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D. H. SLOAN

2,557,700

RESNATRON ANODE WITH COOLING MEANS

Filed Nov. 30, 1948

2 Sheets-Sheet 1

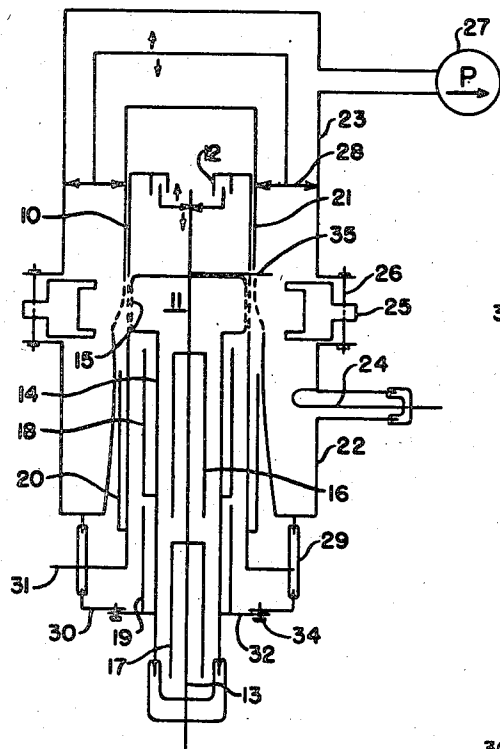


FIG. 1

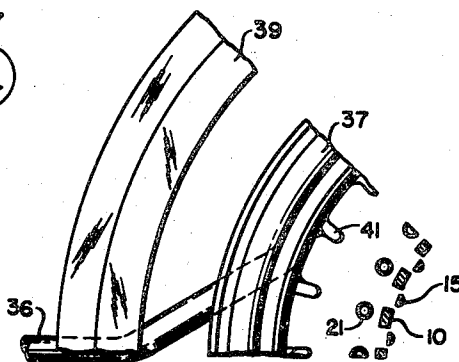


FIG. 2A

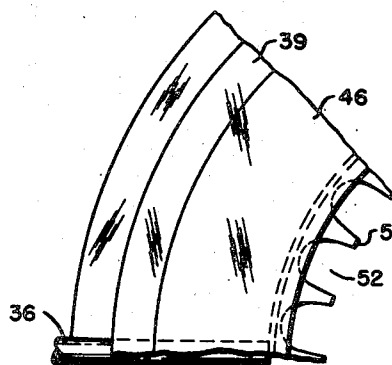


FIG. 3A

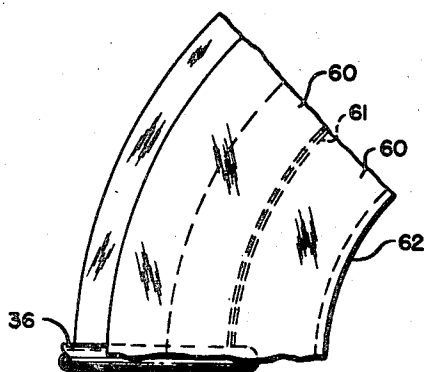


FIG. 5A

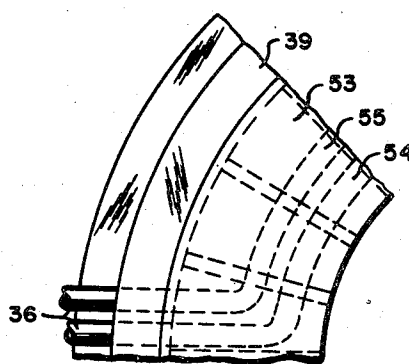


FIG. 4A

INVENTOR.  
DAVID H. SLOAN  
BY *Lawrence Glassman*  
ATTORNEY

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D. H. SLOAN

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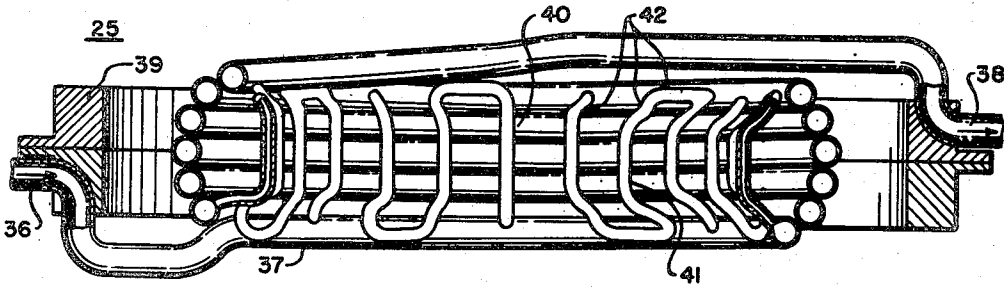


