March 27, 1951 R. B. NELSON 2,546,773

ANODE STRUCTURE FOR SPACE RESONANT DISCHARGE DEVICES

Filed June 23, 1945 2 Sheets-Sheet 1

Fig. 1.

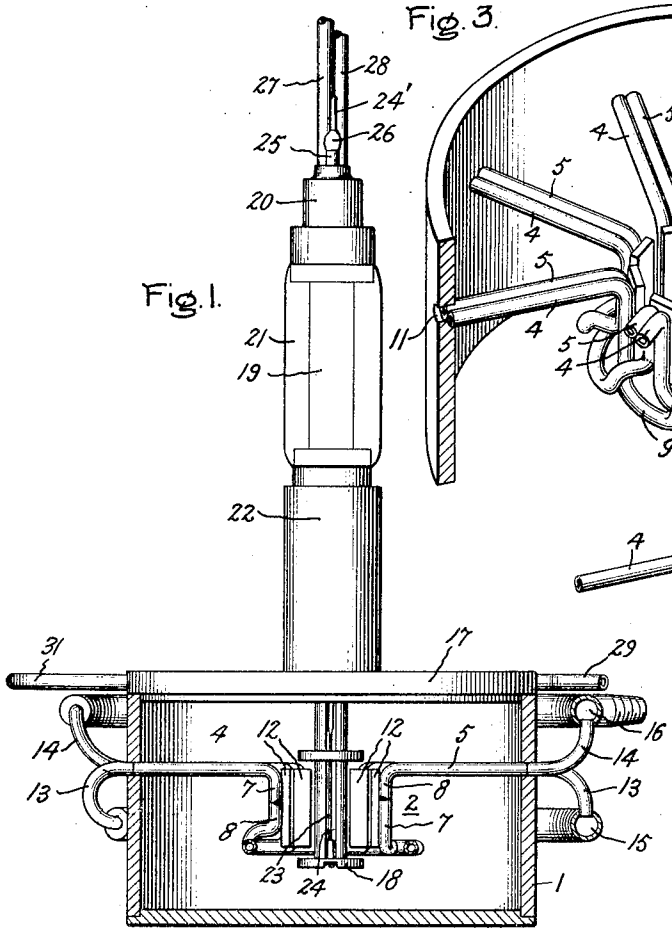


Fig. 3.

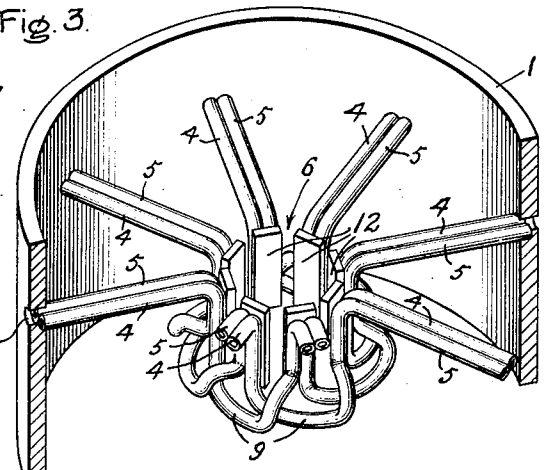


Fig. 4.

