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Kawasaki-shi, Japan
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 [33] **Japan**
 [31] **8243/68**

[50] Field of Search..... 328/230,
 244, 295, 227, 250, 267; 315/39.53, 101, 307;
 331/91

[56]

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[54] **MAGNETRON OPERATING CIRCUIT**
 4 Claims, 13 Drawing Figs.

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 315/39.53, 315/101, 331/91

[51] Int. Cl.....H01j 29/00,
 H01j 25/50

ABSTRACT: In a circuit for operating a magnetron tube by energizing it by the use of a voltage-doubler rectifier circuit, means is provided to temporarily reduce the anode voltage below the normal oscillation voltage after the cathode electrode has been warmed up to normal electron emission temperature.

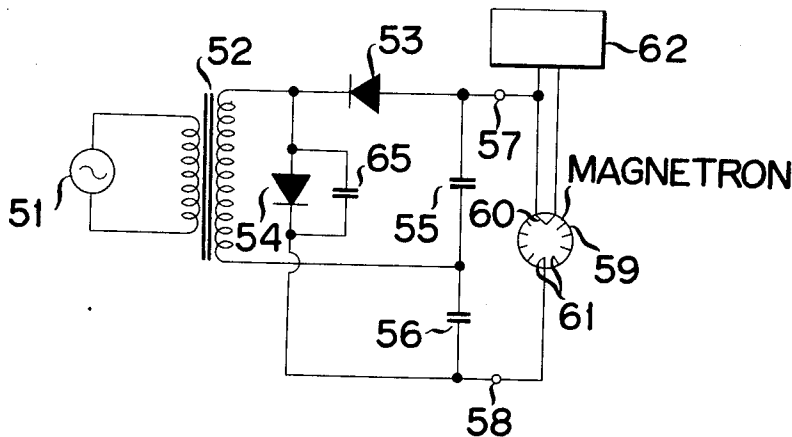


FIG. 1

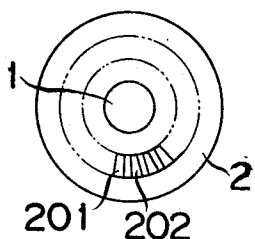


FIG. 2

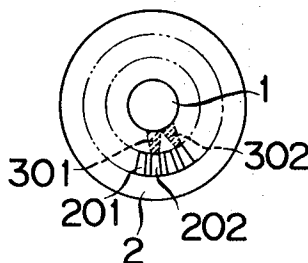
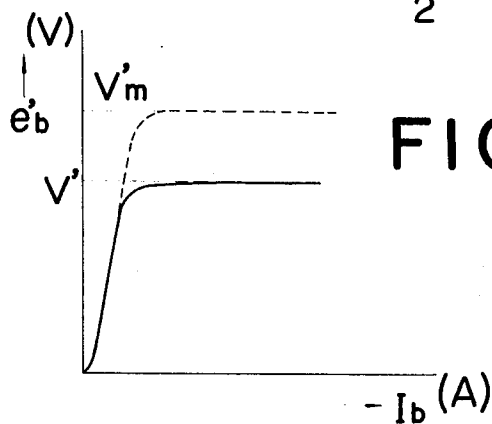