FIG. 2

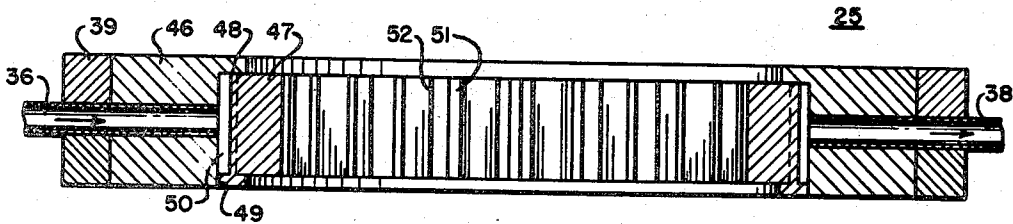


FIG. 3

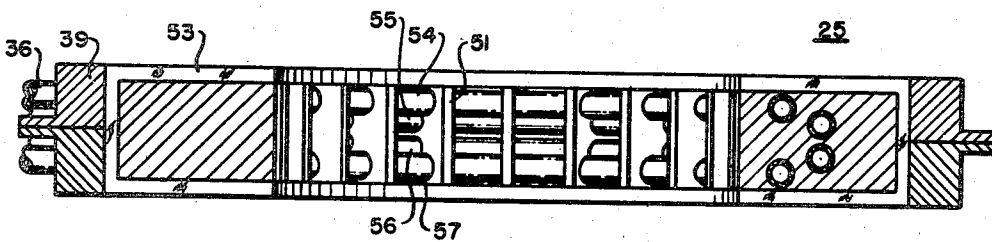


FIG. 4

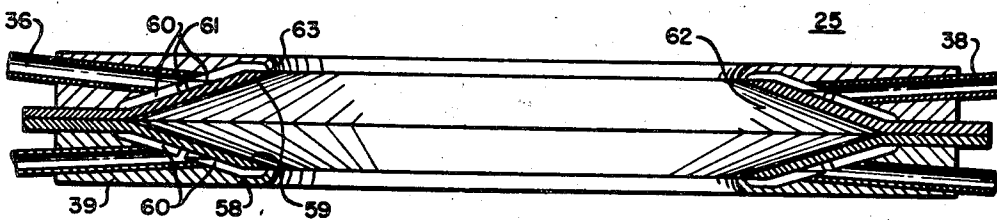


FIG. 5

INVENTOR.  
DAVID H. SLOAN  
BY *Lawrence Glassman*  
ATTORNEY

## UNITED STATES PATENT OFFICE

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## RESNATRON ANODE WITH COOLING MEANS

David H. Sloan, Berkeley, Calif., assignor to the  
United States of America as represented by the  
Secretary of the Army

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4 Claims. (CL 313—31)

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This invention relates to electronic tubes adapted to the production and modulation of very high frequency oscillations. More particularly it relates to anodes for use in resnatron tubes, which anodes are so designed and adapted as to eliminate many difficulties which as a matter of practice have not been solved by the prior art.

A coaxial resnatron comprises two resonators, one connected in the grid-cathode circuit and one connected in the anode circuit. The oscillating fields developed within these resonators have a definite relationship with each other and their electrical components are substantially parallel to the paths of the electrons between the cathode and anode.

The direct-current voltages on the cathode, grids, and anode of the tube are such that a group of electrons is emitted from the cathode only during the peak portion of each half cycle of the oscillating frequency of the resonator of the grid-cathode circuit when the field of that resonator is in such a direction as to aid the direct-current voltage field in the emitting of electrons from the cathode and to aid in their movement toward the anode. This causes sharp and well-defined bursts of energy to be emitted from the cathode at regular intervals. The electrons so emitted arrive at the resonator in the anode circuit and enter that resonator when its field is in such a direction as to oppose the motion of the electrons and hence causes those electrons to give up their energy and produce the desired oscillations in the resonator. A portion of the power developed by this action is fed back to the resonator in the grid-cathode circuit and maintains the desired oscillations therein. The remaining power is extracted by means of an output coupling loop and fed into an output transmission line.

