

March 13, 1951

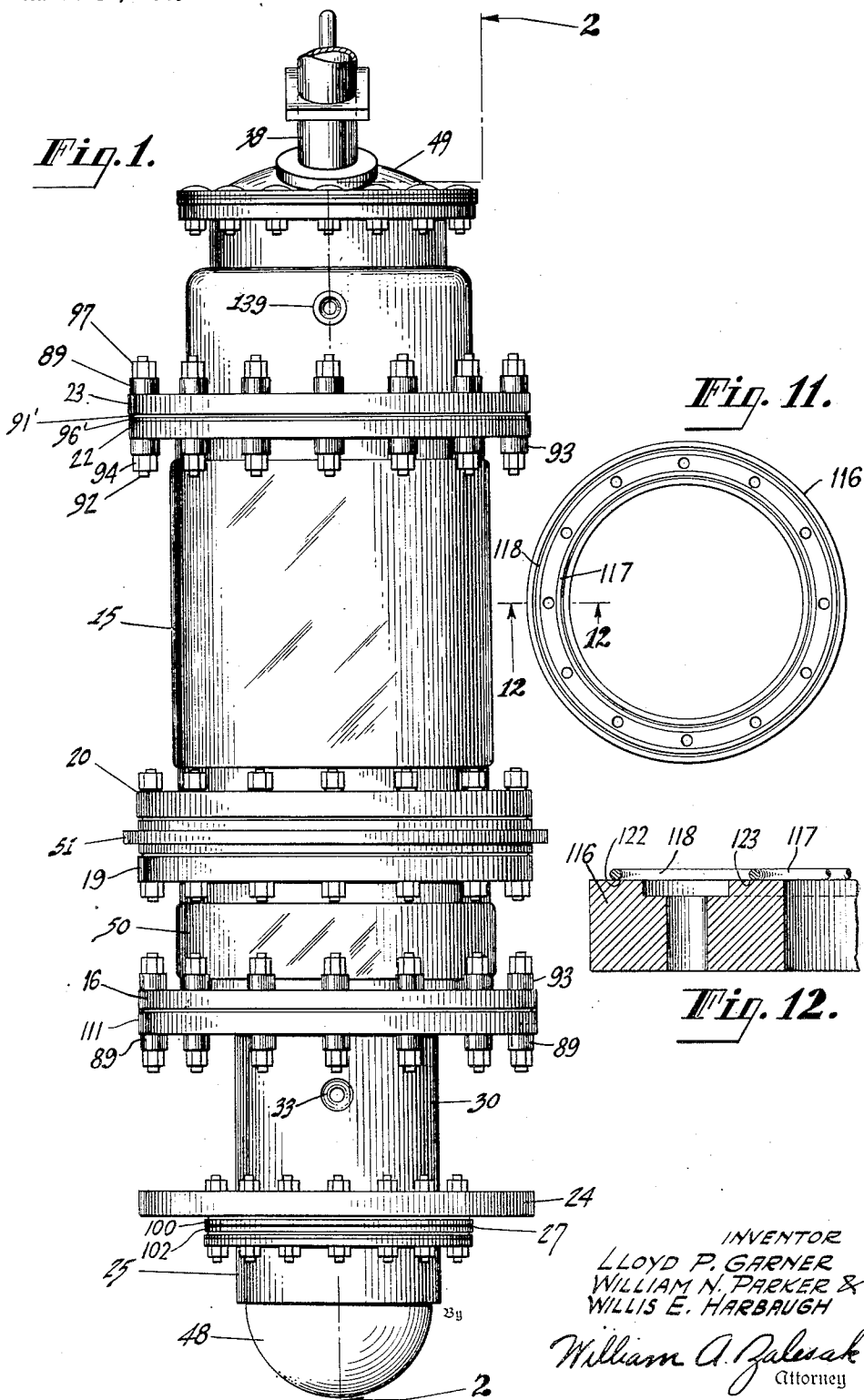
L. P. GARNER ET AL

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HIGH-FREQUENCY HIGH-POWER TUBE

Filed March 17, 1949

4 Sheets-Sheet 1



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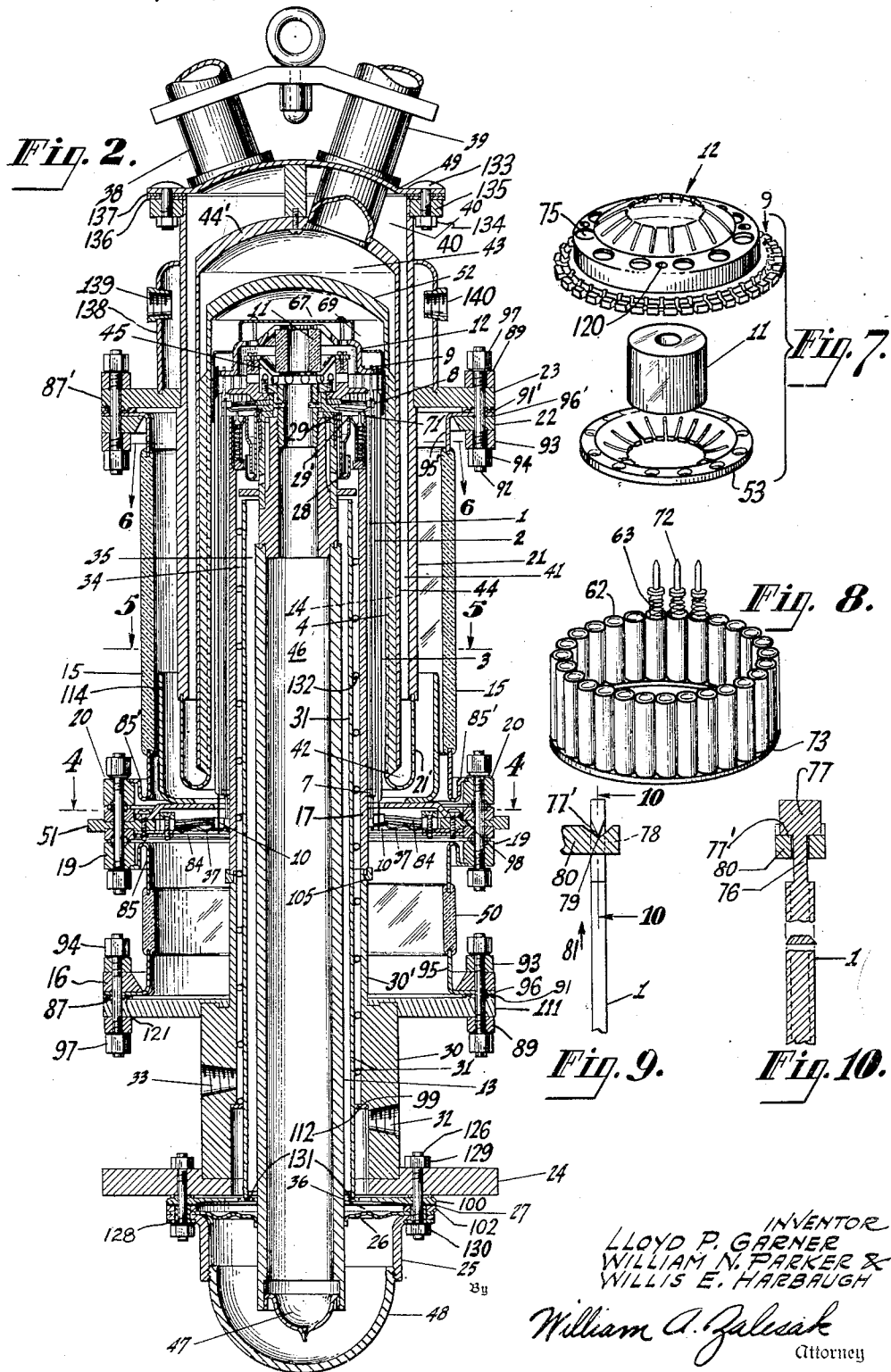
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Fig. 4.

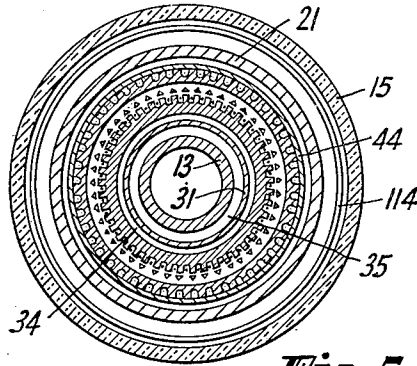
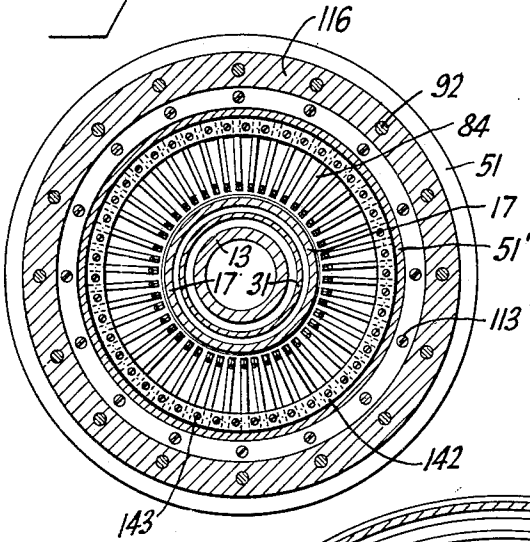


Fig. 5.

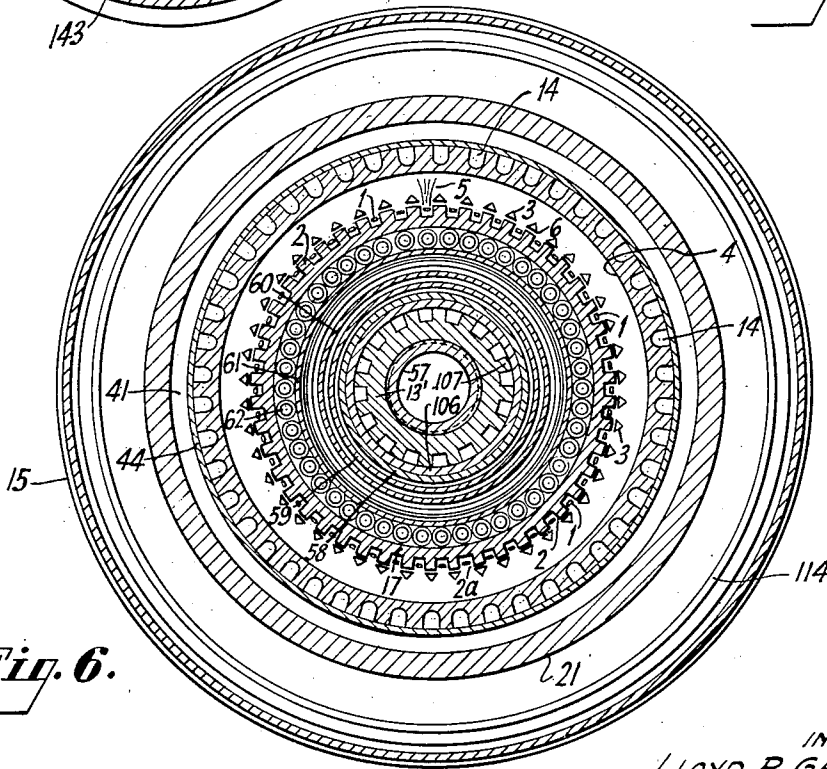


Fig. 6.