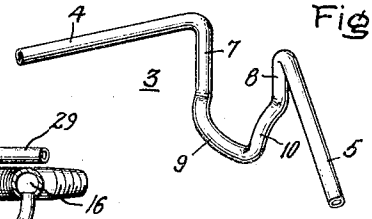
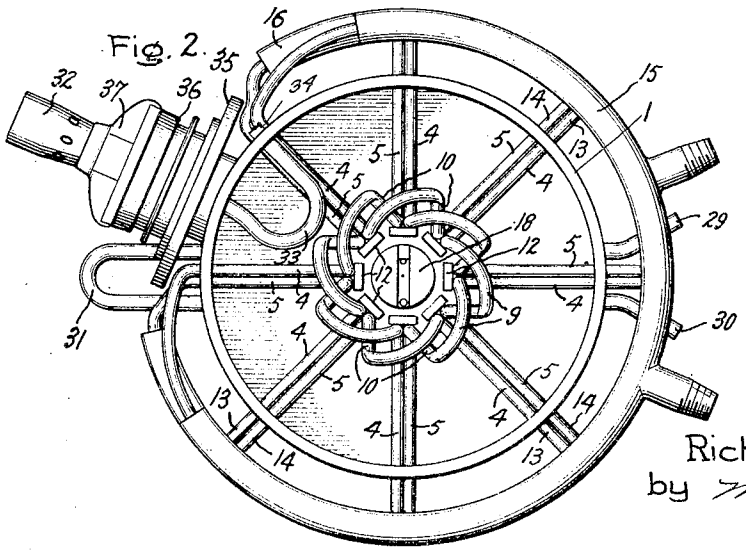


Fig. 2.



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Fig. 5.

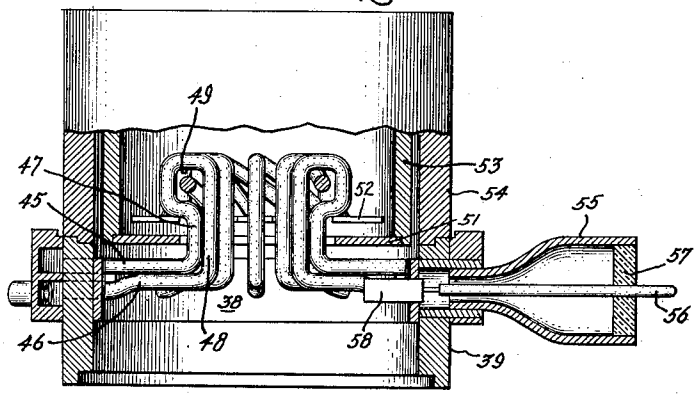
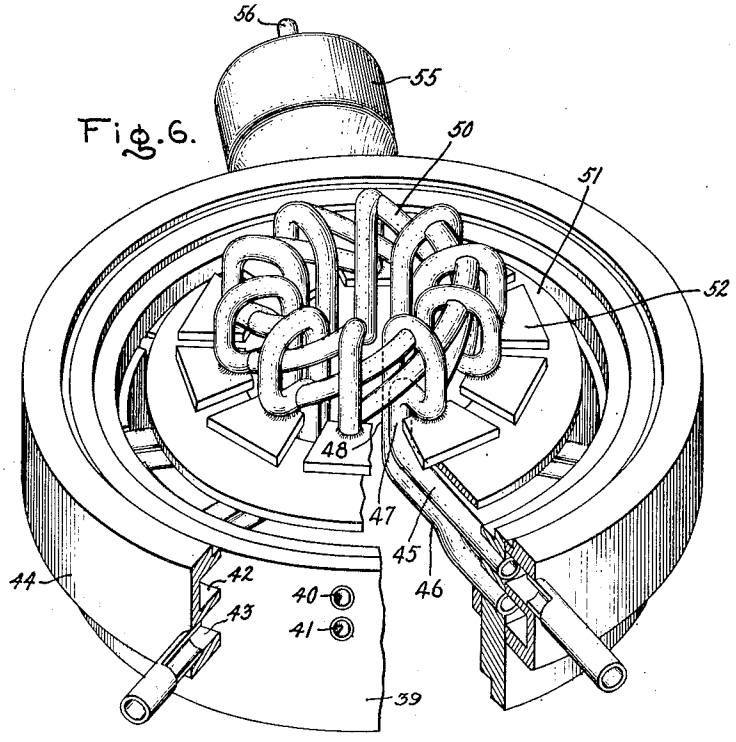


Fig. 6.



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ANODE STRUCTURE FOR SPACE RESONANT DISCHARGE DEVICES

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Application June 23, 1945, Serial No. 601,122

15 Claims. (Cl. 315—39)

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My invention relates to electric discharge devices and more particularly to improved resonant structures and methods of making the same. The invention is well adapted for application to electric discharge devices of the magnetron type.

