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METHOD OF PRODUCING PLANAR GRIDS FOR VACUUM TUBES

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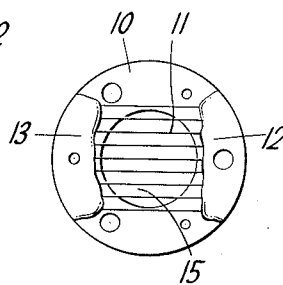
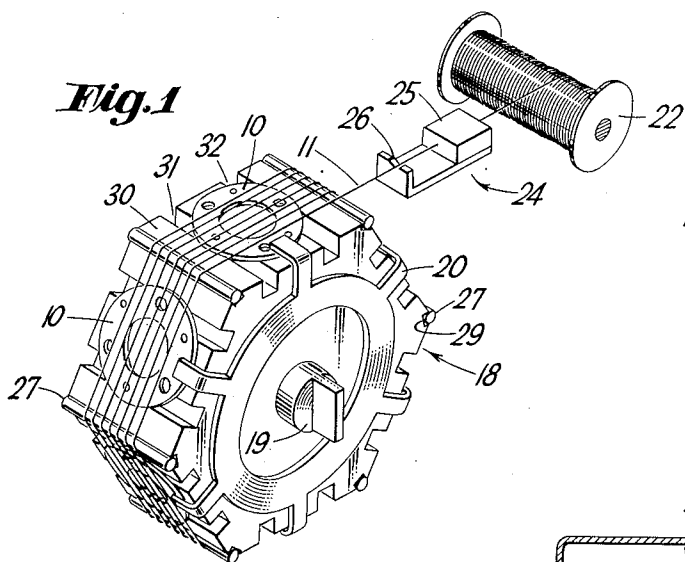


Fig. 5

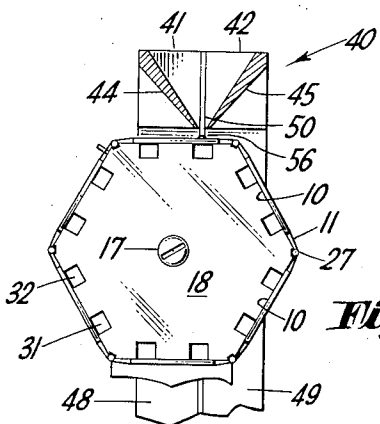
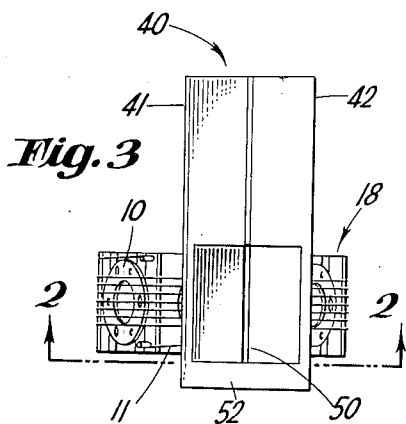


Fig. 2

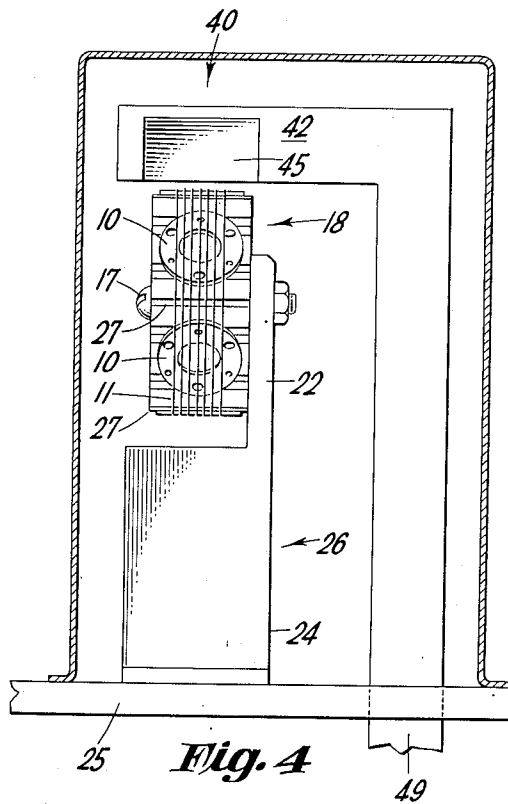


Fig. 4

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METHOD OF PRODUCING PLANAR GRIDS FOR VACUUM TUBES

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6 Claims. (Cl. 29—25.14)

This invention relates to a new and improved method of fabricating planar type grid structures for vacuum tubes and to apparatus for production of grid structures by that method.