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HIGH-FREQUENCY HIGH-POWER TUBE

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Application March 17, 1949, Serial No. 81,932

55 Claims. (Cl. 250—27.5)

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The present invention relates to improvements in high frequency high power tubes, more particularly the application of a novel technique in tube design respecting structural parts. Our technique overcomes sources of serious difficulties in present type tubes from the standpoint of construction, operation, maintenance, etc.

For the purpose of illustrating our invention it will be described in connection with a triode type tube, although it should be understood that it is not limited to that particular construction. In accordance with the common practices embodied in the design of triodes there are three essential electrodes, namely, cathode, grid and anode, concentrically arranged and each electrode performing a recognized function in the operation of the tube. For example, the cathode is the source of the electrons which may be of the direct or indirectly heated type and the grid is juxtapositioned with respect to the cathode and the anode. The grid functions electronically to control the electronic flow between the anode and the cathode, the grid being of a mesh-like structure which may comprise wires or bars spaced apart so as to permit passage of an electron flow originating from the cathode and terminating at the anode. Since the function of the grid is to control the electron flow, it is highly important to avoid any electron collection by the grid which would normally be manifested by undesirable heating thereof. It is of course appreciated that complete prevention of heating up the grid is practically impossible but it is necessary that the grid operating temperature is not permitted to rise sufficiently high to support electron emission.

A typical construction of a conventional type triode high frequency high power tube is represented by tube type designation 9C21 officially approved by the Radio Manufacturers Association. In this type tube the cathode electrode consists of a multiple of tungsten wires orientated in a cylindrical array. Each cathode strand or wire is mounted at its opposite ends in an inflexible manner. At the top or upper ends the strands are welded together to form a cluster. The lower ends of the several wires are connected to cathode support rods, the general construction being that of basket shape which is self-supporting. This cylindrical array of wires is much longer lengthwise than in diameter, consequently the mechanical arrangement is fragile and subject to objectionable features such as vibration, warping or the like. With respect to warping, deformation is produced by thermal expansion of the individual cathode wires, and since they are relatively inflexibly mounted at their two ends deformation occurs from expansion. This deformation may

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be quite serious in case of close spacing of the cathode with respect to the grid.

A further objectionable feature accruing from a basket-like structure of the cathode is that large drift spaces are inherently provided permitting gas ion migration.

All of the above mentioned difficulties in the cathode construction are also present in the grid construction. Incidentally in the 9C21 type tube the grid construction is of spiral formation wound in close proximity to the cathode filament. It is apparent that in accordance with such a grid construction no provision is made to employ electron optics for the reduction of grid space current absorption.

The anode which surrounds the grid is a cylinder of some high thermal conductivity material such as copper which is utilized for cooling effects. The outer surface of the anode is conventionally cooled by air blowing past a multiplicity of fins, or by water flowing over said outer surface.

The foregoing difficulties with respect to the 9C21 type tube may be summarized as consisting of the following inherent weaknesses: self-supporting cathode not applicable to very large power tubes, particularly where there is close cathode-grid spacing; magnetic effects are produced; large gas ion paths are inherent; the cathode wires are not independently mounted; and the structure presents high reactance.

Obviously a tube construction which eliminates or greatly reduces such difficulties as described above makes it possible to design a high frequency high power tube having improved performance by virtue of being able to control more closely critical tolerances between tube elements. We accomplished this result by a technique or manufacturing approach hereinafter described.

It is an object of the present invention to provide a unique tube structure derived from the utilization of a novel technique for the production and/or consolidation of structural parts of the tube.

Another object of the invention is to design mechanically the structural parts which function electronically so that the standardization of said parts with respect to functional characteristics is for all intents and purposes reduced to unity of design irrespective of the required overall characteristics of a given tube.

Another object is the provision of a tube construction differing radically from constructions of the prior art in that the technique we employ contemplates making the component parts of the tube in conformance with a standardized pattern adapted to be applied in the assembly of unit parts composing this pattern, said unit parts varying only as to size and/or numbers so that

specified tube requirements may be obtained without departure in fundamental detail of basic design, and thus permit a wide variation in tube requirements including size of tube, capacity or power output, etc. without constantly re-designing the tube structure.

Another object of the invention is the provision of a tube construction which permits the assembly of component parts within very close critical tolerances between adjacent elements, and in such a manner that such critical tolerances may be maintained under general operating conditions of the tube.

Another object is the provision of a novel technique in tube design which lends itself to the use of means of assembly of the structural parts so that an extremely accurate and simplified tube construction is obtained through consolidation of the component elements of the tube.

Further objects of the invention relate to the manufacture of vacuum tubes having superior performance characteristics in the following respects: very high power gain; very small driving power and are capable of operating at high frequencies and developing high power; very small gas conduction paths are obtained and electrode lead reactances are materially reduced over prior art structures; cathode heat currents do not give rise to large external detrimental magnetic fields; employ electron optics for the reduction of grid space current absorption; and more particularly the production of a tube structure characterized by simplicity of parts; ease of assembly and accessibility to said parts.

A special object of the invention is the design of structural parts of the tube which may be united or fabricated into sub-assemblies which form components of the main tube structure, said fabrication being effected by the application of instrumentalities contemplated by our novel technique or philosophy herein disclosed.

A further specific object of considerable importance is the provision of an individual pantographic mounting device for each cathode element and grid element so that the expansion or deformation of a given wire has no influence upon the others. This arrangement removes any limitations of overall or aggregate size of the tube, thus permitting a great deal of latitude in the size, rating, etc. of tubes to which our invention is applied.

Another specific object is the provision of a gas tight readily demountable envelope for an electron discharged device which permits ready access to the active electron regions of the device while at the same time permitting normal operation of the device while same is not connected to a vacuum pump.

Other objects relating to matters of design, construction of parts, method of assembly, instrumentalities employed to effect assembly, etc. will manifest themselves as the description proceeds.

In accordance with the present invention, there is provided a tube structure characterized by basic principles of design and/or construction which contribute generally to the fabrication of a tube which is composed of a unitary structure comprising subassemblies of multiple elements, which elements may be standardized with respect to characteristic structures, but varied materially as to size, shape and the like and which may be assembled to meet given specifications.

A principal component part of the tube is a sectionalized cathode and grid which is non-self-supporting. Means, such as a pantographic sys-

tem to independently support the several sections, is provided. Each of these sections is mounted inflexibly at one end and flexibly at the other end, and motions of the sections are substantially restrained except in one direction. Many advantages are derived therefrom, as for example, clip-in mounting devices are provided which facilitate easy replacement of a damaged grid or cathode section; the length, number and cross section of the grid and cathode sections may be varied to suit the circumstances, etc.

An anode is provided which is arranged concentrically and coaxially with the cathode and grid structures. An electron optical system including a beam forming element is interposed between the cathode and the grid. Means are provided for cooling the anode which is entirely closed within an outside envelope. By circulating water or some other coolant through the cooling system, the anode may be very substantially cooled so that the tube may be operated at high powers.

There are details of construction which will be obvious as the description proceeds, such as means for constantly maintaining the various sections of the cathode and grid under tension; the manner in which the outer envelope of the tube is rendered vacuumtight through mechanical seals composed of various elements, etc. Other features relate to the manner in which tube parts or structures are consolidated, as for example, by the use of R.F. induction welding; the type of glass-to-metal seals employed for concentric cathode heating system, etc.

Referring to the accompanying drawings,

Figure 1 is a tube, completely assembled, embodying the invention;

Figure 2 is a longitudinal section of the tube shown in Figure 1;

Figure 3 is an enlarged sectional view showing partly the tube as illustrated in Figure 2;

Figure 4 is a cross-sectional view taken on the line 4—4 of Figure 2 showing particularly the pantograph arrangement;

Figure 5 is a sectional view taken on the line 5—5 of Figure 2 showing particularly the array of the electrode assembly and electron optical system;

Figure 6 is a sectional view taken on the line 6—6 of Figure 2 illustrating an enlargement of the electrode assembly, electron optical system and means for maintaining tensioning in the spring supported elements for flexibly mounting one end of the cathode sections;

Figure 7 is an exploded view of the grid supporting construction carried at the top of the tube;

Figure 8 is a perspective view showing the details of the spring mounting arrangement for the upper end of the cathode;

Figures 9 and 10 are sectional views showing the knife edge mounting of the sectionalized cathode and/or grid strands, this mounting being of a construction which permits supporting said sections in demountable form;

Figure 11 is a top plan view of the flange for hermetically sealing the tube parts when assembled; and

Figure 12 is an enlarged sectional view on the line 12—12 of Figure 11 showing in more detail the construction involved for the sealing flange.

For the purpose of illustration, we have shown a triode, high frequency, high power tube but it will be understood that the invention is applicable to other types of tubes. The tube illus-

trated embodies an electron optical or beam forming system which may be used to great advantage in reducing the electronic driving power required together with improving operation efficiency. The essentials of the beam forming electron optical system employed herein is shown in various views of the drawings, as for example, Figures 2, 3, 5 and 6. In Figure 6, the reference character 1 represents the cathode or electron emitting surface, 2a represents the beam forming cavity into which the cathode 1 is mounted in such a way that the cathode or electron emitting surface is recessed or dropped below the protruding edges of the beam forming elements.

The beam forming elements 2 are (see Fig. 3) operated at an electrical potential which is substantially the same as the cathode potential. The protruding corners of beam forming element 2 function electronically to focus the electron beam so that the beam is not intercepted by the grid electrodes. Grid elements 3 are arranged and supported so as to be spaced away from the beam forming elements 2 and removed from the electron stream which emerges from the cathode within the beam former. The shape of the grid element cross-section may take a variety of forms such as for example a triangular cross section. In determining the cross-sectional shape for the grid element 3, it is essential that the edge 5 be relatively thin in the direction parallel to a line drawn between the cathode 1 and the anode 4. The reason for this is that as the electron beams 5 diverge in the region of the grid electrode, it is desirable that the electrode be so shaped that there will result a minimum of electron collection by the grid sections. The thickness of the grid 3 will influence some of the electrical characteristics of the tube other than those having to do with the electron collection. For instance, if the grid were made in a shape of a thin sheet with very little thickness in the direction toward the anode, the effectiveness in controlling electron flow without much electron absorption, would be excellent. Such a grid, however, would not shield the cathode from the anode potentials very effectively and such a grid would result in very poor cut-off characteristics and a tube having a low μ . Yet, on the other hand, if the grid were made rectangular for instance, and with a substantial dimension in the direction of the anode, it would result in a tube having extremely high μ but very poor electron collection characteristics. However, if rigidity was a determining factor, such a shaped grid would be mechanically very rugged. We have found a triangular, half-round or trapezoidal cross-section offers a satisfactory compromise in grid cross-section shapes. Such a shape allows a small dimension (thin edged) in the region adjacent the edges of the beam forming cavities while retaining other characteristics of mechanically rugged, high μ and thermal capacity desirable in any large, high power vacuum tube.

