March 26, 1968 E. T. DU PRE 3,375,343

ELECTRON DISCHARGE DEVICE ASSEMBLY METHOD

Filed Aug. 31, 1964 6 Sheets-Sheet 1

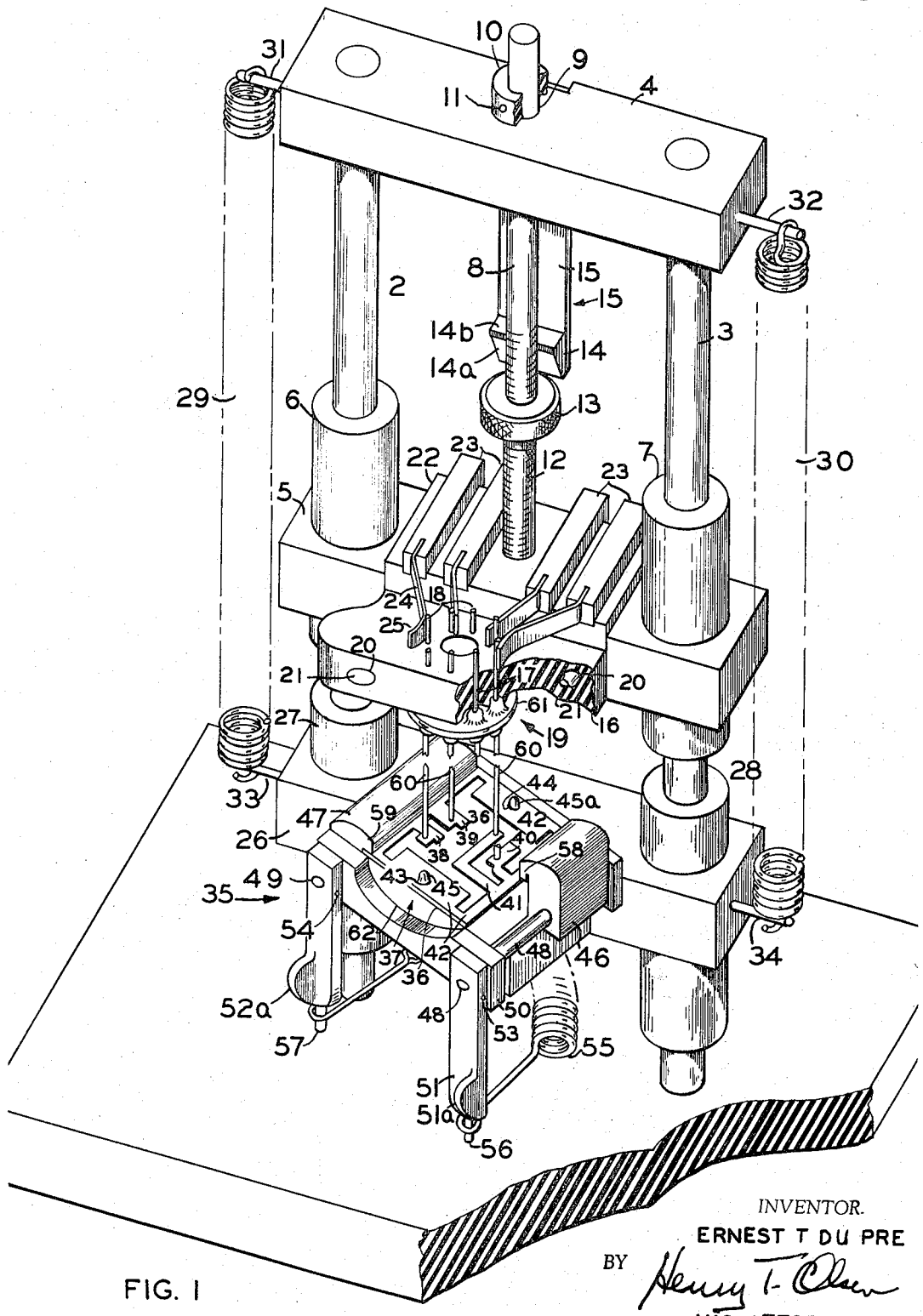


FIG. 1

INVENTOR.
ERNEST T DU PRE
BY Henry T. Olsen
HIS ATTORNEY

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ELECTRON DISCHARGE DEVICE ASSEMBLY METHOD

Filed Aug. 31, 1964 6 Sheets-Sheet 2

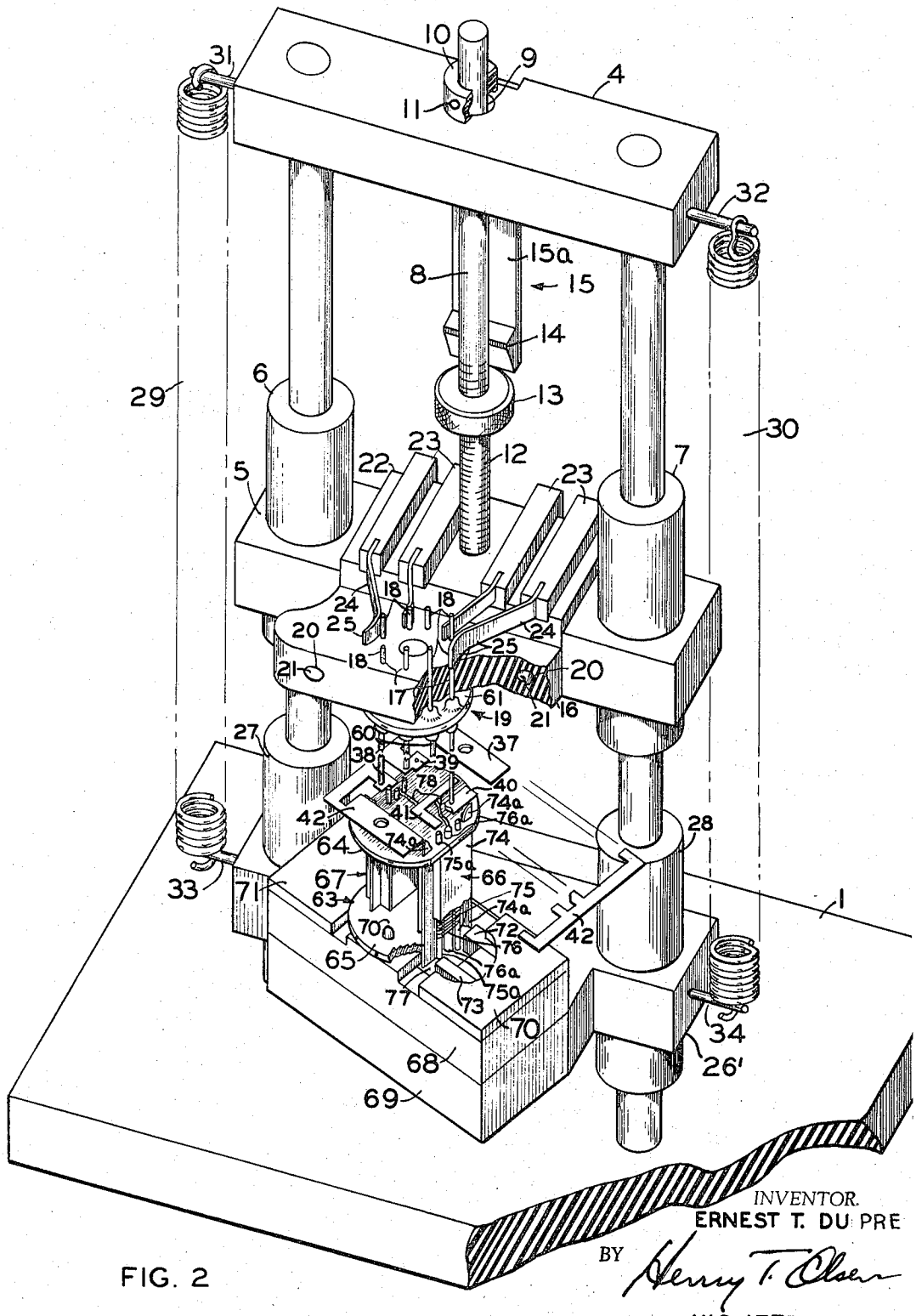


FIG. 2

INVENTOR.
ERNEST T. DU PRE
BY
HIS ATTORNEY

ELECTRON DISCHARGE DEVICE ASSEMBLY METHOD

Filed Aug. 31, 1964 6 Sheets-Sheet 3

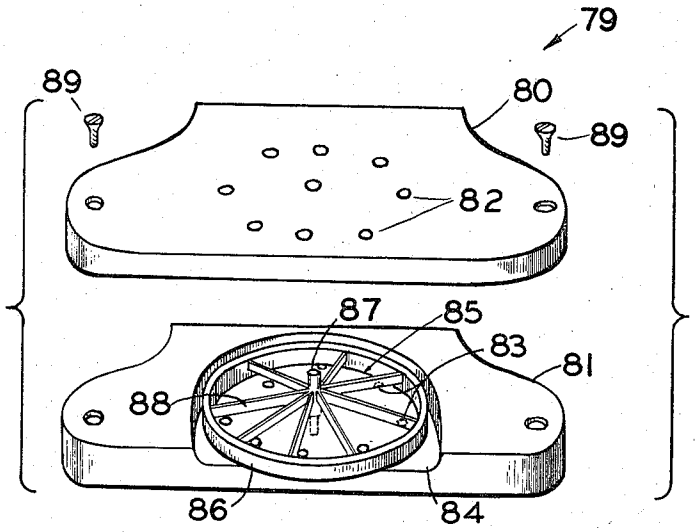


FIG. 3

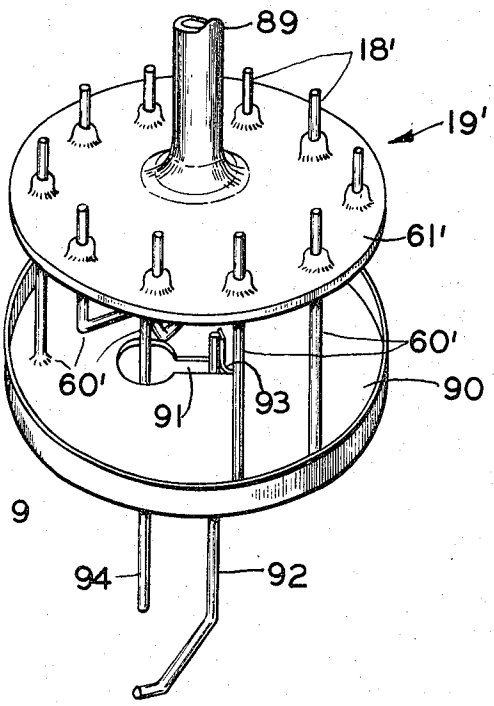


FIG. 4

INVENTOR.
ERNEST T DU PRE
BY Henry T. Olsen
HIS ATTORNEY

ELECTRON DISCHARGE DEVICE ASSEMBLY METHOD

Filed Aug. 31, 1964 6 Sheets-Sheet 4

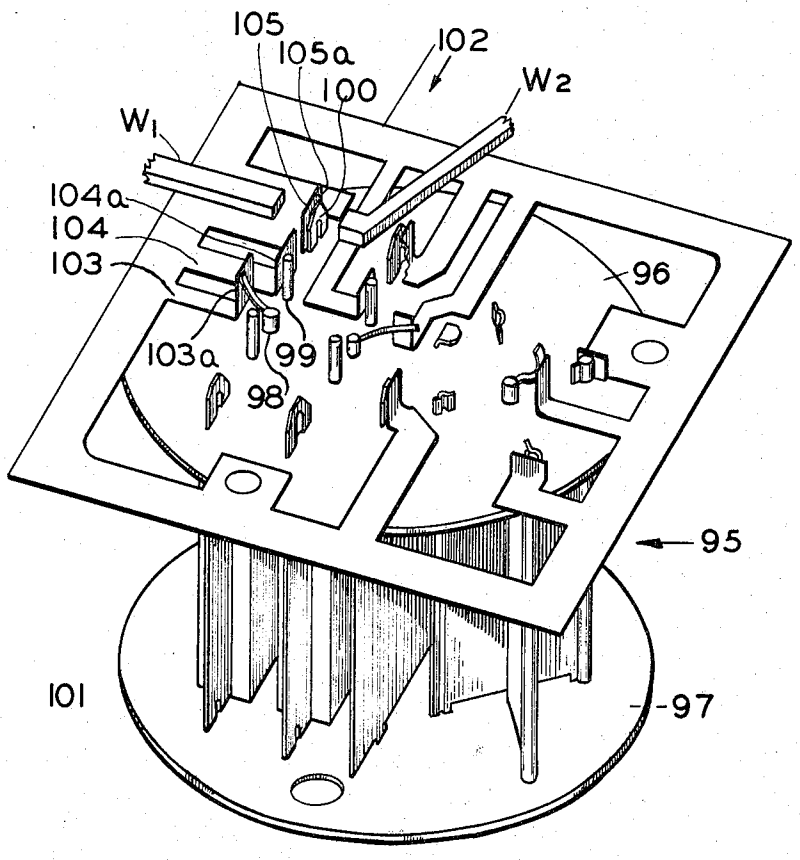


FIG. 5

INVENTOR.
ERNEST T. DU PRE
BY Henry T. Olsen
HIS ATTORNEY

March 26, 1968 E. T. DU PRE 3,375,343

ELECTRON DISCHARGE DEVICE ASSEMBLY METHOD

Filed Aug. 31, 1964 6 Sheets-Sheet 5

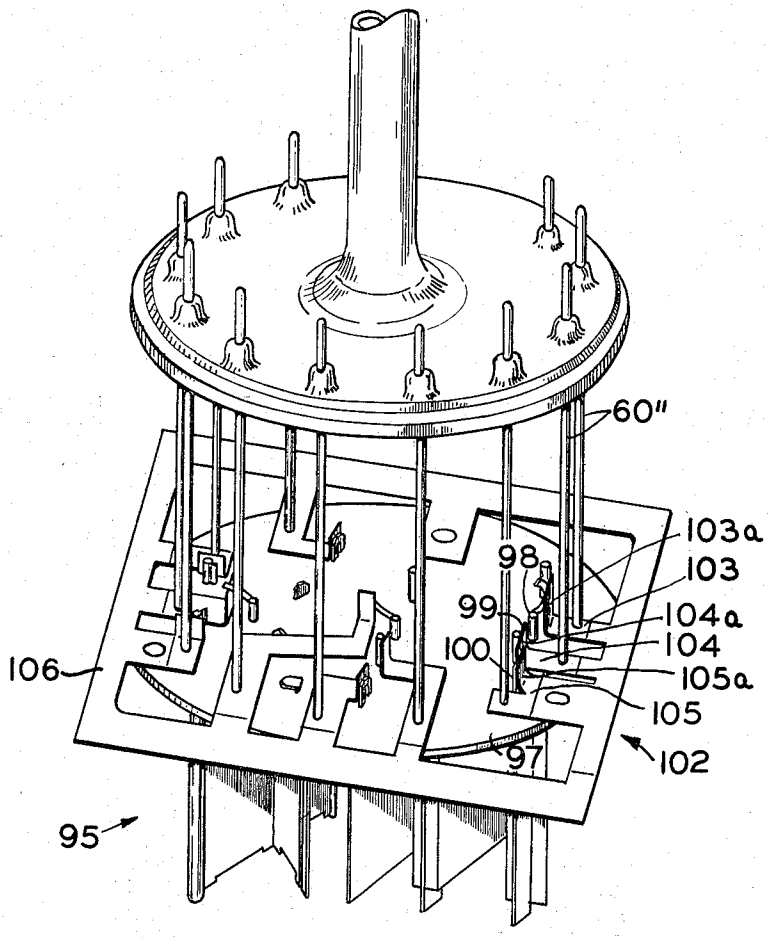


FIG. 6

INVENTOR.
ERNEST T. DU PRE
BY Henry T. Olsen
HIS ATTORNEY

March 26, 1968 E. T. DU PRE 3,375,343

ELECTRON DISCHARGE DEVICE ASSEMBLY METHOD

Filed Aug. 31, 1964 6 Sheets-Sheet 6

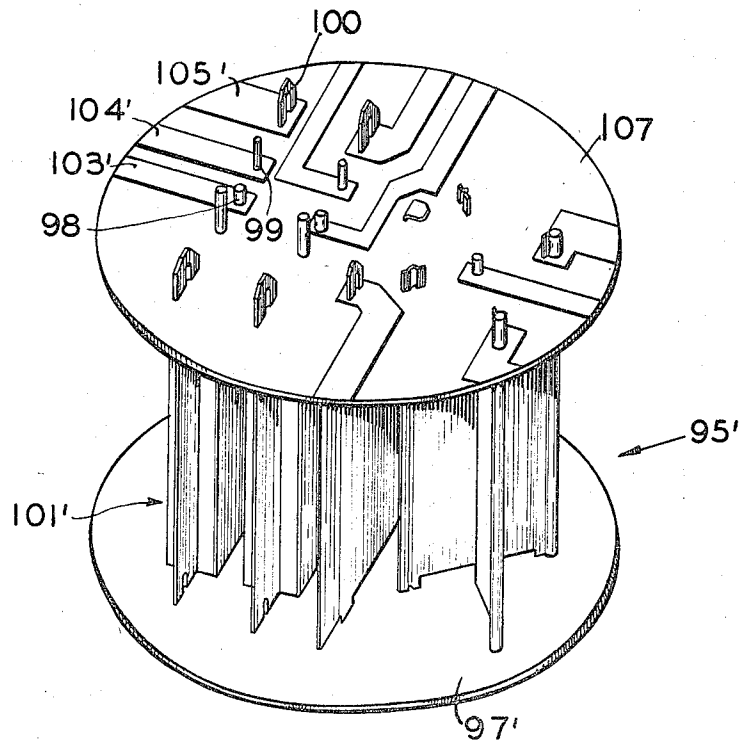


FIG. 7

INVENTOR.
ERNEST T. DU PRE
BY Henry T. Olsen
HIS ATTORNEY

United States Patent Office

3,375,343

Patented Mar. 26, 1968

3,375,343

ELECTRON DISCHARGE DEVICE ASSEMBLY METHOD

Ernest T. Du Pre, Tell City, Ind., assignor to General Electric Company, a corporation of New York

