United States Patent [19]

Sievers et al.

[11] **3,873,883**

[45] **Mar. 25, 1975**

[54] **POSITIVE IGNITION POWER SUPPLY FOR A MAGNETRON**

[75] Inventors: **Carl J. Sievers; Ronald C. Wagner,** both of Highland, Ill.

[73] Assignee: **Basler Electric Company,** Highland, Ill.

[22] Filed: **Sept. 25, 1973**

[21] Appl. No.: **400,546**

[52] **U.S. Cl.** ..... **315/105,** 315/200 R, 315/276, 315/291, 328/262, 331/185

[51] **Int. Cl.** **H03b 9/10**

[58] **Field of Search** ..... 315/94, 101, 105, 200 R, 315/276, 291, 282, 307, 352–354; 328/258, 328/230, 262, 267; 330/47; 331/185, 186

[56] **References Cited**

UNITED STATES PATENTS

3,392,309	7/1968	Hickman	315/94
3,569,855	3/1971	Noda	331/185 X
3,611,027	10/1971	Koinuma et al.	315/101 X
3,651,371	3/1972	Tingley	328/262 X
3,760,291	9/1973	Levinson	331/186 X

Primary Examiner—Paul L. Gensler
Attorney, Agent, or Firm—Koenig, Senniger, Powers and Leavitt

[57] **ABSTRACT**

A power supply for a magnetron which provides a microwave output and has an anode, a cathode, and a filament circuit. The magnetron has proper and improper modes of oscillation. The supply includes a step-up transformer which has a primary winding for connection to an a.c. power source and at least one secondary winding. Means, including a full wave voltage-multiplying rectifier circuit interconnected with the secondary winding and the anode-cathode circuit of the magnetron, apply a time-varying voltage across the anode-cathode circuit of said magnetron. The filament circuit of the magnetron and the anode-cathode circuit thereof are simultaneously energized; and the application of the time-varying voltage across the anode-cathode circuit insures that the magnetron goes into its proper mode of oscillation when the filament has substantially reached its operating temperature.