The general arrangement just described of the cathode, grid and anode will be fully appreciated by reference to Figures 5 and 6 which show that the electrode elements are concentric and coaxial in the order mentioned.

To enlarge somewhat upon some of the foregoing statements, reference may be made to Figure 2, bearing in mind the same reference characters represent corresponding parts throughout the several views. It will be seen that the section of the hot cathode element 1 is trapezoidal with its wider face furnishing the electron emis-

sion. The cathode is relatively long, the one in the tube illustrated being approximately 8 inches and made of wire of tungsten or thoriated tungsten mounted within a beam former 2. Each section of the cathode has one end inflexibly mounted adjacent the bottom as at 7 and its other end flexibly mounted adjacent the top as at 8. The flexible mounting 8 is achieved through a construction hereinafter more fully set forth in greater detail.

For the present, it may be stated, the flexible mounting functions to provide mechanical constraint, i. e. prevent freedom of movement of the sections of the cathode except longitudinal movement of said sections. The cathode, being an element which runs at elevated temperature, will expand when heated under operating conditions.

This expansion and contraction of the tungsten cathode wires is adequately accommodated in the flexible mounting construction 8. The mounting device 3 incorporates tensioning means so that tension is maintained along the axis of the several cathode sections but other forms of freedom of movement are constrained. A more detailed discussion of the flexible cathode and grid mounting devices will occur later.

Since the geometry of the cathode 1 and beam former system is extremely critical, it is necessary to mount the cathode within the beam former by means of a device which holds it critically in position but it is also necessary that the beam forming element 2 be constructed in such a way to yield very high precision. This feature will be manifested more fully hereinafter.

For the sake of convenience, the various sections or elements of both the cathode and the grid electrodes are sometimes herein referred to as each section constituting an electrode, but in reality, because they are joined or connected together electrically, from an operational standpoint it is truly but one cathode and one grid electrode each composed of a plurality of sections or elements independently mounted. The grid sections are somewhat similar to the cathode sections with respect to being sectionalized, form of mount, number of sections employed, etc. The grid sections run at a variety of temperatures and for that reason will operate in such a way that their lengths will vary. Like the cathode sections, the grid sections are mounted inflexibly as at 9 and longitudinally flexible as at 10. The device for achieving flexibility of mounting is similar to the cathode flexible mounting device 3. These flexible mounting devices are of a pantographic-like construction and will be described more fully hereinafter. It will be noted that the inflexible grid mounting 9 is a continuation of a circular metal piece in the shape of a hat 12 which hat is insulated by insulating member 11 from a central metal member 13 which conducts heating power to the cathode (see particularly Figures 3 and 7).

The anode 4 is a smooth cylindrical surface which surrounds the entire cylindric array of cathode and grid sections or elements. Its electronic function is to maintain appropriate potentials and electric fields to facilitate electron flow, as is normally the function of an anode. It also serves as an electron collector. Because of its electron collection function, it is subjected to considerable heat. The heat of the anode is so intense that it is necessary to remove heat therefrom by some external means, such as a fluid cooling system. The cooling system will be described

more particularly hereinafter. It may be noted, however, as shown in Figure 2, that the anode of the present tube is located partially within the glass envelope insulating member 15 which is a departure from the usual conventional practice of making the anode an externally cooled electrode.

As pointed out hereinabove, each cathode section 1 is connected to a flexible mounting device 3 adjacent their upper ends and an inflexible lower mount 7. The flexible mounting device 3 is seen to be connected to a tubular member 13' which is internally threaded adjacent its upper end to receive a threaded extension 57. Tubular member 13' is in turn connected to and serves as an extension of the central metal tubular member 13. The mounting at 7 is connected to another tubular member or cylinder 17 which is concentric with member 13 and which is in turn connected at its lower end to a cylindrical extension 30' of cylinder 30. A ring 111 is connected to the end of cylinder 30; the end of the cylinder from which extension 30' extends serving as a convenient shoulder to receive ring 111 which forms an outwardly extending flange. Connected to the other or lower end of cylinder 30 is a ring 24 which serves as an external cathode heating power terminal and which supports terminal 25. Terminal 25 serves as the other cathode terminal being electrically connected to central tubular member or cylinder 13 through a flexible diaphragm 26. Though flexible diaphragm 26 is substantially rigid in a radial direction, it is sufficiently flexible axially so that while serving as a support and radial spacer for cylinder 13 it affords the cylinder some longitudinal flexibility the purpose of which will be pointed out hereinbelow. As will be apparent, the seal between ring 24 and terminal 25 is watertight and each is insulated from the other.

Insulating member 11, which insulates the grid sections from the cathode, is connected to a metal piece or support member 53 which is in turn connected by bolts 74 to mounting member 45. Mounting member 45 together with the flexible mounting 3 is clamped to a ring 56 which is L-shaped in section and which is in turn clamped against a ledge 106' on sleeve 106. As was pointed out, insulating member 11 supports top hat 12 from which each of the grid strands or elements is suspended while each is tensioned axially at its other or lower end by a flexible mounting device 10 clamped to ring 18 and extending inwardly therefrom. Ring 18 is supported from grid terminal ring 51 by bolts 113 threaded through an inwardly extending portion of ring 51 as well as an off-set portion of a radially inwardly extending apertured shield 51'. On shield 51' and spaced radially outward from the anode is an upwardly extending shield 114 the lower end of which is turned into form a lip which may be brazed or soldered to shield 51'.

The anode is cylindrical, closed at one end by an enclosure 52 and at the other end is turned out and back upon itself forming a somewhat U-shaped extension 21' to which the anode lead cylinder 21 is connected. As most clearly shown in Figure 6, the outer surface of the anode is serrated or channeled to form channels 14 with cylinder member 44 which fits snugly around the anode. An anode terminal ring 23 is connected to cylinder 21 from which it extends outwardly.

It may be seen, particularly from Figure 2, that each of the electrodes, i. e., cathode, grid and anode are connected to relatively large continuous and low impedance, radio frequency leads. For

instance, it can be seen that the cathode radio frequency lead consists of the mounting device at 7, cylindrical conductors 17, 30', a terminal ring 111, gasket 91, cylinder 95 and flange 16 which system of connection provides a continuous low impedance R. F. lead from the ring 111 outside the vacuum enclosure, through the vacuum enclosure to the cathode 1. It may be pointed out also that the same terminal provides connections to the beam former element 2. The grid lead system on the cathode side consists of flexible mounting device 10, conducting member 37, ring-like lead 18, retainer ring 141, steel ring 116', wire gasket 117', flange 19, glass sealing member 85, wire gasket 118', and ring 51. It will be seen that the grid lead impedance on the cathode side is quite low. The grid lead on the anode side includes ring 51, steel ring 116, wire 118, flange 20, glass sealing member 85', wire 117, shield 51' (shield 114), mounting 10 and is likewise a low impedance lead. The anode lead can be seen to consist of the cylindrical surfaces 21, 21', ring 23, gasket 91', cylinder 95' and flange 22. This lead, like the others, is also a low impedance continuous path from outside the envelope at 23 to the anode surface 4 within the active electron region. In addition to these various lead devices being of low electrical impedance, they are likewise arranged in such a manner that excellent inter-circuit shielding is obtained. It will be noted that the grid terminal ring 51 as well as flanged shield 51' connected thereto, together with the ring-like member 18 and flexible mounting device 10, constitute a sort of partition between the anode-grid circuit and the grid-cathode circuit.

As will be noted from the above, the cathode is of the directly heated type, being composed of a plurality of elements which form an electrical whole or entity but which may be varied as to size, length, number, etc. They are independently mountable with respect to each other and are flexibly supported at one end and inflexibly held at the other. It is obvious that cathode heating power must be supplied to the cathode at these two points. The inflexible mounting 7 is arranged to connect cathode elements at that point to the beam former which is an extension of the cylinder 17. The flange 24 serves as an external cathode heating power terminal. At the flexible mounting point 3, the cathode heating power is conveyed through the flexible pantograph-like mounting device to which said cathode power is forwarded from the inner most cylinder 13 which cylinder is electrically connected to terminal 25 through flexible diaphragm 26. Insulation between the beam former and the upper end of sleeve 106 on extension 13' of cylinder 13 is provided at 28 at the upper end of the beam former structure. The seal at 28 serves several important functions. It must not only insulate the beam former cylinder from the lead cylinder 13 but it must also withstand air and water pressure and retain mechanical juxtaposition of the beam former and cylinder 13 in the region where it is mounted.

As previously mentioned, because of the heat developed by the cathode in close juxtaposition with the beam former, it is necessary that the beam former be cooled. This is achieved in the construction illustrating the invention by forcing water into a tubular water inlet 32 which supplies water to channel 36 from which it moves upwardly through the concentric channel 35 and

through tubular extension 13' and over a water partition 31, and then spirals down water channel 34 against the inside surface of the copper member from which the beam forming elements are formed. Water then continues down channel 34 and is withdrawn from the tube at water outlet 33.

Since a very effective electron optical system is employed in our tube, the grid electron absorption is very small hence the grid heating is of sufficiently small amount to make possible the use of radiation for dissipation of the grid heat losses. At the flexible grid mounting device 10, heat is removed by means of a copper conducting member 37. This heat conducting path from the grid at 10 to the ring 18 is provided so that excessive heating of the flexible mounting device may be avoided.

The anode cooling path may be described as follows. Water is forced into the system through inlet 38 which is connected to a cavity header 40 closing the upper end of cylinder 21 which, in turn, communicates with a long, thin cylinder cavity 41 through which cavities water flows to the region 42 where its direction is reversed and it is forced up through narrow serrated water channels or grooves 14 which channels present an increased water-copper interface for the removal of heat from the inner surface of the anode 4. From these slotted grooves 14, water moves upwardly into cavity 43 and subsequently leaves through tube 39. It will be seen, the thin cylinder member 44 acts as a partition between cavity 41 and the slotted or grooved water channels in the anode metal as shown at 14. This partition extends down to the region 42 as indicated.

The channels 14 may be somewhat spiral in shape to improve the structural strength of the anode cylinder. Thus, each of the channels may execute a one-half turn around the cylinder. In addition to increasing the strength of the anode cylinder over one with straight channels, there is also increased cooling efficiency because of the increase in the turbulence in the coolant.

It may be seen that openings satisfactory for exhausting the tube are provided by the inside surface of cylinder 13 communicating through holes in the mounting member 45. After exhaust, the exhaust tube is pinched off at a position near 47 and protected from damage by a cap 48 threaded into the cathode mounting terminal 25 as indicated. During the exhaust operation, the anode water circulating appurtenances 38, 39, and header 49 water partition 44 need not be in place. This is permissible because that part of the anode cooling system is not part of the vacuum tube envelope or evacuated system.