Filed Aug. 31, 1964, Ser. No. 393,304
4 Claims. (Cl. 219—96)

ABSTRACT OF THE DISCLOSURE

The invention provides a method of manufacturing electron discharge devices having an insulating stem that supports a plurality of stem leads which are of equal length and which are supported in parallel axial relation with respect to the device, and in which selected ones of the stem leads are to be connected at the inner ends thereof to an interconnecting plate of conducting material; the method of assembly being further characterized in that when the inner ends of the selected stem leads are maintained in alignment with the interconnecting plate, an electrical potential difference is applied between the interconnecting plate and the inner ends of the stem leads to effect forging engagement therebetween to produce a percussive weld.

This invention relates to an improved electron discharge device assembly and to the method of manufacturing an electron discharge device to provide the improved assembly.

Present-day electron discharge devices ordinarily include a cage structure comprising an assembly of the electrodes of the device and a stem of insulating material including a plurality of conducting leads secured therein in mutually insulated fashion. A glass or metal envelope is provided which encloses the cage structure and is hermetically sealed to the stem member to provide an evacuated or gas-filled chamber for the cage structure. The conducting leads, hereinafter referred to as stem-leads, are electrically interconnected through the stem to a corresponding plurality of terminal pins which provide for mounting the device in a standard tube socket, the other end of stem leads, referred to as the inner ends, also being joined, as by welding, to appropriate connector surfaces of the electrodes to enable electrical connection thereto and to provide mechanical support of the cage structure within the envelope.

One of the most costly and most time-consuming operations in the manufacture of an electron discharge device comprises the joining or welding of the stem-leads to the electrode connector surfaces. In accordance with prior art techniques, each of the stem-leads of the stem must be formed, as by bending, to establish an effective positioning thereof adjacent the electrode connector surface to which it is to be joined. Ordinarily, this stem-lead forming can be, and is, accomplished in automated fashion by a machine including a number of dies designed, both in their own shapes, and in their manner of actuation, for achieving the desired forming of the leads. However, the different stem-lead forms required by different tube types necessitates a relatively large, expensive inventory of different dies and actuating mechanisms for the machine for the different tube types. Further, when changing the type of tube being manufactured, a considerable expense, both from the standpoint of down-time and the actual man-hours involved, is involved in the changing of these dies and of their actuating mechanisms for properly forming the stem-leads to accommodate the different configuration of the electrode connector surfaces.

