Oct. 5, 1948. J. W. McNALL 2,450,763

ULTRA HIGH FREQUENCY GENERATOR VACUUM TUBE AND CATHODE STRUCTURE THEREFOR

Filed July 3, 1943 2 Sheets-Sheet 1

FIG. 1

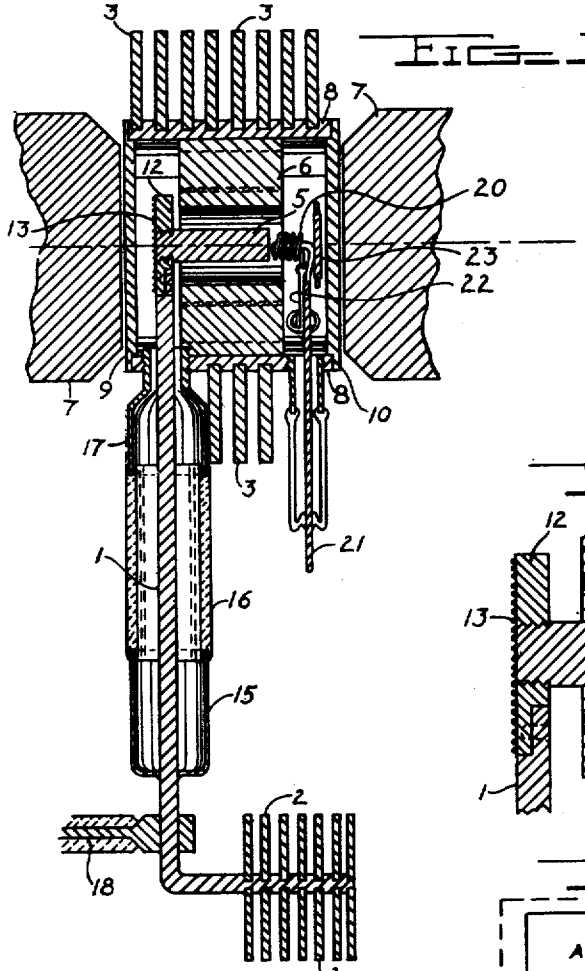


FIG. 2

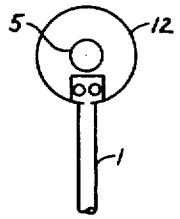


FIG. 3

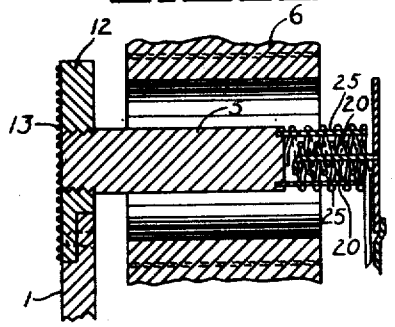


FIG. 4

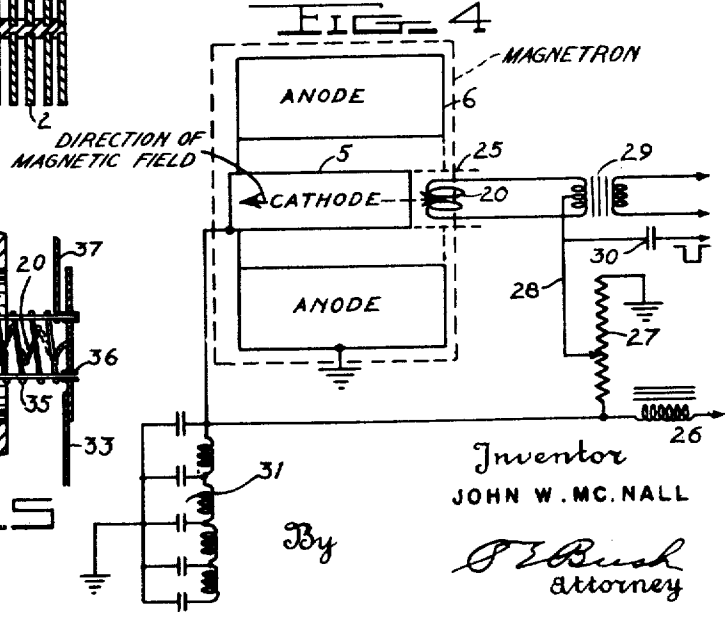
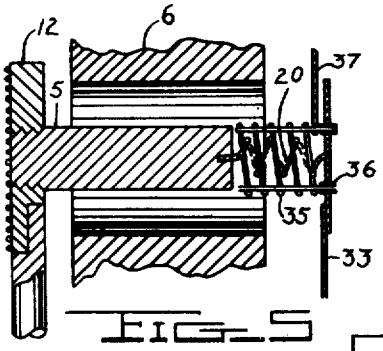


