March 8, 1949. F. H. McINTOSH 2,463,635

ELECTRON DISCHARGE DEVICE AND METHOD OF MAKING THE SAME

Original Filed Oct. 22, 1943 4 Sheets-Sheet 1

Fig. 1.

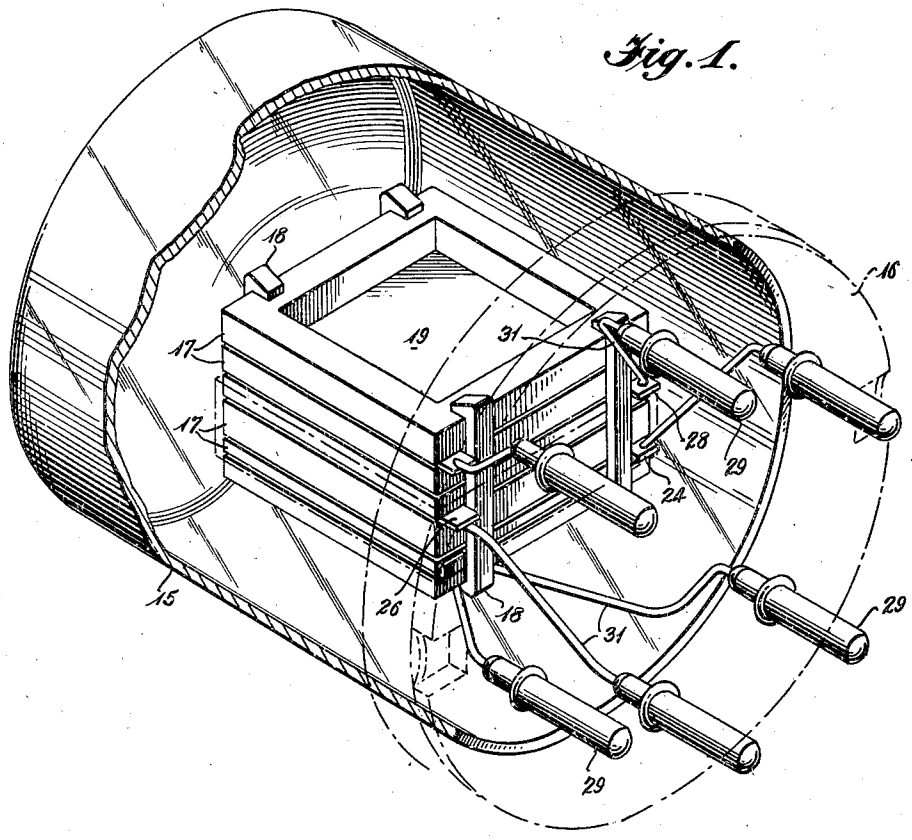


Fig. 5.

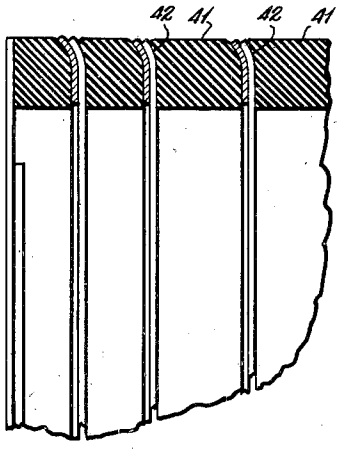
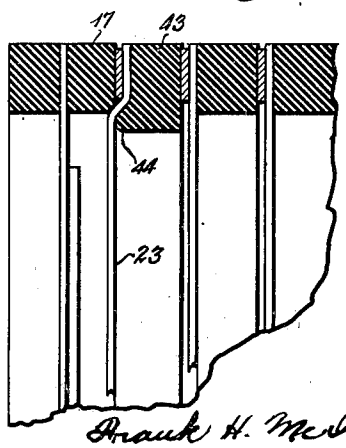


Fig. 6.



