July 28, 1959 C. A. WHITELEY 2,896,307

GRID MANUFACTURING PROCESS

Filed May 14, 1954 2 Sheets-Sheet 1

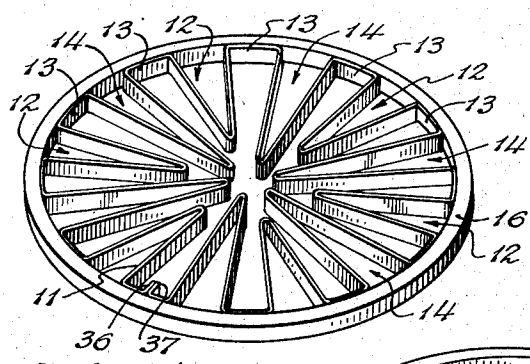

Fig. 1.

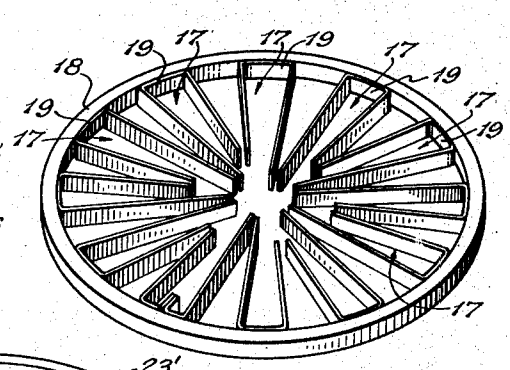

Fig. 2.

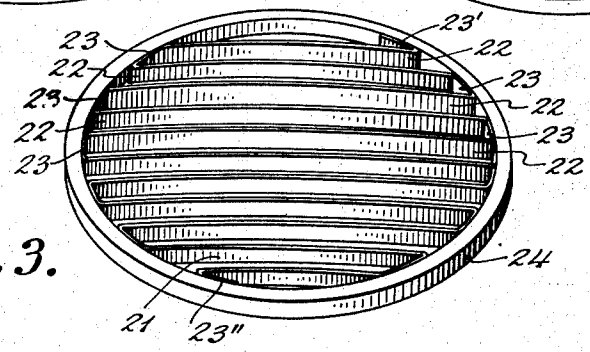

Fig. 3.

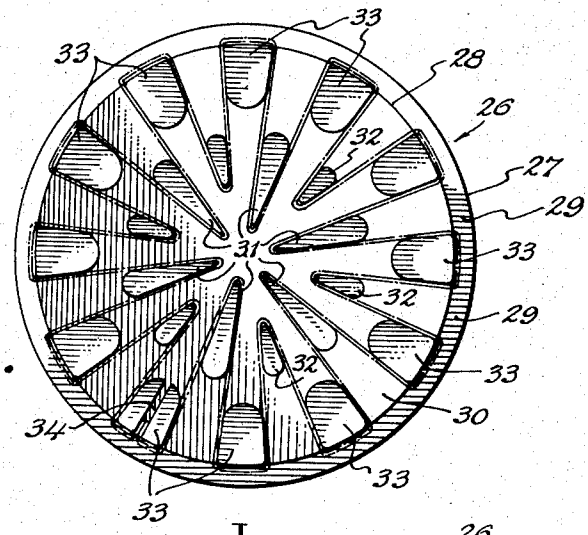

Fig. 4.

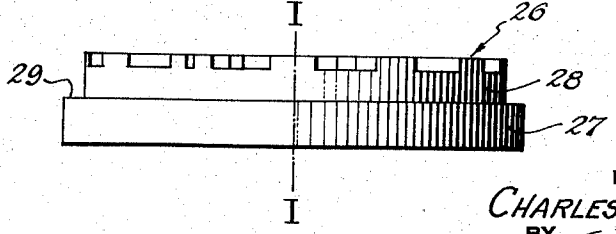

Fig. 5.