Following the stem-lead forming operations, as taught by the prior art, the stem-leads are welded to the respectively associated electrode connector surfaces by resistance welding. The resistance welding is performed mannually by an operator who positions the stem and the cage structure such that they are properly aligned, one with the other, and such that the corresponding stem-leads are adjacent the respectively associated connector surfaces of the electrodes. Next, while maintaining this relationship, the operator positions a selected one of the stem leads and the corresponding one of the electrode connector surfaces intermediate two welding electrodes which are then actuated to bring the selected stem-lead and corresponding connector surface into close mechanical engagement. While maintaining the engagement, current is passed between the electrodes and through the stem-lead and connector surface to provide a resistance weld therebetween. The operator then causes the welding electrodes to be retracted, and manipulates the cage and electrode to perform, sequentially, a resistance weld between each one of the stem-leads and the corresponding one of the connector surfaces of the electrodes.

Despite the prior forming of the stem-leads, the intricacy of the design of the cage structure invariably requires that the operator, additionally, manually form the stem-leads to enable appropriate interconnection thereof with the respectively associated connector surfaces. The intricacy of this resistance welding operation may readily be appreciated by considering the number of welds, i.e., about a dozen, required to be preformed in an electron discharge device of the miniature variety which may contain within a single envelope, despite its small size, two or more independent electron discharge systems, such as the well-known double triode and double pentode vacuum tubes.

In accordance with standard mass production techniques, a plant ordinarily will engage in the manufacture of as many as a hundred types of electron discharge devices during a period of a month. During this period, an individual operator will be called upon to perform the resistance welding operations of positioning respectively associated stem-leads and connector surfaces intermediate welding electrodes on many tube types. As each type will have a modified stem-lead configuration to accommodate the changed configuration, the operator must develop a new manner of manipulating the stem and cage structure to achieve the proper and most efficient handling positions thereof in performing the resistance welds. During such a changeover period in the production schedule, an individual operator's production rate ordinarily drops by as much as 50%. This, of course, must be avoided if at all possible since the construction of electron discharge devices requires the utmost in efficiency and maximum work output from each operator in the production line if the maximum benefit to the consumer and to the manufacturer is to be realized.

The prior art has attempted to overcome this problem of stem-lead forming by employing metallic straps which are individually welded to each of the stem-leads and, in turn, welded to the electrode connector surfaces. Although avoiding the stem-forming operation, the use of the straps has proven to be significantly more expensive than the stem-lead forming technique since the straps are an added manipulation problem and, in fact, requires that the operator in the assembly line perform twice as many resistance welds as heretofore. Further, the very basic problem of the operator's drop in output when changing production to a different type of electron discharge device is still present.

The present invention teaches a technique of tube manufacture offering greatly reduced costs, both in assembly equipment, and in operator's time on a production line. The invention comprises both a new method of manufacture for manufacturing electron discharge de-

vices and a new and novel structure which is at least electrically and mechanically equal to those of the prior art and of greatly reduced cost. The method of operation taught by the invention and the resulting structure avoid the requirement that an assembly operator become accustomed to any particular tube type. In particular, the stem-forming operation can be totally avoided, if desired, and the assembly operator can perform the identical assembly steps in an identical manner regardless of the type of device being manufactured. In addition to avoiding the intricate manipulating of the stem and cage structure as required by prior art assembly techniques, the welding operation itself, in accordance with the invention, is much faster, providing a plurality of welds in a single step whereas prior art techniques required the performance of a plurality of welds in a number of successive welding steps.

Thus, in addition to achieving higher production rates while manufacturing a particular device, the output level of each assembly operator will be maintained substantially invarient upon changes in the type of devices being manufactured, and, in fact, in most instances the operator need not even be aware of such a change.

Therefore, it is an object of this invention to provide an improved method for the assembly of electron discharge devices.

Another object of this invention is to provide an improved method for the assembly of stem and cage structures in an electron discharge device.

A further object of this invention is to provide an improved method for the assembly of stem and cage structures of an electron discharge device which eliminates the necessity of stem-lead forming.

Still a further object of this invention is to provide an improved method eliminating the necessity for stem-lead forming and employing percussive welding techniques in the manufacture of electron discharge devices.

It is still another object of this invention to provide an improved method which avoids the necessity of a production line operator becoming acclimated or accustomed to the configuration of a particular type of electron discharge device to assemble the devices quickly and efficiently.

Still a further object of this invention is to provide an improved method for use in the assembly of the stem and cage structures of an electron discharge device providing higher production levels and reduced cost.

Yet another object of this invention is to provide an improved method for the assembly of electrode cage and stem structures of an electron discharge device wherein an operator's output level remains unaltered upon a change in the production schedule.

It is still a further object of this invention to provide an assembly for an electron discharge device of improved electrical and mechanical quality but of greater economical benefit.

It is yet another object of this invention to provide an electron discharge device having an electrode cage and stem assembly of greater economic benefit and simplified construction but of high quality electrical and mechanical characteristics.

It is yet a further object of this invention to provide an electron discharge device having an electrode cage and stem assembly joined by a percussive welding operation.

It is yet another object of this invention to provide an electron discharge device which can be assembled without the necessity of stem-lead forming.

Other objects and advantages of this invention will be apparent to those skilled in the art and will be made clear as the following description proceeds.

In accordance with one preferred embodiment of the invention, the improved assembly is to be employed with a standard electrode cage providing a plurality of electrode connector surfaces which are to be secured to a corresponding plurality of stem-leads supported by and

formed integrally with a stem at the inner ends thereof. The stem comprises a planar insulating member, generally of circular configuration, and the stem-leads are supported thereon in a generally circular array and extend therefrom in mutually parallel fashion. An interconnecting plate of conducting material is formed to provide a plurality of interconnecting bands extending from an associated one of the electrode connector surfaces to a position on the periphery of the interconnecting plate, the positions about the periphery corresponding to selected inner ends of the array of stem-leads.

In assembling the device, the interconnecting plate may be received by an appropriate support member in the apparatus depicting the invention and the stem, with the stem leads thereof cut to equal lengths, may be received by a second support member. The stem is positioned such that the stem-leads are displaced from, but axially aligned with, a corresponding one of the interconnecting bands. An electrical potential difference is established between the plurality of stem-leads and the interconnecting plate and these elements are then brought into forging engagement, providing a percussive weld between each of the stem-leads and its respectively associated interconnecting band. Subsequently, or if desired, previously, the interconnecting plate is joined to the electrode connector surfaces by a substantially identical percussive welding technique; alternatively, a resistance weld may be effected between a lip member provided on the terminal end of each interconnecting band and the associated electrode connector surface.

The invention may readily be understood by reference to the following drawings, in which:

FIGURE 1 is a perspective view of apparatus useful in carrying out one of the steps of the assembly operation,

FIGURE 2 is a perspective view of apparatus useful in carrying out another one of the steps of the assembly operation,

FIGURE 3 is a detailed, exploded view of a modified portion of the apparatus of FIGURES 1 and 2,

FIGURE 4 is a perspective view of an electron discharge device formed in accordance with the method of the invention,

FIGURE 5 is a perspective view of a partial assembly in accordance with an alternative embodiment of the invention,

FIGURE 6 is a perspective view of the structure of FIGURE 5 showing the completed assembly of a cage electrode structure and a stem in accordance with the alternative embodiment of the invention shown in FIGURE 5, and

FIGURE 7 is a perspective view of a further alternative embodiment of the invention.