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ELECTRON DISCHARGE DEVICE AND METHOD OF MAKING THE SAME

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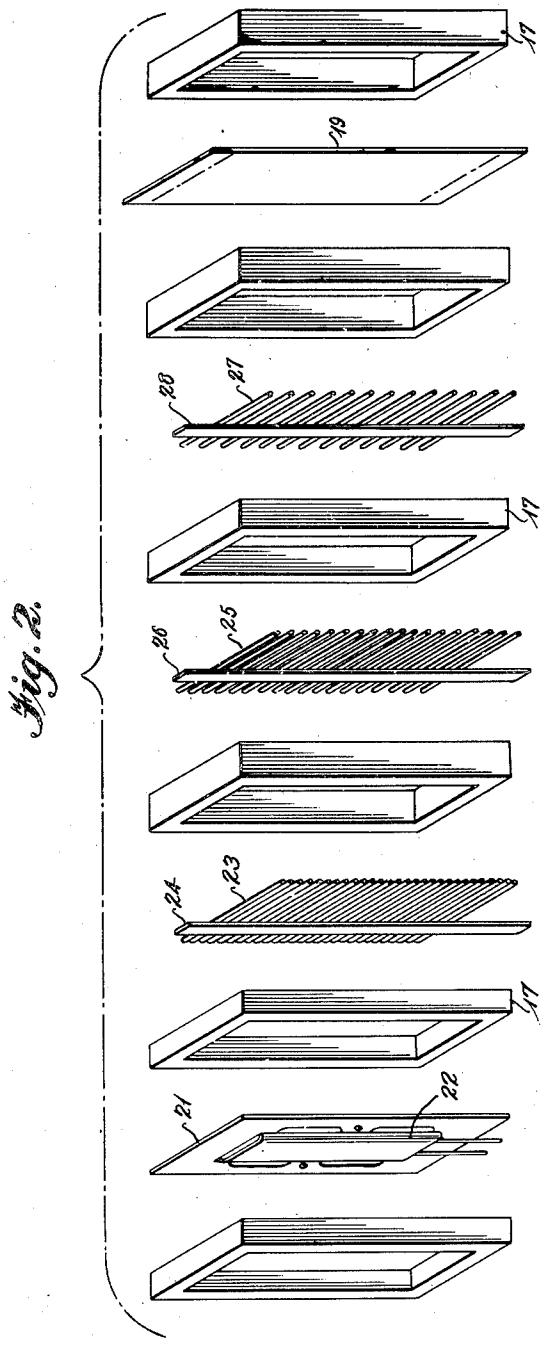


Fig. 2.

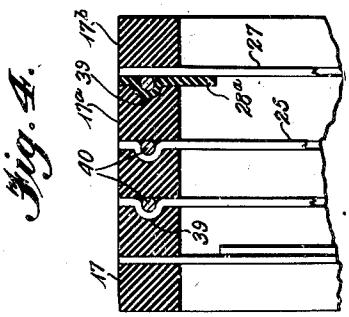


Fig. 4.

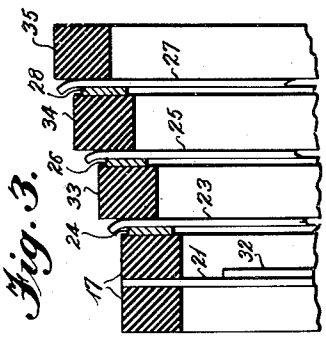


Fig. 3.

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Fig. 7.