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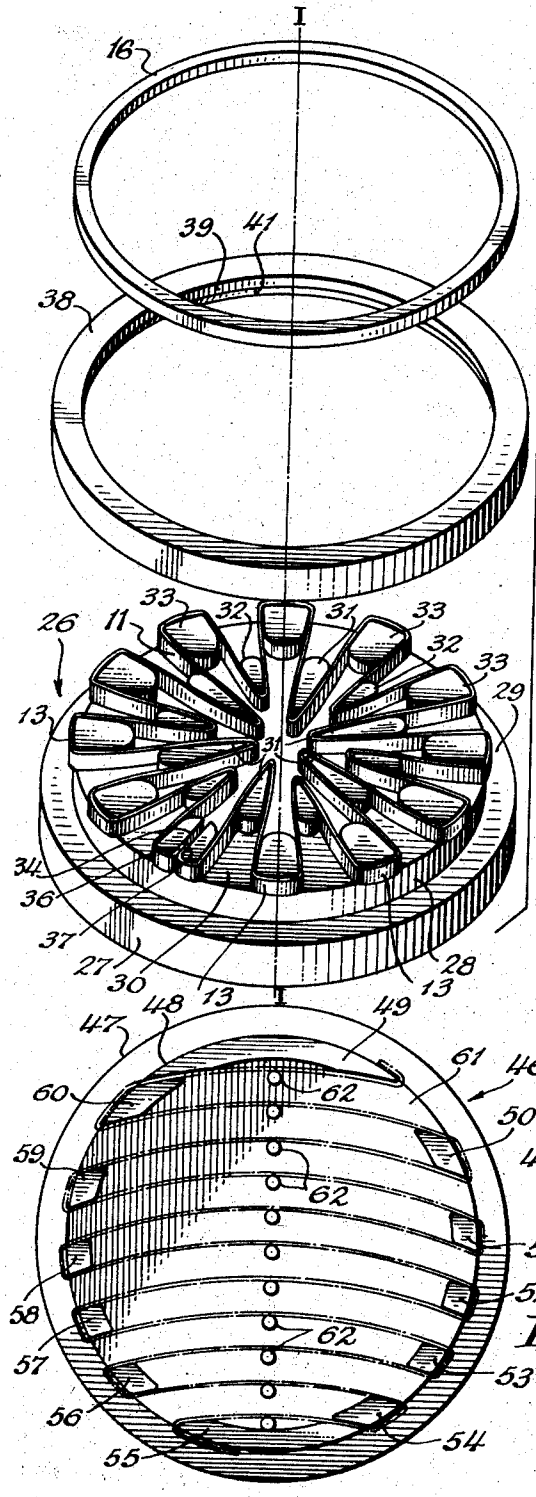

Fig. 6.

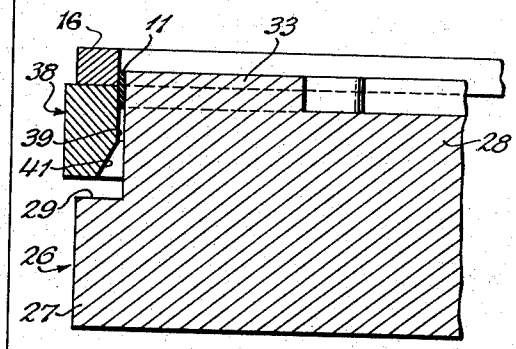

Fig. 7.

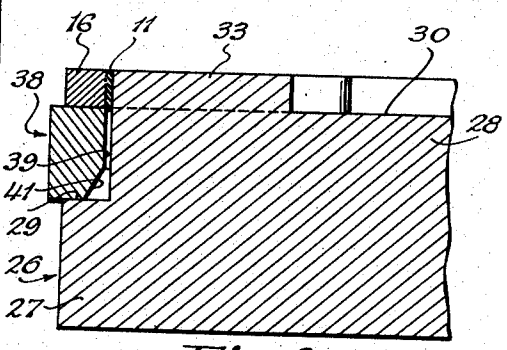

Fig. 8.