Many magnetron constructions have been employed in which the anode includes a plurality of resonant or tuned circuits arranged in symmetrical relation about a central opening in which the cathode of the device is located. Many of these anodes have been formed by machining suitable openings in a copper block in such a manner that the bounding surfaces of the openings provide the tuned circuits of the anode. These anodes have required a considerable amount of accurate machining and in addition have not been capable of dissipating large amounts of heat.

In accordance with the teachings of my invention, I provide an improved resonant structure, particularly adapted for the anode structure of a magnetron, which is preferably formed of a plurality of elements of tubing which are shaped so that they may be assembled to provide an array of tuned circuits about a centrally located opening which is adapted to receive a cathode.

It is an object of my invention to provide a new and improved electrode structure including a plurality of coupled tuned circuits.

It is another object of my invention to provide a new and improved anode structure for electric discharge devices of the magnetron type which is simple in construction and which may be readily cooled by the passage of cooling fluid therethrough.

It is still another object of my invention to provide a new and improved method of assembling resonant structures from a plurality of similar pre-formed elements.

In one illustrated embodiment of my invention a plurality of identical elements of copper tubing are bent in such a form that each element forms a portion of the bounding surfaces of adjacent tuned circuits in the assembled anode. The number of elements employed is equal to the number of tuned circuits in the anode structure and these elements are assembled to provide a circular array of tuned circuits about a central opening which is adapted to receive the cathode. The alternate anode sections are connected by conducting straps which form a portion of the individual elements from which the anode is assembled. The anode structure is mounted within a suitable envelope, such as a copper cylinder, and the ends of each of the elements employed in making up the anode assembly extend through

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the side wall of the envelope and communicate with suitable headers in such a manner that cooling fluid may be circulated through all of the tubing employed in the anode assembly. It is apparent that this construction avoids the necessity of accurate machining and facilitates cooling of the anode structure. In accordance with another illustrated embodiment of my invention, each anode section is formed of a length of tubing which is bent back upon itself and into a substantially L-shaped section. These pieces of tubing are then assembled in a cylindrical member which forms a part of the tube envelope with the open ends communicating with a header surrounding the envelope and with the L-shaped sections lying in equally spaced radial planes within the envelope.

For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims. In the drawing, Fig. 1 is an elevational view, partially in section, of a magnetron device embodying my invention; Fig. 2 is a bottom view of the magnetron illustrated in Fig. 1 with the lower end wall removed; Fig. 3 is a perspective view, partially in section, of a portion of the device shown in Fig. 1 and illustrating the details of construction of the anode assembly; Fig. 4 is a perspective view of one of the several identical tubular elements from which the anode is assembled; Fig. 5 is an elevational view, partially in section, of a modification of my invention, and Fig. 6 is a perspective view of a part of the assembly of Fig. 5.

Referring now to the drawing, I have shown my invention embodied in a magnetron including a generally cylindrical envelope 1, preferably formed of good conducting material such as copper. Within the envelope 1 is an anode structure designated generally by the numeral 2 and comprising an assembly of pre-formed members 3 of rod-like stock, such as copper tubing. These members, as illustrated in Fig. 4, include a pair of arms 4 and 5 lying in a common plane and extending radially from a center which coincides with the center of the aperture 6 of an anode assembled from a plurality of the individual elements 3. Extending at right angles from the plane of the arms 4 and 5 are arms 7 and 8, respectively, which in the assembled anode form axially extending parts of alternate anode segments facing the central opening of the anode. The element 3 is completed by an arcuate section 9 and an offset portion 10 connecting the ends of

