Dec. 6, 1949 W. T. COOKE ET AL 2,490,030

HIGH-FREQUENCY TUBE STRUCTURE

Filed June 28, 1940 2 Sheets-Sheet 1

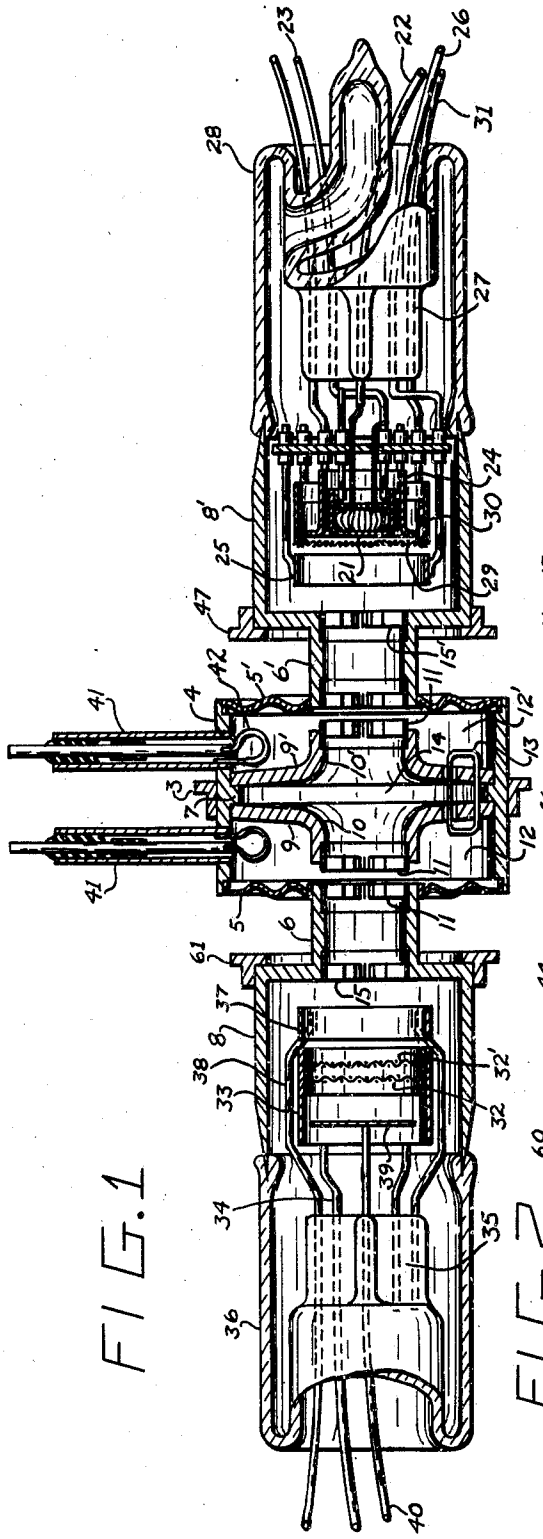