A form of planar grid, which is commonly used in the art, consists of a small, washer-like ring frame with grid wires stretched across one face of the ring parallel to a diameter, and fastened thereto, so as to lie across the central opening of the washer-like frame, through which the electrons pass from cathode to anode in the operation of the tube.

It is an object of this invention to provide an improved process for quantity production of planar grids affording a more satisfactory and uniform product at a reduced cost and permitting an increase in the number of grid turns per inch that may be applied.

It is a further object of my invention to provide a process that does not require the use of engineers or skilled technicians in the production of such grids, but which may be carried on by reasonably skilled labor accustomed to the manufacture of tubes.

In the past, many difficulties have been encountered in manufacturing such grids. Among the more troublesome of these may be mentioned:

(1) Variation in angular velocity of the wire feed spool.

(2) Limitation on the minimum diameter of wire that could be used, and, therefore, on the grid turns, per inch.

(3) Non-uniformity of the grids produced, resulting in high manufacturing shrinkage and high production costs.

(4) Loss of tension in the grid wires caused by excessive heating of the wires during the process of attaching them to the frame.

(5) Loss of tension in the grid wires caused by the grid frame contracting more than the grid wires as the grid cools after brazing.

(6) Flow of solder out over the surface of the grid wires in the active area of the grid.

The difficulties arose out of the method heretofore used for winding and brazing the grids. According to conventional practice, a pair of frames were placed one on each side of a flat mandrel which rotated at uniform angular velocity during the winding operation. This resulted in the angular velocity of the feed spool varying from zero to some maximum value twice during each revolution of the mandrel. This, in turn, required that with each velocity pulse or jerk on the wire, the wire, instead of merely being subjected to enough tension to overcome the dynamic friction of the tensioning device, had to withstand sufficient tension to overcome the static friction of the tension device and accelerate the feed spool as well. If the tension device were adjusted so that the wire was nearly at the breaking point during peak acceleration, the average tension in the wire was only a small fraction of the maximum value. This in turn placed a limitation on the number of turns per inch which could be applied because the finer wire which must be

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used to allow the use of higher turns per inch suffers an even smaller ratio of average to peak tension. This is due to the fact that the frictional and accelerating forces of the wire spool are as high for the fine wire as for the larger wires.

Other difficulties arose due to the use of a high melting-point solder. It was necessary to use gold, having a melting point of 1063° C. in order to braze the tungsten or molybdenum wire to the molybdenum frame. No solder with a lower melting point satisfactorily wets molybdenum.

Still other difficulties arose from the fact that the mandrels carrying the wound grids on each side had to be brazed in a hydrogen bell jar, one side at a time. Each time the grid was heated to brazing temperature some of the wire tension was lost. Frequently, even though the grids were wound at the maximum tension the wire would stand without breaking for more than ten percent of the time, the completed grids had no tension left in them.

In addition to the shrinkage of grids above described, costs were high because after completion of one set of grids the mandrels had to be individually polished by hand, a very expensive operation. All these problems had existed for some time, but until my invention there was no solution to them.

According to my invention, all these difficulties are eliminated or greatly reduced, enabling the grids to be manufactured in quantity production at greatly reduced cost and with greatly improved uniformity of product.

An object of the invention resides in the provision of an improved method of brazing or otherwise bonding a plurality of filamentary elements, such as grid wires, to a supporting member provided with an aperture across which the wires extend. In certain types of vacuum tubes the grid assembly is fabricated, prior to being mounted within the tube, and consists of a disc of molybdenum or other metal, centrally apertured, with a plurality of grid wires extending in parallel relation across the aperture with end portions brazed or otherwise bonded to one surface of the disc, and maintained under tension to prevent sagging when heated. The present invention is primarily directed to improvements in the manufacture of this type of grid structure, although the principles may be employed in the manufacture of similar articles for other intended uses.

The invention further encompasses improvements in the application of induction brazing as applied to the manufacture of vacuum tube grid structures. More specifically such improvements include employment of radio frequency electrical energy to effect induction flash brazing of grid wires to an apertured supporting member in a manner to prevent buckling of the grid wires during the brazing operation and to insure maintenance of optimum tension in each wire upon subsequent cooling of the assembly.