FIG. 3

FIG. 5

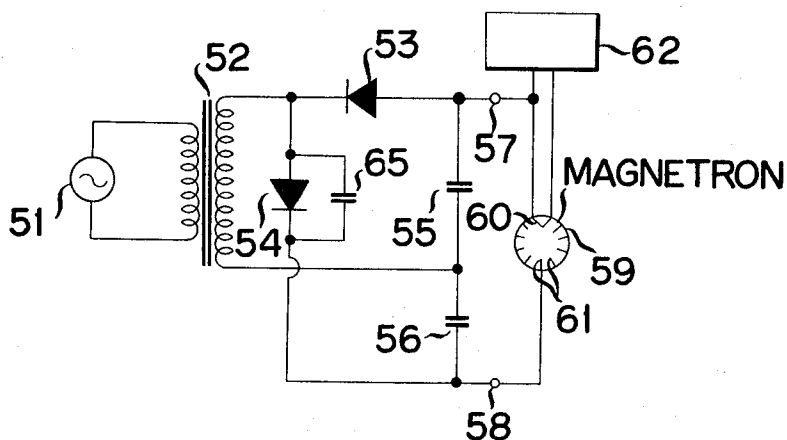


FIG. 4a

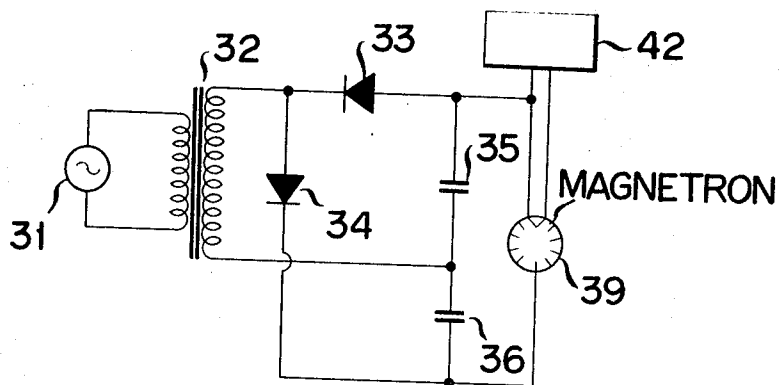


FIG. 4b

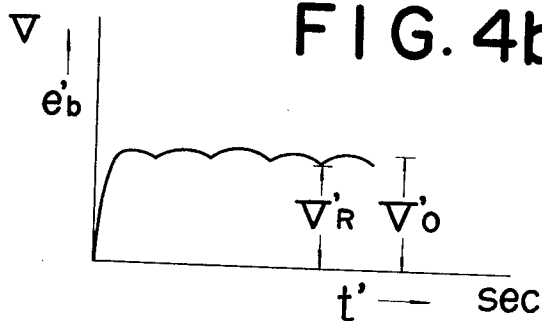
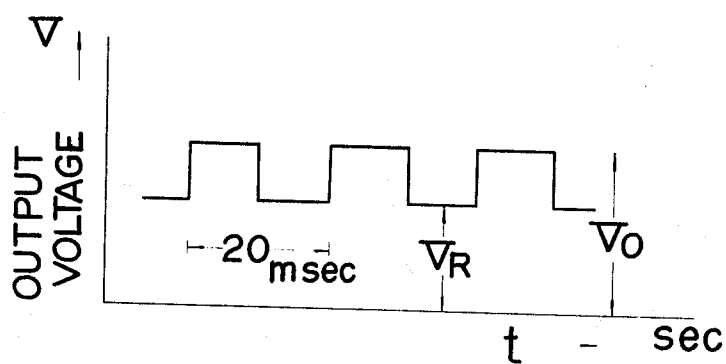


