said vane elements having substantially the same cross-sectional area with the longer dimension of each cross-sectional area extending in a direction substantially parallel to the axis of said ring member, the transverse ends of said vane elements directly abutting the inner surface of said ring member and being bonded thereto.

3. An electron permeable grid structure comprising a ring member having an inner diameter of less than approximately 0.1 inch, a plurality of spaced curved vane elements mounted within said ring member, said vane elements being curved in the same direction within a plane containing said ring member, said plane being perpendicular to the axis of said ring member, each of said vane elements having substantially the same cross-sectional area with the longer dimension of each cross-sectional area extending in a direction substantially parallel to the axis of said ring member, the transverse ends of said vane elements abutting the inner surface of said ring member and being bonded thereto, the corresponding narrow edges of said vane elements having polished coplanar surfaces.

4. A grid structure comprising a plurality of spaced, curved metallic ribbon elements mounted edgewise within a supporting member, said supporting member having inner and outer surfaces, the maximum linear distance between any two points on said inner surface of said supporting member being less than approximately 0.1 inch, said ribbon elements being curved in the same direction within a plane containing said supporting member, each of said ribbon elements having substantially the same cross-sectional area with their transverse ends directly abutting and joining the inner surface of said supporting member.

5. In electron-permeable apparatus having an axis, a circularly-shaped mounting ring symmetrically disposed about said axis, said ring having an inner diameter of less than approximately 0.1 inch, and a plurality of spaced metallic vanes having cross-cut ends directly abutted and supported by said ring, each of said vanes being relatively wide compared to the thickness thereof with the wide dimension oriented in a direction parallel to said axis, whereby a relatively small cross-sectional area is presented to an electron beam aligned with said axis, said vanes forming a section of a flat spiraloid structure.

6. A method of forming an electron discharge tube grid structure comprising the steps of forming a disc comprised of interleaving spiraloid ribbon members of different metals, brazing said members together to rigidity said disc, cutting a grid blank from a sector of said disc, mounting said grid blank in a mounting ring, and removing elements of one of said metals which constitute part of said grid blank.

7. The method of forming an electron discharge tube grid structure comprising the steps of winding iron and tungsten ribbons to form a disc structure comprised of interleaving spiraloid members, brazing together said ribbons to rigidify said disc, grinding both faces of said disc to transform said disc to a desired thickness, plating said ground faces, cutting a sector from said plated disc, edge-grinding said sector into a circular grid blank, mounting and brazing said grid blank in a mounting ring, grinding said mounted grid blank to a finished thickness, and chemically removing the plating and iron from said grid blank to form tungsten vanes supported in said mounting ring.

8. A method of fabricating a grid for electron discharge devices comprising the steps of forming a disc-like structure having arcuate members of desired grid material separated by arcuate members of material different from said desired grid material, bonding said arcuate members together to consolidate said disc-like structure, removing a section from said disc-like structure to form a suitable grid blank of desired grid configuration having arcuate laminated elements of said members, bonding a supporting means to said grid blank to support the arcuate elements of said desired grid material, and removing from said grid blank, elements of said material different from said desired grid material to form a rigid grid structure having

spaced arcuate grid elements mounted in said supporting means.

9. A method of forming a grid structure for electron discharge tubes, comprising the steps of winding tight interleaving spiraloid members from ribbons of dissimilar materials, one of said materials being of the desired grid material and the other of said materials being a temporary material to be subsequently removed, the spiraloid members of said desired material being separated by the spiraloid members of said other material, bonding said spiraloid members of said ribbons together to form a rigid disc-like structure, cutting from a sector of said disc-like structure, a grid blank comprising arcuate laminations of ribbons of said dissimilar materials bonded together, bonding the ends of said arcuate laminations to a supporting means, and removing said temporary material present in said grid blank to reduce said blank to a set of spaced arcuate ribbon portions mounted in said supporting means.

10. A method of forming a grid structure for electron discharge tubes, comprising the steps of winding first and second chemically dissimilar metallic ribbons into a disc-like structure comprised of interleaving spiraloid members, the spiraloid member of said first metallic ribbon being separated by the spiraloid member of said second metallic ribbon, brazing said spiraloid members to form a rigid structure, cutting a sector from said structure to form a grid blank of desired configuration and size, mounting and brazing said grid blank to a supporting frame, and etching the mounted section to remove portions of said second chemically dissimilar metallic ribbon present therein.

11. A method of fabricating a grid for electron discharge devices, comprising the steps of winding at least two elongated members of dissimilar materials into a substantially flat structure having tight interleaving convoluted members, one of said materials being of desired grid material and the other of said materials being a temporary material to be subsequently removed, the members of desired material being separated by members of said other material, bonding said convoluted members to consolidate said substantially flat structure, removing a section from said structure to form a grid blank of desired configuration, said grid blank being comprised of laminated elements of said members, bonding the ends of the elements of desired grid material to a grid supporting means, and removing the elements of said other material present in said grid blank to reduce said blank to a set of spaced elements of desired grid material mounted in said supporting means.

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