Other objects include improvements in apparatus for carrying out the method. An important feature of such apparatus resides in the confinement of heat flow resulting from the brazing operation in a manner to prevent metal flow along the grid wires within the aperture area of the grid disc, since the presence of such solder is injurious to the tube in which the grid is used, inasmuch as the solder melts and vaporizes when the grid is mounted in close proximity to the cathode, and in addition may promote the formation of undesired sulfides as a result of exposure to ordinary industrial atmospheres.

From the general improvement and simplification of methods and apparatus for manufacture of vacuum tube grid assemblies, in line with the above stated objectives, and as described in detail below, other applications will become apparent to persons skilled in this art without

departure from the scope of the invention as set forth in the appended claims. In the drawings, in which like parts are identified by the same reference numerals:

Fig. 1 shows in perspective apparatus for winding grid wire over mandrel supported apertured disc-like grid elements.

Fig. 2 is a front elevational view of apparatus employed in the fabrication of grid assemblies and incorporating principles of the invention.

Fig. 3 shows in plan an indexable mandrel and associated induction heating apparatus. Fig. 4 illustrates details of the high frequency coil structure of Fig. 3 adapted to establish flux density transversely of a mandrel such as shown in Figs. 1, 2 and 3.

Fig. 5 shows in plan, a grid structure, the wires of which have been wound and brazed by the method and apparatus herein described.

Certain electron tubes, such as the so-called planar grid tubes, employ flat type grid assemblies which are mounted transversely of the tube envelope in spaced relation to the cathode and anode structures. Grid structures of this type which have heretofore been used, are commonly in the form of a washer-like centrally apertured disc 10, as shown in Fig. 5, with a plurality of grid wires 11 stretched across one face thereof and brazed at 12 and 13 with grid wires 11 extending, under tension, across a central aperture 15 which is aligned, upon assembly of the tube, with the cathode and anode structure. Such grid structures, and the type of electron tubes in which they are employed, are shown and described in Patent 2,553,580 of Paul Haas, issued May 22, 1951, and assigned to the assignee of the present invention. In that application both grid and anode structures are secured to supporting electrodes which extend transversely of and project through the tube envelope in sealing engagement therewith. Since the present invention does not relate to the tube structure per se, further reference is limited to the grid structure only, and to the improved method and apparatus for fabricating such structures, as above mentioned.

As shown in Figs. 1 through 4, apparatus for reducing the improved method to practice includes a polygonal work mandrel, generically designated 18, preferably of a material of high heat resistivity, and electrical insulating properties, such as a commercial product, known as Lava, although other materials such as ceramics having these properties may be employed. Mandrel 18 is first rotatably mounted on spindle 19 to a suitable winding device, not shown, for application of a continuous grid wire in a manner shown in Fig. 1. Discs 10 have been mounted as shown to each polygonal face of mandrel 18 and retained by a ring star clamp 20 to prevent displacement of the discs 10 during the winding operation. If desired, a pair of such ring star clamps may be employed, one on each side of the mandrel. A feed spool 22 is rotatably mounted in a position to permit feeding of wire 11 about the mandrel 18 and discs 10, mounted thereon, as spaced by wire guide device 24, which includes a tensioning device pictorially represented by block 25 and a guide means represented by notched block 26.

Polygonal mandrel 18 is preferably as near a cylinder as is practical to provide a large angle between planes. For example, a hexagonal mandrel, two and one half inches in diameter provides supporting areas sufficiently large to carry the grid frames for certain tubes. Such a mandrel closely resembles a cylinder as to uniformity of demand from wire feed spool 22, permitting employment of greater tension on tensioning device 25 than heretofore allowed with more residual tension resulting in the wire after winding, since the consequent reduction of velocity changes insures substantially constant tension during the winding operation.