FIG. 6



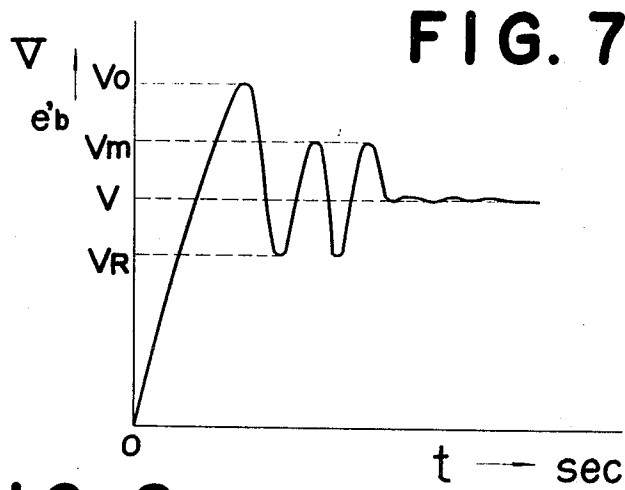


FIG. 8

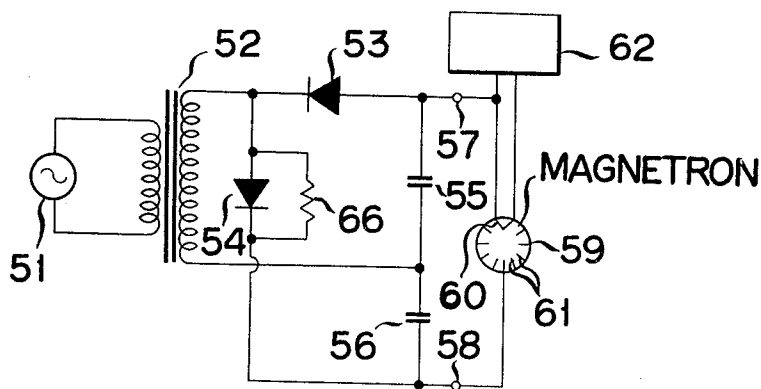


FIG. 9

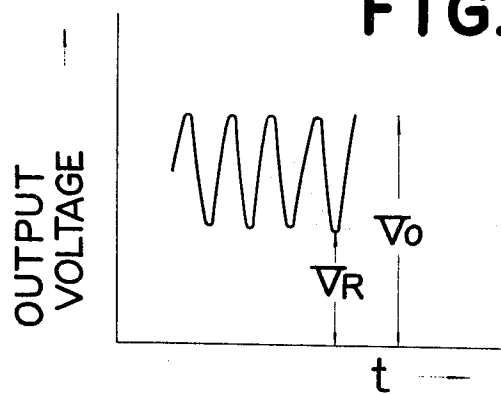


FIG. 10

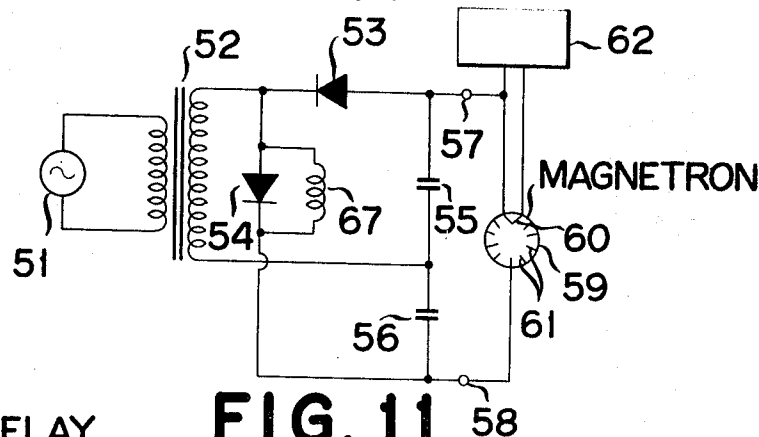
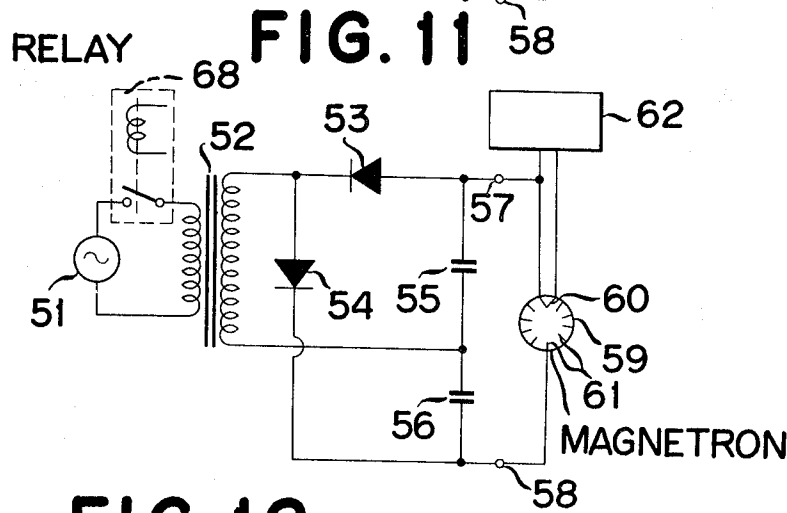
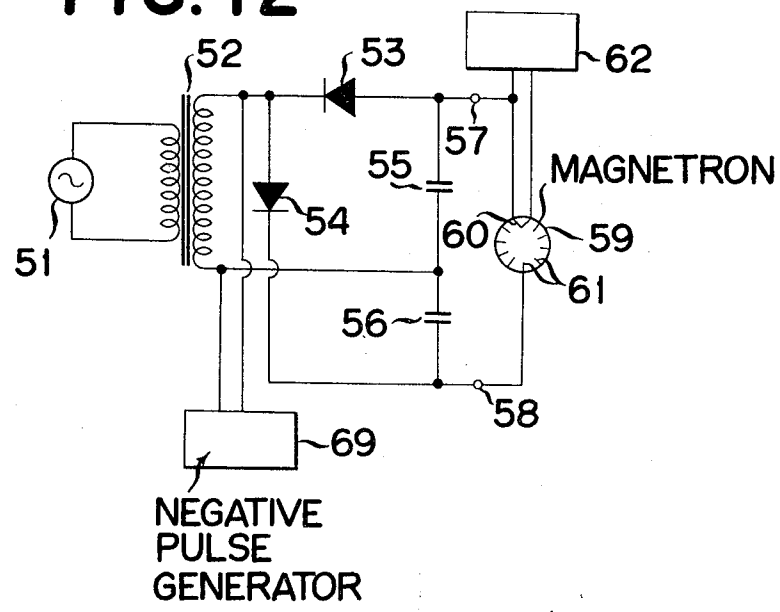