FIG. 5



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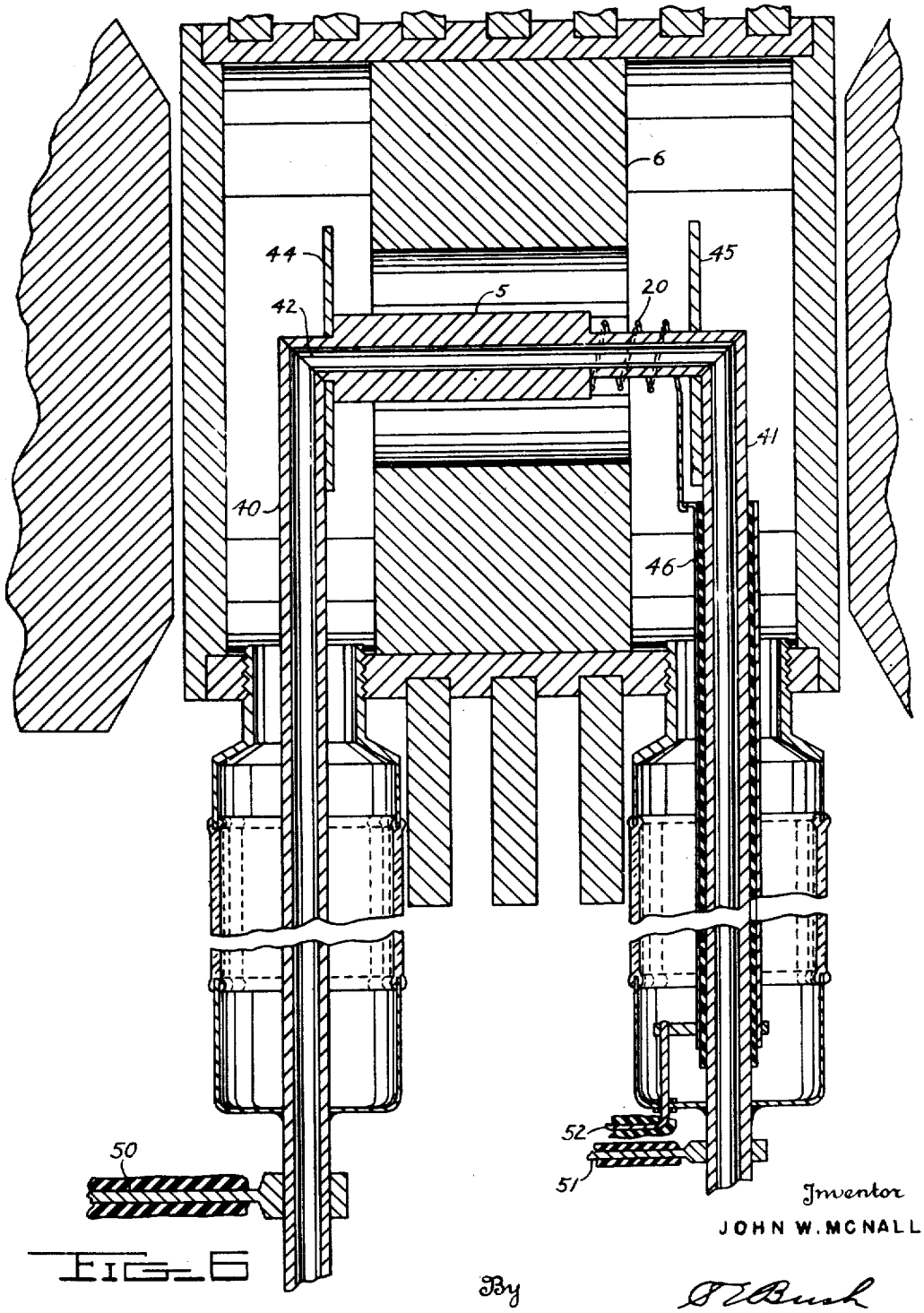


FIG. 6

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2,450,763

ULTRA HIGH FREQUENCY GENERATOR VACUUM TUBE AND CATHODE STRUCTURE THEREFOR

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Application July 3, 1943, Serial No. 493,444

18 Claims. (Cl. 250—36)

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This invention relates to magnetron oscillator tubes for the production of ultra-high-frequency electrical oscillations and particularly to the design and construction of cathode structures adapted for the production of magnetrons having unusually long service life. The present invention makes use for the emitting surface of the cathode of materials having characteristics of high secondary emission.

Heretofore magnetron tubes for the production of high intensity pulses of ultra-high-frequency electric oscillations have usually been provided with oxide-coated cathodes because of the high peak currents obtainable from the high electron efficiency of the oxide type of thermionic emitting surface. Although the peak currents obtained with oxide-coated cathodes have been high, the life of tubes so provided have been undesirably short because of the volatility of the oxide coating. In the oxide-coating cathode the temperature is maintained above a desired lower limit by means of an internal heater, but a further rise in temperature is usually produced during operation by electron bombardment which rise in temperature may damage the cathode unless the power input to the tube is limited.

It is an object of the present invention to provide a long-life cathode for a magnetron tube. It is a further object of the present invention to provide a reliable cathode structure for a magnetron transmitting tube employing the phenomenon of secondary electron emission as a source of a major portion of the electron stream emitted during operation. Still a further object of the present invention is to provide a suitable auxiliary emitter for initiating emission from the main portion of the cathode. Still a further object of the invention is to provide means associated with such an auxiliary emitter for controlling the operation of the tube.