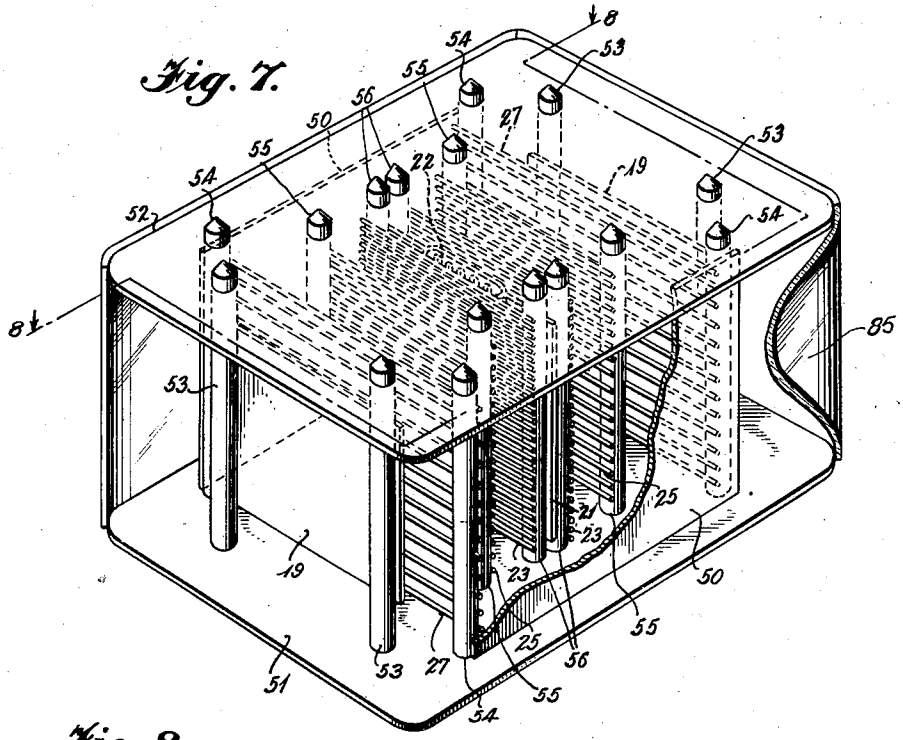
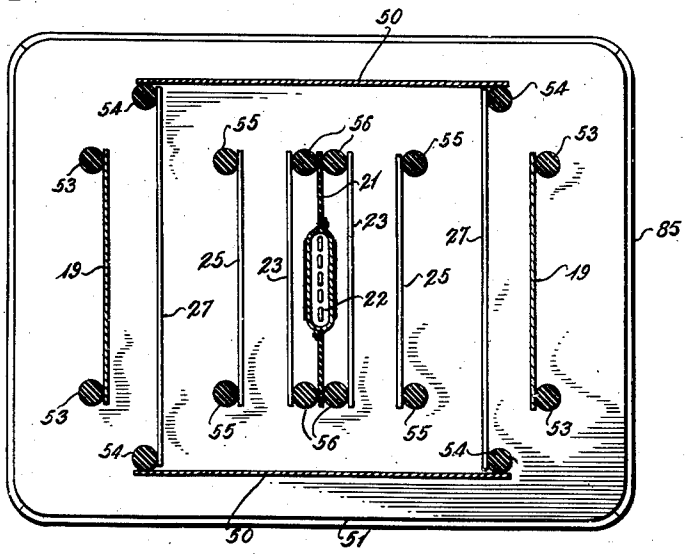


Fig. 8.



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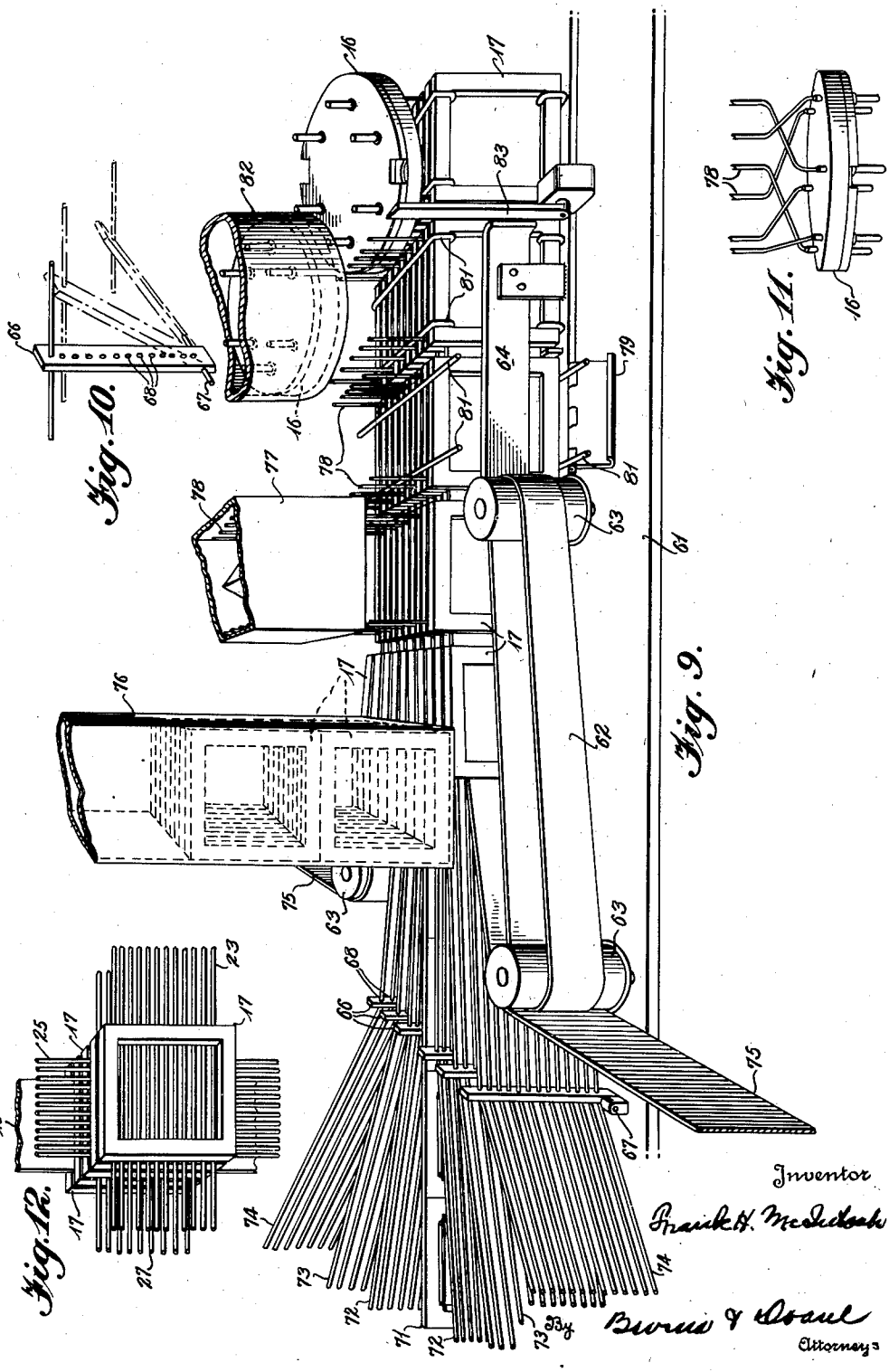
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ELECTRON DISCHARGE DEVICE AND METHOD OF MAKING THE SAME