the arms 7 and 8. The element 3 thus comprises a single piece of tubing bent to form two radial arms which are spaced by an angle equal to twice the angle between adjacent tuned circuits in the anode assembly. As clearly shown in Fig. 3, the elements 3 are arranged in a circular array with the corresponding arm of each successive element displaced by an angle equal to half the angle between the arms of a single element. With the elements thus arranged, a circular assembly results in which the arms of two elements lie adjacent one another at a number of equally spaced points equal to the number of elements employed. In the illustrated embodiment, eight elements are employed and the resultant structure includes eight tuned circuits. It will be apparent from the foregoing that the circuits are uniformly spaced in a circular array and each spans an angle of 360° divided by the number of circuits. Since the arms of each element are spaced by twice the angle spanned by the individual circuits, the spacing of the arms is

$$\frac{720°}{n}$$

where n is the number of circuits. As is well understood by those skilled in the art, the arms 4 and 5 provide the predominately inductive reactive component of each of the tuned circuits, while the portions 7 and 8 of adjacent circuits, which are closely spaced about the central opening 6, form the predominately capacitive portions of each of the tuned circuits. In accordance with the improved method of my invention the anode structure is assembled by placing the individual elements 3 in the envelope 1 with the ends of the arms 4 and 5 received in suitable openings 11 formed in the wall of the envelope. The elements are positioned by means of a jig which holds the elements in accurately assembled relation with respect to one another and with respect to the wall of the envelope. While held in this manner the elements are soldered along the junction of the adjacent arms 4 and 5 and 7 and 8 to form a relatively rigid unitary final structure.

In the illustrated embodiment, in order to render the central space more symmetrical, rectangular copper bars 12 have been soldered to the faces of the adjacent arms 7 and 8. While providing a smooth surface for the anode faces in this manner has been found desirable, it is not essential to the satisfactory operation of the device. Also, as clearly shown in Figs. 2 and 3, the arcuate portions 9 and offset portions 10 of each of the elements 3 connect the alternate anode sections with one another progressively around the anode structure. These connections, commonly known as straps, render operation of the device in the desired mode more stable; the desired mode being a resonant condition in which alternate anode segments are at the same high frequency potential.

In order to provide for cooling of all of the anode elements 3, the ends of the arms 4 and 5 of these elements, which terminate in the wall of envelope 1, are connected by elbows 13 and 14, respectively, with headers 15 and 16. It is apparent that cooling fluid introduced into one of the headers passes through the elements 3 in parallel and is collected in the other header.

In the embodiment of my invention illustrated in the drawing, a source of electrons for exciting the resonant anode structure 2 is provided by a generally cylindrical cathode 18 which is positioned centrally in the opening 6 of the anode

structure and supported from the cover plate 17 of the envelope by a tube 19, of steel or other suitable material, which is secured to the upper end of the cathode and to a terminal 20. The terminal 20 is sealed to the upper end of a hollow insulator 21, preferably formed of glass, the lower end of which is sealed to an upstanding flange 22 formed on the cover 17. Although the particular form of cathode employed is not important to the present invention, it may to advantage be of the type described and claimed in the copending Blewett and Langmuir application Serial No. 555,496, filed September 23, 1944, which issued on Jan. 25, 1949, as Patent No. 2,460,119 and assigned to the assignee of the present invention. The cathode 18 may to advantage have at least a surface portion thereof formed of material which is a good secondary emitter such as magnesium or an alloy which is predominately magnesium. A source of primary electrons is provided by a thermionic cathode element 23 positioned in an axially extending recess 24 formed in the surface of the cathode member 18. The lower end of thermionic cathode member 23 is secured to the lower end of the cathode and the upper end is connected with a lead-in conductor 24' which is supported in insulated relation with respect to a supporting tube 25 by a body of glass 26. A pair of conduits 27 and 28 extending into the tube 19 provide means for circulating cooling fluid through the cathode 18 in the manner described more in detail in the above identified Blewett and Langmuir application. The supporting tube 25 and conductors 27 and 28 are all sealed to the terminal 20.

The cover 17 of the envelope may also be fluid cooled, if desired, and in the drawing the conduits 29 and 30 communicate with passages in the cover 17 which are interconnected by a U-shaped conduit 31.