It is known that a number of materials will, when bombarded by electrons, even in the cold state, emit secondary electrons in much greater number than the original bombarding electrons. Typical materials of this type are beryllium and also alloys of silver and magnesium containing from one to fifteen per cent of magnesium and described by Zworykin in vol. 12, J. Applied Physics, at p. 696 (1941). It is possible that the high secondary emissivity of these materials may be due in both above-mentioned instances to a microscopic oxide film, but such oxide film, if it is formed, unlike the oxide coatings of the usual oxide-coated cathodes, is relatively stable under electron bombardment and the emissivity of a

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cathode formed of such material may consequently be expected to keep up over a relatively long service life.

In order to utilize in a practical manner the advantageous service life characteristics of a secondary emission cathode, I have found that it is desirable to provide an auxiliary emitter for initiating the operation of the secondary emitter and also that it is desirable that the auxiliary emitter should have limited emitting capability, so that once secondary emission is initiated the tube current will be provided almost entirely by secondary emission and so that the behavior of the tube will be only slightly influenced by the auxiliary emission. I have found, moreover, that the auxiliary emitter may under certain circumstances be employed as a control electrode. In connection with the use of the auxiliary emitter for control of the operation of the tube independently of the voltage between the secondary emitter and the anode, it may, further, be desirable to provide a grid or screen about the auxiliary emitter, as hereinafter more fully set forth.

The invention is illustrated in the annexed drawings in which:

Fig. 1 is a diametral cross-section of a magnetron tube constructed in accordance with the present invention;

Fig. 2 is an end view of the cathode of the magnetron tube shown in Fig. 1, not including the auxiliary emitter;

Fig. 3 is a diametral cross-section of the central portion of another form of magnetron tube in accordance with the present invention, showing the cathode, the auxiliary emitter, and a portion of the anode;

Fig. 4 is a circuit diagram illustrating the use of the auxiliary emitter as a control electrode to control the operation of the magnetron tube;

Fig. 5 is a diametral cross-section of another form of magnetron tube in accordance with the present invention, this form having a separate grid electrode, and

Fig. 6 is a diametral cross-section, partly broken away, showing a form of magnetron tube having a water-cooled cathode.

In order to take full advantage of the power-handling capabilities (average power, as well as peak power) of cathode structures including a secondary emission surface, it is highly desirable to provide improved means for cooling the cathode, thereby reducing the tendency of the cathode material to vaporize. Secondary emission usually may be initiated readily when the secondary emission cathode is cold, so that excessive cooling is

not likely to occur. Consequently, the apparatus shown in Fig. 1 is provided with a relatively heavy copper lead 1 connected at one end to the secondary emission cathode and at the other end to cooling fins which may, if desired, be cooled by the same air blast as is used to cool the anode fins 3.

In Fig. 1 the cathode is shown in the form of a solid rod 5 made of a material having a high secondary emission characteristic. It is mounted axially with respect to the anode 6. The anode 6 is provided with a plurality of tuned cavities opening into the central hole in the well-known manner. The tube is mounted for operation between the poles of a magnet 7 which is adapted to provide a substantially axial magnetic field. The anode block 6 is mounted within a cylinder 8 which is closed off by end plates 9 and 10 so that the enclosed space may be evacuated. Cooling fins 3 are mounted on the cylinder 8 in order to dissipate the heat produced at the anode during operation of the tube.

The secondary emitter cathode 5 has a diameter approximately the same size as the oxide-coated cathodes commonly used in magnetron tubes, as shown in the drawings. It is supported on a small metal disk 12 which acts to prevent the end plate 9 from drawing electrons out of the anode-cathode space. The "back" side of the disk 12 is preferably provided with a carbon coating shown at 13 for the purpose of improving its radiating qualities in order that heat generated at the cathode may thereby be radiated to the end plate 9 and thence conducted away by the fins 3. The disk 12 and the cathode 5 are supported on a relatively thick copper rod 1. The method of support should provide a joint capable of efficient heat conduction as well as a good electrical connection. A suitable form of joint is shown in Figs. 1 and 2.

The rod 1 and the elements carried by it are fixed in position relative to the anode structure 6, 8 by means of a structure comprising a cup 15 of an alloy of nickel, iron and cobalt known as "Kovar," firmly soldered to the rod 1, a length of glass tubing 16 sealed to the cup 15 and a metal cylinder 17 fastened in a suitable aperture in the anode structure 8 and also sealed to the glass tube 16. A connection for providing the space current of the tube during operation thereof is provided by the wire 18 suitably clamped or fastened to the cathode lead 1. The "Kovar" alloy (more fully described in Scott Patent No. 2,062,335) not only provides a good seal to glass, but because of its relatively low heat conductivity, also maintains a temperature gradient which protects the glass vacuum seal. It has sufficient mechanical strength to support the cathode structure by means of the copper rod.