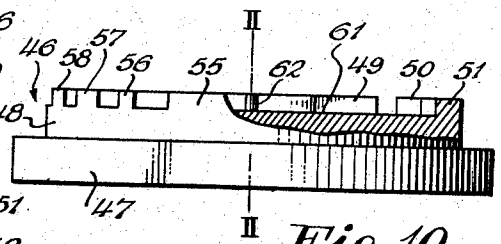

Fig. 10.

Fig. 9.

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GRID MANUFACTURING PROCESS

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Application May 14, 1954, Serial No. 429,807

4 Claims. (Cl. 29—25.14)

The present invention relates to a process of manufacturing grids for use in electron beam tubes such as klystrons, travelling wave tubes and high frequency triodes.

One of the most reliable and efficient kinds of grids prominently used in electron beam tubes is comprised of spaced, cantilever-type vanes mounted upon an annular supporting member and projecting inwardly thereof. The individual vanes of some grids of this type are free from each other at their inner ends within the supporting member. In other grids of this type the vanes of certain pairs of vanes are joined together at their inner ends so that the aforesaid pairs are each comprised of an integral element bent into a desired configuration similar to a V, for example.

Yet another type of grid which has been used in klystron tubes, for example, is comprised of a plurality of spaced vanes extending across the interior of an annular grid supporting member. The vanes are affixed to the inner surface of the aforesaid member at opposite regions thereon with the front and back edges of the vanes being coplanar, respectively.

The vane elements of most grids of the aforedescribed types are formed from thin strip sections of metal. Each section must be of predetermined length and sharply bent at one or more places to form one or more vane elements and integral supporting portions therefor. The supporting portions are made to conform to the inner surface of the annular grid supporting member and are soldered or brazed, for example, to the aforesaid surface.

Heretofore it has been difficult to form grids of the aforedescribed types. Accurate bends are required to be made in the metallic strip sections so that a rugged assembly having a predetermined distribution of grid elements can be produced. Generally such bends have been made while the metallic strip sections are at room temperature, a cold-bending process, and it has been time-consuming and expensive to make the bends with the required precision to provide an accurate and rugged grid assembly. Furthermore, since sharp bends are generally required, the cold-bending process may result in a grid having elements which are unduly weak and fragile at the bends.

It is an object of the present invention to provide an improved process of manufacturing grids for use in electron beam tubes.

It is a further object to provide a process of manufacturing vane type grids which is less time-consuming and less expensive than processes heretofore known in the art.

It is still another object of the present invention to provide a process as aforedescribed for accurately manufacturing vane-type grids of more rugged construction than similar grids of the same type and size heretofore known in the art.

The foregoing objects are attained by a process which includes the steps of: interwinding an elongated metallic element back and forth across parts of the face of a jig

from one to another of a plurality of predeterminedly shaped and distributed protuberances extending from said jig face; heating the assembly comprising said jig and said element to a predetermined temperature and tightening said element about said protuberances so that portions of said element are heat-bent and closely conformed to parts of said protuberances; and cooling said assembly to thereby permanently fix the shapes of the bends in said element and provide a rigid and accurate configuration suitable for a grid in an electron beam tube device.

If the jig has an appreciably higher temperature coefficient of expansion than that of the grid element the tightening part of the process can be effected by heat expansion during the heating step, provided the ends of the grid element are anchored.

Furthermore, if at least some of the jig protuberances are in a ring around the axis of the jig and have outermost parts conformal to an annulus, an annular grid supporting member can be readily bonded to portions of the grid element which are interwound therearound. If the supporting member has a slightly lower temperature coefficient of expansion than that of the jig, the heating step will cause the jig to expand and the aforementioned grid element portions to be compressed against and more closely conformed to the inner surface of the annular supporting member. The bonding is achieved by providing suitable brazing means having a melting point lower than that to which the assembly is heated between the inner surface of said supporting member and the aforesaid grid element portions.