In order that high frequency energy may be extracted from the device, I provide an output circuit including a concentric transmission line including an outer conductor 36 and an inner conductor 32 which terminates in a U-shaped loop 33 positioned to link the flux threading one of the openings in the anode structure defined by adjacent radial arms of the structure. As illustrated in the drawing, the loop may be formed of hollow tubing and have the end thereof extend through the wall of the envelope to provide an externally accessible conduit 34 through which cooling fluid may be introduced. The output transmission line and coupling loop are supported from the side walls of the envelope by a suitable flange 35 to which is secured a fitting 36 which is, in turn, sealed by a body of glass 37 to the inner conductor 32 of the transmission line.

While the operation of the illustrated embodiment of my invention described above is believed to be well understood, it may be described briefly as follows. Electrons emitted by the cathode 18 and the thermionic cathode 23 travel in curvilinear paths in the space between the cathode and the faces 12 of the various anode sections. The curvilinear motion of the electrons is dependent upon the resultant action of an electric field produced by a direct current voltage impressed across the anode-cathode circuit of the device and an axial magnetic field produced in the interelectrode space by suitable permanent or electromagnets. The motion of the electrons constituting the space charge is effective to excite the resonant anode structure at a frequency determined by the geometry of the structure to produce high fre-

quency oscillating currents in the conductive elements of the various tuned circuits forming the anode structure and to produce a high frequency electromagnetic field passing through the openings defined by the various radial arms of the anode structure. Energy is extracted from this high frequency field by the output loop 33 which is coupled to the field linking one of the tuned circuits of the anode structure.

It will be apparent that the anode structure described above may be readily assembled by relatively unskilled labor once suitable jigs for forming the individual elements and positioning the elements in the assembly are available. It is also apparent that the resonant structure may be very effectively cooled by passing cooling fluid through the various pre-formed elements of tubing with the result that the power rating of the device is increased for a given size.

In Figs. 5 and 6 I have shown another embodiment of my invention in which the coupled resonant anode circuits are defined by a plurality of similar vanes or anode sections, each of which is of generally L or J-shaped cross section. As shown in the drawing, the anode sections 38 are supported from a generally cylindrical member 39 which forms a part of the tube envelope in such a manner that the L-shaped sections lie in equally spaced radial planes. Each anode section is formed from a length of rod-like stock, such as copper tubing, which is bent back upon itself and into substantially L shape. As indicated clearly in Fig. 6, the open ends 40 and 41 of the tubing of each anode section lie adjacent one another and extend through the wall of the member 39 and into communication with passages 42 and 43 formed in a header 44 which surrounds the envelope member 39. The header may be formed in any suitable manner and, as illustrated, comprises a circular piece of copper stock in which the passages 42 and 43 are machined. In assembly the member 44 is brazed or otherwise bonded to the outer surface of the envelope member 39. Each of the anode sections includes adjacent radially extending arms 45 and 46 and axially extending arms 47 and 48. At the upper end of each section the axially extending arms 47 and 48 are separated to provide an opening 49. The provision of this opening eliminates a reverse bend in the tubing which would be apt to cause cracking in commercially available copper tubing. As clearly shown in Fig. 6, each anode section is connected with all of the alternate anode sections by a system of straps provided by conductors 50. Each conductor extends from a point above the opening 49 on one section through the opening 49 of the adjacent section to a point below the opening 49 on the next section. With such a system of strapping, the device operates with stability in that mode of oscillation in which alternate anode sections are at the same high frequency potential. In order to provide an extended area on each of the anode sections for cooperation with a tuning member or disk 51, I secure the trapezoidal members 52 to the lower side of each of the loops which define the openings 49. The members 52 all lie in a common plane perpendicular to the axis of the cylindrical envelope member 39.