The secondary emitter cathode 5 as shown on Fig. 1 does not necessarily extend towards the right to the full axial length of the central hole of the anode 6. The extreme right hand axial portion of the central hole of the anode 6 together with a part of the end space is occupied by an auxiliary emitter in the form of a small coil 20 of tungsten wire. It may be pointed out that in general the auxiliary emitter need not extend into the anode cavity at all. The auxiliary emitter coil 20 may be, as shown in Fig. 1, mechanically and electrically independent of the secondary emitter 5, being held in place and supplied with heating current by leads 21 and 22 passing through perforations in the cylinder 8 provided with suitable glass seals. Either lead 21 or 22 carries a disk or "hat" 23. The disk 23 serves to prevent excessive drawing out of electrons from the anode-cathode space by the end plate 10.

When the proper voltage is established between the cathode 5 and the anode 6, when the proper magnetic field is maintained by the magnet 7, and when the auxiliary emitter 20 is energized to provide a small amount of emission, such as ½ ampere space current at most, the magnetron will operate so that electrons will bombard the cathode 5 to produce secondary emission which builds up extremely rapidly when once initiated. The magnetron may then draw peak currents as high as 10 amperes or even more. Such very high current intensities are obtained with intermittent short-pulse operation, where the average currents are considerably smaller. Short-pulse operation is usually desired, although with cathode structures according to the present invention high peak currents can be expected even with greater duty cycles than those previously customary. In short-pulse operation only a small space current need be provided by the auxiliary emitter 20, for instance about 18 milliamperes is quite sufficient (for the standard "K7" magnetron). Such a space current may be provided by passing 6.8 amperes of current through 4.5 centimeters of 12 mil tungsten wire. Once oscillations are initiated by the space current provided by the auxiliary emitter, the oscillations are able to build up to a constant peak value in less than 0.1 of a microsecond, so that substantially square pulses of energy may be produced with a magnetron arranged as described. The magnitude of the substantially constant peak current depends upon the voltage of operation, the intensity of the magnetic field, and possibly on the nature of the secondary emission cathode. For a given voltage a beryllium cathode will give a peak current only about ⅔ as great as the peak current that can be obtained with an oxide coated cathode of similar size, but the beryllium cathode may nevertheless be preferable on account of its longer probable service life. A cathode made of a silver alloy containing a few per cent (1 to 3%) of magnesium, however, has been found to produce peak currents of substantially the same magnitude as those that can be obtained from a comparable oxide-coated cathode, thus combining the advantages of long service life and high electron emissivity.

I have found that it is undesirable to provide more than a small portion of the necessary total peak emission of the tube from the auxiliary emitter 20. An auxiliary emitter having an excessive amount of emission, such, for example, as one with an extensive oxide-coated heated surface tends to make the distribution of the space current unsymmetrical and tends to make the behavior of the magnetron too dependent upon the temperature of the auxiliary emitter. Operation of the magnetron of Fig. 1 with the auxiliary emitter providing as much as one-half ampere of peak space current has been found successful, but operation with the auxiliary emitter providing more than 10% of the peak space current, provided from an oxide coated "hat" was found to be relatively unsatisfactory. The greater the proportion of space current the auxiliary emitter provides, beyond a certain fairly small proportion depending upon conditions of operation, the lower, in general, the efficiency of the tube will be. I prefer to arrange the auxiliary emitter so that it occupies a small portion of the space normally occupied by the cathode and does not extend very far out of the central hole in the anode and to

adjust the heating current and thus the electron emissivity so that the auxiliary emitter provides a space current amounting to a considerably smaller proportion of the total desired space current than the proportion of the amount of cathode surface replaced by the auxiliary emitter bears to the total normal cathode surface. Being located at the end of the cathode, the auxiliary emitter receives comparatively little electron bombardment and its temperature is therefore practically fixed by the heating current alone. For this reason the leads 21 and 22 may be held in simpler structures than the sealing arrangement associated with the lead 1, as indicated in a general way on Fig. 1.

In operation, the anode of the magnetron is normally grounded in order that it and the magnet need not be insulated from ground. The cathode lead therefore usually require high-voltage insulation. In operation, a magnetron constructed according to Fig. 1 should be arranged to maintain the auxiliary emitter 20 at a voltage approximating that of the cathode, which is to say that when the cathode 5 is suddenly made highly negative with respect to the anode in order to produce a pulse of oscillations, the auxiliary emitter 20 should likewise be simultaneously impressed with a high negative voltage. It may be advantageous to make the voltage of the auxiliary emitter with respect to the anode slightly different from that of the cathode, for instance, slightly less negative. The utility of such arrangements will be explained more fully in connection with Fig. 4.

Fig. 3 shows a form of composite cathode construction especially adapted for control of the operation of the tube by the adjustment of the auxiliary emitter potential. In this form of the invention a grid structure 25 is provided on the end of the secondary emitter cathode 5 and surrounds the auxiliary emitter 20. Thus when the auxiliary emitter 20 and the cathode 5 are approximately at the same potential the grid structure 25 will repel electrons emitted by the auxiliary emitter and prevent them from ultimately bombarding the cathode 5. If, however, the auxiliary emitter is made slightly more negative than the grid structure 25, electrons will be accelerated away from the auxiliary emitter 20, after which they will excite the tube and bombard the cathode 5. A typical method of utilizing such a structure is shown in Fig. 4.