FIG. 12



MAGNETRON OPERATING CIRCUIT

This invention relates to a magnetron device operated by the output voltage from a voltage-doubler rectifier circuit and more particularly to an improved voltage-doubler rectifier circuit, for restraining a moding phenomenon or changing quickly the moding to normal oscillation of a magnetron tube.

As is well known in the art (shown in FIG. 1) an ordinary magnetron tube comprises a cathode electrode 1, a plurality of vane shaped split anode 201, 202 surrounding the cathode electrode, means to establish magnetic field in the axial direction of said electrodes, and means to apply an operating voltage between anode and cathode electrodes to create electric oscillation. Due to inherent back heat of the magnetron tube the cathode temperature is higher than the warmup temperature by about 100° C, for example. Usually, in order to elongate the operating life of the magnetron tube, the cathode temperature is maintained at a correct value at the time of oscillation, and the cathode temperature during warmup period is maintained low so that it is impossible to emit sufficient quantity of electrons at the beginning of oscillation.

As a result, even when an operating voltage is impressed across the anode and cathode electrodes the magnetron tube cannot oscillate at the normal oscillating voltage V' because the cathode temperature and hence electron emission are low at the time of application of the operating voltage. Thus, as shown in FIG. 3, the tube begins to oscillate only when voltage reaches a voltage (moding voltage $V'm$) higher than the normal oscillating voltage V' . Such a phenomenon is termed as the moding phenomenon. More particularly, as shown in FIG. 2, during normal oscillation, the number of electron spokes 301, 302 is equal to one-half of that of vanes 201, 202 of an anode electrode 2. Once such a moding phenomenon occurs the number of electron spokes becomes larger or smaller than one-half of the number of vanes 201, 202, thus resulting in instability of the oscillation frequency of the magnetron tube. Due to high voltage of the moding phenomenon, the cathode electrode is overheated to shorten its operating life and to impair the efficiency of the tube. Generally the relation between the moding voltage $V'm$ and normal oscillating voltage V' can be expressed as follows:

$$V'm > V' \text{ and } V' \Phi 2/3V'm$$

The magnetron apparatus shown in FIG. 4a, wherein the operating voltage of the magnetron tube is supplied from a voltage-doubler rectifier circuit, has been used because of its high-power factor, small size transformer and other advantages. More specifically, as shown in FIG. 4a the voltage of an AC source 31 is applied to a magnetron tube 39 through a transformer 32 and a voltage-doubler rectifier circuit comprising a plurality of silicon rectifiers 33, 34 and condensers 35 and 36. A heating power is applied to the magnetron tube 39 from a heater source 42. The no load waveform of the output voltage e_b of the rectifier is shown by a curve of FIG. 4b. As the maximum anode voltage $V'o$ is selected to be higher than the moding voltage the relationship between the maximum anode voltage $V'o$ and the normal oscillation voltage V' is expressed by

$$0 < V' < V'm < V'o$$

and the normal oscillation voltage V' is smaller than the minimum anode voltage $V'r$, that is $V' < V'r$. Upon application of the anode voltage, it increases to a value substantially equal to the maximum anode voltage $V'o$ which is higher than the moding voltage $V'm$ thus resulting in the moding phenomenon. As shown in FIG. 4b, the ripple of the anode voltage supplied by the voltage-doubler rectifier circuit is small and since the minimum ripple voltage $V'r$ is larger than the normal oscillation voltage V' , the magnetron cannot assume the normal oscillating state after the warmup period, thus continuing to show the moding phenomenon.