Large glass insulating cylinders 15 and 50 are respectively associated with flanges 22, 20, 19 and 16. These various flanges are glassed in a vacuumtight manner by a device to be described later in connection with a more detailed description of the envelope mounting means. The various vacuumtight members may be seen to be anode enclosure 52, anode surface 4, extension 21', anode lead cylinder 21, ring 23, gasket 91', flange 96', cylindrical member 95', glass cylinder 15, cylindrical member 85', flange 20, wire gasket 117, steel ring 116, ring 51, steel ring 116', wire ring gasket 117', cylindrical glass sealing member 85, glass cylinder 50, cylindrical member 95, flange 96, gasket 91, ring 111, cylindrical extension 30', beam forming extension or lead cylinder

17, ring 64, sleeve 61, seal at 28, sleeves 106 and 59, extension 13', exhaust tube 13 and pinch-off 47. In the cathode heating lead system, flexible copper diaphragm 26 conducts heating current to cylinder 13 and also provides limited mechanical flexibility between elements 25 and cylinder 13 so that expansion due to the temperature differences may be absorbed in the diaphragm 26 rather than to unduly strain the seal at 28.

It should be observed that the electron conduction space in the present tube is kept to such dimensions that electron and ion paths are short. This feature is obvious when one considers the electron conduction space in the region of the cathode, beam former, grid and anode.

Special precautions are taken to shield long radial spaces as occur in the inactive beam former region from ion migration. Shield 69 (see Figures 2, 3) is provided for that purpose. It operates at the potential of the grid top hat 12 and extends as a concentric cylinder around the grid mounting device 9 and axially downward to a point just below the top end of the beam former. This shield prevents the movement of gas ions from the anode 4 radially inward towards the mounting device 8 and the exhaust region of member 45. At the lower end of the active electronic region near the cathode support 7, there exists no opportunity for ions to move in long paths radially inwardly.

Figures 9 and 10 represent the device for mounting the cathode and grid strands or sections and which will be described in detail with reference to the cathode mounting at 8. This device contemplates providing cathode wires or bars with ground notches or grooves or reduced cross sections as shown at 76 which provides a head 77 formed by the intersection of the original large and the ground small cross section 76. After grinding the section is placed in a press provided with a suitable die and hot headed or forged to form knife edge 77'. For use in conjunction with such a knife headed wire, we have found that a notch 78 combined with a V-groove 79, in a copper block 80, provides a unique means for mounting cathodes with a tensional force in the direction of arrow 81. It can be seen that the knife head on the cathode section or wire will seat and center itself in the V-groove 79. We have found tungsten wire to be of sufficient mechanical strength at elevated temperatures to withstand sufficient tensional force and to insure excellent and sufficient contact between the copper block 80 and the wire 1. Such a mounting expedient obviates the necessity for employing tedious welding means in the mounting of cathode or grid wires. Such a mounting means also further provides a simple method for mounting tube structures without the use of heat. W. N. Parker application Serial No. 95,432, filed May 26, 1949, and assigned to the assignee of the present application describes in detail and claims the knife edge mounting and method of making the same.

The temperature along a cathode wire section is greatly influenced by a notch therein. Referring to Figure 10 it is apparent that because of heat conduction from cathode 1 back through block 80 and the mount at 8 there would be a temperature gradient along the cathode in the absence of the notch and constricted portion 76 so that the proper temperature for emission would be reached a substantial distance away from the mounting. By enlarging the groove and thus the constricted portion 76 a relatively poor thermal path is provided; the region immediately

below the notch in Figure 10 being at substantially the same temperature during operation as a point removed therefrom along the cathode. By providing such a lead loss correction emission is obtained from substantially the entire length of the cathode element with a substantial saving in heating current. Such an electrode structure is described and claimed in the application of L. P. Garner, Serial No. 95,398, filed May 26, 1949, and assigned to the assignee of the present application.

Referring to Figure 3 the inflexible cathode mount 7 is seen to be accomplished by the previously mentioned clip and groove arrangement. The groove and notches are provided in band 7 which band is made separate from the beam former array 2 and fastened thereto by solid diffusion taking place between gold plated band 7 and beam former 2. This operation is accomplished in pressure fixtures and at temperatures below the melting point of either gold or copper. The flexible grid mounting 10 is also accomplished by use of the aforesaid V-notch and groove clip arrangement. The enlarged knife head on the end of the grid wire 3 is mounted in a small V-groove in copper block 80' which is made integral with other parts of the grid pantograph 10 by means of gold diffusion. The laminated pantograph 10 is built up of thin laminations 84 of high speed tool steel copper-clad and gold diffused at the extreme ends as indicated. The high speed tool steel laminations are heat treated to form springs. In other words in the case of the grid pantograph 10 the laminations 84 which serve as hinges also serve as tension springs.

Each copper mounting block 80' is provided with flexible copper lamination 37 to conduct heat from the grid at points of contact to ring 18. This precaution is taken for two reasons, one being that high speed tool steel will lose its temper when heated above certain critical temperatures and another reason being to provide additional radio frequency conductivity to the grids from ring 18 on the cathode-grid side in which cavity enormous radio frequency currents may flow.

Reference may now be had more particularly to Figures 7 and 8 which are fragmentary perspective views of the upper end of the tube structure, showing in detail the regions beyond the actual electronic region. It was seen that the cathode 1 is flexibly mounted at 8 in a pantograph-type mounting which provides flexibility only for longitudinal deformations of the cathode sections. The means for supporting or anchoring the cathode wires in such pantographic mounting device was described with reference to Figures 9 and 10, namely, the clip-type cathode mounting. Tension for maintaining excellent thermal, electrical and mechanical contact between each of the cathode wires 1 and its pantograph notch arrangement at 8 is provided by a spring 63 in a cavity of circular cross section inside tube 62. Tubular members 62 may be concentrically arranged in respect to a ring or base member 73 and corresponding in number to the cathode sections. In each instance the spring 63 acts against the base of a small pointed insulating member 72 which, in turn, exerts force against an arm device 71 (see Figure 3) which pivots about a fulcrum in ring 56 and exerts pressure on the under side of the cathode pantograph at 68. The insulating member 72 is required because the spring is at the potential of the far end of the cathode 1.

The cathode pantograph mounting device 8

consists of a large number of very thin laminations 32 of copper which laminations are joined or bonded at their extreme ends but left free between the bonded regions. This free region of laminations provides a very flexible hinge-like and pantograph-like device which can flex perpendicular to its plane. The device being made of copper presents relatively high thermal and electrical conductivity required to supply the cathode heating current. The cathode heating current is conducted from lead 13, 13' through flange 106', ring 56 to the pantograph device then to the clip and to the end of the cathode wire 1.

The independent flexible mounting and the clip-in mounting for the electrode elements is described and claimed in said Garner application Serial No. 95,398, filed May 26, 1949. In the application of W. E. Harbaugh Serial No. 95,442, filed May 26, 1949, are described and claimed the specific pantograph-like electrode element supports shown herein. Said Harbaugh application is also assigned to the assignee of the present application.

As an aid in guaranteeing accuracy of juxtaposition, and for other reasons to be discussed later, the vacuum seal at 23 possessing considerable mechanical strength and adequate insulating properties is mounted adjacent to the upper end of the beam forming element 2. This seal includes an appropriately shaped array of concentric metal sleeves 59, 60, sealed with glass 65, in such a manner as to give a vacuumtight seal and one of great mechanical strength. U-shaped portion 66 of member 59 serves to aid immensely in supplying mechanical strength. The concentric seal is installed by R. F. induction welding at 29 and 29' into sleeves 58 and 61 which sleeves have previously been silver soldered to their respective proper lead members.

In order that each cathode wire be mechanically independent of adjacent and/or all other cathode wires the cathode mounting pantograph 8 is arranged to have a separate hinge and clip joint for each cathode together with tension device 71, insulator 72, spring 63, and spring cavities 62.

In Figure 6 it can be seen that each spring cavity is associated with a particular cathode wire only. The spring cavities 62 are arranged in a cylindrical cluster and all joined together by silver soldering at their ends to ring 73. This entire array can be fitted into a cavity between the beam former and sleeve 61 after completion of the R. F. induction welding operation at 29, 29'. As is apparent in Figure 3, the beam former is recessed adjacent its upper end and a ring 64 connected thereto at the shoulder forms a seat for ring 73. Ring 64 may be provided with an annular slot into which the lower end of sleeve 61 may be soldered.

Heat conducted from the cathode clip mounting 8 back through the pantograph laminations 82 is further conducted through member 56 to a sleeve 106 connected to tubular extension 13'. Extension 13' (Figure 3) above the portion thereof to which sleeve 106 is affixed, is set back with partitions 107 radially disposed between extension 13' and sleeve 106 forming channels 107' which communicate with one another at the upper ends thereof over the upper edge of partitions 107. Flange 106' on sleeve 106 is silver soldered to extension 13'. Sleeve 106 extends somewhat below water partition 31 and carries an arcuate ledge member 108 extending outwardly therefrom and over channel 35. Alternate

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channels 107' communicate with channels 35 by means of passages 109 formed in extension 13' while the remaining channels 107' communicate with channel 34 through the region above ledge 108 by means of holes 110 in sleeve 106. Thus, coolant travels from channel 35 up through passages 109 and alternate channels 107' over partitions 107 and down through those channels 107' which communicate with channel 34 through holes 110. It is apparent that an effective arrangement is provided for removing the heat conducted from the mounting 3.

It should be seen at this point that the mechanical mounting of each cathode wire or element is such as to guarantee its mechanical independence from all other cathode wires. Associated cathode wires are mounted inside beam forming cavities in such a way that no cathodes can be greatly influenced by other associated cathodes.

The grid electrode 3 is seen to mount inflexibly in the clip type mount at 3. This mounting device is supplied in grid support hat 12. Grid support hat 12 is in turn held in position mechanically and insulated by insulating member 11. The insulating member 11 is preferably made of a ceramic body silver soldered or otherwise sealed to grid support hat 12. The detail of this silver soldering structure will be further discussed later. The insulator 11 is further silver soldered to member 53 which is supported mechanically by mounting member 45 which in turn is supported by the cathode pantograph structure at 55. The ceramic to metal silver soldering technique provides sufficiently strong and rugged connection between metal and ceramic parts that it is possible to mount the grid support hat 12 in a machine which holds it with respect to grid mounting grooves at 9 and machine shoulder 83 in such a way as to guarantee parallelism and concentricity. Shoulder 83 is then mounted on mounting member 45 which in turn has been accurately located with respect to the cathode pantograph by means of shoulder 55 and screws 54 threaded through ring 144 and screws 54'. The actual assembly of part 53 to 45 is conducted by passing screws 74 into place through holes 75 in grid hat 12. The holes 75 in grid hat 12 are subsequently closed to ion conduction paths of ion shield 67 which also prevents ions from migrating into the inner surface of the insulator 11 from the grid anode region. Shield 67 is held in place on grid hat 12 by means of bolts 119 in threaded engagement with tapped holes 120.