Fig. 4 is a circuit diagram illustrating a method of exciting a magnetron in accordance with the present invention. The auxiliary emitter is fed by a filament transformer 29. The anode is grounded and the cathode is provided with a high negative voltage with respect to the anode through a current-limiting choke 26. A suitable proportion of this high negative voltage with respect to the anode is impressed upon the auxiliary emitter 20 by adjustment of the potentiometer 27, the variable contact of which is connected through the wire 28 to the transformer 29, which provides the heating current for the auxiliary emitter 20. A condenser 30, one side of which is connected to the wire 28, serves to couple the auxiliary emitter circuit to a source of negative pulses which are adapted to initiate operation of the magnetron tube at the desired moment. Since the auxiliary emitter 20 is at a voltage less negative with respect to the anode than the voltage of the cathode 5, by virtue of the adjustment of the potentiometer 27, the tube will remain normally quiescent, the thermionically emitted electrons being confined to the immediate neighborhood of the emitter 20 by the relatively negative voltage of the grid structure 25. When a negative pulse is impressed upon the auxiliary emitter 20 through the condenser 30, however, the voltage of the emitter (the potentiometer 27 having a very high resistance) will for a short period be more negative than the cathode 5 and its associated grid 25, so that electrons will then proceed from the emitter 20 into the cathode-anode space. The tube will begin to oscillate and the cathode 5 will be bombarded by electrons and will provide secondarily emitted electrons, so that the space current will rapidly build up to a constant value.

The current thus developed by operation of the tube will rise to its high peak value much more rapidly than the current is able to rise in the choke 26. A reactive pulse-forming network 31, of the voltage-fed type, is, however, provided between the cathode and ground and is normally maintained in a charged condition by the cathode voltage. When the tube begins to operate, the rapidly increasing space current is therefore provided by the discharge of the network 31. The network 31 is designed in accordance with known practice to provide a "rectangular" discharge characteristic and is designed to work into a load impedance approximately equal to the most representative value of the impedance of the magnetron during operation. Because of the magnetron's ability to build up its space current rapidly to a high peak value, the initiation of operation of the magnetron as aforesaid is substantially equivalent to suddenly discharging the network 31 through a load impedance approximately equal to its designed image impedance. The cathode-anode voltage will therefore almost immediately fall to half its former value and then remain at that level for a predetermined period depending upon the design of the network 31, after which it will suddenly fall to zero, bring the operation of the magnetron to an end. The choke 26 is of such a magnitude that when the network 31 has thus discharged the anode voltage is still held too low for operation of the magnetron. By this time the short pulse impressed upon the condenser 30 has passed, so that the auxiliary emitter 20 is again unable to stimulate further operation of the magnetron. The magnetron will thus remain quiescent as the anode voltage gradually builds up in consequence of the charging of the network 31 through the choke 26. After the network 31 is again charged another negative pulse is impressed upon the auxiliary emitter 20 through the condenser 30 and a new cycle of operation is initiated. In this connection the provision of cooling means for the secondarily emissive portion of the cathode is important, as the temperature of such portion is thereby kept low enough to prevent thermionic emission therefrom when the anode potential builds up again, leaving the thermionic auxiliary emitter and its grid in full control.

It is possible in some cases to employ the auxiliary emitter 20 as a sort of control electrode even without the provision of a grid structure 25. For this purpose, however, it is usually necessary to operate the auxiliary emitter 20 at a voltage much more positive with respect to the cathode 5 and less negative with respect to the anode 6 than in the cases where a grid structure is used, in order to prevent the initiation of oscillations in the magnetron which are necessary for electron bombardment of the cathode and the resulting secondary emission. It is doubtful that such an arrangement without a grid structure would be

practical for operation at high cathode-anode voltages.

Fig. 5 shows another form of cathode structure adapted for operation of the general type described in connection with Fig. 4. In this arrangement one end of the auxiliary emitter 20 is connected to the cathode 5 while the other end is connected to a lead 33. The voltage of the auxiliary emitter with respect to the anode will therefore be substantially the same as that of the cathode 5. The action of the auxiliary emitter 20 is, however, controlled by a grid structure 35 which is not in contact with the cathode and which is insulated, as at 36, from the structure supporting the auxiliary emitter. An independent lead 37 is brought out of the vacuum tube for controlling the potential of the grid 35. In such an arrangement an auxiliary voltage supply with its positive terminal connected to the cathode voltage supply and its negative terminal connected to the grid 35 should be provided to maintain the grid 35 at a voltage more negative than that of the cathode 5 in order to prevent excitation of secondary emission. Then, by a suitable means inserted in the grid voltage supply a positive pulse may be impressed upon the grid, of sufficient amplitude to permit emission from the auxiliary emitter 20 to pass through the grid for a short period of time. A cycle of operation will then be initiated after the manner of operation described in connection with Fig. 4.