FIG. 1

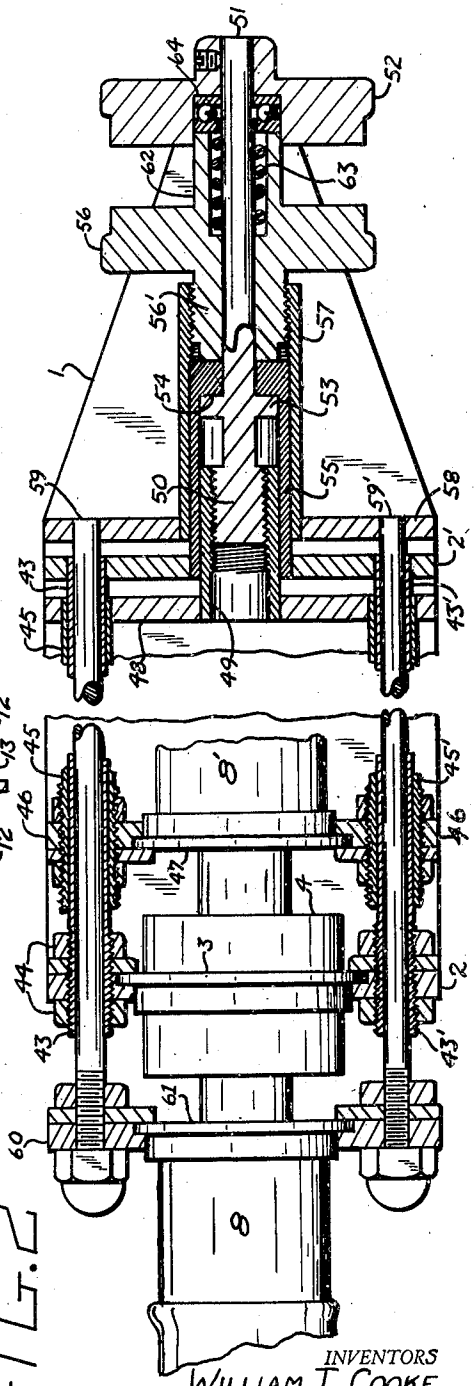


FIG. 2

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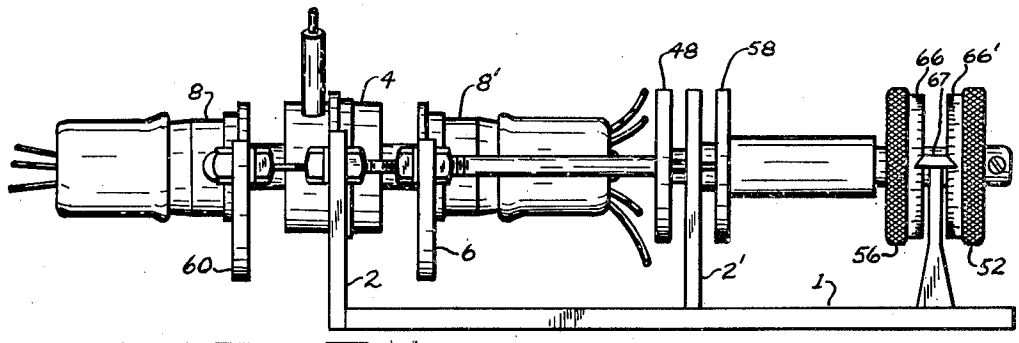