In fabricating the grid pantographs extensive use of the solid diffusion method of joining metals is made. The radial array of grid pantographs 10 are mounted between rings 13 and 142 which are clamped thereto by bolts 143 in threaded engagement with retainer ring 141. Bolts 113 threadedly engaged to ring 141 serve to connect the same to ring 51 (see Fig. 3) in such a way as to guarantee the V-notches being concentric with the beam former 2. In this way the tube assembly is expedited in that no individual adjustments are required for each grid wire.

As mentioned earlier the vacuum- or gastight envelope is demountable, it being held together by a large number of bolts such as 92 in Figs. 1, 2 and 3. It can be seen that the insulating glass member 50, Fig. 2, is sealed at its two ends to cylindrical members 85 and 95, such members being of a satisfactory alloy to permit glass-to-metal sealing. Glass sealing member 95 is seen to be flanged at 96, such flange having small radius beads 87, one being inside the bolt circle

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and the other being outside the bolt circle. The glass sealing alloy flange 96 is copper brazed to flange 16 of the same general analysis but of lower quality. The heavy flange 16 serves primarily as a mechanically rigid member capable of withstanding considerable mechanical force without causing deformation of the glass seal at the extremity of 95. The beads 87 are provided to facilitate applying enormous local pressures to softer metal gasket 91. The gasket 91 is positioned between highly polished lands 121 on ring 111 and the polished beads 87 on flange 96. By means of bolts 92 provided with nuts 94 and 97 and washers 93 and 89, the system can be seen to be adapted for squeezing flat copper gasket 91 with enormous local pressures under beads 87. It has been found that when sufficient pressure is applied to a system of this character to guarantee plastic flow of gasket 91 there can be produced a vacuumtight yet demountable seal. In an envelope satisfactory for a demountable vacuum tube and yet applicable to a vacuum tube which may be sealed off and baked and processed in a manner satisfactory for attaining high vacuum it is necessary that the demountable joint be made a refractory device. Bolt 92 is a heat treated bolt made from a tool steel alloy which has "red-hard" characteristics. By virtue of these "red-hard" characteristics together with elongation characteristics such a bolt may be used as a spring. These bolts 92 are compounded and heat treated so that they will withstand long bake-outs at temperatures of 450° C. without losing their temper and at the same time without suffering normalization. In other words nuts 97 and 94 may be drawn up so tight as to cause an elongation in bolt 92 corresponding to a tensile stress of approximately 200,000 pounds per square inch and when the bolt under this elongation is baked for many hours at 450° C. the spring action of the bolt is not seriously impaired. In other words, when the bolt is baked in the stressed and elongated condition it does not seriously normalize or strain relieve but retains an enormous tensile stress.

Since ring 111 and flange 16 are of a lower expansion material than bolt 92 it is necessary that some expansion compensating means be provided. This means is provided in washers 93 and 89 which washers are built of a material having a sufficiently high expansion coefficient to equalize the total expansion of bolt 92 with that of flange 16 and ring 111. By this means it is possible to bake the tightened system for many hours without the unit stress or strain being substantially modified.

The material of which bolts 92 are made is an alloy compounded by the Carpenter Steel Company and sold under the name "883." The washers as 93, 89 and so forth, are made of a stainless steel "18-8." The rings 23, 111, flanges 5, 16 and 22 are made of "Kovar." The nuts 94, 97 and so forth, are made of "13-4-1" tool steel. The nuts and bolts are heat treated to high hardness for reasons of strength as well as reasons which have to do with preventing "freezing" under long high temperature bakeout.

The detail of the anode gastight demountable seal or joint is in all respects similar to the one just described between ring 111 and flange 96. Glass member 15 (Figures 2 and 3) is sealed at its two ends to cylindrical members 85' and 95' similar to members 85 and 94. The flange 96' on member 95' is copper brazed to flange 22 while member 85' is similarly connected to flange 20.

As will be noted the corresponding parts of the two seals have been identified in the drawings by the same numerals with those relating to the parts of the anode seal having a prime affixed thereto.

A ring 116 and wire gaskets 117 and 118 utilized in effecting the demountable gastight seal at the grid terminal ring 51 is shown in detail in Figures 11 and 12. In Figure 3 it is clearly apparent that ring 51 has two annular grooves, one in its upper and one in its lower surface. Rings 116, 116' are brazed or otherwise connected into each of the grooves. Each ring 116, 116' has an annular groove in its face opposite to that connected to ring 51, forming lands 122, 123 which are highly polished. A suitable material from which rings 116, 116' may be formed is Carpenter Steel Company alloy sold under the name "Vega." The air hardening characteristics of this alloy give sufficient hardness when heated to the silver soldering temperature required to join this material to copper. Flanges 19 and 20 are made of Carpenter Steel Company alloy "883" which air hardens to adequate hardness at copper brazing temperatures (1100° C.) when the flanges are joined to glass sealing cylinders 85, 85'. Flanges 19 and 20 also are provided with highly polished lands 124, 125 similar to lands 122, 123 on ring 116 (Fig. 12). Wire gaskets 117, 118 are interposed between the respective complementary lands on the abutting rings and flanges as shown in Figure 3. As in the case of the anode and cathode terminal bolts 92 and nuts 94, 97 are utilized to apply enormous pressure to cause plastic flow of the copper wire gaskets.

In order to render flanges 19 and 20 vacuum- or gastight they are electroplated with approximately a .0015 inch thickness of copper previous to their being brazed to their respective cylinders 85, 85'. Rings 116, 116' are also rendered vacuumtight by first coating with approximately .001-.0015 inch copper and then .00075 inch silver prior to silver soldering said rings to ring 51 utilizing the Ag-Cu eutectic solder which forms from the coatings.

It is apparent that two types of demountable gastight compression seals, that at the grid terminal and those at the cathode and anode terminals, have been described and either may be utilized as desired.

Referring once more to Figure 2 and as pointed out hereinabove, the central cathode lead 13 is electrically connected with terminal 25 through flexible diaphragm 26. Terminal 25 is insulated from flange terminal 24 by means of a mica washer 27 which washer is clamped between stainless steel rings 100 and 102. This insulated seal is watertight because cooling water inside cavity 36 must be kept within the water cooling system. These stainless steel rings 100 and 102 are also provided with pressure intensifying lands as indicated to guarantee watertight seals between flanges 24 and the flanges of lead 25 and the diaphragm 26. Bolts 126 of stainless steel "18-8" and nuts 128, 130 effect the watertight seal as described above. Bushing 127 of ceramic or the like as well as mica washer 128 serve to insulate bolts 126 and nuts 130 from terminal 25. Diaphragm 26 is provided to insure sufficient longitudinal flexibility to cathode conductor 13, 13' to guarantee that during processing or operation should excessive temperature differences occur between conductor 13, 13' and beam former 2 cylinders 17, 30, 30' that excessive mechanical

strain would not be imposed upon the vacuum-tight seal 28. The diaphragm 26 is sufficiently well water cooled to insure safe operation even though a cathode current of several thousand amperes may be required to heat the cathodes.

As previously pointed out water for cooling the various internal structures of the tube is admitted through inlet 32 which communicates with channels 33, 35, 107' and 34, and is withdrawn through outlet 33. The water partition 31 (Fig. 2) can be seen to be silver soldered at 131 to the inner portion of ring 100 and has a flange 112 abutting a shoulder 99 on the inside of cylinder 30. Copper tubing 132 is wound around partition 31 to form a helix which serves to guide the cooling water in a spiral path as it travels downward in channel 34. In addition tubing 132 spaces partition 31 from cylinder 17.

As described above, the pantographic mounting consists of a large number of thin laminations shown schematically joined rigidly in two extreme end regions, said end regions being separated by parallel slidably laminations. Because of the ununited long portions of laminations, the device is very flexible and because of the geometric shape resulting from the aggregate stack thickness of the laminations, the device flexes in a manner similar to the well-known pantograph which is the basis for designating the construction as a pantographic mounting. As a pantographic mounting device flexes in a plane perpendicular to the plane of the laminations, the deflected end remains substantially parallel to its original position. By virtue of this feature, the mounting will introduce little or no bending movement in the cathode and/or grid mounted therein.

It will be noted that the pantographic mounting device is quite rigid with respect to all degrees of freedom except that in a plane perpendicular to the plane of the laminations in their bonded regions. This plane which is perpendicular to the plane of laminations is chosen as the plane in which freedom in one degree or direction is provided the elements being supported or carried in the pantographic mounting devices. As previously pointed out, the freedom of motion in one degree or direction is required for each section or element of a cathode or grid wire on account of the elongation thereof due to expansion. This inherent elongation of the wire is accommodated by the flexing of the pantographic mounting device perpendicular to the plane of its laminations in their bonded regions. It can thus be seen that the pantograph constrains motions perpendicular to the axis of elongation or the axis of the wire. With each wire provided with an individual mounting device, it is obvious that no cathode or grid wire section in a structure of any size is in any way influenced by expanding or deforming of any other wire similarly mounted. Obviously, the introduction of such a mounting device as contemplated by our construction, obviates limitations of over all or aggregate size of such devices. Further, a tube may be constructed comprising literally an unlimited number of such independent mounting devices with the assurance that no cathode or grid wire section will be influenced by any other cathode or grid wire section.

The cathode 1 as shown in the electron optical device of Figure 6 can be seen to be of a trapezoidal cross section. The wire originally is round in cross section but may be deformed or shaped trapezoidally by heating the round tungsten wire

in a hydrogen atmosphere and moving the wire hot into roller-type tubes one of which rollers is ground with a recessed annular contour corresponding to the smaller face contours of the tungsten wire. As the wire proceeds through the set of rollers it assumes a trapezoidal cross section in one pass therethrough. The grid elements 3 of the present tube are likewise made of tungsten by a process of forming round wires into other cross sections more appropriate for use as grid elements in the electron optical system. The apparatus for forming the cathode and grid wires are expedients which are not specifically parts of the present invention but are utilized therein to facilitate the production of our tube. As indicated the cathode and grid sections are made of tungsten however other suitable metals may be utilized.

Another novel feature of construction of the present invention relates to insulating member 11 which is supported on metal member 53. Briefly, the process involves silver soldering or fusing by copper brazing or otherwise the ceramic member 11 to the dish-shaped metal hat 12 and dish-shaped metal piece 53. In order that a satisfactory metal to ceramic bond be insured and that said bond be insured between metals and ceramics of widely different thermal expansion characteristics, the metal pieces in the region in contact with the ends of the ceramic are serrated in such a manner as to form finger pieces or small areas of metal in contact with the ceramic so that the stresses resulting from thermal expansion mismatches of the metal and ceramic do not exceed the rupture strength of the ceramic material. This facilitates the making of accurate insulated parts or support structures. The strength of such a metal to ceramic bond or seal is sufficiently great that the grid support 12 may be mounted in a machine and so mounted with respect to the mounting notches 9 that the ledge 83 of metal part 53 joins through ceramic 11 to hat 12 and may be directly machined to critical diameters and face shaped. This procedure greatly simplifies accurate mounting of the grid hat 12 with respect to central conductor 13.