In FIGURE 1, the apparatus of the invention is shown to include a base member **1** having vertical, parallel guide arms **2** and **3** joined at the top by a cross bar **4**, cross bar **4** being fixedly secured thereto, as by welding. An upper support bar **5** is fixedly secured to bearings **6** and **7** to enable reciprocating vertical motion of the upper support bar **5** along the guide arms **2** and **3**. A shaft **8** is fixedly secured to the upper support bar **5** and slidingly received within an aperture **9** in the cross bar **4**, collar **10** being fixedly mounted to the shaft **8** by a set screw **11** and abutting the top surface of cross bar **4** to limit the downward motion of the upper support bar **5**. Shaft **8** includes an external thread portion **12** receiving an internally threaded knurled kob **13**, which engages a stop **14** of spring latch **15**. As the upper support bar **5** is raised, the knurled knob **13** rides against an inclined portion **14***a* of stop **14**, deflecting spring member **15***a* of the spring latch **15** until knurled knob **13** is raised thereabove. Upon releasing the upper support bar **5**, knurled knob **13** rests upon a horizontal portion **14***b* of stop **14**, and maintains the upper support bar **5** in the elevated position. Knurled knob **13** may be adjusted on the threaded

portion 12 of shaft 8 to adjust the height of the upper support bar in its elevated position, and similarly, collar 10 may be adjusted in its position on shaft 8 by set screw 11 to regulate the distance the upper support bar 5 descends upon disengaging the spring latch 15 from the knurled knob 13.

A stem holder 16 is mounted on the upper support bar 5 and is provided with a plurality of apertures 17 for receiving pins 18 of a standard stem, the stem being indicated generally by the numeral 19. The stem 19 may be maintained within stem holder 16 by frictional engagement of the pins 18 thereof within the apertures 17. For convenience in inserting the stem 19 into the stem holder 16, the latter is provided with apertures 20 which enable stem holder 16 to be removed from, and subsequently slidingly received upon studs 21, the latter being secured to the upper support bar 5.

An insulating block 22 is mounted fixedly on the upper support bar 5 and has secured to the surface thereof a plurality of welding current conductor assemblies 23. Each of the welding assemblies 23 includes a flexible pin-engaging element 24 formed of a resilient electrically conducting material, such as copper. The pin-engaging elements 24 include angular portions 25 such that, upon sliding stem holder 16 along studs 21 to the position shown, the angular portions 25 resiliently engage a corresponding one of the pins 18 and provide electrical contact therewith. Only four welding assemblies 23 have been shown for purposes of clarification in illustration, although the actual number thereof is not limited. In the actual device, a number of welding assemblies 23 will be employed to the extent necessary for providing electrical connections to each of the pins 18.

A lower support bar 26 is fixedly secured to bearings 27 and 28 to enable reciprocating vertical motion of the lower support bar 26 along the guide arms 2 and 3. The lower support bar 26 is resiliently maintained at a predetermined position by coil springs 29 and 30, the latter being suspended from pins 31 and 32, respectively, secured to cross bar 4 and engaging pins 33 and 34, respectively, secured to the lower support bar 26. A support unit 35 is secured to the lower support bar 26 for resilient reciprocating motion therewith. The support unit 35 includes a support bed 36 on which an interconnecting plate 37 is received.

Interconnecting plate 37 includes a plurality of interconnecting bands, four of which are shown as the elements 38 to 41, and a peripheral portion generally indicated by the numeral 42. The peripheral portion 42 is provided with apertures 43 and 44 which coact with studs 45 and 45*a* to properly locate the plate 37 on bed 36.

Clamps 46 and 47 are mounted on shafts 48 and 49, respectively, for pivotal motion. The shafts 48 and 49 are received at one extremity in a suitable bearing member provided at the rear of bed 36 and pass through front bearing member 50. Actuating arms 51 and 52 are secured to the shafts 48 and 49, respectively, by set screws 53 and 54. A coil spring 55 engages the pins 56 and 57 on the actuating arms 51 and 52, respectively, for imparting forces thereto respectively directed in counterclockwise and clockwise fashion, thereby effecting the desired biasing of clamps 46 and 47 to the positions indicated.

Clamp 46 is shown in cut-away fashion to facilitate the illustration of the manner in which its clamp face portion 58 extends over and bears against the peripheral portion 42 of the interconnecting plate 37 for securing the latter in the position shown. Clamp 47 contains a similar clamp face portion 59 which, similarly to the portion 58 of clamp 46, secures the interconnecting plate 37 to the support bed 36.

In operation, the upper support bar 5 is raised, knurled knob 13 bearing against the surface 14*a* of stop 14 and deflecting spring latch 15. Knurled knob 13 then rests upon the upper surface 14*b* of the inclined stop 14 to maintain the upper support bar 5 and its associated structures at an elevated position. As noted earlier, knurled knob 13 may be adjusted in its position along the threaded portion 12 of shaft 8 to vary the elevation of the upper support bar 5 when retained by the spring latch 15; the selection of this adjustment is determined in accordance with the size of stem 19 employed for the type of device being manufactured and, in particular, will vary depending on the length of the stem-leads 60 which are supported in parallel, axial relation by the insulating base portion 61 of the stem 19. Although the stem-leads 60 are shown broken away, to facilitate the illustration of the apparatus, FIGURE 1 clearly demonstrates the parallel relation in which the stem-leads 60 extend from the insulating base 61 and also the fact that they are of equal length.

For positioning an interconnecting plate 37 on the support bed 36, the operator grasps the lip portions 51*a* and 52*b* of the actuating arms 51 and 52, respectively, and squeezes them together. The clamps 46 and 47, are thereby rotated in a direction opposite to their normal direction of resilient bias, raising their respective clamp face portions 58 and 59 from the clamping position indicated in FIGURE 1. While maintaining the clamps 46 and 47 in this open or receiving position, an interconnecting plate 37 is slid onto the support bed 36 and oriented on locating studs 45 and 45*a* whereafter the actuating arms 51 and 52 are released and caused to return to their engaging, or clamping, position by the coil spring 55. A thumb slot 62 is provided in the front bearing member 50 to facilitate the insertion and removal of the interconnecting plate 37.

The percussive welding operation which the apparatus of the invention is intended to perform is indicated in FIGURE 1 as already having been accomplished. Illustrating the apparatus in this manner facilitates showing the alignment of the interconnecting bands, such as 38 to 41, of the interconnecting plate 37 with selected, corresponding ones of the stem-leads 60. It is apparent, however, that the stem 19 and the interconnecting plate 37, when initially positioned within the stem holder 16 and on the support bed 36, respectively, will be vertically displaced one from the other. It is equally clear, however, that the guide members 2 and 3 accurately define the vertical motion of the upper support bar 5 such that the alignment of the interconnecting bands, such as 38 to 41, along the axes of the corresponding, selected stem-leads 60, is maintained at all times.