Original Filed Oct. 22, 1943 4 Sheets-Sheet 4



Patented Mar. 8, 1949

2,463,635

UNITED STATES PATENT OFFICE

2,463,635

ELECTRON DISCHARGE DEVICE AND METHOD OF MAKING THE SAME

Frank H. McIntosh, Chevy Chase, Md.

Original application October 22, 1943, Serial No. 507,314. Divided and this application November 18, 1946, Serial No. 710,461

2 Claims. (Cl. 250—27.5)

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This invention relates to electron discharge devices and methods of making the same. More particularly, it relates to products adapted for assembly line production with a minimum of hand operations.

In the manufacture of electron discharge tubes of the prior art, it has been customary to make up individual units of the tubes, such as the cathode with heater, the grid and the other elements, and then to assemble them on a base to which an envelope was subsequently applied, sealed off, and evacuated. As the art has developed, the size of the tubes for ordinary amplification and detection has steadily decreased until, at the present time, some of the tubes are so small that hand assembly is highly impractical. Where the spacing of electrodes is critical, and it becomes more so in these very small tubes, hand methods of assembly are not only expensive, but very wasteful and rejections sometimes run as high as ninety per cent. The whole tendency of development has, therefore, been to accentuate the production difficulties and expenses so characteristic of hand assembly.

The present invention consists primarily in producing a structure in which the elements are all suitably arranged to permit automatic machine or jig assembly. The electrodes may be made of sheet or wire stock and passed through the machine to be cut off after being placed in position. In this way, nothing except possibly the heaters for the cathodes will require individual assembly. It, therefore, becomes possible to make up tubes by machine on an assembly line basis, with their characteristics substantially fixed and unvarying. The number of rejects will be enormously reduced, and the replacement of damaged parts very readily provided for. Among the objects of this invention may be mentioned the production of an electron discharge tube capable of machine assembly, possessing precision fixed spacing of the elements, mechanical stability, long life, substantial freedom from microphonic noise, and ready adaptation to particular specialized problems. An important feature of the process is that it permits changes and variations in the product by simple machine adjustment, without change in the basic process or mechanism for performing it.

Other advantages will appear from the following description when read in conjunction with the accompanying drawings, in which:—

Figure 1 is a perspective view of an electron discharge tube embodying the present invention, a portion of the envelope being broken away to show the interior construction;

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Figure 2 is an exploded view showing the interior parts of the tube of Figure 1 prior to their assembly;

Figure 3 is a modification in which the spacing elements of the tubes are arranged to provide an unobstructed path for the electron emission;

Figure 4 is a modification in which means is provided for increasing the leakage path between electrodes in the assembled tube;

Figure 5 is a view showing a modified scheme for clamping the insulating and control elements together;

Figure 6 is a view showing another method of increasing the leakage path between tube elements, and a method of effectively placing the control grid close to the cathode;

Figure 7 is a perspective view of the interior structure of an electron discharge tube of modified form, the envelope and base being removed;

Figure 8 is a horizontal sectional view substantially on the line 8—8 of Figure 7;

Figure 9 is a diagrammatic view of one form of apparatus suitable for carrying out methods embodying the present invention;

Figure 10 is a detailed view of the mechanism for varying the spacing of the grid wires as they are fed to the machine of Figure 9;

Figure 11 is a detail view of a base to which are attached both terminals and prongs, this base being suitable for hopper feeding in the apparatus of Figure 9; and

Figure 12 is a perspective view showing the structure of Figure 1 with certain of the grid wires laid parallel to the axis of the cathode to minimize tube capacity.