This type resnatron ordinarily is arranged for ready disassembly and evacuated continuously by a pump. It is, in essence, a grounded-grid tetrode oscillator built on the coaxial line principle with the entire operating system in a vacuum. The cathode and control grid are built into a coaxial line which is surrounded by the second coaxial line comprising the screen grid and anode in which the radio frequency power is generated. This type construction has been generally adopted by the art since the triode type resnatrons are capable only of limited power outputs at very high frequencies.

The coaxial construction removes an inherent anode-to-cathode capacitance so that a feedback capacitance between these two electrodes must be introduced artificially.

The phase shift,  $\phi$ , between the oscillations in the two resonators must lie between zero degrees and 90 degrees. Hence the control grid reaches its maximum positive potential with respect to the cathode  $\phi$  degrees of angular time before

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the anode reaches its maximum negative potential with respect to the screen grid. At the frequency of oscillations of the resnatron this angular time corresponds to the actual time required for the average electron to go from the control grid to the anode resonator.

The screen grid is held at some direct-current potential higher than the grid swing. This causes all of the electrons which have passed through the grid to be given a tremendous forward acceleration. Due to their greater average speed to electrons make their journey to the anode in a shorter time than is the case with a triode oscillator. This results in more of their energy being given to the decelerative field of the anode because this field has less time to vary. It is now seen that transit-time troubles are reduced by use of the tetrode oscillator and that they cease to be a serious limiting factor if the anode is designed to function as outlined above.

The coaxial resonator arrangement allows the electronic elements to be located at optimum points within the resnatron. The tube is made large enough to enable water cooling of all parts of it. The coaxial arrangement allows use of a large cathode surface and high voltages so that large peak power can be drawn in short time intervals with efficient class C oscillation.

The anode is substantially in the shape of a cylindrical ring and is secured on the tube structure by bolts. A rubber gasket is used to insure a good vacuum seal and a tin gasket inside the rubber to afford good electric contact.

Such a tube structure as described above has introduced a new era in the generation of high frequency power but has suffered serious operational difficulties due to the incorrect structural design of the anode used. Many different types of anodes have been employed but none have solved all of the serious problems; namely, interference from secondary emission, and transit-time distance as a factor limiting the performance of the tube.

It is an object of the present invention to provide a resnatron anode which will give long and efficient operational service.

It is also an object of the present invention to provide a resnatron anode of substantially cylindrical shape which provides adequate cooling and eliminates overheating.

It is another object of the present invention to provide a resnatron anode which eliminates transit-time distance as a factor limiting the performance of the tube.

It is a further object of the present invention to provide a resnatron anode which reduces interference from the secondary emission of electrons.

Other objects, features, and advantages of this invention will suggest themselves to those skilled in the art and will become apparent from the following description of the invention taken in

connection with the accompanying drawings in which:

Fig. 1 is a diagrammatic view of a resnatron which can be readily disassembled to remove the anode;

Figs. 2, 3, 4 and 5 are cross-sectional views on a plane through the axis of the tube as shown in Fig. 1 showing various embodiments of the anode;

Figs. 2a, 3a, 4a, and 5a are views of portions of the various embodiments of the anode on a plane perpendicular to the axis of the tube as shown in Fig. 1, corresponding to Figs. 2, 3, 4, and 5, respectively, and including in Fig. 2a an indication of the relative positions of the cathode filaments and the control and screen grid openings as they are arranged in the embodiments of the other figures.

The specific types of anodes described in this specification are adapted for use in coaxially constructed resnatrons which can be readily disassembled. However, it is understood that the principles of this invention apply to anodes for any type of resnatron.

Referring to Fig. 1 there is shown diagrammatically the entire resnatron including an inner coaxial resonator comprising the control grid tube 10 and the cathode structure 11, with an adjustable condenser 12 at the top of the cathode structure for tuning the resonator. The cathode structure comprises an axial conductor 13 and an outer concentric conductor tube 14 with a plurality of equally spaced filament members 15 parallel to and equi-distant from the axis and each connected at one end to conductor 13 and at the other end to conductor tube 14. A plurality of one-quarter wave chokes 16 and 17 on cathode conductor 13, 18 and 19 on cathode conductor tube 14, and 20 on grid tube 10 prevent energy loss from this cavity through the heater and grid bias circuits.