An object of this invention is the provide an improved magnetron operating circuit wherein an operating voltage from a voltage-doubler rectifier circuit is supplied to a magnetron and which can eliminate the moding phenomenon.

Another object of this invention is to provide a magnetron operating circuit by means of which the magnetron can operate at a stable oscillation frequency.

A still further object of this invention is to provide an improved magnetron operating circuit which can prevent overheating of the cathode electrode of the magnetron tube thus elongating the operating life thereof.

Briefly stated, in accordance with this invention there is provided a magnetron operating circuit comprising a voltage-doubler rectifier circuit for supplying an operating voltage to a magnetron, and means to temporarily decrease the anode voltage of the magnetron below the normal oscillation voltage when the cathode electrode is brought to a condition capable of emitting a sufficient number of electrons, to eliminate the moding phenomenon.

The present invention can be more fully understood from the following detailed description when taken in connection with the accompanying drawings, in which:

FIG. 1 is a diagram to show the construction of a conventional magnetron tube;

FIG. 2 is a diagram to explain the moding phenomenon of a magnetron tube;

FIG. 3 shows the anode current (I_b) viz anode voltage (e_b) characteristics of a conventional magnetron tube;

FIG. 4a is a circuit diagram of a conventional voltage-doubler rectifier circuit for energizing the magnetron tube;

FIG. 4b shows a waveform of the output voltage of the voltage-doubler rectifier circuit;

FIG. 5 shows a connection diagram of a magnetron tube employing a novel voltage-doubler rectifier circuit;

FIG. 6 shows a waveform of the output voltage of the voltage-doubler rectifier circuit shown in FIG. 5;

FIG. 7 is a characteristic curve to explain the normal oscillation condition of the magnetron apparatus shown in FIG. 5;

FIGS. 8, 10, 11 and 12 show connection diagram of modified embodiments of this invention; and

FIG. 9 shows no load output voltage of the voltage-doubler rectifier circuit shown in FIG. 8.

As shown in FIG. 5, the primary winding of a high-voltage transformer 52 is connected across an AC source 51 and to one terminal of the secondary winding of the high-voltage transformer 52 is connected the cathode electrode of a first silicon rectifier 53, the anode electrode thereof being connected to a first output terminal 57. This terminal is connected to the other side of the secondary winding of the transformer 52 via condenser 55. The other side of the secondary winding is connected to a second output terminal 58 via a second condenser 56, and a second silicon rectifier 54 is connected between second output terminal 58 and said one or upper terminal of the secondary winding. As shown, the anode electrode of the second rectifier 54 is connected to the cathode electrode of the first rectifier 53, and a condenser 65 is connected in parallel with the second rectifier. The cathode electrode 60 of magnetron tube 59 is energized by a heater source 62 and the cathode electrode 60 is also connected to the first output terminal 57, while the anode electrode 61 is connected to the second output terminal 58.

Thus, the alternating current supplied by the AC source 51 is full-wave rectified by rectifiers 53 and 54 and smoothed out by condensers 55 and 56. The rectified voltage is then applied across anode and cathode electrodes 61 and 60 of magnetron tube 59 to cause it to oscillate. Where the source is a 50 cycle alternating current, the no load voltage wave appearing across output terminals 57 and 58 can be shown in FIG. 6. The lower value V_R of the output voltage varies dependent upon the capacitance C_p of condenser 65 and when the capacitances C_o of condensers 55 and 56 are represented by $C_o = C_p$ the value of V_R is expressed by

$$V_R \approx \frac{1}{2} V_o$$

where V_o represents the upper value of the ripple. Where $C_p \approx \frac{1}{2} C_o$ then $V_R \approx 0.67 V_o$. Thus, by proper selection of the capacitance C_p of condenser 65, it is possible to reduce the

lower value V_R of the ripple to a value below the normal operating voltage V of magnetron 59 thus satisfying the relation