FIG. 3

FIG. 4

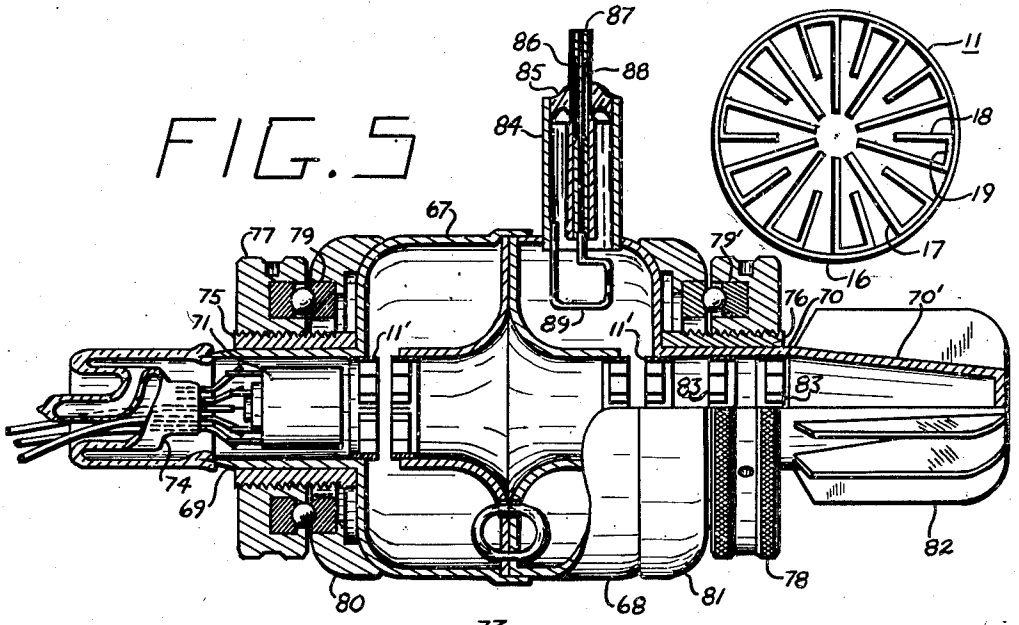


FIG. 5

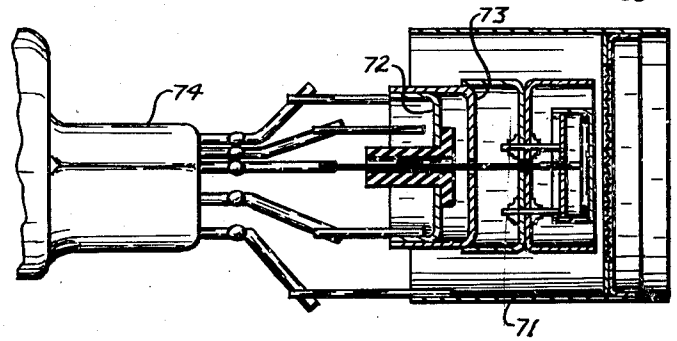


FIG. 6

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UNITED STATES PATENT OFFICE

2,490,030

HIGH-FREQUENCY TUBE STRUCTURE

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Application June 28, 1940, Serial No. 342,912

26 Claims. (Cl. 250—27.5)

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This invention relates, generally, to high frequency radio apparatus and the invention refers, more particularly, to a novel high frequency tube structure employing hollow resonators of the general type disclosed in application Serial #168,355 filed October 11, 1937, by Russell H. Varian, now Patent No. 2,242,275, issued May 20, 1941.

The principal object of the present invention is to provide an improved electron-collecting structure for electron-beam tubes using cavity resonators, adapted for efficient collection of electrons and dissipation of their kinetic energy after they have served their useful purpose in the tube.

A further object is to provide an improved grid structure, especially adapted for use with cavity resonators, and easily fabricated into tubes of the present type.

Other objects and advantages will become apparent from the specification, taken in connection with the accompanying drawings wherein the invention is embodied in concrete form.

In the drawings:

Fig. 1 is a longitudinal sectional view of a tube structure in which the present invention may be used, with the tuning means removed therefrom.

Fig. 2 is a partial sectional view in plan with parts broken away showing the tube structure of Fig. 1 assembled with its tuning means.

Fig. 3 is a view in elevation of the tube structure of Fig. 1 and tuning means therefor.

Fig. 4 is a view in elevation of the novel grid of the present invention.

Fig. 5 is a partial longitudinal sectional view of a modified tube structure incorporating the novel electron collector of the present invention, and

Fig. 6 is an enlarged sectional detailed view of a portion of the structure of Fig. 5.

Similar characters of reference are used in all of the above figures to indicate corresponding parts.

Referring now to the structure of Figs. 1 to 3 of the drawings, the reference numeral 1 designates a base upon which the high frequency tube structure is adapted to be supported. Base 1 has upstanding posts 2 and 2', post 2 being provided with a suitable groove in its upper portion for fixedly receiving an annular flange 3 provided on the resonator casing 4 of the tube structure. The casing 4 is shown of cylindrical shape and is provided with ends consisting of annular corrugated and flexible diaphragms 5 and 5' which are joined at their outer peripheries to the rigid cylindrical portion of casing 4 and are connected