Referring first to Figure 1 of the drawing, reference character 15 designates an envelope of conventional type, capable of construction by any improved practice found in the art. 16 designates a base, to which the envelope 15 is sealed, the base being of any suitable insulating material. Mounted within the envelope is an assembly composed of a plurality of frame elements 17, which may be of any suitable insulating material, these elements being assembled as indicated, with electrodes and terminal leads placed between them and secured in place by clamps 18. This manner of clamping insures permanent and effective electrical contacts, and maintains the electrodes under sufficient tension to discourage sagging and other changes which might alter the characteristics of the tube.

The relation of the parts in the assembly of

Figure 1 will be clearly understood from reference to Figure 2, in which the exploded view indicates the position of the various parts prior to their assembly in the unit. As here indicated, the frame elements 17 are square in cross section, but it is obvious that in practice they may assume various forms. For example, they may be circular in form. The unit may be embodied in any suitable type of structure without regard to the number of elements used. For example, it may be a triode. However, since the problem of clearances becomes increasingly acute as the number of control elements is increased, and since the problem appears in an accentuated form in the pentode, a pentode has been here illustrated.

In Figure 2, reference character 19 indicates the usual plate, which is disposed at the most remote position from the cathode 21 with its heater 22. Reference character 23 designates the control grid having a terminal connection 24. 25 is the high voltage or screen grid, having a terminal plate 26, and 27 is the cathode or suppressor grid having a terminal plate 28. As indicated, these parts shown in Figure 2 are assembled in abutting relation and secured together by the clamps 18 (Fig. 1), thus holding the parts in properly spaced relation for efficient operation, the spacing being predetermined by the thickness of the various frame elements 17. When securely clamped together, these frame elements hold the parts in fixed position, with all of the electrodes under tension. This not only insures good electrical contact, but maintenance of proper contact and of proper tension in the various elements throughout the life of the tube. Another advantage of this structure is that if any of the elements should fail; if, for example, the heater 22 should be burned out, it would be possible to dismantle the assembly, replace the burned-out heater element and reassemble the parts, without altering the characteristics of the tube and without wasting any of the parts which make up the assembly. It would be necessary merely to replace the envelope, seal it and evacuate the tube in the case of a tube of the vacuum type. If the structure should be a tube of the gas-filled type, reassembly would, of course, require a new filling of gas in order to make the structure operative.

After the clamps 18 are secured in position and the asembled unit placed on the base 16, the envelope 15 may be placed, evacuated or filled with gas, and then sealed off.

In Figure 1, the various terminals carried by the base 16 are indicated generally by the reference character 29. Each of these terminals is secured in the base 16 and has a lead 31 contacted with its respective connector place, and is held in position without soldering or welding, by the clamping together of the assembled unit made up of the various frame elements, together with the electrodes. Obviously welded or soldered contacts may be used if desired. Control electrodes fabricated in this manner are characterized by having a single point electrical contact between each wire and the terminal plate. Hence, the electrode wires are never short circuited and no paths are afforded for the flow of circulating or eddy currents. It is possible in a structure of this type to utilize the plate 19 as an end closure for the unit. When so used this plate could function readily to radiate heat and thus cool the tube.

It is indicated in Figures 1 and 2 that the cross section of the tube is rectangular or square and that each of the frame elements 17 has the same cross sectional area. Inasmuch as the electron beam from the cathode tends to diverge as it travels away from the cathode, Figure 3 indicates a scheme whereby the effect of this divergence may be utilized to increase the efficiency of the tube. In Figure 3, reference character 17 indicates a frame element similar to the frame element shown in Figures 1 and 2, the two first frame elements holding a cathode 21 with an emitting surface 32. Interposed between a second frame element 17 and a larger successive frame element 33 is the control grid 23, corresponding to that of Figure 2. Here, the next frame element is designated 34 and it cooperates with the frame element 33 in holding the screen grid 25. The next frame element 35, which is of still greater diameter than the element 34 cooperates with the frame element 34 to hold the plate 27. In this figure, the structure illustrated is a screen grid triode, and the frame elements are held together in a manner similar to that indicated in Figure 1. It will be seen that the divergence of the electron flow path is such that the major portion of the electrons emitted from the emitting surface 32 will strike the plate 27, whereas, if the frame elements 33, 34 and 35 were of the same diameter as the element 17, substantial numbers of these electrons would strike the frame elements and be deflected or absorbed instead of striking the plate directly as in the case of the structure of Figure 3. This arrangement has the additional advantage of providing a convenient means for tying the electrodes together in a double tube structure when a complete set of electrodes is disposed on each side of the cathode.