10 Claims, 7 Drawing Figures

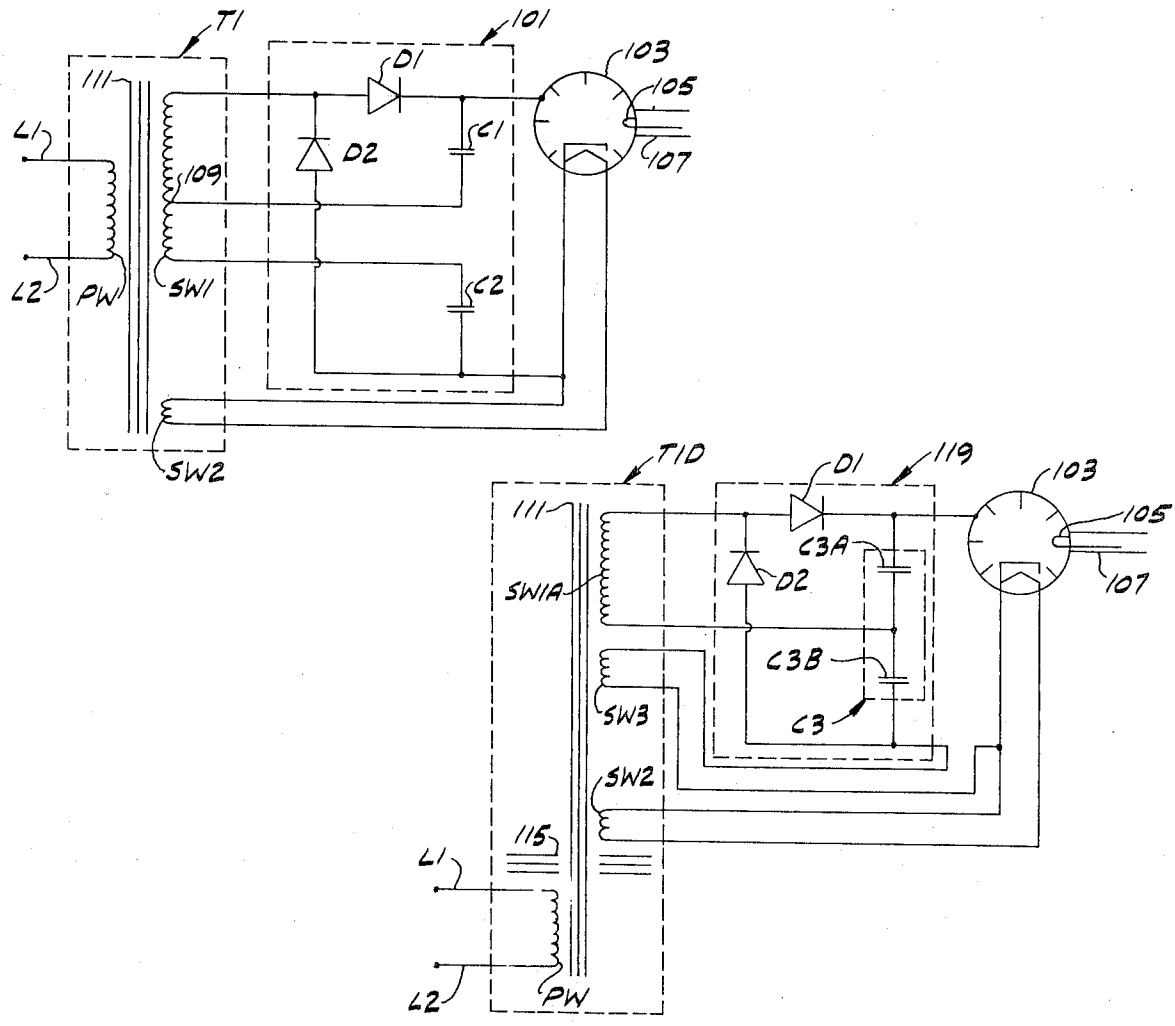


FIG. 1

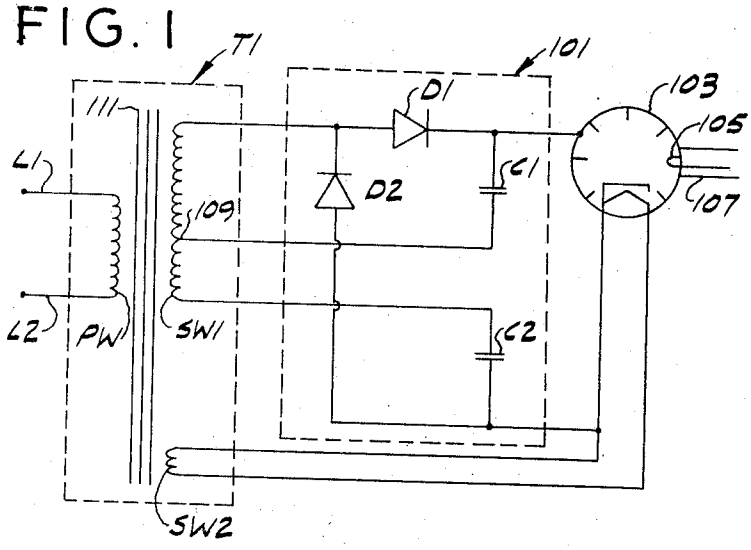


FIG. 2

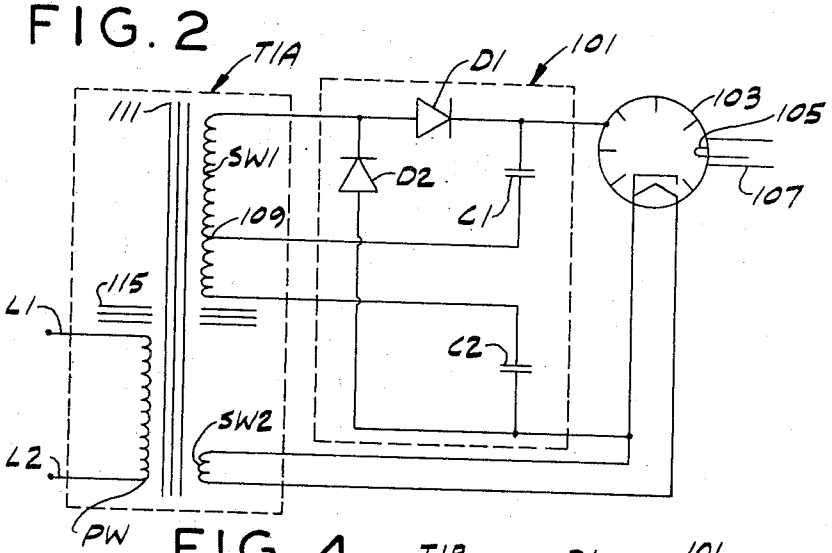


FIG. 3

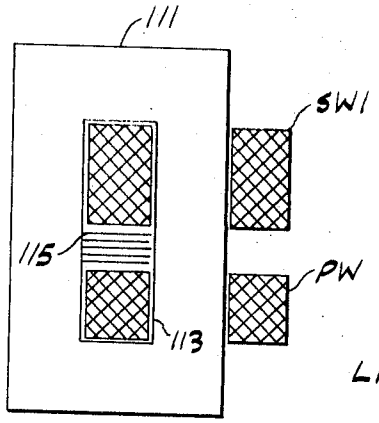


FIG. 4

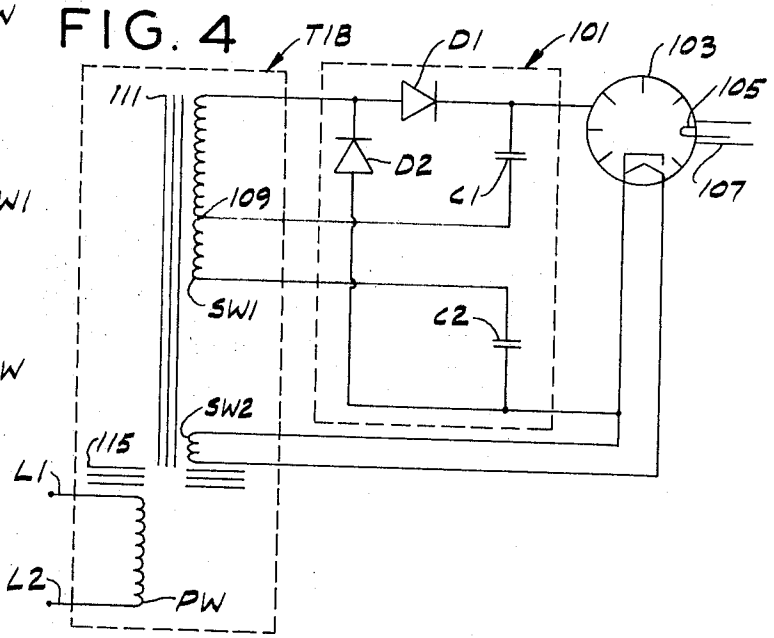


FIG. 5

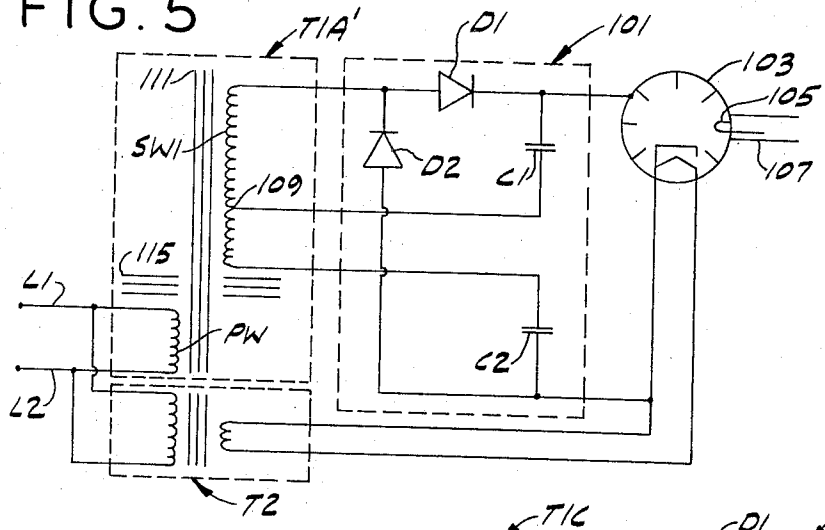


FIG. 6

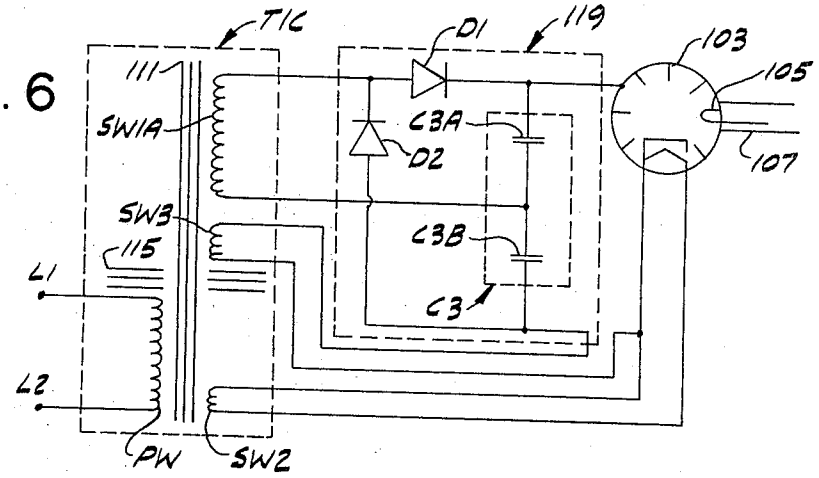
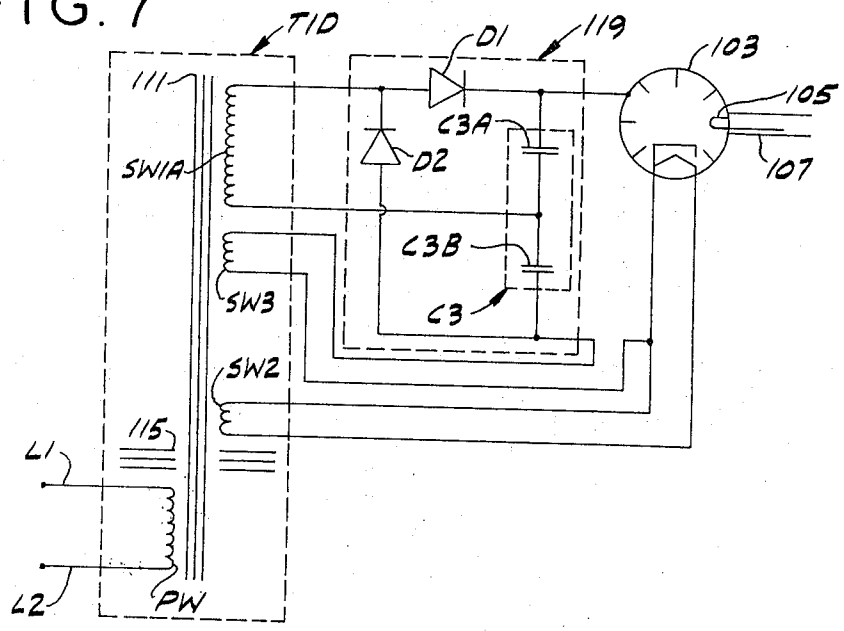


FIG. 7



POSITIVE IGNITION POWER SUPPLY FOR A MAGNETRON

BACKGROUND OF THE DISCLOSURE

This invention relates to power supplies for magnetrons and more particularly to power supplies which include a voltage multiplying circuit and which insures that the magnetron goes into its proper mode of oscillation.

Heretofore, power supplies for magnetrons used for commercial application (for example, microwave ovens) have typically employed both half-wave and full-wave rectifier circuits, such as disclosed, for example, in U.S. Pat. No. 3,396,342 to produce high voltage