To perform the percussive welding operation, an electrical potential difference is established between the stem-leads 60 and the interconnecting plate 37. For this purpose, suitable electrical potential is applied individually, to the plurality of welding assemblies 23, in any suitable manner; likewise, a suitable electrical potential is applied to the support unit 35. In practice, it is found preferable to maintain the support unit 35 at ground potential; further, it is preferable that the stem holder 16 be formed of an insulating material, whereby the entire apparatus with the exception of the electrode welding assemblies 23 and their flexible pin-engaging elements 24, is maintained at ground potential. An advantage of using a plurality of individual welding assemblies 23, is that different levels of operating potentials may be applied to selected ones of the pins 18 and their respective, electrically interconnected stem-leads 60. This latter arrangement may be particularly desirable and even necessary where either selected ones of the stem-leads 60 or their associated interconnecting bands such as 38 to 41, or both, are formed of different sizes or types of metal, requiring different welding potentials.

To perform the percussive weld, after the electrical potential difference has been established between the stem-leads 60 and the interconnecting plate 37, the spring latch 15 is deflected in a direction toward the rear of the apparatus, thereby releasing knurled knob 13 from the stop 14. The upper support bar 5 falls, by force of

gravity, causing the stem leads **60** to be driven against the respectively associated ones of the interconnecting bands **38** to **41**. The equal length of the stem-leads **60** causes a plurality of spark gaps to be created between the inner ends thereof and each of the respectively associated interconnecting bands **38** to **41**. These arcs create an intense localized heating, both of the region of each of the interconnecting bands **38** to **41** toward which the associated stem-leads **60** is approaching, and also of the terminal ends of each of the selected stem-leads **60**.

The acceleration of the upper support bar **5** as it falls, due to the force of gravity, brings the terminal ends of the stem-leads into sharp impact with their associated interconnecting bands **38** to **41** in a forging engagement, providing a percussive weld therebetween. The magnitude of the impact and electrical potential difference between the stem-leads **60** and the interconnecting bands **38** to **41** is determined in accordance with known percussive welding techniques and depends upon the characteristics of the material of which the stem-leads **60** and the interconnecting plate **37** are formed. To insure the production of good percussive welds, it is preferable to cut the inner ends of stem-leads **60** at a small angle with respect to their axes.

Springs **29** and **30** are selected to provide sufficient resiliency in the positioning of the lower support bar **26** such that, upon the impact of the stem-leads **60** on the interconnecting plate **37**, the lower support bar **26** will descend slightly to remove undue strain from the stem-leads **60**, thereby preventing their buckling or bending.

Following the percussive welding or joining of the stem **19** and the interconnecting plate **37**, these assembled elements may be transferred to a second machine such as that shown in FIGURE 2 for percussive welding of the interconnecting plate **37** to a cage structure **63**. The apparatus of FIGURE 2 is essentially identical to that of FIGURE 1, with the exception of the structure carried by its support bar **26'**, and identical numerals are employed for indicating the corresponding portions. The upper and lower support bars **5** and **26'** of FIGURE 2 are displaced a greater distance apart than the upper and lower supporting bars **5** and **26** of FIGURE 1 to accommodate the additional height of the cage structure **63** in FIGURE 2.

Cage **63** includes upper and lower insulating spacers or micas **64** and **65** between which are secured electrode structures **66** and **67**. Although the cage structure **63** may comprise any type of electron discharge device, the one shown in FIGURE 2 is of the double triode variety, each of the electrode structures **66** and **67** constituting an operating electron discharge device.

The cage structure **63** is received on a supporting base **68**, the latter being secured to a laterally extending arm **69** of the lower support bar **26'**. The supporting base **68** is formed on the surface thereof to receive a particular cage structure **63** and includes an aligning stud **70** and, preferably, a second such stud (not shown) which passes through suitable apertures provided in the lower mica **65** to align the cage structure **63** on the supporting base **68** in proper relation to the assembled structure comprising the stem **19** and the interconnecting plate **37**. Cover plates **70** and **71** are provided on the supporting base **68**, cover plate **70** being broken away to indicate current conducting welding assemblies **72** and **73**.

A portion of the anode **74** of the electrode structure **66** is broken away to indicate the internal elements, namely grid support rods **75** having a wire wound grid thereabout, and a cathode **76**. The electrodes **74** to **76** provide connector surfaces **74***a* to **76***a* extending through the lower mica **65**.

In the usual case, the cage structure **63** will have an identical array of electrode connector surfaces **74***a* to **76***a* connector surfaces **74***a* to **76***a* extending through the lower micas **64** and **65** and likewise, the electrode structure **67** will have an identical array of electrode connector surfaces whereby the cage structure **63** is completely symmetrical through 180° about either a vertical or a horizontal axis. In some instances, such symmetry will not exist in the cage structure **63** and the lower mica **65** may be formed to provide both a keying and a guide in the positioning thereof on the supporting base **68**.

Welding assemblies **72** and **73** engage the lower connector surfaces **74***a* and **75***a*, respectively, of the anode **74** and the grid support rod **75** to provide electrical contact thereto. The number of such welding assemblies **72** and **73** and the configuration and orientation thereof is, of course, designed in accordance with the particular electrode structures supported within the cage structure **63**.

In operation, the upper support bar **5** is raised and retained in an elevated position by the engagement of knurled knob **13** on the stop **14** of the spring latch **15**. The cage structure **63** is positioned on the supporting base **68** in the manner indicated. Next, the stem holder **16**, with the previously welded assembly of stem **19** and interconnecting plate **37** inserted therein, is received on the studs **21**. Appropriate welding potentials are applied to the welding assemblies **23** and communicated through the resilient pin-engaging elements **24** thereof to the pins **18** and thence through the stem-leads **60** to the associated ones of the interconnecting bands **38** to **41**. Further, the welding assemblies **72** and **73** complete an electrical circuit through the anode **74** and the grid support rod **75** to establish an electric potential between ground at the connector surface **74***a* and **75***a*.

Spring latch **15** is then deflected, releasing the knurled knob **13** and enabling upper support rod **5** to drop, as hereinbefore described. Electric arcs are established between the interconnecting bands **38** to **41** and the electrode connector surfaces **74***a* and **75***a* of electrode structure **67** and **74***a* and **75***a* of electrode structure **66**, respectively.

As hereinbefore described, the electric arcs create an intense heating between the associated elements which, upon impact, undergo a forging engagement and provide a percussive weld therebetween.

The cathode connector surfaces **76***a* of both the electrode structures **66** and **67** are shown to include conducting leads **78** secured thereto as if performed in a prior manufacturing step; if desired, however, suitable interconnecting bands may be provided therefor in the interconnecting plate **37** to enable percussive welding thereto in the same manner as with the electrode connector surfaces **74***a* and **76***a* of the anodes **74** and grids **76**, or these connections may be accomplished by a subsequent manufacturing step.

Following the double percussive welding steps, the peripheral portions **42** of the interconnecting plate **37** may be removed, as by breaking along suitably delineated rupture seams to finish the assembly, however, it is generally preferable to break off the peripheral portion prior to the second percussive welding step.