As illustrated in Fig. 5, the tuning member is supported from a cylindrical member 53 which is arranged concentrically with the tube envelope. This member is joined in vacuum-tight and axially-movable relation with respect to the member

54 which forms an extension of the envelope member 39 in the manner described and illustrated in my copending application S. N. 601,123 filed concurrently herewith which issued on Feb. 7, 1950, as Patent No. 2,496,887 and assigned to the assignee of this invention. In the interest of simplifying the drawing, the lower end wall of the envelope has been omitted. It will be understood that this end wall will carry the cathode of the device in much the same manner as the upper end wall 17 carries the cathode of the modification illustrated in Figs. 1 and 2. High frequency electrical energy is extracted from the resonant anode structure of the device by a concentric transmission line connection including an outer conductor 55 connected with the envelope member 39, and an inner conductor 56 supported concentrically with the conductor 55 by a body of glass 57 and terminating at its inner end at a loop 58 which is joined to the radially extending portion of one of the anode sections 38.

The operation of the modification of my invention shown in Figs. 5 and 6 is the same as that described in connection with the modifications of Figs. 1–4, inclusive. Electrons emitted by a cathode received in the cylindrical space defined by the axially extending portions of the various anode sections move in curvilinear paths under the combined action of mutually perpendicular magnetic and electric fields to excite the resonant anode structure into high frequency electrical oscillation. The frequency at which the oscillations occur is determined by the geometry of the structure and the position of the tuning structure including the disk 51. The tuning structure and the manner in which it operates to control the operating frequency of the device is more fully described in my above-mentioned copending application. The members 53 and 54 of Fig. 5 correspond to members 44 and 45 of the tuning arrangement shown in that application.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention in its broader aspects, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. A space resonant structure including a plurality of tuned circuits arranged in circumferentially spaced relation about a central opening within which the electrons constituting the space charge for exciting the structure are adapted to move comprising a plurality of similar conducting elements of rod-like stock with each element including two arm portions extending at right angles to each other, said elements being supported in fixed relation in a circular array with one arm portion of each element extending radially in a plane common to the corresponding arm of the remaining elements and the other arm portion extending in the same direction from said plane as the other arm portions of the remaining elements to define the central opening of said structure.

2. An anode structure of the type including a plurality of tuned circuits arranged in spaced relation and communicating with an opening within which the electrons constituting the space charge for exciting the anode are adapted to move comprising a plurality of similar conducting elements of rod-like stock with each element

including arm portions spaced by twice the spacing of adjacent circuits, and means supporting the elements in fixed relative positions in an array with the corresponding arms of each element displaced progressively in the array by an amount equal to the spacing between adjacent circuits.

3. A space resonant structure including a plurality of tuned circuits arranged in circumferentially spaced relation about a central opening within which the electrons constituting the space charge for exciting the structure are adapted to move comprising a plurality of similar conducting elements of rod-like stock with each element including arm portions spaced circumferentially by an angle equal substantially to

$$\frac{720}{n} \text{ degrees}$$

where n is the number of tuned circuits of the anode structure, means supporting said elements in a circular array in fixed relative positions with the corresponding arms of each element displaced progressively in the array by an angle equal substantially to

$$\frac{360}{n} \text{ degrees}$$

4. A space resonant structure comprising a plurality of coupled resonant circuits supported in a circular array and defined by a plurality of similar elements of bent tubing including outwardly extending arms, and a pair of headers surrounding said array of circuits defined by said elements, said elements being supported in a circular array with the ends of said outwardly extending arms connected respectively with said headers.

5. A space resonant anode structure for an electric discharge device including an envelope and a pair of headers surrounding the anode structure, said anode structure comprising a plurality of coupled resonant circuits defined by a plurality of elements of bent tubing assembled in said envelope and supported in a circular array with each element including radially extending arms, the ends connected respectively with said headers.

6. An anode structure including a plurality of space-resonant circuits mounted in a circular array about an opening, said circuits being defined by a plurality of elements of tubing each including a pair of radially extending arms joined together by a connecting portion at the inner ends thereof providing a continuous passage between the outer ends of said arms, one of the arms of each of said elements being in a plane common to the corresponding arms of the remaining elements and with the connecting portions extending substantially perpendicular to said plane and defining gaps communicating with said opening.