d.c. which is applied to the anode-cathode circuit of the magnetron. While full-wave bridge rectifiers were preferable because of their somewhat higher efficiency, such power supplies require relatively expensive components such as a supply transformer insulated for full voltage at both ends of the secondary winding and a bridge comprising four high piv diodes. Such power supplies have also been regulated to avoid the problems of poor regulation of the a.c. supply, as illustrated in U.S. Pat. Nos. 3,396,342 and 3,407,333.

Another type of power supply for a magnetron which has been used includes a voltage doubler. Voltage doublers have several advantages over a bridge circuit in that with the voltage doubler the secondary voltage of the transformer is only half that required with the bridge, only two high piv diodes are required, only one end of the secondary winding has to be insulated for full magnetron anode-cathode voltage, and with the voltage-doubler capacitors are positioned across the anode-cathode circuit providing protection from voltage transients. However, such power supplies required a time delay relay to allow the filament to come up to temperature before the anode-cathode voltage was applied because otherwise the magnetron tended to go into an improper mode of oscillation or would fail to oscillate. Because the filament-cathode circuit is at a very high potential, the contacts of such a time delay relay, due to insulation requirements, could not practically be connected in a secondary winding of the supply transformer serving to energize the filament circuit of the magnetron. Therefore, a separate filament transformer was required, with the contacts of the relay being connected in the primary of the transformer supplying the high voltage to the anode-cathode circuit thereby delaying application of the high voltage until the filament approaches its operating temperature. This, of course, greatly increased the cost of the magnetron power supply.