The foregoing process and all of the objects and advantages of the present invention will become more apparent to those skilled in the art from the following detailed description of the invention taken in connection with the accompanying drawings in which:

Figs. 1, 2 and 3 are perspective views of three different types of grids which can be manufactured in accordance with the process of the present invention;

Fig. 4 is a plan view of a jig for forming the grid shown in Fig. 1;

Fig. 5 is a side view of the jig shown in Fig. 4;

Fig. 6 is an exploded view in perspective illustrating the aforementioned jig, a grid element interwound thereon and ring members utilized in the grid forming process;

Fig. 7 is an enlarged sectional view of the jig and interwound grid element of Fig. 6, and shows the position of the ring members shown in Fig. 6 at an intermediate stage in the grid forming process;

Fig. 8 is a sectional view of the jig and interwound element similar to that shown in Fig. 7, and shows the position of the ring members shown in Figs. 6 and 7 at a further stage in the grid forming process;

Fig. 9 is a plan view of a further jig for forming the grid shown in Fig. 3; and

Fig. 10 is a side view, partly in section, of the jig shown in Fig. 9.

A first grid assembly manufactured in accordance with the process of the present invention is shown in Fig. 1. This assembly is comprised of a thin metallic element **11** which is bent to form a plurality of V-shaped sections **12**, supporting portions **13** and V-shaped sections **14** symmetrically disposed about an axis of an annular metallic supporting member **16**. The supporting portions **13** are rigidly fixed to or mounted upon the inner surface of member **16**. The vertexes of V-shaped sections **12** are located inward of member **16** by equal distances along alternate ones of equally spaced radii of member **16**. The vertexes of V-shaped sections **14** are located further inward of member **16** by equal distances along other alternate ones of the aforementioned equally spaced radii of member **16**.

The grid assembly shown in Fig. 1 is of the cantilever type since there is no support of the arms or vanes of the V-shaped sections **12** and **14** at their inner ends within the grid supporting member **16**. Since certain pairs of arms are joined together at their inner ends to form the V-shaped sections **12** and **14**, the grid shown in Fig. 1 is usually designated as a pyramid-type grid.

A modification of the pyramid-type grid illustrated in Fig. 1 is shown in Fig. 2. In the latter figure the grid is comprised of a plurality of J-shaped metallic sections **17** rigidly mounted and symmetrically disposed upon the inner surface of an annular, metallic supporting member **18**. Bent portions **19** of sections **17** are utilized to rigidly support each section upon member **18**. The adjacent sections **17** of the cantilever type grid assembly shown in Fig. 2 are mirror images of each other. Therefore, this assembly could be readily formed from the structure shown in Fig. 1 merely by cutting or shearing the V-shaped sections thereof at their apexes.

Yet another type of grid assembly which can be manufactured in accordance with the process of the present invention is illustrated in Fig. 3. This assembly is comprised of a thin metallic element **21** formed into a plurality of curved vane sections **22** and supporting portions **23**. The supporting portions **23** are rigidly mounted upon the inner surface of an annular, metallic supporting member **24**. A uniform spacing is provided between the vane sections **22** with the narrow front and back vane edges being coplanar, respectively. The grid assembly shown in Fig. 3 is known in the art as an arched-vane grid. The vane sections **22** are curved so that changes in temperature to which the grid may be subjected will not cause the front and back edges thereof to deviate from their original planes.

Referring to Figs. 4 and 5, a cylindrical mandrel or jig **26** is provided for forming the grid assembly shown in Fig. 1. The jig **26** is comprised of a bottom cylindrical section **27**, an upper coaxial cylindrical section **28** having a smaller diameter than section **27**, a flat, annular jig seat **29** outward of section **28** at the top of section **27**, and a plurality of spaced protuberances **31**, **32** and **33** extending from a flat upper face **30** of jig section **28**.

The sides of protuberances **31**, **32** and **33** are perpendicular to the face **30** of section **28**. Each protuberance has the same thickness along the axis I—I through the center of jig **26**. This thickness should generally be as large as the width of the metallic element **11** shown in Fig. 1.

The protuberances **31** are all of the same size and shape. Six of these protuberances **31** are symmetrically disposed in a ring concentric with the aforementioned axis I—I of jig **26** as shown in Fig. 4. The innermost ends of protuberances **31** nearest the axis I—I of jig **26** are spaced from the axis of jig **26** by equal distances determined by how far inward it is desired for the V-shaped elements **14** of Fig. 1 to project. These innermost ends are located at positions corresponding to the apexes of the aforementioned V-shaped sections **14**.