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at their inner peripheries to aligned tubular projections 6 and 6' provided on cylindrical end shells 8 and 8' of the tube structure. End shell 8' has an indirectly heated cathode structure 21 therewithin, the filament of the cathode being supplied through leads 22 and 23, extending through the press 27 provided in the sealing bell 28. A heat retaining and focussing sleeve 24 surrounds the emitter 21. An additional focussing ring 25 is positioned in front of the cathode assembly 21—24 for the purpose of collimating the electron stream leaving cathode 21. This ring 25 is adapted to be connected to a suitable external potential by way of lead 26 extending through the press 27. A space charge control grid 29 is shown located in front of the emitter 21, this grid being shown as a stocking weave and having its periphery confined between the two rings of an annular supporting member 30, which member is connected to an external lead 31 adapted to be connected, for example, to a suitable modulation source. A stream of electrons as collimated by ring 25 passes through tubular projections 6' and 6 and centrally through the resonator casing 4.

The rigid cylindrical shell of the casing 4 is provided on its inner surface with an internally projecting flange 7 that serves to space apart two spun resonator diaphragms 9 and 9', these diaphragms being formed with oppositely projecting tubular neck portions 10 and 10' that are aligned with, though slightly separated from, the inner ends of the tubular projections 6 and 6'. The opposed ends of tubular member 6 and neck portion 10 are provided with opposed grids 11. Similarly, the opposed ends of tubular member 6' and neck portion 10' are provided with opposed grids 11.

As thus constructed, two hollow or cavity resonators 12 and 12' are formed within the interior of resonator casing 4, the resonator 12 being defined by the space between flexible diaphragm 5 and diaphragm 9 and the other resonator 12' being defined by the space between flexible diaphragm 5' and diaphragm 9'. A feedback or coupling loop 13 is shown extending through diaphragms 9 and 9' for coupling the oscillating electromagnetic fields of resonators 12 and 12' as when the tube structure is employed as an oscillator or regenerative amplifier.

The ends of the tubular projections 6 and 6' joining the shells 8 and 8' are shown provided with grids 15 and 15' that are similar to grids 11. The construction of these grids 11 and 15 is shown in detail in Fig. 4. These grids consist of an outer ring 16, to the inner surface of which

are secured, as by spot welding, a series of approximately J-shaped grid elements. These grid elements each comprise radially inwardly projecting long and short legs 17 and 18 which are connected together at the ring 16 by a connecting portion 19. Thus, in producing this grid a series of the J-shaped grid elements are made and then are secured in mutually spaced relation to the inner surface of ring 16. This grid has the advantage of simple construction, ease of assembly and is not injured by thermal expansion and contraction of legs 17 and 18 in use since the inner ends of these legs are free.

The end shell 8 has a detector grid assembly contained therewithin, this assembly consisting of spaced grids 32 and 32' that are carried by a sleeve 33 having a lead 34 connected thereto and extending outwardly through the press 35 of the sealing bell 36 for connection to a suitable source of potential.

A collimating ring 37 is positioned in advance of the grids 32 and 32' and is connected by a lead 38 to a suitable source or potential, whereby this ring will serve to reduce any dispersive tendencies of the stream, while the same is approaching grids 32 and 32'. A collecting plate 39 is provided and connected to external lead 40 for conveying away electrons passing through grids 32 and 32'.

Resonator 12' is shown provided with a concentric line terminal post 41 that extends through the cylindrical wall of resonator casing 4 and has an internal loop 42 for supplying energy to or removing the same from the interior of resonator 12'. If desired the resonator 12 may also be provided with a concentric line terminal post or posts as illustrated.