Figure 4 illustrates a further modified structure, in which the frame element 17 has the same structure as that indicated in Figures 1 and 2, but means is provided in the form of an insulated element 28*a* interposed between the plate 27 and the two frame elements 17*a* and 17*b*, to increase the leakage path between the plate 27 and the screen grid 25. By the use of an insulating member of this character, which would necessarily assume a configuration similar to that a frame element 17, it becomes possible to decrease the spacing between the various electrodes without decreasing the leakage path between them. Figure 4 not only shows the element 28*a*, but it indicates how the various frame elements may be grooved as indicated at 39 to assist in holding the electrodes under tension when the frame elements are assembled and clamped together. Here the terminals 40 are round as indicated.

Figure 5 is a partial sectional view similar to that of Figure 4, but showing a modified structure whereby the clamping action between the various frame elements is increased. Here the frame elements designated 41 have curved faces 42 adjacent their points of contact with the various electrodes. This arrangement may be advantageous when the electrode material is cut off by machine shears as in Figure 9.

Figure 6 is a view similar to Figure 5 of a still further modified construction which makes it possible to space the electrodes closely, and particularly the control grid with respect to the electron emitting surface, without decreasing the leakage path between electrodes. Here, this result is accomplished by substituting for one of the frame elements 17 a special frame element

43, carrying a rib 44, which contacts with the electrode, in this instance the control grid 23.

It is indicated above that the grid electrodes are all of tensioned wire. This may be true also of the plate. The fact that the wires are assembled under tension and supported at both ends makes it unnecessary to rely upon the stiffness of the material for support. Consequently a wire of smaller gauge and, hence, of greater efficiency may be used. While wire is the preferred material it is obviously practicable to use woven mesh, photo-etched or perforated sheet stock as electrode material, and such use is contemplated when it is expedient. Where wires are used in building up the grids, the wire spacing may be varied as desired to produce tubes having variable mu characteristics. The wire grid structure also has a marked advantage over prior art structures in that the wires are not short circuited, and hence do not cause circulating or eddy currents to flow. Where grid wires are wound about conducting posts and welded at each point of contact, as in the usual practice, numerous paths for the flow of undesirable eddy currents are formed.

In Figure 2 it is indicated that the electrode wires in adjacent electrodes are parallel, but alternate sets may be made parallel to the axis of the cathode in order to cut down the tube capacity, especially at high frequencies. For example, and as indicated in Figure 12, the wires of grid 25 might extend parallel to the indicated position of contact strip 26. In this way no wires would contact an insulating frame directly in line with similar wires of the next electrode contacting their frame. The position of the contact strip 26 would, of course, have to be approximately changed to make it cross the wires. This structure is produced by placing the wires alternately vertically and horizontally, observing the relation of the wires of grid 25 to other conductors as indicated above.

The structure so far described involves a radical departure from the usual practice in making vacuum tubes. While the basic underlying idea is that of making each of the electrodes uniplanar and in placing all of the electrodes in the assembled structure under tension and in parallel spaced relation so as to permit continuous or jig assembly, this arrangement involves the use of specially-constructed parts such as the frame elements. It is possible, however, to make use of stock materials of types which are available according to present practice and to assemble them by machine, so as to accomplish many of the advantages of the present invention and to eliminate the disadvantages of prior art structures. A completed tube unit, assembled in this way is indicated in perspective in Figure 7, Figure 8 being a horizontal section to indicate more clearly how the various elements are placed. In the structures of Figures 1 and 2, it has been indicated that the tube employs a single set of electrodes in combination with the cathode. It is, however, possible to duplicate the structure and embody the functions of two tubes in one, using a single cathode having two emitting surfaces on opposite faces. In other words, it is possible to duplicate in Figure 2, to the left of the cathode 21, a set of grids as indicated on the right, and a plate, so that the tube will embody a single cathode, six grids and two plates. Figures 7 and 8 indicate how this double structure can be carried out without radical departure from present practice, but achieving

substantial benefits which are characteristic of the improved practice contemplated according to the present invention.