The protuberances **32** are also of the same size and shape, though having a different size and shape than the protuberances **31**. Six protuberances **32** are symmetrically interposed between the six protuberances **31**, respectively. The innermost ends of protuberances **32** nearest the axis I—I of jig **26** are spaced from the aforesaid axis by equal distances determined by how far inward it is desired for the V-shaped elements **12** in Fig. 1 to project, these ends being located at positions corresponding to the apexes of the aforementioned V-shaped sections **12**.

The protuberances **33** are also of the same size and shape, and are symmetrically disposed in a ring concentric with protuberances **31** and **32**. Twelve protuberances **33** are provided in the particular jig construction illustrated. Each of protuberances **33** is arranged to be opposite a space between a protuberance **31** and a protuberance **32**. One side of each protuberance **33** is substantially aligned with a side of an adjacent protuberance **31**, the other side of each protuberance **33** being aligned with a side of an adjacent protuberance **32**. The outermost parts or ends of protuberances **33** farthest from axis I—I of jig **26** are conformal with the cylindrical side of the section **28** of jig. **26**.

One of the protuberances **33** is divided in half to provide a slot **34** through the middle thereof. The width of the slot **34** is made slightly larger than twice the thickness of the metallic element **11**. This is done so that end portions **36** and **37** of element **11** can be anchored in slot **34** during the grid forming process.

The dot-dash lines back and forth across parts of the face **30** of jig **26** in Fig. 4 illustrate generally the positions that V-shaped elements **12** and **14** and portions **13** of the grid shown in Fig. 1 would assume if this finished grid were seated upon the face **30** of jig section **28** to envelop the jig protuberances. It can readily be seen, therefore, that the particular sizes, shapes and locations of protuberances **31**, **32** and **33** are specifically determined in accordance with particular configuration of the grid to be formed.

The jig **26** shown in Fig. 4 is composed of metal having a relatively high temperature coefficient of expansion compared with the temperature coefficient of expansion of the metal of grid element **11**. The jig **26** including its protuberances **31**, **32** and **33** is formed by machining, casting or any other conventional jig forming process known in the art.

Referring to Fig. 6, the element **11** shown interwound upon jig **26** is originally in the form of a flat strip of metal having a greater width than thickness. A first end portion **36** of the metallic strip is inserted edgewise into the slot **34** of one of the protuberances **33** of the jig **26** to begin the grid forming process. The strip is then bent in a clockwise direction around one half of the outermost part of this protuberance **33**, drawn toward the axis I—I of jig **26** across part of its face along the aligned sides of the aforesaid element **33** and the most adjacent element **32**, bent around the innermost curved end of this protuberance **32**, and drawn back along the aligned sides of the aforesaid element **32** and the next protuberance **33** displaced in a clockwise direction from the protuberance **33** containing the slot **34**. This procedure is continued until the metallic element **11** is interwound back and forth around the outermost end part of each protuberance **33** and the innermost end part of each protuberance **32** and the innermost end part of each protuberance **31**. One narrow edge of element **11** is maintained in abutment with the face **30** of section **28** of the jig **26**, the opposite narrow edge thereof being coplanar with the tops of protuberances **31**, **32** and **33**.

After the interwinding of element **11** about all of the jig protuberances, a second end portion **37** is bent around the other half of the outermost part of the protuberance **33** containing the slot **34**, and inserted into the slot **34** adjacent the first end portion **36**. The two end portions **36** and **37** of element **11** should fit tightly within the slot **34** to thereby anchor the ends of element **11** with respect to the jig **26**.

A ring element **38** preferably composed of the same metal as jig **26** is shown in Fig. 6 in concentric relationship with the jig. The thickness of element **38** along its axis is equal to the thickness of jig section **28** along the axis I—I. An upper inner section **39** of ring element **38** has an inner diameter which is larger than the diameter of jig section **28** by an amount which is slightly greater than the thickness of element **11**. A lower inner section **41** of element **38** is chamfered. This is shown more clearly in Figs. 7 and 8.