Prior to the winding operation which is done in a conventional manner, apparent from Fig. 1, grid wire 11 has one end secured to the mandrel, and the opposite

end tied thereto after winding. The manner in which the discs 10 are prepared for soldering, prior to the winding operation, is described below. Upon completion of the winding operation mandrel 18 is removed from the winding device, spindle 19 removed, and the mandrel mounted by bolt 17 on a support member 26 of a size convenient for bench use. The particular member shown includes an upright bracket portion 22 of reduced thickness, and a laterally extending base plate 24 for rigid support on a bench or other supporting surface 25. Smooth glass cane inserts, 27 are positioned within slots 29 at the corners of the polygonal mandrel to insure uniform application of the grid wire 11 during winding, since rough corners have been found to result in a helical winding of non-uniform spacing. While mandrel 18 as shown is of hexagonal configuration, as described above, it is understood that the invention is not limited to any one type of mandrel, nor is it limited to the use of mandrels generally, since the inventive concept is applicable to other means of indexing discs 10, together with a uniformly spread overlay of grid wires 11 to an area of concentrated high frequency electrical energy, described below, while supporting the discs and wires in a manner to confine heat flow substantially to localized areas during the brazing operation. Advantages reside in the employment of a rotatable mandrel, since the grid wire may quickly be helically applied with a uniformity of spacing and tensioning not otherwise so readily obtained. Simplicity and low manufacturing costs also favor mandrel type indexing over more complicated equipment.

Each work receiving surface of mandrel 18, such as 30, Fig. 1, is provided with a pair of transverse slots 31 32, so spaced that each apertured disc 10, when centered on the surface, extends across slots 31 and 32, with the area to be brazed, as shown at 12, Fig. 5 located centrally of each slot. The wires are applied under tension, however, since during tube use, the grid wires heat to a greater extent than does the supporting disc, hence sufficient cold tension must be applied to insure against sagging of the wires, which would result in changed electrical characteristics, or even in short circuits to the cathode. With the mandrel indexed to the position shown in Fig. 4, the brazing of the grid wire, transversely of the coil formed thereby, is as follows.

A work coil, generically designated 40, and best shown in Figs. 2 through 4 is positioned immediately above a selected disc 10 to which grid wire 11 is to be brazed. While wire 11 is continuous, hence singular, the convolutions are cut after both ends are brazed to each disc 10, hence will hereinafter be referred to as a plurality of wires 11. The function of work coil 40 is to concentrate high frequency electrical energy, carried to coil 40 by conductors 41 and 42, from a suitable source, not shown, the energy concentration being confined to a limited area of disc 10, to the grid wires 11 within that area, and to bonding material, applied to the wires within that area to effect the desired braze, as described below. Coil 40 consists of a single turn including horizontal going and return portions 41 and 42, Figs. 2 and 3. Portions 41 and 42 are closely adjacent having therebetween only a narrow slot or space 50 through which may be dropped a length of solder in wire form, properly to position the solder across the grid wires 11 just prior to application of the R. F. energy.

A feature of the present invention resides in the structure of work coil 40. As shown in Figs. 2 through 4, the coil preferably is constructed of rigid stock, such as copper or other electrically conducting material. As shown, the coil material may be rectangular in cross section. The coil 40 includes a pair of supporting electrodes 48 and 49, Fig. 2, adapted for connection to a source of high frequency electrical energy and positioned upright as shown in Fig. 4. Upright portions 48 and 49 lead into horizontally disposed portions 41 and 42, Figs.

2 and 3, both upright and horizontal portions being closely spaced as shown at 50. The horizontal portions 41 and 42 extend beyond the vertically positioned mandrel 18, Figs. 3 and 4, to be integrally or otherwise joined at 52 to form a closed loop. Through an area of greater width than the mandrel 18 and in registry therewith, the stock of portions 41 and 42 is milled to form diagonally disposed downwardly tapering portions 44 and 45 as best shown in Fig. 2. The structure just described serves as a work coil for concentrated application of high frequency electrical energy to grid discs 10 and the grid wires wound thereon to effect brazing of the wire to the grid. It has been found that the diagonally disposed portions 44 and 45 of reduced thickness effectively concentrate electrical heating energy as applied transversely of the mandrel face, within the area immediately adjacent the solder as shown at 56, Fig. 2. Direct heating of the portions of the disc running generally parallel to the grid wires is thus avoided, minimizing the differential contraction and expansion experienced between grid wires and disc fabricated of different materials. Undesirable heating of these portions of the disc by conduction from the heated portions may be minimized by reducing the duration of the time of application of high frequency energy to a minimum.