Referring now to Figure 7, the reference characters 51 and 52 designate insulating plates which may be of mica or other similar material held in spaced relation by insulating or metal posts 53, 54, 55 and 56. Since this figure represents a double structure, the two mica sheets 51 and 52 are secured together by eight pairs of these insulating posts, each terminating in the mica sheets 51 and 52. The two plates 19 are supported by the posts 53. These posts when made of ceramic material, such as glass, may have the plates secured together by a slight fusion of the glass to form overhanging gripping lips. Similarly, the suppressor or space charge grids 27 are supported by the posts 54. Posts 55 support the two high voltage or screen grids 25, and posts 56 support externally the two control grids 23, and internally the cathode 21, with the enclosed heater 22. The cathode must be mounted in an insulating sheet to insulate it from the posts 56 and thus prevent short circuit of the control grids. The relation of these parts is indicated more clearly in the horizontal section of Figure 8, and it will be seen that each of the emitting surfaces of the cathode 21 is directed against one of the two sets of grids and plates. In such a structure the two grids 23 will be electrically connected. Similarly, the two grids 25 will be electrically connected and similarly for grids 27, 27 and plates 19, 19. This arrangement then is connected as a single pentode.

When the posts 53, 54, 55 and 56 are of metal the electrode wires may be welded to them. Welding surfaces can be inserted between the parallel electrodes and pressure applied during the welding. The wires and posts may then be cut off. The bottom plate 51 may be attached to a conventional tube base and connections made substantially as in Figure 1. This welded assembly may be made in a process similar to that shortly to be described.

The two mica spacer plates 51 and 52 may be enclosed in the usual glass envelope having a base carrying prongs which are connected by leads from the various electrodes and control elements of the tube structure. It is also possible, by making the sheets 51 and 52 of glass to complete the envelope by welding a glass strip around the periphery of the assembly shown. Such a glass strip is indicated at 85 in Figs. 7 and 8. When the plates 51 and 52 are of mica obviously the use of such a strip is not practicable. The structure may be readily shielded by the addition of shielding plates as indicated at 50, or these may be omitted.

It will be seen that structurally the arrangement of Figure 7 is quite similar to that of Figures 1 and 2, in that all of the elements are uniplanar, all of the planes are parallel in the finished tube, and all grid wires are under tension and supported at both ends. This eliminates all grid wire winding operations and insures uniform spacing of the parts while making it possible to adapt the arrangement to continuous assembly line construction or for assembly on a suitable jig. Figures 7 and 8 show a structure in which raw sheet and wire stock may be utilized and adapted to the scheme indicated in Figures 1 and 2.

While devices of the present invention are capable of fabrication in numerous ways, the particular advantage of these structures lies in the

fact that they are suitable for assembly line construction, especially where the control elements of the tubes, such as the plates and the various grids, are made up of continuous bar or strip material. It is possible to make up the cathodes from continuous strip material which is punched at intervals to receive a heating element, and the heaters may be assembled in the strip so that the strip as a whole, carrying the heater elements, may be fed to the machine. This will be more clearly understood from a reference to Figure 9 of the drawing, in which reference character 61 designates a machine bed forming a raceway between two sets of feeding belts, one of them, designated 62, being driven from one of the pulleys 63. A similar belt is disposed at the back of the machine, so that the two of them form a converging throat, terminating between two spaced parallel guide members 64, secured to the base of the machine as indicated in the drawing.

Mounted at the incoming end of the raceway are a plurality of combs 66, pivoted about horizontal pivots 67, on the machine base. The details of this comb arrangement are shown in Figure 10, where it is indicated that the perforations 68, through which the grid wires pass, provide for maximum spacing of these wires by adjusting the position of these combs. As indicated in dotted lines in Figure 10, the spacing can be varied to suit requirements; that is, the spacing decreases as the comb approaches a horizontal position. Suitable clamping means with calibrated spacing indicators may be provided to hold these combs in any adjusted position. For simplicity, these clamping means are omitted from the illustration.

This apparatus produces a double pentode structure of the type shown in Figures 1 and 2 of the drawing, except that the parts are duplicated as in Figures 7 and 8. Passing into the throat from suitable reels is a strip of cathode material 71 containing the heater elements as indicated more clearly in Figure 2 of the drawing. The line of separation between the individual cathodes is indicated, but the severance is not complete. Passing outwardly from this central cathode are sets of parallel moving grid wires 72 of the control grid, 73 of the screen grid, and 74 of the suppressor or space charge grid. The plate material appears at 75.