A great advantage of the cathode structures of the present invention lies in the fact that the power capability of the magnetron tubes employing such cathode structures may be considerably increased by providing means for cooling the secondary emission cathode. The cathode temperature appears to be the chief limiting factor on the average power (averaged over the duty cycle) that may be obtained from a magnetron tube. The small amount of heating applied to the auxiliary emitter is sufficient to provide for the rapid initiation of oscillations at the desired moment, whereas the rest of the cathode may operate "cold" and, by the provision of suitable cooling means, may be maintained below temperatures that are too high for operation with a reasonable service life.

Fig. 1 illustrates a typical arrangement for air cooling of the cathode, the heat being first conducted and radiated away from the cathode and then further dissipated by air cooling. Fig. 6 shows an arrangement for providing water cooling of the cathode 5. In this arrangement the cathode 5 is supported at both ends by hollow cylindrical leads 40 and 41. The central hole of these leads communicates with a central hole 42 bored in the cathode 5, thus permitting the circulation of water through the cathode. In this arrangement the cathode is provided with two "hats," the disks 44 and 45. The auxiliary emitter 20 in this case is connected at one end to the cathode 5 and at the other end to a lead 46 which has the form of a conductor coaxial with the lead 41. The insulation between the conductors 41 and 46 need only be able to withstand voltages of the order of the heater voltage impressed across the auxiliary emitter 20. This arrangement provides for economy in the number of highly insulated vacuum seals required, although it has a disadvantage of not being adapted for use of the auxiliary emitter 20 as a control electrode. If desired, a suitable grid electrode might be provided as in Fig. 5.

In the arrangement of Fig. 6 both the cathode

leads 40 and 41 are brought out of the magnetron anode structure through vacuum-sealed structures of the type shown at 15, 16, 17 in Fig. 1. A wire 50 is shown connected to the lead 40 for applying the cathode-anode potential. Wires 51 and 52 are provided for connection to a source of heating current for exciting the auxiliary emitter 20. Such a source is preferably a filament transformer having high-voltage insulation between the windings.

The rest of the water circulation system, including the necessary pump and reservoir (not shown) should of course be insulated from ground when the anode is operated at ground potential. In such case the pump, reservoir and water connections might be enclosed in an insulated compartment and the pump might be driven by a shaft of insulating material. If desired, however, the water connections from the magnetron cathode to a grounded pump and reservoir can be made long enough to provide a high resistance path to ground.

In the manufacture of magnetron tubes in accordance with the present invention the usual steps of outgassing the elements, evacuating the tube and ageing it are to be followed. If desired, a heater might be provided in the cathode simply for the purpose of obtaining a high outgassing temperature, the heater being left unused in operation of the tube. The preliminary treatment of the cathode 5 before the tube is put into service (ageing and the like) and also the treatment during the evacuation process should be designed to produce a secondary emission characteristic which is stable with time rather than to produce a less stable but initially higher degree of secondary emission. The stable type of secondary emission has a sufficient "gain" in the number of electrons emitted per bombarding electron to provide ample build-up of the space current.

What I desire to claim and secure by Letters Patent is:

1. A magnetron oscillator tube having a generally annular anode and a compound cathode, said cathode comprising a major cylindrical secondary emissive portion extending substantially coaxially for the greater part of the length of the space enclosed by said anode and comprising also a relatively small thermionic portion disposed coaxially with said major portion and extending therefrom a distance approximately equal to the radius of said major portion, said major portion being adapted to emit secondary electrons upon electron bombardment even when cold, and said small portion being adapted to be heated independently of said major portion and to emit electrons thermionically when so heated.

2. A magnetron oscillator tube having a generally annular anode, a cathode of secondarily emissive material projecting axially therethrough except for a relatively short length beyond the extremity of said cathode, and an auxiliary emitter adapted to be heated independently of said cathode and to emit electrons when so heated and located in substantial alignment with said cathode.

3. A magnetron oscillator tube having a generally annular anode and a compound cathode substantially enclosed by said anode and comprising a relatively large secondary emissive portion, including the central portion of said cathode, having a surface of a material adapted to emit secondary electrons upon electron bombardment, and comprising also a relatively small thermionic portion adapted to be heated inde-

pendently of said large portion and to emit electrons thermionically, the emitting capacity of said major portion to said minor portion being in the ratio of approximately 10 to 1.

4. A magnetron oscillator having a generally annular anode, a secondarily emissive cathode disposed axially with respect to said anode, a thermionic auxiliary emitter and a grid structure surrounding said auxiliary emitter and adapted to control, by virtue of its voltage relative to said auxiliary emitter, the transit of electrons emitted from said auxiliary emitter towards the anode-cathode space.

5. A magnetron oscillator according to claim 4 in which said grid structure is supported on and connected to said cathode and in which said auxiliary emitter is not electrically connected to said cathode and is adapted to be impressed with a positive voltage with respect to said cathode.