SUMMARY OF THE INVENTION

Among the several objects of the invention may be noted the provision of a magnetron power supply which permits simultaneous energization of the anode-cathode and filament circuits of the magnetron and which will reliably go into its proper mode of oscillation when the filament reaches operating temperature; the provision of such a power supply which applies to the magnetron anode-cathode electrodes and filament, regulated voltages substantially independent of voltage fluctuations in the a.c. power source; the provision of such a power supply providing the anode-cathode circuit of the magnetron with protection from voltage transients; the provision of such a power supply minimizing transformer insulation requirements; the provision of such a power supply avoiding the use of time delay devices and separate filament transformers; and the provision of such a power supply which is efficient in operation and may be economically manufactured. Other objects and features will be in part apparent and in part pointed out hereinafter.

Briefly, a power supply of the present invention supplies power to a magnetron which provides a microwave output and has an anode, a cathode, and a filament circuit, the magnetron having proper and improper modes of oscillation. The supply includes a step-up transformer having a primary winding for connection to an a.c. power source and at least one secondary winding. Means including a full-wave voltage-multiplying rectifier circuit interconnected with the secondary winding and the anode-cathode circuit of the magnetron applies a time-varying voltage across the anode-cathode circuit of the magnetron. The filament circuit of the magnetron and the anode-cathode circuit thereof are simultaneously energized whereby the application of the time-varying voltage across the anode-cathode circuit insures that the magnetron goes into its proper mode of oscillation when the filament has substantially reached its operating temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic circuit diagram of one embodiment of a magnetron power supply of the present invention;

FIG. **2** is a schematic circuit diagram of another embodiment of the present invention providing regulated voltage to the anode-cathode circuit of the magnetron;

FIG. **3** diagrammatically illustrates the construction of a high leakage reactance transformer utilized in the FIG. **2** power supply;

FIG. **4** is a circuit diagram of another embodiment of the present invention providing regulated voltages to both the filament and anode-cathode circuits of the magnetron;

FIG. **5** is a circuit diagram of another embodiment of the present invention using a separate filament transformer;

FIG. **6** is a circuit diagram of another embodiment of the present invention having a supply transformer with two regulated and one unregulated secondary windings; and

FIG. **7** is a circuit diagram of another embodiment of the present invention having a supply transformer with three regulated secondary windings.

Corresponding reference characters indicate corresponding parts through the several views of the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. **1**, a power supply of this invention includes a step up transformer T1 and a full-wave voltage-multiplying rectifier **101** which supply power to a magnetron **103** which in turn generates microwave power picked up by a probe **105** for transfer by a wave guide **107** to a horn or the like in a microwave oven (not shown). The circuitry functions to step up the voltage from an a.c. source L1,L2 which supplies power at conventional line voltages of 118 or 235 v.a.c., and to multiply and rectify the stepped up voltage to provide a time-varying voltage across the

anode-cathode circuit of the magnetron. How a time-varying component is introduced into the output of rectifier circuit **101** will be discussed hereinafter.

A magnetron will not consistently go into its proper mode of oscillation and may not even oscillate if a non-varying voltage is applied across the anode-cathode circuit at the same time the filament voltage is applied, i.e., before the filament reaches operating temperature. However, in accordance with this invention, by applying a time-varying voltage to the anode-cathode circuit, the anode-cathode and filament circuits may be simultaneously energized and the magnetron will consistently go into the desired mode of oscillation when the filament comes up to temperature.

Transformer T1 comprises a primary winding PW connected to the power source, a secondary winding SW1 interconnected with voltage doubler **101,** and another secondary winding SW2 connected to the filament of magnetron **103.**

The full wave voltage-multiplying rectifier **101** includes a diode D1 and a capacitor C1 series-connected from one end of secondary winding SW1 to a tap **109,** the anode of D1 being connected to one end of the secondary winding while the junction between D1 and C1 is connected to the anode of magnetron **103.** A diode D2 and a capacitor C2 are series-connected across the entire secondary winding SW1, the cathode of D2 being connected to one end of the secondary winding while the junction between D2 and C2 is connected to the cathode of magnetron **103.**