The seal at 28 is mounted in the tube in a manner utilizing high frequency induction welding and covered by a co-pending application filed by L. P. Garner and W. N. Parker and bearing Serial Number 17,824, filed March 30, 1948.

The intensely cooled anode 4 as previously described is so constructed that the outer extension 21' may be made of the same piece of copper as the intensely cooled bombarded region 4 in which the cavities 14 are formed. The thin wall tubular extension 21' is made to fold back around region 42 as indicated (Figures 2 and 3). It may be seen with reference to Figure 2 that the external anode water connecting and directing system 38, 39, 49 and water partition 44 are mounted together in such a way that they need not be installed until the tube has been processed and is ready for operation. The header 49 is seen to be connected by bolts 133 secured by nuts 134 to steel ring 135 silver soldered to cylinder 201 adjacent the upper end thereof. A copper ring 136 is silver soldered to steel ring 135 and to cylinder 21. A rubber or cork gasket 137 between ring 136 and header 49 serves to make the seal watertight. Prior to the assembly of the header 49 to cylinder 21 a flange (not shown) may conveniently be utilized to close the end of cylinder 21 during processing of the tube or the anode water

cavity may be evacuated with header 49 in place. An auxiliary jacket 138, the lower end of which may be connected to ring 23, is provided around the upper portion of cylinder 21 and has an inlet 139 and outlet 140. During a late stage of the vacuum processing when the cathode strands or sections are heated and the anode surface is heated by radiation from the cathodes, the anode temperature rises to approximately 800° C. To avoid deleterious oxidation of the outer surfaces of the anode and adjacent parts this is carried out in a vacuum or a non-oxidizing atmosphere. Heat radiated from the anode heats up cylinder 21 and by circulating coolant through jacket 138 rupture of the anode terminal seal is prevented. Also the silver solder joint between cylinder 21 and extension 21' is kept from being melted by the heat by providing cooling at the upper end of cylinder 21. When a vacuum obtains in the anode water cooling region the anode is protected against collapse as a result of the difference between the internal low pressure and external atmospheric pressure which otherwise would be present.

In processing the tube illustrated, the lower end of cylinder 13 is connected to a vacuum pump and the interior electron region is evacuated. The cathode wire sections are flashed at somewhat below operating temperature for short intervals and then the tube is placed in a vacuum oven for bake-out where the temperature is gradually raised to 400° C. and maintained for several hours. The temperature is then gradually lowered to room temperature and water is admitted through inlet 32, following which the anode is processed as described above. After the anode has cooled, header 49, etc. is installed and the cathode is heated to somewhat above operating temperature. Further out-gassing is then carried on by the conventional method of electron bombardment of the grid and anode. Finally the tube may be sealed by pinching off metal tube 47 as indicated in U. S. Patent No. 2,427,597 issued to L. P. Garner.

A tube having the following internal spacings and with forty-eight discrete cathode sections and forty-eight discrete grid sections having an approximate active length of 7.5 inches when tested by us had a power output of 500,000 watts with a plate voltage of 20,000 v., driving power 1,000 watts, and cathode heating power 13,000 watts. The anode active surface was spaced 0.320 inch from the beam former (protruding surfaces) while the beam former channels 2a were 0.100 inch in width. The active surface of each cathode section was 0.056 inch in width and set back in its beam former channel to a depth of 0.25 inch. Each grid section was 0.062 inch thick in the direction toward the anode and spaced 0.030 inch from the beam former.

The glass envelope, together with means for mounting and constructing the same, may employ ordinary conventional glass blowing practice employed in the manufacture of envelope glass-to-metal seals. We prefer to form each of the cylinders 15 or 50 from a pair of glass spools. They are constructed, however, in such a way that conventional glass blowing practice of jigging is used only in glassing the metal to one end of a glass spool at a time, the other end of each glass spool remaining unattached until later when the free ends of glass of each spool are joined to form cylinder 15 or 50 while the metal flanges associated with each of the unattached glass spools are held in a precision jig

which guarantees extraordinary accurate joining of the glass spools to insure that the metal flanges are parallel, concentric and/or coaxial. This jiggling device consists essentially of flanges to which the envelope flanges are rigidly mounted, said jiggling flanges being supported on a central rod or mandrel which is held in a single glass lathe chuck. By utilizing the mandrel to guarantee coaxial and parallel condition of the envelope flanges rather than two glass lathe chucks, it is possible to achieve a substantially higher degree of accuracy in the mechanical physical location of the flanges than could be achieved through the use of current glass lathe techniques. After the flanges have been glassed and the two flanged members joined, the sealed edges of the flanges 16, 19, 20 and 22 are lapped to guarantee sufficient flatness to avoid warping and consequent breaking of glass during the subsequent mounting operation which involves bolting the insulating spool flanges to lead rings.

Though we have described our invention with respect to the specific tube illustrated we do not desire to be limited thereto since various modifications within the spirit and scope of our invention may be made thereto. As for example, the cathode and grid sections though having been shown as flexibly mounted at one end and inflexibly at the other may also be flexibly mounted at both ends. Furthermore, instead of positioning the cathode centrally and the anode as the outermost electrode their order may be reversed and the anode may be centrally located. Other modifications also readily suggest themselves, each of the electrodes may be arranged in single planes, and therefore the foregoing are offered by way of illustration and not by way of limitation. Therefore, while our invention is subject to obvious modifications by those skilled in the art, it is intended to cover all such modifications as come within the scope of the appended claims.

We claim:

1. An electron discharge device, comprising an electrode having an array of mechanically separate elements, a control electrode having an array of mechanically separate elements, and a mount for said electrodes including resilient means for independently tensioning each element of said electrode and each element of said control electrode.

2. An electron discharge device, comprising a pair of supporting conductors in spaced apart relation, one of said supporting conductors having a plurality of channels formed therein, an electrode having a plurality of discrete spaced apart elements one in each of said channels and connected adjacent one end thereof to said supporting conductor, flexible means removably connected to each of said elements adjacent the other end thereof and supported on the other of said conductors, and resilient means on said channeled conductor and in engagement with said flexible means.

3. An electron discharge device, comprising a supporting conductor having a plurality of channels formed therein, an electrode having a plurality of discrete spaced apart elements one extending through each of said channels and connected adjacent one end thereof to said supporting conductor, and means separately and independently tensioning each of said elements adjacent the other end thereof.

4. In an electron discharge device, a pair of supporting conductors in spaced apart relation, one of said supporting conductors having a plu-

rality of channels formed therein, an electrode having a plurality of discrete spaced apart elements one extending through each of said channels and connected adjacent one end thereof to said supporting conductor, flexible means removably connected to each of said elements adjacent the other end thereof and supported on the other of said conductors, resilient means supported on said channeled conductor and insulatingly engaging said flexible means, and means insulatingly connecting and spacing said conductors.

5. In an electron discharge device, in combination, a beam forming electron optical system interposed between a cathode and an anode and a flexible pantographic mounting mechanism for said cathode.

6. In an electron discharge device, in combination, a beam forming electron optical system interposed between a cathode and an anode, a flexible mounting mechanism for said cathode, said cathode being composed of separately mounted discrete elements, each of said elements adjacent the ends thereof being removably connected to said mounting mechanism through a slot formed therein, and resilient means for maintaining each of said elements taut under all conditions.

7. In an electron discharge device, an electrode having an array of discrete spaced apart elements, coaxial and concentric liquid cooled supporting conductors in spaced apart relation, flexible means connected to each of said elements and to one of said supporting conductors, resilient means on the other of said supporting conductors and in engagement with said flexible means, each of said sections being connected to said other supporting conductor at a point remote from said flexible means, and a partition positioned in the space between said supporting conductors and coaxial therewith.

8. An electron discharge device, comprising an electrode having an array of discrete elements, coaxial and concentric liquid cooled supporting and conducting members in spaced apart relation, flexible means supporting each of said sections and supported on the inner one of said members, resilient means on the outer member and in engagement with said flexible means, each of said sections being connected to the outer member at a point remote from said flexible means, and a partition positioned in the space between said members and coaxial therewith, said outer member having an inlet and outlet communicating with the channels formed by said partition, said inner member having channels therein adjacent said flexible means and communicating with the channels between the inner and outer members for conducting heat away from said flexible means.

9. An electron discharge device, comprising coaxial and concentric liquid cooled supporting conducting members, the outer member having a plurality of channels formed therein, an electrode having a plurality of discrete elements one extending through each of said channels and connected adjacent one end thereof to said outer member, a plurality of mutually independent flexible means one for each of said sections and supporting the same adjacent the other end thereof, said flexible means being supported on said inner member, a plurality of resilient means on said outer member one for each of said flexible means and engaging the same, a partition positioned in the space between said members and coaxial therewith, said outer member having an inlet and outlet communicating with the chan-

nels formed by said partition, and said inner member having channels therein adjacent said flexible means and communicating with the channels between the inner and outer members for conducting heat away from said flexible means.

10. In an electron discharge device, a cathode having a circular array of a plurality of elongated discrete and separate elements, a grid having an array of a plurality of elongated discrete and separate elements concentric with said cathode, and a beam forming conducting member electrically connected to the cathode and having a plurality of channels formed in its surface one for each of said cathode elements, each of said cathode elements extending through one of said channels, and said grid elements being angularly radially offset from said cathode elements.

11. An electron discharge device, comprising a circular array of a plurality of discrete cathode elements, inner and outer coaxial conducting supporting members, a circular array of a plurality of flexible means mutually independent at the end thereof where each one supports one of said cathode elements, said flexible means being supported on said inner member, each of said elements being connected to the outer member at a point remote from said flexible means, a circular array of tubular members supported on said outer member adjacent the flexible means, and a plurality of resilient means one in each of said tubular members and engaging one of said flexible means.

12. An electron discharge device, comprising a circular array of a plurality of discrete cathode elements, inner and outer coaxial conducting supporting members, a circular array of a plurality of flexible means mutually independent at the end thereof where each one supports one of said cathode elements, said flexible means being supported on said inner member, each of said elements being connected to the outer member at a point remote from said flexible means, said outer member having a recessed portion forming a shoulder adjacent said flexible means, a circular array of a plurality of tubular members one for each of said flexible means and positioned on said shoulder, a plurality of resilient means one in each of said tubular members, and insulating members one slidable in each of said tubular members, said resilient means urging said insulating members against said flexible means.