$$V_R < V < V_m < V_o,$$

where V_m represents the moding voltage. When the voltage shown in FIG. 6 is supplied across the anode and cathode electrodes of the magnetron from the voltage-doubler rectifier circuit before the temperature of the cathode electrode 60 reaches a sufficient temperature, the electron emission thereof is not sufficient so that the moding phenomenon occurs when the voltage reaches the moding voltage V_m which is larger than the normal oscillation voltage V . However as shown in FIG. 7, after elapse of the warmup period of the cathode electrode 60 during which the cathode temperature is increased by the current supplied from heater source 62 and by dint of the moding phenomenon, the magnetron 59 comes to operate the normal oscillation under the condition that the electron emission becomes sufficient to assure normal oscillation because the lower value of the voltage V_R decreases below the normal oscillation voltage. Condensers 55 and 56 having a capacitance, e.g., $C_o = 0.25$ microfarad and condenser 65 having a capacitance, e.g., $C_p = 0.1$ to 0.125 microfarad, the breakdown voltages of which are respectively 2,000 volts are used. During the half cycle in which the diode 54 is in the nonconducting state, the condenser 65 is charged by electric charges stored in the condenser 56. Therefore, the terminal voltage across the output terminals 57 and 58 is reduced to less than the normal oscillation voltage, as shown in FIG. 6, during said half cycle.

Alternatively, condenser 65 shown in FIG. 5 can be substituted by a resistor 66, as shown in FIG. 8, in which case no load voltage as shown in FIG. 9 appears across output terminals 57 and 58. In one example, the resistor 66 had a resistance value of 50 kilohms.

In a still further modification shown in FIG. 10, an inductor 67 is substituted for condenser 65 in FIG. 5. In one example, the inductor had an inductance of 1 henry.

It will be clear that condenser 65, resistor 66 or inductor 67 may be connected in parallel with the first rectifier 53 with equal results.

Further, instead of providing condenser 65 as shown in FIG. 5, a relay 68 may be included on the primary or secondary side of transformer 52 as shown in FIG. 11, and after completion of the warming up of the cathode electrode 60 of a magnetron tube 61, for example, 2 or 3 seconds after energizing the operating circuit, the relay may be opened for a moment.

In a modification shown in FIG. 12, a negative pulse generator 69 is connected across the secondary winding of transformer 52 to apply at least one negative pulse after the cathode electrode has been warmed up to the operating temperature so as to reduce the anode voltage below the normal oscillation voltage.

Thus, this invention can effectively prevent occurrence of undesirable moding phenomenon when the magnetron is sup-

plied with an operating voltage from a voltage-doubler rectifier circuit whereby such problems as causing instability of the oscillation frequency of the magnetron, overheating of the cathode electrode, shortening of the operating life and decrease of the magnetron efficiency can be prevented.

What is claimed is:

1. A magnetron operating circuit, comprising a magnetron tube, a source of alternating current, a transformer to boost the output voltage of said source, a first rectifier having an electrode connected to a first output terminal of the secondary winding of said transformer, a second rectifier having an electrode connected to said first output terminal in a polarity opposite to that of said electrode of said first rectifier, a first condenser connected between the other electrode of said first rectifier and a second output terminal of said secondary winding, a second condenser connected between the other electrode of said second rectifier and said second output terminal of said secondary winding, said first and second condensers being connected in series across the anode-cathode circuit of said magnetron to provide a rectified double voltage for energizing the anode-cathode circuit of said magnetron tube, means for temporarily reducing the anode-cathode voltage of said magnetron tube below its normal oscillation voltage and said means for reducing the anode-cathode voltage comprising a negative pulse generator connected across the secondary winding of said transformer so as to apply at least one negative pulse to the secondary circuit after elapse of the warmup period of the cathode electrode of said magnetron tube.

2. A magnetron operating circuit according to claim 1 wherein said negative pulse generator is connected across the secondary winding of said transformer between said secondary winding and said rectifiers.

3. A magnetron operating circuit, comprising a magnetron tube, a source of alternating current, a transformer to boost the output voltage of said source, a first rectifier having an electrode connected to a first output terminal of the secondary winding of said transformer, a second rectifier having an electrode connected to said first output terminal in a polarity opposite to that of said electrode of said first rectifier, a first condenser connected between the other electrode of said first rectifier and a second output terminal of said secondary winding, a second condenser connected between the other electrode of said rectifier and said second output terminal of said secondary winding, said first and second condensers being connected in series across the anode-cathode circuit of said magnetron to provide a full-wave rectified double voltage for energizing the anode-cathode circuit of said magnetron tube, and means for temporarily reducing the anode-cathode voltage of said magnetron tube below its normal oscillation voltage to obtain a ripple voltage, said reducing means comprising an impedance connected in parallel with either one said first rectifier and said second rectifier.

4. A magnetron operating circuit according to claim 3 wherein said impedance comprises a condenser.

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