In operation, the capacitors charge to different d.c. levels during alternate half cycles of the a.c. power source. During the half cycle when the top of secondary winding SW1 is positive with respect to the bottom, the voltage applied across the anode-cathode circuit is the sum of the charge on capacitor C2 and the voltage developed across secondary winding SW1, and capacitor C1 is charged to the potential across the top portion of winding SW1 (from the top thereof to tap **109**). On the other half cycle the applied voltage is the sum of the charge on capacitor C1 and the voltage developed between tap **109** and the top of the secondary winding, and capacitor C2 is charged to the full voltage of winding SW1. Viewed on a steady state basis the voltage applied across the anode-cathode circuit of the magnetron is therefore a composite of the lower charge potential of capacitor C1, the portion of the alternating voltage developed across the lower few turns of secondary winding SW1 (between tap **109** and the lower end of the winding), and the somewhat higher charge potential of capacitor C2, and thus constitutes a time-varying voltage. The application of this time-varying voltage across the anode-cathode circuit insures that the magnetron will go into its proper mode of oscillation when the filament reaches operating temperature. Therefore, the anode-cathode and the filament circuits of the magnetron can be energized simultaneously with the magnetron consistently going into the desired mode of oscillation.

It should be noted that by rising full-wave voltage-multiplying rectifier **101** a time delay relay and a separate filament transformer are not required and the voltage provided by secondary winding SW1 need be about only half that required by the anode-cathode of the magnetron **103.** Another advantage provided by the use of a voltage-multiplying circuit is that both ends of the secondary winding SW1 do not have to be insulated for full anode-cathode voltage because during operation the upper end of the secondary SW1 alternates between 0 volts and full anode-cathode voltage while the lower end is held (by capacitor C2) substantially at one-half full voltage. Also, as compared to a bridge rectifier, only two high piv diodes are required in voltage multiplying circuit **101.** Capacitors C1 and C2, whose presence across the anode-cathode circuit provides protection from voltage transients, are sized large enough both to cause a slightly leading power factor at the output of secondary winding SW1 and so that power drawn from them by the anode-cathode circuit does not substantially discharge the capacitors during their respective noncharging half cycles of the a.c. power source. The capacitors thus perform a double function of transient voltage protection and power factor improvement. Finally, a full-wave rectifying circuit is, of course, much more efficient than a half-wave rectifier.

Referring to FIG. **2,** another embodiment of the present invention is shown. This circuit is identical to that of FIG. **1** except that a transformer T1A is of the high leakage reactance variety. This type of transformer as will be discussed below, is adapted to supply a regulated secondary voltage. Regulation of the anode-cathode voltage is very desirable because small changes in anode-cathode voltage cause substantial changes in anode-cathode current. FIG. **3** diagrammatically illustrates the construction of the basic high leakage reactance transformer optionally used in this invention to provide regulation of both anode-cathode and filament supply voltage. Such transformers have been known for many years, a description of the construction of a similar device being found in U.S. Pat. No. 2,143,745. It is sufficient to note that the transformer includes a magnetizable core **111** having a window **113** with a magnetizable shunt **115** substantially bridging the window but leaving a small air gap. This provides a high reluctance shunt path across the window between a primary winding PW and a secondary winding SW1. The shunt functions as an alternate path for the magnetic flux so that under certain conditions, as will be discussed hereinafter, the core in the vicinity of the secondary winding SW1 will become saturated without the core in the vicinity of the primary being saturated, the secondary winding thereby providing a substantially constant potential. Primary winding PW is wound on the core **111** on one side of shunt **115** while secondary winding SW1 is wound on the core **111** on the opposite side of the shunt. Additional secondary windings may be wound on the core **111** on the same side of shunt **115** as the primary winding or they may be wound on the core **111** on the side of the shunt opposite the primary winding (same side as secondary winding SW1). Although FIG. **3** shows a U-I or core-type construction, magnetizable shunts can also be used in an E-I or shell-type construction to provide similar results.

Regulation of the time-varying voltage across the anode-cathode circuit of the magnetron is accomplished by causing the portion of core **111** in the vicinity of secondary winding SW1 to be driven into saturation before the remaining portion of the core is saturated. The capacitive reactance of capacitors C1 and C2 is sufficient to cause a slightly leading power factor at the output of secondary winding SW1 when a normal supply voltage is applied to the primary winding PW. This slightly leading power factor causes the voltage

across secondary winding SW1 to rise to a magnitude greater than the voltage of primary winding PW multiplied by the turns ratio of the two windings. Since the magnetic coupling between that section of core **111** in the vicinity of secondary winding SW1 with that section of core **111** in the vicinity of primary winding PW is incomplete due to the action of shunt **115**, the section of the core near secondary winding SW1 is driven into saturation before the remaining section of the core. Therefore, the a.c. voltage across secondary winding SW1 as well as the time-varying voltage across the anode-cathode circuit of the magnetron will be substantially independent of the voltage fluctuations in a.c. power source. Since the secondary SW1 provides an output which although slightly leading is very close to unity power factor at nominal power source voltages, the operation of the circuit is very efficient.