13. An electron discharge device, comprising a cathode forming a circular array and composed of a plurality of individual elements, water cooled coaxial and concentric supporting conductors, a plurality of flexible means one individually supporting each of said cathode elements and supported on the inner one of said conductors, each of said elements being connected to the outer conductor at a point remote from said flexible means, said outer member having a recessed portion forming a shoulder adjacent said flexible means, a circular array of tubular members on said shoulder one for each of said flexible means and connected to said outer conductor, a plurality of resilient means one on each of said tubular members and each engaging one of said flexible means, means insulatingly connecting and spacing said conductors at the ends thereof adjacent said flexible means, and an axially flexible conducting diaphragm connected to said inner conductor adjacent the other end thereof and insulatedly supported from said outer conductor.

14. An electron discharge device, comprising a cathode and grid structure each forming a circular array and concentrically mounted, said cathode and grid each being composed of a plurality of individual bar-shaped elongated elements, and means individually tensioning each element of said cathode and each element of said grid.

15. An electron discharge device, comprising a plurality of elongated bar-shaped individual cathode elements arranged in a circular array, a plurality of elongated bar-shaped individual grid elements arranged in a circular array concentric with said cathode elements, and means individually and independently tensioning each of said cathode and grid elements in the direction of their longitudinal axis.

16. An electron discharge device, comprising a pair of coaxial and concentric supporting conductors, a plurality of elongated individual cathode elements, means readily removably connected to each of said elements adjacent the ends thereof and connected to said conductors for tensioning said elements longitudinally, a plurality of elongated individual grid elements in spaced relation with said cathode elements, a grid support member insulated from and supported on one of said conductors, each of said grid elements being supported by said grid support member adjacent one end thereof, and resilient means readily releasably connected to each of said grid elements adjacent the other end thereof for tensioning the same.

17. An electron discharge device, comprising a pair of coaxial and concentric supporting conductors, a plurality of elongated spaced apart cathode elements, means quick detachably connected to each of said cathode elements adjacent the ends thereof and connected to said conductors and tensioning said cathode elements longitudinally and supporting the same in a cylindric array, a plurality of elongated spaced apart grid elements, a grid support member insulated from and supported on one of said conductors, each of said grid elements being supported by said grid support member adjacent one end thereof, a grid terminal, and resilient means supported from said grid terminal and quick detachably connected to each of said grid elements adjacent the other end thereof for tensioning and positioning the same in spaced relation to said cathode elements.

18. An electron discharge device, as described in claim 17, wherein said resilient means comprises a plurality of spaced resilient members readily removably connected to said grid terminal.

19. An electron discharge device, as described in claim 17, wherein said resilient means comprises a plurality of spaced resilient members one for each of said grid sections and releasably clamped in circular array to said grid terminal.

20. An electron discharge device, comprising a pair of coaxial concentric hollow supporting conductors, a plurality of elongated spaced apart cathode elements each individually quick detachably flexibly supported on said conductors, a grid support including an insulating member removably supported on one of said conductors, a grid terminal, a plurality of spaced apart resilient members releasably supported from said grid terminal, a plurality of elongated spaced apart grid elements equal in number to said cathode elements and each individually quick

detachably flexibly supported by said grid support and said resilient members.

21. An electron discharge device, as described in claim 20, wherein said grid support further comprises an apertured cup shaped member having an outward extending peripheral flange, said insulating body has an aperture therethrough in registration with the aperture in said cup shaped member, and a shield is supported on said cup shaped member and connected thereto which closes said apertures and is adapted to form an ion barrier.

22. An electron discharge device, as described in claim 21, wherein a second shield is connected to said cup shaped member, surrounds said peripheral flange, and extends to the active region of the device, said shields being electrically connected to said grid elements.

23. An electron discharge device, comprising a reentrant anode having an end thereof turned back upon itself, a hollow anode conductor coaxial with said anode and connected to said turned back portion, a header connected to said anode conductor, a cooling fluid partition depending from said header and extending between said reentrant anode and said conductor, said anode having channels formed therein and communicating at one end with the region between the anode and the partition and at the other end communicating with the region between said partition and said conductor.

24. An electron discharge device, comprising a reentrant anode having a closed end and the other end turned back upon itself, an anode conductor coaxial with said anode and sealed to said turned back portion, a header demountably connected to said anode conductor, a cooling fluid partition depending from said header and extending between said reentrant anode and said conductor, said anode having channels formed therein along at least a portion of its inactive surface, said partition snugly surrounding said anode so as to close all but the ends of said channels, said channels communicating at one end with the region between the anode and the partition and at the other end communicating with the region between said partition and said conductor.

25. In an electron discharge device, in combination, a beam forming electron optical system interposed between a cathode and an anode, said optical system including beam forming cavities into which sections of the cathode are positioned within the protruding edges of the beam forming elements, a sectionalized grid the sections of which have a thin edge formed by an acute angle with the surface opposing the beam former, said thin edge being positioned in a direction perpendicular to a line drawn between the cathode and the anode, thus minimizing electron collection by the grid elements.

26. An electron discharge device, comprising a plurality of spaced cathode elements, means movably supporting each of said cathode elements in a mutually independent array, an electron optical system including a beam former, said beam former having spaced recesses within which are located individual sections of the cathode, said beam former constituting means for focusing electrons.

27. An electron discharge device, comprising concentrically and coaxially arranged cathode, beam former, grid and anode structures forming cylindrical arrays, said cathode and grid each including a plurality of spaced elements, said elements and beam forming surfaces being of equal

number and the arrangement of the beam former being of intermediate diameter to the cathode array diameter and the grid array diameter, a pantograph for mounting said cathode, a pantograph for mounting said grid, means for cooling said anode, and an enclosing envelope for all of said electrode structures.

28. An electron discharge device, comprising concentrically and coaxially arranged cathode, beam former, grid and anode structures forming cylindrical arrays, said cathode and grid each including a plurality of spaced elements, said beam former having recesses with beam forming surfaces intermediate said recesses, said elements and beam forming surfaces being of equal number, one of said cathode elements being located in each of said recesses, the beam forming surfaces being of intermediate diameter to the cathode array diameter and the grid array diameter, each of said beam forming surfaces being angularly coincident to one of said grid elements.

29. An electron discharge device, comprising concentric cylindrical arrays of spaced cathode elements and spaced grid elements, a pantographic system independently supporting each element of said cathode array and each element of said grid array, an anode having a cylindrical surface which surrounds the cylindrical array of electrode elements, means for focusing the electron stream, and cooling means comprising a plurality of members forming channels through which a cooling liquid is circulated.

30. An electron discharge device comprising concentrically and coaxially arranged unitary structures including a cathode, beam former, grid and anode having progressively different diameters in the order mentioned, said cathode and said grid further comprising a plurality of mechanically independent elements.

31. An electron discharge device, comprising a beam forming electron optical element having a plurality of spaced cavities formed therein and interposed between a cathode and a grid, said cathode comprising a plurality of spaced elements which elements are out of round in cross section, each of said elements being mechanically independent of the others and confined within said spaced cavities.

32. An electron discharge device, comprising a beam forming electron optical element having a plurality of spaced cavities formed therein and interposed between a cathode and a grid, said cathode comprising a plurality of spaced elements one in each of said cavities which elements each have a trapezoidal cross section, said elements being mechanically independent of each other.

33. In an electron discharge device, in combination, a beam former integrated into an electrode system comprising a cathode, a grid and an anode so as to produce an electron optical system, the cathode and the grid each comprising a plurality of spaced and individually mounted elements, the cathode elements having an emitting surface at least on one side and constituting the source of an electron stream, the beam former being recessed intermittently so as to form spaced cavities into which the several cathode elements are dropped within the protruding edges of the beam forming elements, the grid elements being arranged and supported away from the beam former and without the electron stream.

34. In an electron discharge device as described in claim 33, wherein the beam forming element operates at substantially the potential of the cathode.

35. In an electron discharge device as described in claim 33, wherein each cathode element is trapezoidal in cross section and each grid element is triangular.

36. In an electron discharge device as described in claim 33, wherein each grid element is trapezoidal in cross section and the broadest surface thereof faces the beam former.

37. In an electron discharge device as described in claim 33, wherein each cathode element has a cross section with one side larger than the others and said larger side being disposed toward the opening of said beam former cavity.

38. In an electron discharge device as described in claim 33, each of said grid elements having one side broader than the others and disposed toward the beam former surface, each of the adjoining surfaces of the grid element being of less area than the surface opposing the beam former.

39. In an electron discharge device having at least two spaced apart terminals surrounding the same and sealed to conductors which extend into the device, an insulating member surrounding said device and having metallic flanges sealed thereto at the ends thereof, said insulating member being disposed between said terminals with each of said flanges opposed to one of said terminals, a metallic gasket softer than said terminals and flanges and interposed between each of said opposed terminals and flanges, the associated flanges and terminals having a plurality of aligned holes formed therethrough and in an endless array, each of said flanges having continuous endless bead portions projecting from the surface thereof, and in registration with said gaskets one being positioned inwardly of said holes and one outwardly, the bead portions on the flanges registering with the bead portions on the opposed terminals, a plurality of threaded means one extending through each of said holes, means in threaded engagement with each of said threaded means and applying sufficient pressure to said associated flanges, bead portions, gaskets and terminals to join them in airtight relation.

40. In an electron discharge device, as described in claim 39, wherein said threaded means further comprises bolts having red-hard characteristics capable of retaining a tensile stress of approximately 200,000 pounds per square inch while being baked at a temperature of approximately 450° C.

41. In an electron discharge device, as described in claim 39, wherein said threaded means further comprise bolts and wherein said terminals and said flanges are of lower expansion material than said bolts, and washers of sufficiently high expansion coefficient to substantially equalize the total expansion of said bolts with that of said terminals and flanges are interposed between each of the means in threaded engagement with said bolts and the flanges and terminals associated therewith.

42. In an electron discharge device, a terminal encircling said device, an insulating member forming part of the air-tight enclosure of said device and having at least one end provided with a flange sealed thereto, and means readily demountably sealing said insulating member to said terminal, said means comprising a second flange of thicker cross section than said first mentioned flange and sealed thereto, said second flange encircling said device and having an endless array of holes formed therein, a ring sealed to said terminal, said ring and said terminal having holes formed therein in registration with the holes in

said second flange, said second flange and said ring being in registration one with the other and having continuous complementary lands one inwardly of the array of holes and one outwardly thereof, one wire gasket between the complementary lands on said terminal and second flange, and a plurality of means extending through said aligned holes and maintaining said terminal and second flange under sufficient compression to form an airtight seal between said complementary lands and said wire gaskets.

43. In an electron discharge device having a ring-shaped terminal sealed through the airtight envelope thereof, means readily removably connecting said terminal to said envelope comprising a pair of annular flanges one connected to each end of said envelope and in opposed relation, said terminal extending between said flanges, a pair of rings one sealed to each side of said terminal and in registration with one of said flanges, each of said rings being associated with one of said flanges, said associated rings and flanges having complementary lands formed therein which are in registration, a plurality of holes extending through said flanges, rings and terminal intermediate said lands, wire gaskets positioned between each of said complementary lands, and a plurality of means one extending through each of said holes and maintaining said flanges and rings under sufficient compression to form an airtight seal between said complementary lands and said wire gaskets.