Concentric with this grid cathode resonator there is a second resonator in the circuit of the screen grid and anode which comprises the screen grid tube 21 and the two portions 22 and 23 of the anode housing, the lower portion 22 of the anode housing including the output coupling loop 24. The anode 25 is retained between the lower section 22 and upper section 23 of the anode housing by any conventional means such as the bolts 26. A vacuum pump 27 is connected to the upper portion 23 of the anode housing. A shorting annulus 28 is adjustably mounted in the space between the upper portion of screen grid 21 and the upper portion 23 of the anode housing for tuning the outer resonator. This shorting means 28 and the condenser 12 would ordinarily be made adjustable from outside the housing but to simplify the disclosure, the structure necessary to accomplish this has been omitted from the drawing.

An insulating and sealing tube 29 joins the lower end of anode housing 22 to cathode mounting member 30 and also supports the grid 10 and its connecting lead 31. The outer cathode tube 14 includes a flange 32 which is attached to its mounting member 30 by any conventional means such as bolts 34. The filament members 15 and the adjacent portions of the screen grid 21 and control grid 10 are shown diagrammatically in broken lines; the openings in these elements are between adjacent pairs of filamentary or tubular members parallel to the axis with the filaments 15 in line with the openings of the screen grid 21 and control grid 10. A removable feedback prong

35 is inserted into a portion of the cathode structure through the openings in the screen grid 21 and control grid 10 to provide the necessary feedback for operation as an oscillator.

Referring more particularly to Figs. 2 and 2a, the anode structure is generally designated by 25. The cooling arrangement for the anode consists of a pump which produces a main water flow which enters the anode structure 25 through inlet 36 and flows through pipe 37 wound as a layer on the outer surface of a tore having the same axis as the anode and the entire resnatron and leaves the pipe 37 at outlet 38. The several turns of pipe 37 of anode 25 appear in cross section as a series of circles arranged in an arc. A suitable supporting ring 39 is provided to hold the anode in proper position in the resnatron. Smaller pipes 40 like the large pipe 37 are made of copper and extend across the width of the anode with central straight portions 41 parallel to the axis of the tore and the cathode generally, and connecting portions 42 leading to pipe 37 or to another straight portion. It has been found practical for proper water circulation through pipes 40 to have three portions 41 and the necessary connecting portions 42 in each pipe 40. This means that there are eight such pipes 40 in a single anode, if the common twenty-four filament cathode is to be used. Fig. 2a shows clearly the physical arrangement of the portions 41 shown in Fig. 2, and also shows diagrammatically the relative position of the filaments and screen and control grid openings.

This form of anode has as many portions 41 as the tube has filaments. The portions 41 of pipes 40 in combination with pipes 37 form re-entrant pockets and their inward extension reduces the diameter of the coaxial arrangement at this point and shortens the transit-time distance from the screen grid to the anode. It reduces this distance to such an extent that it is no longer a limiting factor in the operation of the tube.

The velocity of the water flow through the pipe 37 and pipes 40 is such that it insures an efficient heat transfer. The parallel arrangement of water flow is particularly important from a practical viewpoint since it means a very substantial reduction in the size of pump which may be used.

Referring now to Figs. 3 and 3a the cylindrical anode structure is also generally designated by 25 and may include a supporting ring 39 as in Fig. 2. The outer anode element 46 is made of copper so that it will diffuse quickly the heat which it absorbs as a result of the operation of the tube and includes inlet and outlet water apertures 36 and 38 which may be located at any convenient place around its circumference. The inner anode element 47 fits closely against element 46 at 48 and 49 and is properly sealed therein to leave a water channel 50. The water is forced by a suitable pump through inlet 36 around channel 50 and through outlet 38. Fins 51 extend inward from the inner anode element 47 and correspond in number to the number of filaments used. The pockets 52 are milled in the element 47 parallel to the axis of the anode. The re-entrant pockets 52 reduce the screen-to-effective-anode plane distance and help prevent secondary electrons from being pulled away from the anode by the radio frequency field of the screen grid. Fig. 3a affords a better understanding of the shape of the twenty-four fins than can be gained by reference to Fig. 3, and the relative position of the cathode and grid elements is the same as in Fig. 2a.

Referring to Figs. 4 and 4a the anode structure is also generally designated by 25. The main anode housing 53 is constructed of copper or other material of high conductivity. The twenty-four fins 51 made of copper and corresponding to the filaments are placed in the housing 53. Rapid heat transfer or cooling is accomplished by use of a plurality of cooling tubes 54, 55, 56 and 57, which extend substantially the full circumference of the housing 53. Water enters these tubes through inlets 36 and leaves through similar outlets in the portion of the structure eliminated by cross-sectioning. The fins 51 rapidly conduct the heat to the tubes 54, 55, 56 and 57 where it is carried away by the water flowing therein. As is seen from Figs. 4 and 4a there are pockets or re-entrant portions between fins 51, extending back to the tubes 54, 55, 56 and 57.