The continuous strip material be it wire or sheet stock, may be de-gassed by heating in an inert atmosphere in accordance with known practice before it enters the machine.

Disposed above the throat of the machine is a hopper 76, through which are fed sets of frame elements 17 sufficient in each layer to produce a double pentode as indicated. When a set of insulating elements is fed downwardly between the spaced strips of element material, the assembly passes forward continuously until it is diposed under a second hopper 77, from which are fed the sets of lead wires which are adapted to be clamped into the assembly so as to insure good electrical contact between the leads and the control elements of the units. After the assembly passes the hopper 77, the mechanism causes the side rail 64 to be swung inwardly sufficiently to compact the frame elements and to bring them in close contact with the leads 78, whereupon clamping material 81 is fed across the guideway by any suitable means. The forming members 79 operate by swinging upwardly to engage and bend the clamps about the frame elements, as indicated at 81. Similar forming members (not shown) will be used above the frames to bend the top clamps down. At this time, bases 16, which may have the contact prongs already applied to them, are fed downwardly from a hopper 82 and dropped into position. Those bases may also carry the leads already connected to the prongs as indicated in Figure 11. With the assembly thus completed as a unit, a rotating cutting or shear device indicated at 83 swings downwardly between units to sever the grid, plate and cathode strips, thus releasing a completed unit as indicated. This assembly takes place continuously so long as the hoppers are kept filled with material, and so long as strip material and bar stock is fed into the raceway. While the terminal members 78 are indicated as being fed in finished form from the hopper 77, it will be understood that they may be fed from continuous bar stock and cut off as soon as the assembly passes the hopper 77. It is also to be understood that suitable mechanism will be utilized for actuating the parts disclosed, but since actuating mechanism of this type is well known in the art, it is not illustrated in the drawings. When the units are completed, they may be placed in an envelope ready for sealing off, and will then appear as in Figure 1. While the process has been described in connection with a double pentode having an internal structure corresponding to that shown in Figures 1 and 2, it will be obvious that it may be adapted to the manufacture and assembly of various arrangements indicated in the drawing including the form shown in Figures 7 and 8. The addition of the envelopes and the sealing off may obviously comprise steps in the process of Figure 9.

It will be clear from the foregoing description, that the present invention offers numerous advantages over prior art schemes. It makes it possible for the first time to assemble electron discharge devices by a continuous process which insures uniformity of product, especially as regards spacing of the elements with respect to each other. This is important, particularly in tubes of small sizes and those having five electrodes where the clearances are critical and highly important. It will also be understood that while the invention has been decribed as being carried out by a continuous method of assembly, it will be possible to assemble the elements by means of jigs, upon which the various operating parts are set up. Here, again, the advantage of using raw stock will be apparent. The invention, therefore, not only offers the advantage of high speed production with improved efficiency and material reduction in labor costs, but it will also result in a material saving in the number of rejects and, consequently, in a marked decrease in the cost of production for both reasons.

The invention has been described in the form of two embodiments of the electron discharge device and a single method of assembly, but it will be understood that the invention is not so limited, and it is intended that the following claims shall be construed broad enough to cover all equivalent structures so long as they are clear of the prior art. It is to be understood that the concept of manufacturing tubes having their electrodes under tension is a broad concept which when coupled with the machine assembly herein shown and described is not limited to the precise tube configuration disclosed. Consequently, the present disclosure is intended to be generic and to cover variations in the design when this tension arrangement is present.

This application is a division of my application

Serial No. 507,314, filed October 22, 1943, now Patent No. 2,415,360 dated February 4, 1947.

Having thus described the invention, what I claim is:

1. An electron discharge tube unit comprising a pair of parallel spaced glass sheets, a plurality of spaced pairs of posts for holding said sheets in spaced relation and for supporting tube electrodes, an electrode bridging each pair of posts, and a glass strip wound about said unit to bridge the space between plates and sealed thereto to complete a sealed envelope.

2. An electron discharge tube comprising a pair of parallel spaced sheets of insulation, a plurality of pairs of glass posts secured to said sheets to hold them in rigid spaced relation, said pairs of posts being in spaced planes, and electrodes made up of parallel spaced wires mounted in bridging relation to the posts of each pair and secured to the posts by fused glass.

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