Assuming that the tube apparatus has been evacuated and is connected for operating as a receiver, for example, the electron stream from emitter 21 in passing between grids 11 of resonator 12' will have its velocity recurrently altered due to its passage through the relatively weak alternating field set up in resonator 12' by the action of terminal post loop 42 supplied from a suitable antenna or other high frequency source. In the drift space 14 provided within casing 4 between resonator 12' and resonator 12, the faster electrons will overtake the normal velocity electrons, while the latter will overtake the slower electrons so that the electrons enter resonator 12 in groups and set up therein an amplified version of the standing field in resonator 12' as is explained in the above mentioned patent. Owing to the fact that the diaphragms 9 and 9' flare away from the electron stream to provide a relatively large annular space around the stream in the drift space, dispersive action of the drift space walls on the stream is reduced to a minimum, thereby aiding in preventing spreading of the beam. Also, by having the drift space coextensive with the resonators 12' and 12, the overall dimension of the tube is greatly reduced, thereby shortening the electron stream and aiding in preventing spreading of the same. For efficient operation it will be apparent that the collimated beam leaving emitter 21 should pass through the resonators and the drift space and thereafter approach detector grids 32 and 32' without appreciable spreading.

When the tube structure is used as an oscillator, feed-back can be obtained either by using loop 13 or by coupling the terminal posts 41 of resonators 12 and 12' by a detachable concentric line. If modulation is desired, the modulation potential is applied to space charge control grid 29. The output of resonator 12 may be connected to an antenna by coupling the latter to a terminal post 41 of resonator 12.

Referring now to the tuning means shown in Figs. 2 and 3, the end portions of tubular guide sleeves 43 and 43' are threaded through apertures provided in post 2 on opposite sides of the casing 4 and are fixed to this post as by lock nuts 44. Sleeves 43 and 43' extend slidably through additional sleeves 45 and 45'. Sleeves 45 and 45' have inner end portions threaded through apertures provided in a yoke 46 that is fixed upon a flange 47 secured to the end shell 8'. The outer end portions of sleeves 45 and 45' are secured to a cross-head 48 that is provided with a central tubular extension 49 into which is adjustably threaded a plug 50 provided on the inner end portion of a rod 51, the outer end portion of which has a knurled knob 52 fixed thereon. Rod 51 is provided with a collar 53 abutting shoulder 54 provided on a tubular projection 55 provided on the post 2'. The outer ends of tubular guide sleeves 43 and 43' are secured within apertures provided within post 2'.

A second knurled knob 56 is turnably mounted upon the rod 51 and has a hub portion 56' that is adjustably threaded into a tubular extension 57 provided on a cross-head 58 having the ends of rods 59 and 59' secured thereto, which rods are slidable longitudinally within the guide sleeves 43 and 43'. The other ends of rods 59 and 59' are secured to a yoke 60 that is fixed upon a flange 61 attached to the end shell 8. Knurled knob 56 is provided with a tubular extension 62 that surrounds the rod 51 and houses a rather stiff compression spring 63 which bears at one end against the knob 56 and at its other end against an antifriction bearing 64 carried by knob 52. This spring serves to take up any back lash that may be present in the threads of the tuning means.

In use, since posts 2 and 2' are fixed upon the base 1, the guide sleeves 43 and 43' together with resonator casing 4 and tubular projection 55 are held stationary. By turning knob 56 the tubular extension 57 of cross-head 58 is moved to the right or left with respect to extension 55 depending on which direction knob 56 is turned, thereby moving cross-head 58 and rods 59 and 59' to effect a corresponding movement of yoke 60 and flange 61 and serving to effect relative movement of grids 11 of the resonator 12, the flexible corrugated diaphragm 5 permitting such relative movement to take place. Thus, by turning knob 56, resonator 12 may be tuned to resonator 12'. Similarly, by turning knob 52 the rod 51 is turned, thereby effecting longitudinal movement of tubular extension 49 provided on cross-head 48 and effecting longitudinal movement of sleeves 45 and 45' which in turn effect relative movement of the grids 11 of resonator 12', thereby tuning this resonator with respect to resonator 12. If desired, both knobs 56 and 52' may be turned simultaneously thereby effecting gang tuning of the resonators. These knogs are provided with graduations 66 and 66' cooperating with a fixed index 67 for indicating the amount of tuning. Owing to the great flexibility of the diaphragms 5 and 5' the resonators may be tuned an indefinite number of times without injury thereto.