The annular grid supporting member **16** is also shown in Fig. 6 in concentric relationship with jig **26** above element **38**. Member **16** is composed of a metal having a temperature coefficient of expansion slightly lower than the temperature coefficient of expansion of jig **26**.

The inner surface of member **16** is plated with suitable brazing material for bonding member **16** to the outer portions **13** of the grid element **11**. The inner diameter of member **16** is of the same order of magnitude as the inner diameter of section **39** of ring element **38**.

The ring element **38** is first located in relation to the jig **26** at the position shown in Fig. 7, the chamfered section **41** thereof facilitating the placing of element **38** down over the end of the jig **26** so that part of section **39** of element **38** forces the outer portions of grid element **11** inward toward the outermost end parts of the jig protuberances **33**. The annular member **16** is then placed on top of element **38** as shown in Fig. 7 so that part of this member also engages the outer portions of element **11**. The member **16** and element **38** are then pushed downward until the bottom of element **38** abuts the annular jig seat **29** and the bottom of member **42** rests upon the top of element **38** at the locations shown in Fig. 8. The outermost portions of grid element **11** outward of jig protuberances **33** are, therefore, maintained in compression toward the end parts of the protuberances **33** by the annular grid supporting member **16**.

The parts shown in Fig. 6, after being assembled as shown in Fig. 8, are then placed in an oven and heated in a hydrogen atmosphere to a temperature above the melting point of the brazing material on the inner surface of member **16**. During the heating the jig **26** expands rapidly outward of its axis. The outward expansion of jig **26** from its axis causes element **11** to be tightened about the jig protuberances **31**, **32** and **33** because of the fact that element **11** has a much lower temperature coefficient of expansion and its ends are anchored in the slot **34** of a jig protuberance **33**. Thus, the outer portions **13** of element **11** are heat-bent and conformed to the outermost end parts of the jig protuberances **33** and the apexes of the V-shaped sections of element **11** are heat-bent and conformed to the innermost ends of protuberances **31** and **32**.

If the inner diameter of member **16** is properly chosen relative to the diameter of jig section **28**, the thickness of element **11**, and the difference in expansion of jig **26** and member **16** because of their different temperature coefficients, the portions **13** of element **11** become firmly compressed against the inner plated surface of member **16** during the heating. This occurs because the member **16** has a slightly lower temperature coefficient of expansion than jig **26**. Therefore, since the assembly is heated to a temperature above the melting point of the brazing material plated to the inner surface of member **16**, the outer surfaces of the portions **13** of element **11** can become rigidly bonded to the inner surface of member **16**.

After heating the assembly for a sufficient time at the proper temperature, the jig **26**, ring element **38** and annular member **16** are removed from the oven and allowed to cool. The jig **26** contracts and element **11** becomes firmly affixed to member **16** upon hardening of the brazing material. After cooling, the grid assembly can be readily removed from the jig **26**.

In one particular type of grid which has been made by the aforedescribed process to have a configuration as shown in Fig. 1, the grid element **11** is composed of tungsten. The supporting member **16** for such a grid is composed of a nickel-copper alloy containing 63 to 70 percent nickel. Copper brazing material is employed for bonding or fixing the inner surface of member **16** to portions **13** of grid element **11**. The copper has been plated to the inner surface of member **16** before the grid assembling and brazing steps, for example.

The assembly comprising jig **26** and element **38** utilized to form grids of the particular materials described above is composed of a high chromium stainless steel type No. 302 as described on pages 3–19 of Kent's Mechanical Engineers' Handbook, 11th ed., "Design Shop Practice." This type steel is desirable because it has a much higher temperature coefficient of expansion than that of tungsten. Furthermore, the surfaces of an assembly of such material become oxidized during the heating process so that the grid element **11** and annular grid supporting member **16** will not become bonded to the steel by the copper brazing material. Sufficient oxidation occurs, even in a hydrogen gaseous atmosphere, because of an inherent content of moisture therein. If desired, moisture can be added to the gaseous atmosphere to increase this oxidation during the heating of the jig.