6. A magnetron oscillator according to claim 4 in which said grid structure is an independent electrode provided with a suitable lead and adapted to be impressed with a substantial negative voltage relative to the average voltage of said auxiliary emitter.

7. A circuit for producing intermittent pulses of ultra-high-frequency oscillations including a magnetron tube having an annular multicavity anode and a compound cathode comprising a secondarily emissive cathode and a relatively small thermionic auxiliary emitter, means for preventing thermionic emission of said emitter from exciting said tube in the absence of a trigger pulse applied to said circuit, a reactive pulse-forming network adapted to discharge upon initiation of oscillations in said tube by emission from said auxiliary emitter with the formation of a substantially rectangular electrical pulse, means including a source of high voltage for impressing a relatively high potential between said cathode and said anode and for charging said reactive pulse-forming network, and current limiting means connected in series with said source of high voltage adapted to permit the discharge of said network as aforesaid and to reduce the said voltage between said anode and said cathode at the end of such discharge to a value low enough to interrupt oscillations of said tube.

8. A circuit for producing intermittent pulses of ultra-high-frequency oscillations including a magnetron tube having an annular multicavity anode and a compound cathode comprising a secondarily emissive cathode and a relatively small thermionic auxiliary emitter, a reactive pulse-forming network adapted to discharge upon initiation of oscillations in said tube with the formation of a substantially rectangular electrical pulse, means including a source of high voltage for impressing a relative high potential between said cathode and said anode and for charging said network connected between said cathode and said anode, means for normally maintaining said auxiliary emitter at a voltage positive with respect to said secondarily emissive cathode and negative with respect to said anode and means associated therewith for periodically causing the potential of said auxiliary emitter to assume for a short period a potential of approximately the same as that of said secondarily emissive cathode, and current limiting means connected in series with said source of high voltage and adapted to reduce the said voltage between said anode and said cathode for a predetermined time after the discharge of said network to a value low enough to interrupt oscillations of said tube.

9. A circuit for producing intermittent pulses of ultra-high-frequency oscillations including, a magnetron having an annular multicavity anode and a compound cathode comprising a secondarily emissive cathode and a relatively small thermionic auxiliary emitter, said secondarily emissive cathode having an extension in the form of a grid structure enclosing said auxiliary emitter, a reactive pulse-forming network adapted to discharge upon initiation of oscillations in said tube with the formation of a substantially rectangular electric pulse, means including a source of high voltage connected through a current limiting means for impressing a relatively high potential between said cathode and said anode except for a predetermined time after the discharge of said network and for charging a said network, means for maintaining said auxiliary emitter normally at a voltage positive with respect to said secondarily emissive cathode, and associated means for periodically causing said auxiliary emitter to be at a potential at least as negative with respect to said anode as said secondarily emissive cathode, for a short period of time.

10. A circuit for producing intermittent pulses of ultra-high-frequency oscillations including, a magnetron tube having an annular multicavity anode and a compound cathode comprising a secondarily emissive cathode and a relatively small thermionic auxiliary emitter and having also a control grid surrounding said auxiliary emitter, a reactive pulse-forming network which discharges upon initiation of oscillations in said tube with the formation of a substantially rectangular electric pulse, means including a source of high voltage provided with current limiting means whereby a relatively high potential is impressed between said cathode and said anode except for a predetermined period after the discharge of said network and adapted also to charge said network, means for normally maintaining the potential of said control grid at a potential negative with respect to said auxiliary emitter and for periodically for short duration bringing said potential of said control grid to a value at least as positive as the potential of said auxiliary emitter.

11. A magnetron oscillator tube having a generally annular anode and a compound cathode positioned coaxially therein, said cathode comprising a relatively large secondary emissive portion and a relatively small thermionic emissive portion in axial juxtaposition with said large portion, and means for cooling said large portion of said cathode, said last-mentioned means including a channel passing through said large portion of said cathode adapted for the circulation of a cooling fluid through said large portion of the cathode.

12. A magnetron oscillator tube having a generally annular anode and a compound cathode positioned substantially coaxial therewith, said cathode comprising a relatively large secondary emissive portion, and comprising also a relatively small thermionic portion positioned in axial juxtaposition with said large portion, and means for cooling said large portion of said cathode, said means including a relatively thick cathode lead, cooling fins attached to said lead external of said tube, and a carbon coated disk in heat conducting relationship with said cathode whereby said disk radiates heat from said cathode towards said anode.

13. A magnetron oscillator tube having a generally annular anode and a compound cathode, said cathode comprising a major cylindrical sec-

ondary emissive portion extending substantially coaxially for the greater part of the length of the space enclosed by said anode and comprising also a relatively small thermionic portion disposed coaxially with said major portion and extending therefrom a distance approximately equal to the radius of said major portion, said thermionic portion being adapted to be heated independently of said major portion and to emit electrons thermionically when so heated, and heat transfer means connected to one end of said major cylindrical portion for providing cooling thereof.