The tube structure of Figs. 5 and 6 is even more compact than that shown in Fig. 1, the structures of these latter figures being especially suitable for use with somewhat longer wave lengths of the order of 40 cm., for example. In this form of

the invention the two resonator casings 67 and 68 are formed with outwardly directed aligned tubular extensions 69 and 70 carrying grids 11' at their inner ends. The emitter structure 71 is contained within tubular extension 69 and is shown provided with a plurality of mutually spaced heat baffles 72 and 73 for the purpose of preventing undue heating of the press 74.

Tuning in this form of the invention is accomplished by use of threaded collars 75 and 76 fixed upon the extensions 69 and 70, which collars have tuning knobs 77 and 78 threaded thereon, which nuts act through anti-friction bearings 79 and 79' to press ring members 80 and 81 against the outer peripheral portions of resonators 67 and 68. Thus, by turning knobs 77 and 78, the portions of casings 67 and 68 extending between the ring members 80 and 81 and collars 75 and 76 are deflected resulting in relative movement of the grids of the resonators and hence tuning the same. The tubular extension 70 is provided with a frusto-conical or tapered portion 70' having cooling fins 82 to effect cooling of this portion of the tube structure, which serves to collect electrons passing through the resonators and through additional grids 83. Extension 70 and tapered portion 70' together constitute a collector means for the electrons.

A novel form of concentric line terminal post 84 is shown in Fig. 5. In this terminal post, a glass seal 85 is secured at its outer periphery to the cylindrical casing of post 84 and at its inner periphery to an extremely thin portion of a metal tube 86 as of copper. Owing to the thinness of this tube portion 86 under seal 85, the metal flexes under thermal expansion and contraction so that the seal is not broken between the glass and the tube. The tube 86 is further reinforced by an inner tube 87 having its portion 88 underlying the seal 85 spaced inwardly from tube 86 to facilitate relative radial movement of tube 86. The loop 89 is attached at one end to the outer casing of the terminal post and at its other end this loop projects into inner tube 87 and is secured therein.

The structure disclosed but not claimed herein and including the terminal post, detector, tube and tuner arrangements is described and claimed in our copending divisional application Serial No. 479,296, filed March 15, 1943, now Patent Number 2,463,519 granted March 8, 1949.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A grid structure comprising a ring member having a plurality of mutually spaced J-shaped grid elements secured thereto, each of said grid elements comprising a short and a long leg and being secured to said ring member at one end with said legs extending radially inwardly of said ring member but terminating short of the center of said ring member.

2. A grid structure comprising a ring member having a plurality of discrete integral grid elements secured thereto, each of said grid elements comprising mutually spaced long and short legs and a connecting portion, the latter portion being secured to said ring member with said legs extending substantially radially inwardly thereof but terminating short of the center of said ring member.

3. A grid structure comprising a plurality of separate integral grid elements, each of said grid elements comprising a short and a long leg joined at one end by an arcuate cross-piece, and joining means securing said cross-pieces in a circular arrangement with said legs extending radially inwardly thereof but terminating short of the center thereof.

4. A grid structure comprising a plurality of discrete integral grid elements, each of said grid elements comprising mutually spaced legs and a connecting portion, and joining means securing said connecting portions in a circular arrangement with said legs extending substantially radially inwardly thereof.

5. A grid structure comprising a ring member and a plurality of discrete integral grid elements, each of said elements comprising mutually spaced legs and a connecting portion, all said latter portions being secured to said ring member with said legs extending substantially radially inwardly thereof.

6. A resonator structure comprising a hollow-body resonator having openings therethrough for the passage of electrons, and a hollow collector enclosing the entire path of said electrons beyond said resonator, said collector being tapered in shape and converging toward the end remote from said resonator.