To form a grid utilizing the particular materials described above the assembly such as is shown in Fig. 8 should be heated in the oven containing the hydrogen atmosphere for six to eight minutes at a temperature between 1120–1140 degrees centigrade. It has been found desirable to place a weight or weights of some sort on top of the jig **26** and interwound element **11** to insure that element **11** does not buckle upward during the heating. After heating, the aforedescribed assembly is removed from the oven for cooling. After cooling the aforementioned weight or weights are removed and the grid is ready to be taken from the jig.

A grid having J-shaped sections **17** as shown in Fig. 2 can be manufactured by first forming a grid as shown in Fig. 1 by the aforedescribed process. Then, the V-shaped sections **12** and **14** are suitably cut or sheared by any suitable tool to provide the J-shaped sections **17** wherein the longer radial arms of adjacent sections are next to each other and the shorter radial arms of adjacent sections are next to each other.

Obviously other cantilever-type grids could also be formed by the aforedescribed process. For example, a pyramid-type grid wherein all of the V-shaped sections such as **12** and **14** of Fig. 1 extended inwardly of the grid supporting ring by equal distances could be made. This would merely require a jig wherein the innermost ends of all of the inner jig protuberances such as **31** and **32** in Fig. 6 were contiguous with the same circle. The apexes of the V-shaped sections of the grid formed therefrom could be cut to form yet another type grid having radial arms extending inwardly of the grid supporting ring by equal amounts with their inner ends free of each other. Furthermore, the apexes of the V-shaped sections could also be cut to form a grid having J-shaped sections wherein a long arm of each J-shaped section is adjacent the short arm of an adjacent section.

Referring to Figs. 9 and 10, a jig **46** is shown for manufacturing an arched-vane grid as shown in Fig. 3. The jig **46** is comprised of a bottom cylindrical section **47**, an upper coaxial cylindrical section **48** having a smaller diameter than section **47**, a first set of protuberances **49—60**, and a set of rod-like protuberances **62** on a flat face **61** of jig section **48**. The jig **46** is composed of a metal having a substantially higher temperature coefficient of expansion than that of the thin metallic element **21** of Fig. 3.

The protuberances **49—60** and **62** all have the same dimensions along the axis II—II of jig **46**. These protuberances are shaped and located as shown in the plan view of Fig. 9 so that the dot-dash lines illustrated therearound and between the protuberances conform generally to the outline of the configuration formed by the narrow edge of grid element **21** of the finished grid shown in Fig. 3.

The parts of protuberances **49—60** farthest from the axis II—II of jig **46** are conformal with the cylindrical side of the section **48** of jig **46**. The sides of the protuberances **49—60** are perpendicular to the jig face **61**.

The rod-like protuberances **62** are also perpendicular to the jig face **61**. Protuberances **62** are equally spaced along a diameter of the jig face **61** and located at the positions shown in Fig. 9 so that the sections **22** of the grid shown in Fig. 3 will attain the proper curvature when forming the grid.

To provide the grid of Fig. 3, an elongated strip of

metal 21 having a greater width than thickness is interwound back and forth across parts of the face 61 of jig 46 from protuberance 49 to protuberance 55, following the general path of the dot-dash lines in Fig. 9. The end portions 23' and 23'' of the element 21 shown in Fig. 3 are bent around ends of protuberances 49 and 55, respectively, to provide suitable anchorage.

Once the element 21 is interwound upon the jig 46 as described, the process of making permanent heat bends in the grid element and mounting the element in an annular grid supporting element 24 is undertaken. This process is identical with that described with reference to Figs. 6–8 so need not be repeated.