7. An anode structure including a plurality of mutually spaced space-resonant circuits in a circular array about an opening and defined by anode sections comprising a plurality of elements of rod-like stock, each element having a pair of radial arms lying in one plane and connected together at their inner ends by a section extending substantially perpendicular to said plane and defining gaps communicating with said opening, said arms being spaced by an angle of

$$\frac{720}{n} \text{ degrees}$$

where n is the number of circuits and said elements being displaced angularly in the structure by an angle of

$$\frac{360}{n} \text{ degrees}$$

the connecting portions also providing conductive connections between alternate anode sections.

8. A space resonant anode structure including an array of space resonant circuits, said structure including a plurality of similar elements of rod-like stock having arms spaced apart a distance equal to a multiple of the distance between corresponding points on adjacent circuits in said array, said elements being mounted with corresponding arms displaced by a distance equal to the distance between corresponding points on adjacent circuits so that said anode structure includes a number of elements in overlapping relation.

9. An anode structure including a plurality of mutually spaced space-resonant circuits in circular array and defined by anode sections comprising a plurality of elements of tubing, each element having a pair of radial arms lying in one plane and connected together at their inner ends, said anode including a number of said elements equal to the number of circuits in the array with corresponding arms of adjacent elements displaced

$$\frac{360}{n} \text{ degrees}$$

where n is the number of elements employed, the connecting portions of the various elements providing a system of straps conductively connecting alternate anode sections.

10. An anode structure including a plurality of mutually spaced space resonant circuits in a circular array and defined by anode sections comprising a plurality of elements of rod-like stock, each element having a pair of radial angularly spaced arms lying in one plane and connected together at their inner ends by a generally U-shaped section lying in a different plane, said anode including a number of said elements equal to the number of circuits in the array with corresponding arms of adjacent elements displaced

$$\frac{360}{n} \text{ degrees}$$

where n is the number of elements employed so that each section includes a portion of two elements, the connecting portions of the various elements providing a system of straps conductively connecting all alternate anode sections.

11. A vane for a space resonant anode structure comprising a section of tubing bent back upon itself and into substantially L shape and providing a continuous passage for fluid through said vane with said passage beginning and ending at the same end of the vane, the tubing at the other end of said vane being separated from itself and providing an opening through the vane.

12. An electric discharge device comprising a space resonant structure including a plurality of vanes, each of said vanes comprising a section of bent tubing and providing a pair of parallel arms connected by an intermediate section extending substantially perpendicularly to said arms, said arms and said sections lying in the same plane, and means mounting said vanes in angularly spaced and radially extending relationship.

13. An electric discharge device comprising a

space resonant structure including a plurality of vanes, each of said vanes comprising a section of bent tubing and providing a pair of parallel arms connected by an intermediate section extending substantially perpendicularly to said arms, said arms and said sections lying in the same plane, means mounting said vanes in angularly spaced and radially extending relationship, and headers connected to the ends of said tubing.

14. An anode structure including a plurality of space resonant circuits mounted around a central opening and defined by a plurality of spaced anode sections, each of said sections including an opening therethrough near the inner end thereof and separated from the central opening by parts of said anode sections, and a plurality of conductors, each of said conductors being electrically connected to a pair of alternate anode sections and extending through the opening in the intermediate anode section.

15. An anode structure including a plurality of space resonant circuits defined by an even number of elements having mutually perpendicular arms, one arm of each element being mounted in a plane common to the corresponding arms of the remaining elements and with the remaining arm of each element extending in the same direction from said plane and defining an opening

within which the electrons for exciting the anode are adapted to move, each of said elements having an opening through the arm defining said first mentioned opening, and a system of conductive members including a number of conductors equal to the number of elements and with each conductor passing through the opening formed in one element and joined with the adjacent elements on either side of said one element.

RICHARD B. NELSON.

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