7. A discharge device comprising a cathode, a hollow body resonator having entrance and exit openings therethrough for the passage of electrons, an extension of said resonator surrounding said exit openings, said extension having a tapered closed portion.

8. A discharge device comprising a cathode, a hollow body resonator having entrance and exit openings for electrons, and a tapered electron collector means having its base completely surrounding the exit openings in said hollow body resonator for preventing lateral escape of electrons which pass through said exit openings.

9. A discharge device comprising a hollow body resonator having two parallel spaced input and exit openings for the passage of electrons therethrough and a collector means about the exit opening of said resonator having a portion constituting an electron-intercepting surface of which the part nearest said openings forms an angle of incidence greater than 45° to the path of electrons emerging from said resonator that the electrons are scattered over the surface of said collector and on reflecting therefrom will continue in a generally forward direction.

10. Electron discharge device comprising first and second hollow resonators, means for projecting a stream of electrons through the interiors of said resonators in succession, said means including a cathode positioned on one side of said two resonators and outside the field of said first resonator, and a collector positioned on the other side of said two resonators and outside the field of said second resonator and in a straight line with said cathode and enclosing the entire path of said stream beyond said resonators, said collector being tapered in shape with its narrow end remote from said resonators.

11. Electron discharge device comprising first and second hollow resonators, each of said resonators having two parallel spaced input and exit openings for the passage of electrons, the exit opening of said first resonator being spaced from the input opening of said second resonator by a

distance at least as great as the distance between the input and exit openings of any one of said resonators, means for projecting a stream of electrons through the openings of said resonators in succession, said means including a cathode positioned on one side of said two resonators and outside the field of said first resonator, and a collector positioned on the other side of said two resonators and outside the field of said second resonator and in a straight line with said cathode and enclosing the entire path of said stream beyond said resonators, said collector being tapered in shape with its narrow end remote from said resonators.

12. Electron discharge device comprising first and second hollow resonators, means for projecting a stream of electrons through the interiors of said resonators in succession, said means including a cathode positioned on one side of said two resonators and outside the field of said first resonator, and a collector positioned on the other side of said two resonators and outside the field of said second resonator and in a straight line with said cathode, said collector being tapered in shape with its narrow end remote from said resonator, and a load circuit in the form of a loop of conductor in the interior of said second resonator.

13. A resonator structure comprising a hollow body resonator having openings therethrough for the passage of electrons, and a hollow collector enclosing the entire path of said electrons beyond said resonator, said collector having a portion thereof internally tapered and converging away from said resonator.

14. Electron discharge device comprising first and second hollow resonators, means for projecting a stream of electrons through the interiors of said resonators in succession, said means including a cathode positioned on one side of said two resonators and outside the field of said first resonator, and a hollow collector positioned in a straight line with said cathode on the other side of said two resonators and vacuously sealed to said resonator to form part of the vacuum envelope of said apparatus, said collector being internally tapered and converging away from said resonator.

15. Electron discharge device comprising first and second hollow resonators, each of said resonators having two parallel spaced input and exit openings for the passage of electrons, the exit opening of said first resonator being spaced from the input opening of said second resonator by a distance at least as great as the distance between the input and exit openings of any one of said resonators, means for projecting a stream of electrons through the openings of said resonators in succession, said means including a cathode positioned on one side of said two resonators and outside the field of said first resonator, and a collector positioned in a straight line with said cathode on the other side of said two resonators and enclosing the entire path of said stream beyond said second resonator, said collector having a portion tapered and converging away from said resonator.

16. Electron discharge device comprising first and second hollow resonators, means for projecting a stream of electrons through the interiors of said resonators in succession, said means including a cathode positioned on one side of said two resonators and outside the field of said first resonator, and a collector positioned in a straight line with said cathode on the other side of said

two resonators and vacuously sealed to said resonators to form therewith part of the vacuum envelope of said apparatus, said collector having a portion tapered in shape and converging away from said resonator, and a load circuit in the form of a loop of conductor in the interior of said second resonator.