Referring to FIG. **4**, another embodiment of the present invention is shown. This circuit and its operation is substantially identical to that of the circuit of FIG. **2** except that a secondary winding SW2 of a transformer T1B, wound on the side of shunt **115** opposite primary winding PW, provides power to the filament circuit of magnetron **103**. Secondary winding SW2, wound on that portion of the core **111** which is driven into saturation, supplies a regulated a.c. voltage to the filament, thus providing regulated voltages to both anode-cathode and filament circuits.

Referring to FIG. **5**, another embodiment of the present invention is shown. This circuit and its operation are also substantially identical to that of FIG. **2** except that a separate filament transformer T2 is employed to supply unregulated a.c. to the filament. Regulated time-varying voltage, however, is still applied to the anode-cathode circuit of magnetron **103**.

FIG. **6** illustrates another embodiment of the present invention. In this power supply, a high leakage reactance transformer T1C includes a trio of secondary windings SW1A, SW2 and SW3. Secondary windings SW1A and SW3 are wound on the side of magnetizable shunt **115** opposite that on which the primary is wound. Interconnected with secondary winding SW1A is a classical voltage doubler **119** which has sufficient capacitive reactance to increase the voltage across secondary winding SW1A to a value greater than the voltage of primary winding PW multiplied by the turns ratio of the two windings, the operation of a high leakage reactance transformer having been discussed above. A power supply utilizing voltage doubler **119** has an advantage over one employing voltage multiplying circuit **101** because the former supply may use a three-terminal capacitor C3 instead of two separate capacitors each with two terminals, and thus effect certain economies. Capacitor C3 has a common electrode for capacitors C3A and C3B thus providing a three-terminal capacitor. Voltage doubler **119** includes diode D1 and capacitor C3A series-connected across the entire secondary winding SW1A, the anode of D1 being connected to one end of the secondary winding while the junction between D1 and C3A is connected to the anode of magnetron **103**. Diode D2 and capacitor C3B also are series-connected across secondary winding SW1A, the cathode of D2 being connected to one end of the secondary winding while the junction between D2 and C3B is connected to one end of the secondary winding SW3. The other end of secondary winding SW3 is connected to the cathode of magnetron **103**. The third secondary winding SW2, wound on the same side of the shunt as the primary, supplies unregulated a.c. to the filament circuit of magnetron **103**.

In operation, capacitors C3A and C3B charge to substantially the same d.c. level during alternate half cycles of the a.c. power source to provide a substantially constant or unvarying voltage. However, the voltage applied across the anode-cathode of magnetron **103** is a regulated time-varying voltage which is a composite of the charge on capacitor C3A, the charge on capacitor C3B, and the alternating voltage supplied by secondary winding SW3.

The circuit of FIG. **7** and its operation are substantially identical to that of FIG. **6** except that secondary winding SW2 of a transformer T1D is wound on the side of shunt **115** opposite primary winding PW thereby also to provide regulated power to the filament circuit of magnetron **103**.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions without departing from the scope of the invention, 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 power supply for a magnetron which provides a microwave output and has an anode, a cathode, and a filament circuit, said magnetron having proper and improper modes of oscillation, said supply comprising:

a high-leakage reactance step-up transformer having a primary winding for connection to an a.c. power source, at least one seconary winding, a magnetizable core having at least one window, and a high reluctance magnetizable shunt path bridging said window between said primary and secondary windings;

means for applying a continuous time-varying voltage across the anode-cathode circuit of said magnetron, said means including a full-wave voltage-multiplying rectifier circuit interconnected with said secondary winding and the anode-cathode circuit of the magnetron, said rectifier circuit having sufficient capacitive reactance to increase the voltage across said secondary winding so that the core in the vicinity of the secondary winding is driven into saturation; and

means for simultaneously energizing the filament circuit of said magnetron and the anode-cathode circuit thereof whereby the application of said time-varying voltage across said anode-cathode circuit insures that the magnetron goes into its proper mode of oscillation when the filament has substantially reached its operating temperature, and whereby said time-varying voltage is regulated so as to be substantially independent of voltage fluctuations in said a.c. power source.

2. A power supply for a magnetron as set forth in claim **1** wherein the means for energizing the filament circuit of said magnetron includes another secondary winding on said transformer connected to the filament circuit.