44. An electron discharge device, comprising a plurality of tubular electrode lead-ins and supporting conductors, a gastight envelope, each of said supporting conductors forming a portion of said envelope and being coaxial and concentric one with the other, a plurality of discrete spaced elements forming a cathode and quick detachably connected to two of said supporting conductors, one of which has a plurality of channels formed in a surface thereof and each of the cathode elements extending in one of said channels, an anode connected to a third one of said supporting conductors and coaxial therewith, an annular grid terminal interposed in said envelope, a plurality of discrete spaced apart elements forming a grid electrode, and means connected to said grid terminal and one of said supporting conductors and quick detachably engaging and supporting each of said grid elements.

45. An electron discharge device, comprising three concentric coaxial supporting conductors, a gastight envelope, each of said supporting conductors forming a portion of said envelope, a cathode, grid and anode, said cathode and grid each comprising a plurality of discrete spaced apart elements, flexible means connected to the innermost of said supporting conductors, each of said cathode elements being quick detachably connected to said flexible means and to the middle one of the three supporting conductors, an annular grid terminal interposed in the envelope wall and surrounding at least the two innermost supporting conductors, additional flexible means connected to said grid terminal, grid support means on the innermost of said supporting conductors, each of said grid elements being quick detachably connected to said last mentioned flexible means and to said grid support means, and said anode being connected to the outermost of said supporting conductors.

46. An electron discharge device, comprising three concentric coaxial supporting conductors, a gastight envelope, each of said supporting con-

ductors forming a portion of said envelope, a cathode, grid and anode, said cathode and grid each comprising a plurality of discrete spaced part elements, flexible means connected to the innermost of said supporting conductors, each of said cathode elements being quick detachably connected to said flexible means and to the middle one of the three supporting conductors, an annular grid terminal interposed in the envelope wall and surrounding at least the two innermost supporting conductors, additional flexible means connected to said grid terminal, grid support means on the innermost of said supporting conductors, each of said grid elements being quick detachably connected to said last mentioned flexible means and to said grid support means, and said anode being connected to the outermost of said supporting conductors, said cathode, grid and anode extending in the region between the middle and outermost of said supporting conductors.

47. An electron discharge device, comprising three concentric coaxial supporting conductors, a gas-tight envelope, each of said supporting conductors forming a portion of said envelope, a cathode, grid and anode, said cathode and grid each comprising a plurality of discrete spaced apart elements, flexible means connected to the innermost of said supporting conductors, each of said cathode elements being quick detachably connected to said flexible means and to the middle one of the three supporting conductors, an annular grid terminal interposed in the envelope wall and surrounding at least the two innermost supporting conductors, additional flexible means connected to said grid terminal, grid support means on the innermost of said supporting conductors, each of said grid elements being quick detachably connected to said last mentioned flexible means and to said grid support means, and said anode being connected to the outermost of said supporting conductors, said cathode, grid and anode extending in the region between the middle and outermost of said supporting conductors, said middle supporting conductor having a plurality of channels formed therein and extending longitudinally thereof, each of said cathode elements extending through one of said channels.

48. An electron discharge device, comprising an envelope, a central tubular supporting conductor forming a portion of said envelope, a cathode and grid each comprising a plurality of discrete spaced apart elements in circular array, means supported on said central supporting conductor and quick detachably connected to each of said cathode and grid elements, another tubular supporting conductor coaxial with said central supporting conductor and quick detachably connected to each of said cathode elements, an annular grid terminal interposed in the envelope wall, means connected to said grid terminal and quick detachably connected to each of said grid elements, an outer tubular supporting conductor coaxial with said central supporting conductor, and an anode connected to said outer supporting conductor.

49. An electron discharge device, comprising an envelope, a central tubular supporting conductor forming a portion of said envelope, a cathode and grid each comprising a plurality of discrete spaced apart elements in circular array, means supported on said central supporting conductor and quick detachably connected to each of said cathode and grid elements, another tubular sup-

porting conductor coaxial with said central supporting conductor and quick detachably connected to each of said cathode elements, an annular grid terminal interposed in the envelope wall, means connected to said grid terminal and quick detachably connected to each of said grid elements, an outer tubular supporting conductor coaxial with said central supporting conductor, and an anode connected to said outer supporting conductor, said other supporting conductor having a plurality of longitudinal channels formed therein, said cathode elements extending in said channels but out of contact with said other supporting conductor in the region of said channels.

50. An electron discharge device, comprising an envelope, a central tubular supporting conductor forming a portion of said envelope, a cathode and grid each comprising a plurality of discrete spaced apart elements in circular array, means supported on said central supporting conductor and quick detachably connected to each of said cathode and grid elements, another tubular supporting conductor coaxial with said central supporting conductor and quick detachably connected to each of said cathode elements, an annular grid terminal interposed in the envelope wall, means connected to said grid terminal and quick detachably connected to each of said grid elements, an outer tubular supporting conductor coaxial with said central supporting conductor, and an anode connected to said outer supporting conductor, said other supporting conductor having a plurality of longitudinal channels formed therein, said cathode elements extending in said channels but out of contact with said other supporting conductor in the region of said channels, said anode and said outer supporting conductor also forming a part of said envelope.

51. An electron discharge device, comprising an envelope, a central tubular supporting conductor forming a portion of said envelope, a cathode and grid each comprising a plurality of discrete spaced apart elements in circular array, means supported on said central supporting conductor and quick detachably connected to each of said cathode and grid elements, another tubular supporting conductor coaxial with said central supporting conductor and quick detachably connected to each of said cathode elements, an annular grid terminal interposed in the envelope wall, means connected to said grid terminal and quick detachably connected to each of said grid elements, an outer tubular supporting conductor coaxial with said central supporting conductor, and an anode having a portion turned back upon itself and joined to said outer supporting conductor, said anode and said outer supporting conductor also forming a part of said envelope.

52. An electron discharge device, comprising an envelope, a central tubular supporting conductor forming a portion of said envelope, means sealing one end of said central supporting conductor in gastight manner, a cathode and grid each comprising a plurality of discrete spaced apart elements in circular array, flexible means connected to said central supporting conductor and quick detachably connected to each of said cathode elements, grid support means connected to the other end of said central supporting conductor and including a pair of dish-shaped members with their concave surfaces opposed, said dish-shaped members having central apertures formed therethrough, the inner portions of said dish-shaped members being serrated, an insulating member joined to said serrated portions, and

spacing said dish-shaped members, one of said dish-shaped members having a peripheral flange with a plurality of notches formed therein, an annular grid terminal interposed in the envelope wall, flexible means connected to said grid terminal and quick detachably connected to each of said grid elements, each of said grid elements also extending through one of said notches and quick detachably connected to said peripheral flange, another tubular supporting conductor coaxial with said central supporting conductor and insulatedly connected to the same, each of said cathode elements also being quick detachably connected to said other supporting conductor, an outer tubular supporting conductor coaxial with said central supporting conductor, and an anode connected to said outer supporting conductor, said cathode elements, grid elements and anode extending in the region between said outer and said other supporting conductors.

53. An electron discharge device, comprising an envelope, a central tubular supporting conductor forming a portion of said envelope, means sealing one end of said central supporting conductor in gastight manner, a cathode and grid each comprising a plurality of discrete spaced apart elements in circular array, flexible means connected to said central supporting conductor and quick detachably connected to each of said cathode elements, grid support means connected to the other end of said central supporting conductor and including a pair of dish-shaped members with their concave surfaces opposed, said dish-shaped members having central apertures formed therethrough, the inner portions of said dish-shaped members being serrated, an insulating member joined to said serrated portions and spacing said dish-shaped members, one of said dish-shaped members having a peripheral flange with a plurality of notches formed therein, an annular grid terminal interposed in the envelope wall, flexible means connected to said grid terminal and quick detachably connected to each of said grid elements, each of said grid elements also extending through one of said notches and quick detachably connected to said peripheral flange, another tubular supporting conductor coaxial with said central supporting conductor and insulatedly connected to the same, said other supporting conductor having a plurality of elongated channels formed along a surface thereof, each of said cathode elements also being quick detachably connected to said other supporting conductor and extending in said channels, the other of said dish-shaped members having a peripheral shoulder, means connecting said shoulder to said central supporting conductor and aligning said notches with the intervals between said channels, an outer tubular supporting conductor coaxial with said central supporting conductor, and an anode connected to said outer supporting conductor, said cathode element, grid elements and anode extending in the region between said outer and said other supporting conductors.

54. An electron discharge device, comprising an envelope, a central tubular supporting conductor forming a portion of said envelope, a cathode and grid each comprising a plurality of discrete spaced apart elements in circular array, means supported on said central supporting conductor and quick detachably connected to each

of said cathode and grid elements, another tubular supporting conductor coaxial with said central supporting conductor and quick detachably connected to each of said cathode elements, an annular grid terminal interposed in the envelope wall, a plurality of spaced apart resilient means connected to said grid terminal and one quick detachably connected to each of said grid elements, an outer tubular supporting conductor coaxial with said central supporting conductor, and an anode connected to said outer supporting conductor.

55. An electron discharge device comprising a gastight envelope, a pair of tubular coaxial electrode lead-ins and supporting conductors forming a portion of said envelope and mounted one within the other, means joining said supporting conductors adjacent one end thereof in insulated gastight relation, a cathode having a plurality of discrete spaced apart elements, flexible means connected to the central one of said supporting conductors and quick detachably connected to each of said cathode elements, each of said cathode elements also being quick detachably connected to the other of said supporting conductors, an annular cathode terminal sealed to the other of said supporting conductors and coaxial therewith, a tubular anode lead-in and support coaxial with said supporting conductors and surrounding the same, a tubular anode closed at one end and sealed to said anode lead-in and support at its other end, said anode extending within said anode lead-in and support and surrounding said supporting conductors, an annular anode terminal sealed to said anode lead-in and support and coaxial therewith, an annular grid terminal encircling the other of said supporting conductors coaxial therewith and spaced therefrom, said grid terminal being intermediate said cathode and anode terminals, said envelope including means joining said terminals in gastight insulated relation, grid support means on one of said supporting conductors and insulated therefrom, a grid having a plurality of discrete spaced apart elements, each of said grid elements being quick detachably connected to said grid support means, and flexible grid support means connected to said grid terminal and quick detachably connected to each of said grid elements.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,572,721	Housekeeper	Feb. 9, 1926
1,944,190	Mouromtseff	Jan. 23, 1934
2,000,567	McCullough	May 7, 1934
2,130,280	Knoll	Sept. 13, 1938
2,160,086	Tonci et al.	May 30, 1939
2,229,957	Crawford	Jan. 28, 1941
2,312,350	Marshall et al.	Mar. 2, 1943
2,392,379	Hansen	Jan. 8, 1946
2,440,248	Chevigny	Apr. 27, 1948
2,449,256	Stevens	Sept. 14, 1948
2,451,987	Sloan	Oct. 19, 1948
2,462,569	Sziklai	Feb. 22, 1949