As above mentioned, methods heretofore employed in brazing the grid wires 11 to the disc 10 have resulted in the flow of the brazing solder along each grid wire 11 into the area defined by aperture 15, to increase the wire diameter marginally of the aperture or even to fill in the space between the wires. Such an increase in wire size or alteration of the electron permeable area is highly undesirable, since it changes the electrical characteristics of the tube and exposes an inferior metal on the grid wires to the electron stream causing difficulties in the intended operation of the tube, such as grid emission. The present invention operates to provide a grid disc in which the solder does not flow onto the grid wires.

With the method of brazing taught herein, the mandrel stays cool and it is possible to employ glass cane inserts 27, as above mentioned, at the corners to provide an extremely smooth winding surface which is highly resistant to the cutting action of the fine grid wire which may be utilized in the grid. The inserts may easily be replaced when accidentally scratched or cut by the grid wires.

For purposes of example, the present invention has been reduced to practice for mass production of grid assemblies, the discs of which are of molybdenum. Since this material cannot be wet by silver solder, which is commonly employed in the manufacture of electron tube interior assemblies, the discs are gold plated, with the gold fused thereto in a dry hydrogen furnace. Gold has a melting point of 1945° F. as compared to 4750° F. for molybdenum. The grid wires used are of platinum coated tungsten, 0.0003 inch in diameter, wound over the discs at 896 wires to the inch. Platinum has a melting point of 3223° F. as compared to 6100° F. for tungsten. The solder used is composed of 60% silver, 30% copper, and 10% tin, with a melting point of 1105° F., which is sufficiently high to withstand internal electron tube temperatures in the types with which the grid structure is used. This solder will wet both gold and platinum at the melting point of 1105° F., but will not wet molybdenum directly. It is used in place of gold because it melts at a lower temperature, thus giving rise to less hot stretching and less differential contraction between the discs and the grid wires.

What I claim is:

1. The method of fabricating planar grid structures comprising constructing an apertured member of metal having a melting point substantially higher than gold, plating said member with gold, maintaining a plurality of filamentary elements of material having a higher melting point than gold in mutually spaced and tensioned

condition and in contiguous relation to a face of said apertured member to extend transversely of the aperture, positioning a solder of lower melting point than gold transversely of said wires for support thereby above a solid portion of said apertured member, and subjecting said solder, wires, and an immediate portion of said apertured member to local, concentrated high frequency electrical energy to braze said wires to said member, said immediate portion being adjacent but spaced from said aperture.

2. In apparatus for winding planar grids, a polygonal work supporting mandrel of high heat resistivity material the faces of which are provided with a pair of spaced transverse channels to provide isolated work contacting surfaces at either end and centrally thereof to reduce heat flow therebetween, means for mounting said mandrel for step by step rotation through a vertical plane, and means for concentrating radio frequency electrical energy within the space immediately above one channel.

3. The apparatus of claim 2, wherein said energy concentrating means comprises a work coil having a portion thereof extending the length of one of said channels midway of the projected area thereof and adjacent the mandrel surface, whereby electrical energy may be applied in proximity to a planate work piece positioned on said surfaces to extend across said one channel.

4. The method of forming a vacuum tube grid assembly consisting of the steps of forming a disc of molybdenum, providing said disc with a central aperture, maintaining said disc against a transversely channeled work supporting member of high heat resistivity in a manner to extend across the channeled portion thereof, extending tungsten wire across the exposed face of said disc in contiguous engagement with the surface thereof, applying silver solder to a portion of said wire at a point of engagement with said disc and within the projected area of said channel, and subjecting said solder and the immediate portions of said wire and disc to radio frequency energy to heat said solder to the melting point and effect an amalgamized bond between the solder, wire, and disc.

5. An induction heating electrode assembly comprising a pair of closely spaced electrically conducting elements joined at one end and adapted for connection to a source of high frequency electrical energy, said electrodes having aligned portions of reduced thickness diagonally disposed in V-configuration for concentration of electrical energy along the apex thereof.

6. The method of forming a planar grid assembly consisting of the steps of mounting an apertured grid disc on a mandrel and supporting parts of said disc to which solder flow is not desired against surfaces of said mandrel, extending wires across the exposed face of said disc in contact with portions of the surface thereof on either side of an aperture, applying solder at points of contact of said wires and said surface portions where said disc is unsupported, and subjecting said solder and contiguous regions of said wire and said disc to a local field of radio frequency energy to heat said solder to the melting point and effect a bond between the solder, wire, and disc.

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