In accordance with this invention, the peripheral portions **42** may be removed in any manner, for example, trimming with shears, or in a cutting die or any other convenient means. However, breaking along rupture seams is preferred and is the subject of the invention disclosed and claimed in application Ser. No. 393,259 (now Patent No. 3,270,391, issued Sept. 6, 1966), filed concurrently herewith and assigned to the same assignee.

In the very simple, and very quick steps indicated to be performed by the apparatus of FIGURES 1 and 2, secure electrical interconnection has been achieved between selected ones of the stem-leads **60** and associated interconnecting bands **38** to **41** of the interconnecting plate **37** and, therethrough, to an associated electrode connector surface. Thus, electrical communication has been established between selected external pins **18** of the insulating base **61** of stem **19** and a desired one of the numerous electrodes within the cage structure **63**. It will

be appreciated that the forming of welds between the cage structure and the interconnecting plate could be performed first, and in certain cases may be preferred.

In FIGURE 3 there is shown an alternative form of stem holder constituting an improvement over the frictional engagement performed by stem holder **16** of FIGures 1 and 2 and permitting the elimination of welding assemblies **23** as shown therein. The stem holder **79** includes upper and lower plates **80** and **81** having a plurality of apertures **82** and **83**, respectively, in axially aligned fashion therein for receiving the pins **18** of stem **19**. A recess **84** is provided in the lower plate **81** for receiving a wheel-like terminal engaging member **85**. The engaging member **85** includes an outer rim **86** of insulating material secured to a centrally disposed hollow shaft **87** by a plurality of flexible conducting arms **88** equal in number to the number of apertures **83** and each of which is normally disposed to one side of an associated aperture.

When assembled, the shaft **87** is securely fixed against rotation within one or both of the upper and lower plates **80** and **81** and the latter are secured together by means such as screws **89**, the rim **86** of the engaging member **85** protruding from the front of the assembled plates **80** and **81**. Shaft **87** is formed of conducting material and provides a terminal to which a welding potential is applied for connection to the flexible conducting arms **88**.

When inserting a stem **19**, such as that shown in FIGURES 1 and 2, into the stem holder **79** of FIGURE 3, the operator rotates the engaging member **85** by applying a force in counterclockwise direction to the rim **86** thereof, causing the flexible conducting arms **88** to pass across and to the opposite side of the apertures **83**. The pin members **18** of a stem member **19** are then inserted through the apertures **83** of the lower plate **81** and into the apertures **82** of the upper plate **80** and the engaging member **85** is released. The resiliency of the flexible conducting arms **88** rotates the engaging member **85** in a clockwise direction, causing each of the flexible conducting arms **88** to engage the pin **18** extending through the aperture **83** adjacent thereto. The engagement of the flexible conducting arms **88** with the pins **18** serves both to retain the stem **19** within the stem holder **79** and to provide electrical connection through each of the pins **18** to the stem-leads **60**. Thus, the conducting arm portions of the apparatus which are at the welding potential are completely enclosed, protecting the operator from accidentally touching such portions and being harmed thereby.

In FIGURE 4 there is shown a simplified variety of an electron discharge device commonly known as a high voltage rectifier. There is again employed a stem **19'** having a plurality of pins **18'** positioned in a predetermined array thereon, the pins **18'** communicating, through the insulating base member **61'** of stem **19'**, with an associated plurality of stem-leads **60'**. The stem **19'** further includes a tubulation portion **89** formed thereon during manufacture of the stem **19'** to facilitate handling thereof during the assembly operation and also to provide an evacuating outlet tube for exhausting the completed electron discharge device. The tubulation **89** is not shown in FIGURES 1 and 2 for purposes of each of illustration.

Rather than the complex cage structure **63** of FIGURE 2, the device of FIGURE 4 employs a discharge plate **90** of circular configuration to which selected ones of the stem-leads **60'** are connected. An aperture **91** is provided in the discharge plate **90** and a first wire-type electrode **92** extends therethrough, the latter being secured, as by resistance welding, to flap **93**. A second electrode **94** extends through the aperture **91**, displaced from the discharge plate **90**, and is connected to one or more of the remaining stem-leads **60'**, these latter being bent to facilitate the connection thereto.

Although the structure illustrated in FIGURE 4 requires forming of the stem-leads **60'** to provide the horizontally extending portions to which the second electrode **94** is welded, the time-consuming task of welding the selected ones of the stem-leads **60'** to the discharge plate **90** is avoided by the percussive welding technique of the invention, with consequent savings in time and production expense. In a single operating step, the stems **19'** is received within the stem holder **16** of FIGURES 1 and 2 and the discharge plate **90**, with or without the electrode **92** attached thereto, is positioned on a suitable support base similar to the support base **68** of FIGURE 2. The selected stem-leads **60'** are then secured to the discharge plate **90** in accordance with the percussive welding technique hereinbefore set out.

To derive even greater benefit from the teachings of this invention, the stem-leads **60** having the horizontally extending portions may be removed, leaving only the vertically-extending portions thereof, and interconnecting bands (not shown) may be secured both to the shortened, vertically-extended portion of the stem-leads **60'** and to the vertically-extending electrode **94** by percussive welding.

Additional modifications in the method of the invention and the use of the apparatus thereof will become apparent from the assemblies shown in FIGURES 5 and 6. In FIGURE 5, a cage **95** is indicated including upper and lower insulating spacers or micas **96** and **97** having securely mounted therebetween a plurality of electrode structures. The electrodes of these electrode structures provide a plurality of connector surfaces, the connector surfaces **98**, **99**, and **100** of the electrodes of electrode structure **101** being selected for purposes of description. An interconnecting plate **102** is provided including a plurality of interconnecting bands, the bands **103**, **104**, and **105** being selected for purposes of discussion. Each of the bands **103–105** includes a traversely extending lip member **103***a*, **104***a*, and **105***a*, respectively, which is to be secured to the associated one of the electrode connector surfaces **98–100**.

The transversely extending lip members **103***a*–**105***a* are formed to be parallel to the direction in which the electrode connector surfaces, such as **99** and **100**, extend. Further, the interconnecting bands **104** and **105** are designed to be of such a length that the operator may position the lip members **104***a* and **105***a* in contiguous relation to the connector surfaces. The operator then performs a plurality of successive resistance welds to provide the completed assembly of FIGURE 5. Illustratively, welding electrodes W_1 and W_2 are shown in disengaged positions on opposite sides of lip member **105***a* and its associated electrode connector surface **100**. Electrodes W_1 and W_2 are moved to a position closely engaging the elements **105***a* and **100** and a current passed therebetween to provide the resistance weld. Electrodes W_1 and W_2 are then retracted, to the position shown, and the plurality of other resistance welds are performed in an identical manner in a series of successive steps. Subsequently, a stem is welded to the interconnecting plate **102** in accordance with the percussive welding technique of the invention in the manner indicated in FIGURES 1 and 2.