Since changes in the aforedescribed process and grid assemblies of different configurations and/or different materials than specifically described herein could be made without departing from the scope of the present invention, 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. A process of forming a grid for an electron beam tube device, comprising anchoring one end of an elongated strip-like metallic element upon a jig having an appreciably larger temperature coefficient of expansion than said metallic element, interwinding said element in edgewise relationship with respect to a face of said jig back and forth in the same plane across parts of said jig face from one to another of a plurality of predeterminedly shaped and distributed protuberances extending from said jig face to thereby provide a substantially planar vane-type grid configuration, anchoring the other end of said element upon said jig, placing a grid supporting member around said element upon said jig in close relationship with portions of said element for bonding between said element and said member upon application of heat, heating the assembly comprising said jig, said element and supporting member to thereby expand said jig relative to said element and tighten said element about said protuberances so that portions of said element are heat-bent to closely conform to parts of the peripheries of said protuberances, and cooling said assembly to thereby rigidly bond said element to said member and permanently fix the shapes of the bends in said element and provide for ready removal of said element from said jig after contraction thereof.

2. A process of forming a grid for an electron beam tube device, comprising interwinding an elongated metallic strip-like element back and forth in the same plane across parts of the face of a jig from one to another of a plurality of predeterminedly shaped and distributed protuberances extending from said jig face and anchoring the ends of said element upon said jig, said jig having an appreciably larger temperature coefficient of expansion than said metallic element, enveloping said protuberances and interwound element with an annular supporting member having a slightly lower temperature coefficient of expansion than said jig and an inner periphery in close proximity with wide portions of said element around parts of a first group among said protuberances, said inner periphery of said supporting member being substantially conformal with said parts of said first group of protuberances and separated from said portions of said element by a material for uniting said member and element in response to heating thereof, heating the assembly comprising said jig, said element and said supporting member to thereby expand said jig relative to said element and supporting member and tighten said element about said protuberances, said wide portions of said element being thereby heat-bent and closely conformed to said parts of said first group of protuberances and said inner periphery of said supporting member, and cooling said assembly to thereby permanently fix the shapes of the bends in said element and unites said element to said supporting member to provide for ready removal of said element and supporting member from said jig after contraction thereof.

3. A process of forming a grid for an electron beam tube device, comprising interwinding an elongated metallic strip-like element having a first temperature coefficient of expansion back and forth in the same plane across parts of the face of a jig in edgewise relationship with respect to said face from one to another of a plurality of predeterminedly shaped and distributed protuberances extending from said jig face, seating a grid supporting ring member upon said jig around the interwound element, said ring member having a lower temperature coefficient of expansion than said jig with the inner surface of said ring member being plated with a brazing material and in close proximity to wide portions of said element about outermost protuberances furthest from the center of said ring member, heating the assembly comprising said jig, the interwound element and the supporting member above a melting point of said brazing material to expand said jig so that said outermost peripheral parts of said outermost protuberances are in closer proximity to said ring element and said interwound element is heat-bent about said protuberances, and cooling the foregoing heated assembly in order to permanently bond said grid element to said ring member and to enable said grid element and supporting ring member to be removed from said jig so as to provide a rugged vane-type grid suitable for electron beam tubes.

4. A process of forming a grid, comprising the steps of: anchoring one end of a thin, elongated metallic strip-like element upon a metallic jig having a plurality of predeterminedly distributed protuberances from a face of said jig, a group of said protuberances being disposed in a ring, said jig having a substantially larger temperature coefficient of expansion than said element; drawing said element back and forth in the same plane in edgewise relationship across parts of the face of said jig and bending said element about parts of said protuberances to form a substantially planar vane-type grid configuration generally like a predetermined configuration suitable for a grid in an electron beam tube device; anchoring the other end of said element upon said jig; placing an annular grid supporting member in surrounding closely spaced relationship with said group of said jig protuberances so that portions of said element are between said group of protuberances and the inner surface of said supporting member, means being provided for brazing said portions to said member; heating the assembly comprising said jig, said element, said supporting member and said brazing means to a temperature above the melting point of said brazing means, the heat causing said jig to expand for forcing said portions of said element in closer relationship with said grid supporting member and said element to become tightened about said protuberances to thereby cause the configuration of said element to more closely conform to said predetermined configuration; and cooling said assembly to rigidify said element and cause said portions to become rigidly bonded to said supporting member by said brazing means.

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