Referring to Figs. 5 and 5a, the anode structure of a further modification is also generally designated by 25. As shown in the drawing the outer supporting ring 39 has been extended inward to form part of the anode water jacket as indicated by the portions 58, but it will be obvious that a separate piece could be used. Further covering means 59 of somewhat conical shape serve to close the inner surface of the water jacket leaving the water channels 60 which are divided for purposes of support by small rings 61. Inlet and outlet pipes 36 and 38 provide the necessary circulation of water through the channels.

It will be noted that in this embodiment there is only a single electron receiving pocket 62 which extends entirely around the anode. The innermost portions of the anode indicated by 63 determine the effective plane of the anode and the pocket 62 between the covers 59 serves substantially the same purpose as the multiple pockets in the other embodiments of the invention, in storing up electrons over certain portions of the cycle and substantially reducing the losses due to secondary emission which otherwise would result.

The secondary emission from an anode due to the impact of primary electrons is often the source of considerable loss of power. When electrons having only a few hundred electron volts of energy strike the anode the secondary emission is copious, but when the energy of the primary electrons amounts to several thousand volts the secondary emission is less pronounced. Hence when operating at high voltages the re-entrant pockets in the anode structure are not essential from the standpoint of secondary emission, but even at high voltages their improvement on the operation of the tube is noticeable. The re-entrant pockets reduce the secondary emission by reducing the field in the region of the emitting surface. Shortly after secondary electrons are produced the field may still have such direction that the electrons are pulled away from the surface. However the fins along the electron path weaken this field to such an extent that electrons do not escape from it before the field is reversed, at which time the electrons are drawn back toward the anode. Secondary electrons emitted when the field is reversed never leave the surface. This region of vanishing field reduces the effective distance of the electrons must travel before completing their journey, and hence these fins become important in overcoming transit-time distance troubles.

Although the physical appearance of some embodiments of this invention somewhat resembles that of certain magnetron anodes it is to be

noted that the operation is entirely different since the re-entrant pockets are not resonant cavities but merely function as part of the anode per se and are connected to a coaxial cavity which determines the resonant frequency.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the scope of the invention.

#### I claim:

1. A cylindrical copper anode for use in an electronic tube for the production and modulation of very high frequency oscillations, said anode including a water-carrying pipe wound concentric to an axis in a coil-like shape and forming the circumference of said anode, a series of water-carrying smaller pipes attached to said first-mentioned pipe to carry a flow of water in shunt with that in the first pipe, protruding portions of said smaller pipes extending toward the axis of said anode and running the entire width of said anode parallel to said axis to form transit-distance-limiting re-entrant pockets which reduce secondary emission, said protruding portions being substantially equi-angularly spaced about and equi-distant from said axis.

2. A cylindrical copper anode for use in an electronic tube for the production and modulation of very high frequency oscillations, said anode including a water-carrying pipe wound concentric to an axis in a coil-like shape and forming the circumference of said anode, a series of internally protruding portions attached to the inner circumference of said pipe and extending toward the axis of said anode and running the entire width of said anode parallel to said axis to form transit-distance-limiting re-entrant pockets which reduce secondary emission, said protruding portions being substantially equi-angularly spaced about and equi-distant from said axis.

3. In a cylindrical copper anode for use in a resonator, a pipe for the circulation of cooling water following a substantially helical path and a plurality of crossover pipes connected to said first-mentioned pipe at intervals along said substantially helical path.

4. A cylindrical anode for use in a high power electronic tube for operation at very high frequencies comprising a cooling-fluid-carrying pipe wound concentrically to an axis in a coil-like shape, the inner surface of said pipe forming the operative surface of said anode, a series of internally-protruding cooling-fluid-carrying pipes attached at both ends to said first-mentioned pipe, at least a portion of each of said internally-protruding pipes being extended in a direction substantially parallel to said axis and being equi-angularly spaced about said axis to form transit-distance-limiting protrusions which reduce secondary emission.

DAVID H. SLOAN.

#### REFERENCES CITED

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

#### UNITED STATES PATENTS

| Number    | Name              | Date          |
|-----------|-------------------|---------------|
| 2,058,878 | Holst et al. .... | Oct. 27, 1936 |
| 2,227,039 | Smith et al. .... | Dec. 31, 1940 |
| 2,436,649 | Kane .....        | Feb. 24, 1948 |
| 2,451,987 | Sloan .....       | Oct. 19, 1948 |