The completed structure is shown in FIGURE 6, each of the stem-leads **60'** being joined to an associated one of the interconnecting bands of interconnecting plate **102** by a percussive weld. The interconnecting plate **102** and the cage **95** have been shown, in FIGURE 6, rotated through 180° about a vertical axis from the position shown in FIGURE 5 to provide an additional perspective for indicating the manner of the formation of the lip members and the resistance and percussive welds. As a final step in this assembly process, the peripheral portions **106** of the interconnecting plate **102** are removed by breaking along the delineations indicated by dotted lines in FIGURE 6.

A further embodiment of the invention is indicated in FIGURE 7 wherein there is shown a cage **95'** identical in form to the cage **95** shown in FIGURE 5 with the exception that the upper mica **96** and the interconnecting

plate 102 of FIGURE 5 have been replaced by interconnecting bands formed directly on an upper support mica 107. The electrodes of the cage 95', such as those of the electrode structure 101', again include electrode connector surfaces extending through the upper mica 107. The interconnecting bands such as 103' to 105' are provided on the upper mica 107 by printed circuit techniques. Further, the conducting surfaces of the interconnecting bands 103' to 105' may extend into, and in coating relation with, the interior walls defining the apertures in the upper mica 107 through which the electrode connector surfaces 94–96, illustratively, extend to provide electrical connection therewith. The connector surfaces may be further secured in the apertures by a solder of conductive adhesive.

The assembly structure of FIGURE 7, may then be positioned directly on a supporting base, such as the supporting base 68, in the apparatus of FIGURE 2 and a stem 19 secured thereto by the percussive welding technique of the invention.

As clearly appears from the foregoing drawings and description of the invention, the highly time consuming and very costly technique of stem-lead forming, as required in the prior art may be totally eliminated through the teachings of this invention. The utilization of a percussive welding technique, as taught by the invention, not only assures the rapid completion of a plurality of individual welds simultaneously, it also avoids the use of resistance welding electrodes and it can totally eliminate the costly, time-consuming step of performing individual resistance welds between each electrode connector surface and an associated stem-lead. One of the primary advantages obtained in eliminating stem-lead forming is that the assembly operators are no longer required to become accustomed to each new electrode configuration, and need not manipulate the device to perform a plurality of resistance welds. Upon a change-over in the production schedule, the assembly operator does not have to become acclimated to a new set of twists and turns in a plurality of intermeshed, intricate stem-leads.

Many modifications and adaptations of the method and apparatus, and the structure manufactured by the method and apparatus, of the invention will readily be apparent to those skilled in the art. For example, the bringing of the parts together to perform the percussion welding need not depend on the force of gravity but may be accomplished by springs or other more positive mechanical means. Thus, it will be understood that the terms, horizontal and vertical, are utilized to indicate the position of parts relative to each other and not necessarily to indicate their specific position in space. Thus, it is intended by the appended claims to cover all such modifications and adaptations as fall within the true spirit and scope of the invention.

What I claim as new and desire to be secured by Letters Patent of the United States is:

1. In the manufacture of electron discharge devices having an insulating stem supporting a plurality of stem-leads of equal predetermined length in parallel, axial relation thereon wherein selected ones of said stem-leads are to be connected at the inner ends thereof to an interconnecting plate of conducting material, a method of assembly comprising:

(a) supporting said interconnecting plate,

(b) supporting said stem with said stem-leads aligned with, but displaced from said interconnecting plate,

(c) contacting said selected ones of said stem-leads in said interconnecting plate to establish an electrical potential difference therebetween, and

(d) effecting relative motion of said stem and said interconnecting plate while maintaining said alignment thereof to bring said inner ends of said selected ones of said stem-leads into forging engagement with said interconnecting plate to produce a percussive weld therebetween.

2. In the manufacture of electron discharge devices having an insulating stem supporting a plurality of stem-leads of equal, predetermined length in parallel, axial relation thereon and an electrode cage including an electrode structure including connector surfaces extending through said insulating support wherein selected ones of said stem-leads are to be electrically connected to associated ones of said connector surfaces, a method of assembly comprising:

(a) cutting said stem-leads to an equal, predetermined length,

(b) forming a planar interconnecting plate into a configuration providing a plurality of interconnecting bands to be connected to the inner end of said selected ones of said stem-leads and to the electrode connector surface associated therewith joined by a peripheral portion,

(c) supporting said interconnecting plate in a horizontal plane,

(d) supporting said stem with said stem-leads depending vertically therefrom and with each of said stem-leads vertically aligned with and displaced from, said associated ones of said interconnecting bands,

(e) contacting said selected ones of said stem-leads and said interconnecting plate to establish an electrical potential difference therebetween, and

(f) moving said stem and said interconnecting plate relative to each other to bring said selected ones of said stem-leads into forging engagement with said associated ones of said interconnecting bands to effect a percussive weld therebetween.

3. An assembly method as recited in claim 2 wherein there are further provided the steps of:

(a) supporting said stem with said interconnecting plate percussively welded thereto and disposed in a horizontal plane,

(b) supporting said electrode cage with said electrode connector surfaces extending transversely to said interconnecting plate, said electrode connector surfaces being vertically aligned with, and displaced from said associated interconnecting bands,

(c) contacting said selected ones of said stem-leads and said electrodes of said electrode structure to establish an electrical potential difference between said interconnecting bands and said electrode connector surfaces,

(d) moving said stem member with said interconnecting plate percussively welded thereto and said electrode cage structure relative to each other to bring said electrode connector surfaces into forging engagement with said associated ones of said interconnecting bands to effect a percussive weld therebetween, and

(e) removing said peripheral portion of said interconnecting plate.

4. In the manufacture of electron discharge devices having an insulating stem supporting a plurality of stem-leads of equal, predetermined length in parallel axial relation thereon and an electrode cage including an electrode structure mounted on an insulating support, the electrodes of said electrode structure including connector surfaces extending through said insulating support wherein selected ones of said stem-leads are to be electrically connected to associated ones of said connector surfaces, a method of assembly comprising:

(a) forming a planar interconnecting plate into a configuration providing a plurality of interconnecting bands which will extend from the inner end of each of said selected ones of said stem-leads to the electrode connector surface associated therewith, each of said interconnecting bands to said associated electrode connector surface and a peripheral portion joining said interconnecting bands,

(b) resistance welding each of said lip portions to said electrode connector surface associated therewith,

(c) supporting said electrode cage to position said interconnecting plate in a horizontal plane,

(d) cutting said stem-leads to an equal, predetermined length,

(e) supporting said stem with said stem-leads vertically depending therefrom, each of said stem-leads being vertically aligned with, and displaced from, said associated ones of said interconnecting bands,

(f) contacting said selected ones of said stem-leads and said electrodes of said electrode structure to establish an electrical potential difference between said selected ones of said stem-leads and said interconnecting plate,

(g) moving said stem member and said electrode cage with said interconnecting plate resistively welded thereto relative to each other to bring said inner ends of said stem-leads into forging engagement with

said associated ones of said interconnecting bands to effect a percussive weld therebetween, and

(h) removing said peripheral portion of said interconnecting plate.

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RICHARD M. WOOD, *Primary Examiner.*

R. F. STAUBLY, *Assistant Examiner.*