17. A discharge device comprising a hollow-body resonator having openings for the passage of electrons therethrough and an electron collector enclosing the entire path of said electrons beyond said resonator means and having its sides constituting an electron-intercepting surface of which the part nearest said openings forms an angle of incidence greater than 45° to the path of electrons emerging through said openings, so that the electrons will not tend to concentrate on a local spot of said collector, and on reflecting therefrom will continue in a generally forward direction.

18. A discharge device comprising a hollow-body resonator having openings for the passage of electrons therethrough and a hollow electron collector vacuously sealed to said resonator about said openings and having its sides constituting an electron-intercepting surface of which the part nearest said openings forms an angle of incidence greater than 45° to the path of electrons emerging through said openings, so that electrons will not tend to concentrate on a local spot of said collector and on reflecting therefrom will continue in a generally forward direction.

19. A discharge device comprising a hollow-body resonator having two parallel spaced input and exit openings for the passage of electrons therethrough and a hollow surface collector means connected to said resonator and enclosing the entire path of said electrons beyond said exit opening, the cross-section of said collector means being closed and having a portion at a very acute angle to the path of said electrons as they pass out of the exit opening of said hollow-body resonator.

20. A discharge device comprising a hollow-body resonator having two parallel spaced input and exit openings for the passage of electrons therethrough and having a hollow surface collector means vacuously sealed to said resonator about said exit opening and forming a portion of the vacuum envelope of said device, the cross-section of said collector means having a closed perimeter with a portion at a very acute angle to the path of said electrons as they pass out of the exit opening of said hollow-body resonator.

21. A hollow body resonator comprising a metal wall having an opening therethrough, a metal member having one face parallel with said opening, said metal member having an electron receiving cavity in said face and a flexible metal sheet interconnecting said member and said wall.

22. A hollow body resonator comprising a metal wall having an opening therethrough, a metal block having one face parallel with said opening, said metal block having an electron receiving cavity in said face, and a flexible metal sheet interconnecting said block and said wall, a casing connected to said wall and flexible metal sheet and adjusting means connected to said block and based on said casing for positioning the face of said block in relation to said opening.

23. A hollow body resonator comprising a metal wall having an opening therethrough, a metal block having one face parallel with said opening, said metal block having an electron receiving

cavity in said face, and a flexible metal sheet interconnecting said block and said wall.

24. A hollow body resonator comprising a metal wall having an opening therethrough, a metal member having one face parallel with said opening, said metal member having an electron receiving cavity in said face and a flexible metal sheet interconnecting said member and said wall, a casing connected to said wall and flexible metal sheet and adjusting means connected to said member and based on said casing for positioning the face of said member in relation to said opening.

25. A hollow body resonator comprising a metal wall having an opening therethrough, a metal member having one face parallel with said opening, said metal member having an electron-receiving cavity in said face, a flexible metal sheet interconnecting said member and said wall, and adjusting means connected to the said member for positioning the face of said member in relation to said opening.

26. A hollow body resonator comprising a metal wall having an opening therethrough, a metal block having one face parallel with said opening, said metal block having an electron receiving cavity in said face and a flexible metal

sheet interconnecting said block and said wall, the outer portion of said block having fins attached thereto.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,923,521	Von Wedel	Aug. 22, 1933
2,163,589	Dallenbach et al.	June 27, 1939
2,167,201	Dallenbach	July 25, 1939
2,222,902	Hahn	Nov. 26, 1940
2,227,372	Webster et al.	Dec. 31, 1940
2,245,627	Varian	June 17, 1941
2,250,511	Varian et al.	July 29, 1941
2,261,154	Hansen et al.	Nov. 4, 1941
2,263,184	Mouromtseff et al.	Nov. 18, 1941

OTHER REFERENCES

Journal of Applied Physics, vol. 10, No. 5, May 1939, pp. 321–327.