14. A magnetron oscillator tube having a generally annular anode and a compound cathode positioned substantially coaxial therewith, said cathode comprising a relatively large secondary emissive portion and a relatively small thermionic portion positioned in axial juxtaposition with said large portion, and means for cooling said large portion of said cathode, said means including a channel passing centrally of said large portion along the axis thereof, and hollow tubing attached to both ends of said channel and extending externally of said tube, said tubing and channel being adapted for the circulation of a cooling fluid therethrough.

15. A magnetron oscillator tube having a generally annular anode and a compound cathode positioned substantially coaxial therewith, said cathode comprising a relatively large secondary emissive portion and a relatively small thermionic portion in axial juxtaposition with said large portion, and heat transfer means for cooling said large portion of said cathode, said heat transfer means including an axially extending channel within said large portion in communication with metallic tubing at either end thereof, said tubing extending externally of said tube for the circulation of a cooling fluid therethrough, the tubing further constituting a cathode lead.

16. A magnetron oscillator tube having a generally annular anode and a compound cathode positioned substantially coaxial therewith, said cathode comprising a large secondary emissive portion and a relatively small thermionic portion positioned in axial juxtaposition with said large portion, and means for cooling said large portion of said cathole, said means including a metallic disk secured to said large portion and disposed in a plane perpendicular to the axis of said cathode, said disk having a carbon coating on the face thereof furthest removed from said large portion whereby said disk radiates heat from said large portion, and a cathode lead connected to said metallic disk.

17. A magnetron oscillator tube having a generally annular anode and a compound cathode, said cathode comprising a major cylindrical secondary emissive portion extending substantially coaxially for the greater part of the space enclosed by said anode and comprising also a small coil of wire having thermionic emitting properties positioned in axial juxtaposition with said major portion.

18. A magnetron oscillator tube having a generally annular anode and a compound cathode positioned substantially coaxially therewith, said cathode comprising a large secondary emissive portion and a small thermionic portion comprising solely a coil of few turns of thermionic wire positioned in axial juxtaposition with said large portion, said coil being adapted to be heated independently of said large portion by passage of current therethrough.

JOHN W. McNALL.

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Disclaimer

2,450,763.—*John W. McNall*, East Orange, N. J. ULTRA HIGH FREQUENCY GENERATOR VACUUM TUBE AND CATHODE STRUCTURE THEREFOR. Patent dated Oct. 5, 1948. Disclaimer filed Oct. 5, 1950, by the assignee, *United States of America as represented by the Secretary of the Navy.*

Hereby enters this disclaimer to claim 7 of said patent.

[Official Gazette November 14, 1950.]

ondary emissive portion extending substantially coaxially for the greater part of the length of the space enclosed by said anode and comprising also a relatively small thermionic portion disposed coaxially with said major portion and extending therefrom a distance approximately equal to the radius of said major portion, said thermionic portion being adapted to be heated independently of said major portion and to emit electrons thermionically when so heated, and heat transfer means connected to one end of said major cylindrical portion for providing cooling thereof.

14. A magnetron oscillator tube having a generally annular anode and a compound cathode positioned substantially coaxial therewith, said cathode comprising a relatively large secondary emissive portion and a relatively small thermionic portion positioned in axial juxtaposition with said large portion, and means for cooling said large portion of said cathode, said means including a channel passing centrally of said large portion along the axis thereof, and hollow tubing attached to both ends of said channel and extending externally of said tube, said tubing and channel being adapted for the circulation of a cooling fluid therethrough.

15. A magnetron oscillator tube having a generally annular anode and a compound cathode positioned substantially coaxial therewith, said cathode comprising a relatively large secondary emissive portion and a relatively small thermionic portion in axial juxtaposition with said large portion, and heat transfer means for cooling said large portion of said cathode, said heat transfer means including an axially extending channel within said large portion in communication with metallic tubing at either end thereof, said tubing extending externally of said tube for the circulation of a cooling fluid therethrough, the tubing further constituting a cathode lead.

16. A magnetron oscillator tube having a generally annular anode and a compound cathode positioned substantially coaxial therewith, said cathode comprising a large secondary emissive portion and a relatively small thermionic portion positioned in axial juxtaposition with said large portion, and means for cooling said large portion of said cathole, said means including a metallic disk secured to said large portion and disposed in a plane perpendicular to the axis of said cathode, said disk having a carbon coating on the face thereof furthest removed from said large portion whereby said disk radiates heat from said large portion, and a cathode lead connected to said metallic disk.

17. A magnetron oscillator tube having a generally annular anode and a compound cathode, said cathode comprising a major cylindrical secondary emissive portion extending substantially coaxially for the greater part of the space enclosed by said anode and comprising also a small coil of wire having thermionic emitting properties positioned in axial juxtaposition with said major portion.

18. A magnetron oscillator tube having a generally annular anode and a compound cathode positioned substantially coaxially therewith, said cathode comprising a large secondary emissive portion and a small thermionic portion comprising solely a coil of few turns of thermionic wire positioned in axial juxtaposition with said large portion, said coil being adapted to be heated independently of said large portion by passage of current therethrough.

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