3. A power supply for a magnetron as set forth in claim **1** wherein said voltage-multiplying circuit includes a first diode and a first capacitor connected

across the entire secondary winding and a second diode and a second capacitor connected across a portion of the secondary winding whereby said capacitors are alternately charged to different d.c. levels during alternate half cycles of said a.c. power source, said full-wave voltage-multiplying circuit being adapted to provide the anode-cathode circuit of said magnetron with a time-varying voltage which is a composite of the charge on each capacitor and a part of the alternating voltage on the secondary winding.

4. A power supply for a magnetron as set forth in claim **1** wherein said voltage-multiplying circuit includes a first diode and a first capacitor connected across the entire secondary winding and a second diode and a second capacitor connected across a portion of the secondary winding whereby said capacitors are alternately charged to different d.c. levels during alternate half cycles of said a.c. power source, said full-wave voltage-multiplying circuit being adapted to provide the anode-cathode circuit of said magnetron with a regulated time-varying voltage which is a composite of the charge on each capacitor and a part of the alternating voltage on the secondary winding.

5. A power supply for a magnetron as set forth in claim **4** wherein the means for energizing the filament circuit of said magnetron includes another secondary winding of said transformer.

6. A power supply for a magnetron which provides a microwave output and has an anode, a cathode, and a filament circuit, said magnetron having proper and improper modes of oscillation, said supply comprising a step-up transformer having a primary winding for connection to an a.c. power source and a first secondary winding, means for applying a continuous time-varying voltage across the anode-cathode circuit of said magnetron, said means including a full-wave voltage-multiplying rectifier circuit interconnected with said seconary winding and the anode-cathode circuit of the magnetron, said rectifier circuit comprising a voltage doubler including a first diode and a first capacitor connected across said secondary winding and a second diode and a second capacitor connected across said secondary winding whereby said capacitors are alternately charged to substantially the same d.c. level during alternate half cycles of said a.c. power source, said transformer having a second secondary winding series-connected with said voltage doubler in the anode-cathode circuit of said magnetron whereby a continuous time-varying voltage which is a composite of the charge on each capacitor and the alternating voltage on the second secondary winding is applied across the anode-cathode circuit of said magnetron, and means for simultaneously energizing the filament circuit of said magnetron and the anode-cathode circuit thereof whereby the application of said time-varying voltage across said anode-cathode circuit insures that the magnetron will go into its proper mode of oscillation when the filament has substantially reached its operating temperature.

7. A power supply for a magnetron as set forth in claim **8** in which the second secondary winding is also of said magnetron includes a third secondary winding of said transformer.

8. A power supply as set forth in claim **6** wherein the transformer is a high-leakage reactance step-up transformer including a magnetizable core having at least one window, and a high reluctance magnetizable shunt path bridging said window between said primary and at least the first secondary winding, and wherein said voltage doubler has sufficient capacitive reactance to increase the voltage across said first secondary winding so that the core in the vicinity thereof is driven into saturation whereby a regulated voltage, substantially independent of voltage fluctuations in said a.c. power source, is supplied by said voltage doubler.

9. A power supply for a magnetron as set forth in claim **8** in which the second secondary winding is also wound on the side of the high reluctance magnetizable shunt path opposite the primary winding.

10. A power supply for a magnetron as set forth in claim **9** wherein the means for energizing the filament of said magnetron includes a third secondary winding of said transformer, and wherein all the secondary windings are wound on the side of the high reluctance magnetizable shunt path opposite the primary winding.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,873,883

DATED : March 25, 1975

INVENTOR(S) : Carl J. Sievers and Ronald C. Wagner

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 61, "by rising" should read -- by using --.

Patent claim 7 should be renumbered as patent claim 8 and should read as follows (column 8, lines 17-20):

-- 8. A power supply for a magnetron as set forth in claim 6 wherein the means for energizing the filament of said magnetron includes a third secondary winding of said transformer. --

Column 8, line 21, "8" should read --7--.

Signed and sealed this 15th day of July 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,873,883

DATED : March 25, 1975

INVENTOR(S) : Carl J. Sievers and Ronald C. Wagner

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 61, "by rising" should read -- by using --.

Patent claim 7 should be renumbered as patent claim 8 and should read as follows (column 8, lines 17-20):

-- 8. A power supply for a magnetron as set forth in claim 6 wherein the means for energizing the filament of said magnetron includes a third secondary winding of said transformer. --

Column 8, line 21, "8" should read --7--.

Signed and sealed this 15th day of July 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks