

[54] **SWITCH IN HALF-WAVE RECTIFIER CIRCUIT**

317/47

[75] Inventor: Tokihide Niu, Takatsuki, Japan

[73] Assignee: Matsushita Electric Industrial, Ltd.,
Osaka, Japan

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[56]

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UNITED STATES PATENTS

3,651,371 3/1972 Tingley 219/10.55 X

Primary Examiner—Bruce A. Reynolds
Attorney, Agent, or Firm—Stevens, Davis, Miller &
Mosher

[57]

ABSTRACT

An electronic oven is provided in which the interruption of an output is controlled by interrupting the current passing in a magnetron of a high voltage circuit.

5 Claims, 5 Drawing Figures

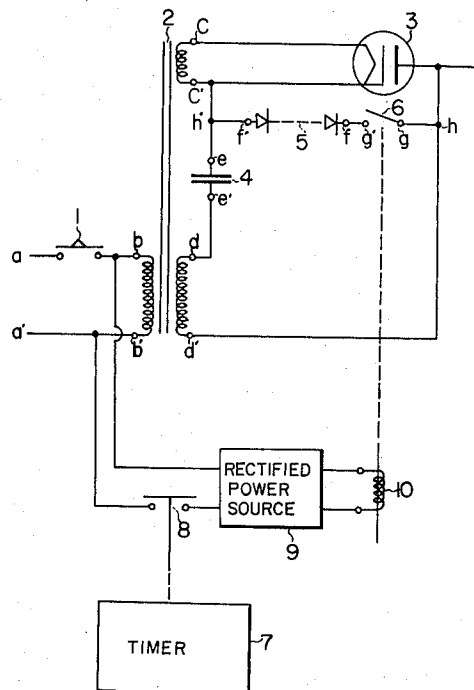


FIG. 1

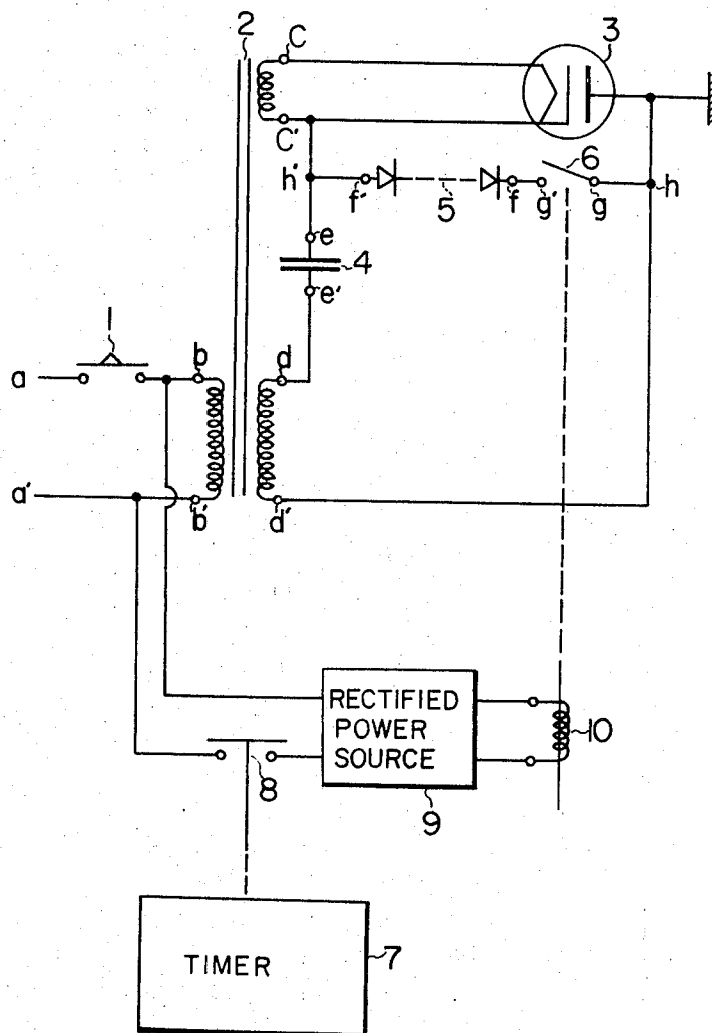


FIG. 2

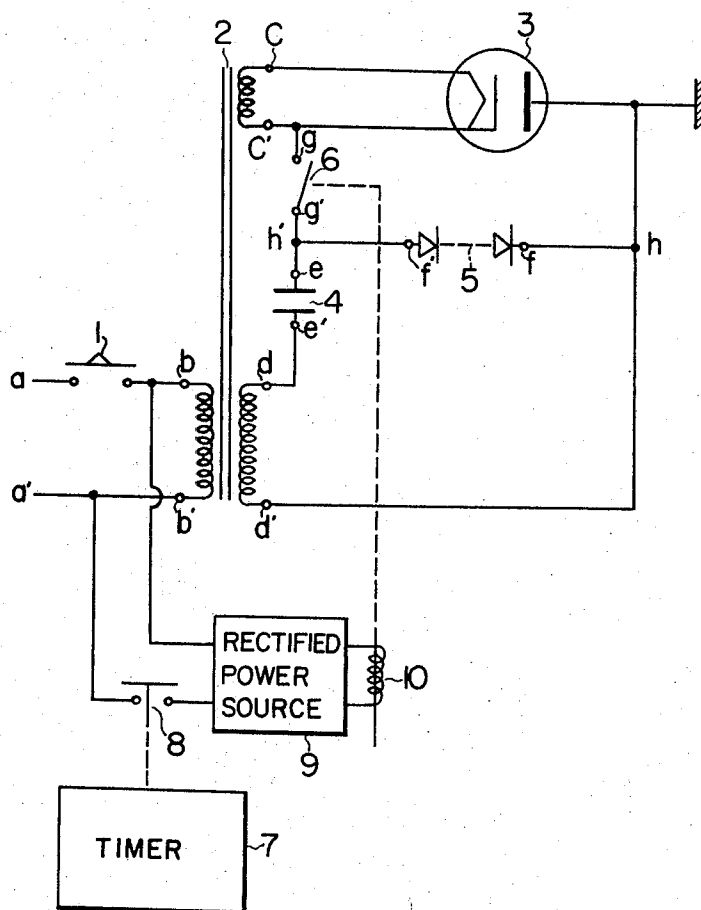


FIG.3

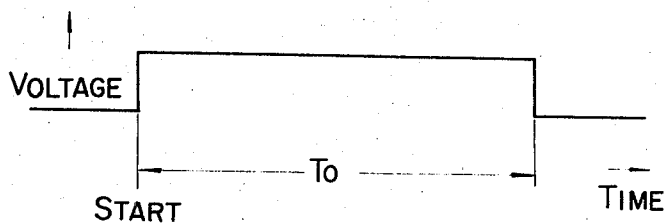


FIG.4

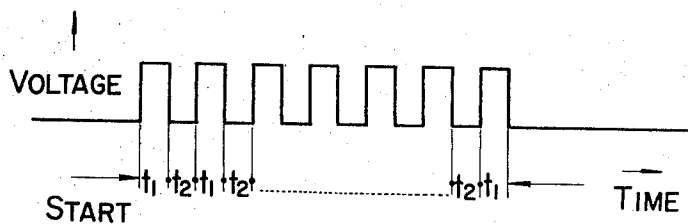
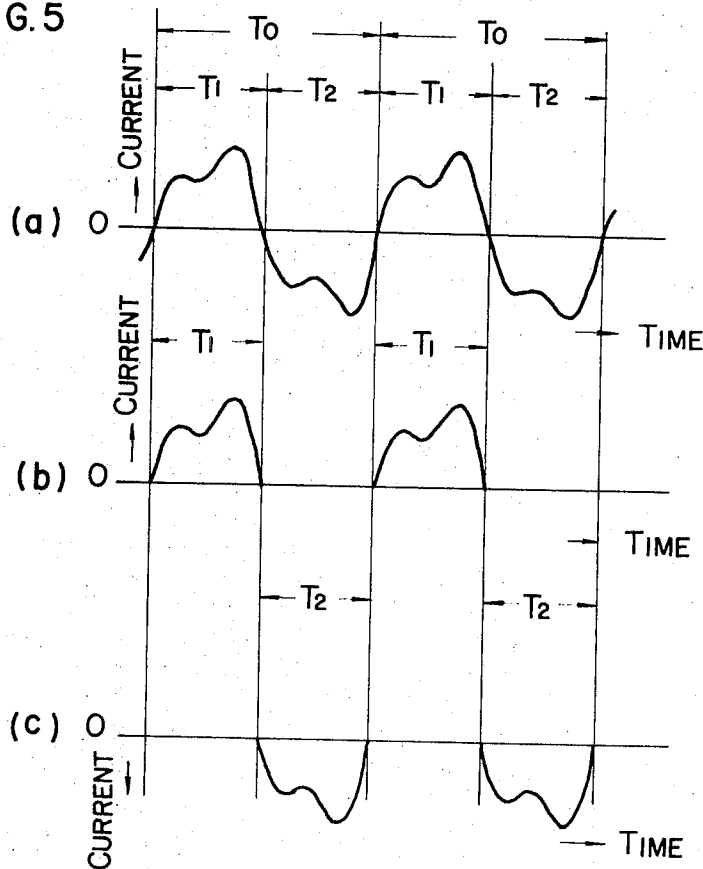


FIG.5



SWITCH IN HALF-WAVE RECTIFIER CIRCUIT

The present invention relates to an electronic oven which is adapted to prevent detrimental effects of a magnetron on other electric equipment during operation of said magnetron.

Cooking systems, such as electronic ovens, in which are utilized induction heating by microwave, have the advantageous feature that foodstuffs can be heated quickly in a short period of time, but on the other hand, had the disadvantage that the heating was so rapid that the interior of the foodstuffs become scorched before the surfaces thereof were sufficiently heated or frozen foodstuffs were heated locally during thawing of said frozen foodstuffs and uneven heating resulted. In order to obviate such disadvantage, in conventional electronic ovens has been employed a method in which the microwave output of the magnetron is reduced according to the type of the foodstuff to be processed, but this method impairs the meritorious feature, i.e., quick heating of foodstuffs, which is the primary purpose of electronic ovens. There has also been employed a method in which the output of the magnetron is interrupted intermittently by an intermittently operative switch or a control switch, such as a semiconductor switching element, provided on the primary side (low voltage side) of a high voltage transformer through which high voltage is supplied to the magnetron, as described, for example, in Japanese Patent Publication No. 16955/68 (Publication Date July 17, 1968) and its Japanese Patent Application No. 44781/65 (Application Date July 23, 1965). In electronic ovens employing this method, the magnetron is actuated when a voltage higher than the output voltage of the magnetron is impressed on the secondary side (high voltage side) of the transformer through the control switch, but at the operation of the switch both the exciting surge current and load surge current of the transformer (occasionally amounting to almost 10 times the normal current) passes in the magnetron. Therefore, a switch of high current capacity has been required in consideration of the operational reliability of the switch and also voltage drops have occurred at the location of the wiring where the current capacity is small due to the surge current, imposing detrimental effects on the other electric equipment. Furthermore, in thawing frozen foodstuffs, when radiation energy is applied to the frozen foodstuff continuously from the magnetron as the ice and water dielectric loss changes, the thawed part (water) is locally heated with the result that uneven heating occurs. In order to avoid the uneven heating, there has been employed a method in which the oscillation and stoppage of the magnetron are repeated frequently and the oscillation of the magnetron is stopped temporarily until the foodstuff to be thawed is heated substantially uniformly by heat conduction. Such method, however, aggravates the above-described problem of surge current, and calls for an additional transformer solely for a heater to heat the cathode of the magnetron since the cathode of the magnetron must be kept heated for effecting oscillation of the magnetron.

The output control system for electronic ovens according to the present invention aims to eliminate such conventional disadvantages, to reduce the surge current occurring at the start of oscillation of the magnetron, and particularly to enhance the reliability of the magnetron in its repeated operations of oscillation and

stoppage and thereby to minimize the influence on other electric equipment.

According to the present invention, a high voltage-control switch is provided in the high voltage circuit, whereby the surge current is reduced and the useful life of the high voltage-control switch is prolonged with high operational reliability, and positive oscillation and stoppage of the magnetron can be obtained. Further, it becomes possible to incorporate the transformer for the heater to heat the cathode of the magnetron in the main transformer. Therefore, the system of the invention as compared with the conventional one comprising an additional transformer is simple in construction and can be provided at a low cost, and is of great industrial advantage.

Other objects, features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which:

FIGS. 1 and 2 show the circuit diagram of embodiments of the electronic oven according to the present invention respectively;

FIGS. 3 and 4 are the waveform diagrams during oscillation and stoppage of the magnetron when the electronic ovens of FIGS. 1 and 2 are in use; and

FIG. 5 shows the waveforms of the currents passing in various portions of the high voltage circuit of the electronic oven.

The construction of the electronic oven according to the invention will be described by way of example hereunder with reference to the drawings. FIGS. 1 and 2 of the drawings respectively show embodiments of the electronic oven of the invention. In the embodiment of FIG. 1, a high voltage-control switch is inserted in a half-wave doubled voltage rectification circuit in the high voltage circuit of the electronic oven. In FIG. 1, terminals *a-a'* are connected to an A.C. power source and, when a power switch 1 is closed, the normal voltage is applied to the primary side (*b-b'*) of a transformer 2. The secondary side of the transformer 2 is provided with terminals *c-c'* for generating the normal voltage necessary for energizing a heater for heating the cathode electrode of a magnetron 3 (said terminals *c-c'* being connected to a magnetron cathode heater circuit), and terminals *d-d'* for supplying the normal voltage to a half-wave doubled voltage rectification circuit to generate a high voltage necessary for causing oscillation of the magnetron 3. The terminal *d'* is connected to the anode electrode of the magnetron 3 and maintained at ground potential.

On the other hand, the terminal *d* is connected to a terminal *e'* of a capacitor 4 and the other terminal *e* of said capacitor 4 is connected to both a terminal *f'* of a rectifier 5 and the magnetron cathode heater circuit. The other terminal *f* of the rectifier 5 is connected to a terminal *g'* of a high voltage-control switch 6 and the other terminal *g* of said switch 6 is connected to the anode of the magnetron 3.

In the embodiment of FIG. 2, the high voltage-control switch is inserted in the magnetron circuit in the high voltage circuit of the electronic oven. In FIG. 2, the terminals *a-a'* are connected to the A.C. power source and, when the power switch 1 is closed, the normal voltage is applied to the primary side (*b-b'*) of the transformer 2. The secondary side of the transformer 2 is provided with terminals *c-c'* for generating the normal voltage necessary for energizing the heater for

heating the cathode electrode of the magnetron 3 (said terminals $c-c'$ being connected to a magnetron cathode heater circuit), and the terminals $d-d'$ for supplying the normal voltage to the half-wave doubled voltage rectification circuit to generate the high voltage necessary for causing oscillation of the magnetron 3. The terminal d' is connected to the anode electrode of the magnetron 3 and maintained at ground potential.

On the other hand, the other terminal d is connected to the terminal e' of the capacitor 4 and the other terminal e of said capacitor 4 is connected to the terminal g' of the high voltage-control switch 6 and a terminal f of a diode 5. The other terminal g of the high voltage-control switch 6 is connected to the magnetron cathode heater circuit and the other terminal of the diode 5 is connected to the anode of the magnetron 3.

For the high voltage-control switch 6 shown in FIGS. 1 and 2, a vacuum switch is suitably used and a vacuum switch of the reed switch type is particularly effectively used since it can be constructed in a small size. The reed switch type vacuum switch is highly resistive to voltage and highly reliable in a vacuum (higher than 10^{-3} mmHg) and a contact separation of about 0.3 - 1.0 mm is sufficient at a voltage (several KV) for the intermittent oscillation and stopping operation of the magnetron, so that the switch becomes small in size. Further, the contact surfaces lie in vacuum and, therefore, are always clean providing for stable contact. Furthermore, the operation of the reed switch type vacuum switch does not call for a large iron core (plunger, yoke) as does an electromagnet relay having contacts exposed in the atmosphere and, therefore, it operates with extremely low noise and a simple driving solenoid is sufficient for its operation. It can be operated by a permanent magnet. Thus, the use of the reed switch type vacuum switch is advantageous in rendering the entire system simple, small in size and highly reliable.

As an example, the operation of the high voltage-control switch 6 by a driving solenoid will be described. In this case, the switch 6 operates when a contact 8 operative in response to a signal from a timer 7 is closed and an exciting current passes in a driving solenoid 10 connected to a rectified power source 9. The waveform of the signal from the timer 7 is shown in FIGS. 3 and 4. FIG. 3 is the case when the magnetron oscillates continuously for a period t_0 and FIG. 4 is the case when the magnetron oscillates for a period t_1 and stops for a period t_2 repeatedly.

The operation of the electronic oven according to the invention will be described hereunder: First of all, the source current (A.C. current) is supplied by closing the power switch 1 and the normal voltages are impressed on terminals $c-c'$ and $d-d'$ of the transformer 2, whereby the magnetron cathode heater is energized. Thereafter the respective portions of the electronic oven operate as follows:

Namely, in FIG. 1, when the high voltage-control switch 6 is in its open position, a voltage equal to the voltage across $d-d'$ is impressed across the cathode and anode of the magnetron 3. The voltage across $d-d'$ is set at a value at which the magnetron 3 does not operate. The voltage supplied from the terminals $d-d'$ is rectified by the rectifier 5 and the voltage across $g-g'$ of the high voltage-control switch 6 is equal to the voltage impressed on the terminal f' of the rectifier 5 when said voltage is positive relative to g , and is zero when said voltage is negative. When the high voltage-control

switch 6 is closed in the non-oscillating state of the magnetron stated above, the current passes in the circuit of $d-e'$ -capacitor- $e-f'$ -rectifier 5- $f-g'$ -switch 6- $g-d'$ and the capacitor 4 is charged to the normal voltage by the rectifying action of the rectifier 5. Therefore, the voltage across $d-d'$ and the voltage charged across the capacitor 4 are overlapped and impressed across the cathode and anode of the magnetron 3, and said magnetron 3 starts oscillating when the voltage across $d-d'$ is regulated so that said overlapping voltage will become higher than the oscillating voltage of the magnetron 3. The system operates in the normal state through the process described above, and the current passes in the rectifier 5 to charge the capacitor 4 when the A.C. voltage at d becomes positive relative to d' . In this case, the voltage across the cathode and anode of the magnetron 3 is substantially zero. On the contrary, when the A.C. voltage at d becomes negative relative to d' , the voltage across $d-d'$ and the charging voltage of the capacitor 4 overlapping therewith are impressed across the cathode and anode of the magnetron 3, with the result that said magnetron 3 starts oscillating and the current passes therein. In this case, the current passing through the rectifier is substantially equal to zero.

In FIG. 2, the normal voltage across $d-d'$ is impressed on the circuit of $d-e'$ -capacitor 4- $e-f'$ -rectifier 5- $f-d'$ (in the closed state of the high pressure resisting switch 6) and a voltage as determined by the circuit is charged in the capacitor 4 by the rectifying action of the rectifier 5. Therefore, the voltage across $d-d'$ and the voltage charged in the capacitor 4 are overlapped and impressed across $f'-f$ of the rectifier. The voltage across $d-d'$ is set such that the voltage across the terminals of the rectifier will become high enough to cause oscillation of the magnetron 3. When the high voltage-control switch 6 is closed in the above-described state in which the high voltage-control switch 6 is open and the magnetron 3 is in the non-oscillating state, the voltage which has been impressed across $f'-f$ of the rectifier 5 is impressed across the cathode and anode of the magnetron 3. Since this voltage is higher than the oscillating voltage of the magnetron 3, said magnetron starts oscillating and the current passes therein. When the system has reached the normal state through the process described above and the A.C. voltage at d has become positive relative to d' , the current passes in the rectifier 5 to charge the capacitor 4 and, in this case, the voltage across the cathode and anode of the magnetron 3 is substantially equal to zero. Conversely, when the A.C. voltage at d has become negative relative to d' , the voltage across $d-d'$ and the charging voltage of the capacitor 4 are impressed across the cathode and anode of the magnetron in overlapping relation, with the result that the magnetron 3 starts oscillating and the current passes therein. In this case, the current passing through the rectifier is substantially equal to zero.

The above-described conditions of FIGS. 1 and 2 will be further described with reference to FIG. 5. In FIG. 5, (a) indicates the waveform of the current passing in the circuit of $h'-e4e'-d2d'-h$; (b) the waveform of the current passing in the circuit of $h'-f'5f-h$; and (c) the waveform of the current passing in $h'-c'-3-h$. In the period T_0 (a fraction of the power source frequency), T_1 is the time in which the current passes through the rectifier 5 and charges the capacitor 4, and T_2 is the time in which the current passes in the magnetron 3

causing it to oscillate. The period T_0 is repeated while the switch 6 is held closed, and the electronic oven serves its purpose. The current passed or interrupted by the high voltage-control switch 6 is a D.C. current in either embodiment of FIG. 1 or 2, so that one of the contacts of the high voltage-control switch 6 always constitutes a negative electrode and the other one of them a positive contact during operation of said switch. Therefore, the polar effect occurs in the wear and tear or transition of the contacts of the switch during operation of the switch and, when both of the positive and negative electrode contacts are made of the same material, one of them is convexed and the other one of them concaved. This phenomenon when occurring causes a degradation of intercontact pressure resistance or fusion-bonding of the contacts, which adversely affects the reliability and service life of the switch. The use of different materials in combination for the positive and negative electrode contacts of the high voltage-control switch 6, e.g., silver or silver-nickel alloy for the negative electrode contact and a refractory alloy, such as tungsten, for the positive electrode contact, achieves a remarkable effect in precluding the phenomenon described above and improving the reliability and service life of the switch. When the high pressure-resistant switch 6 is of a normally closed contact type, continuous heating of the electronic oven is possible with the driving solenoid 10 being held in a non-excited state, whereas when said switch is of a normally open contact type, the driving solenoid 10 needs to be excited for continuous heating operation of the oven. Thus, the use of the normally closed contact type switch is advantageous over the normally open contact type switch since the driving solenoid 10 needs to be excited only as required, for example, for thawing control.

The electronic oven of the construction shown, for example, in FIG. 1 or 2 is advantageous for the manner of use as shown in FIG. 4 in which the oven is operated intermittently repeatedly. This is because, if the repetitive operation is performed by a switch (e.g., the switch 1) on the primary side (low voltage side) of the transformer, as in the conventional electronic ovens, the exciting surge current of the transformer 2 and the load surge current thereof will pass in the transformer in overlapping relation and a current nearly 10 times the normal current will be generated, as stated previously, but in the electronic oven of the construction shown in FIG. 1 or 2, the exciting surge current of the transformer occurs only once at the outset of the repetitive operation shown in FIG. 4 and the surge current occurring on the primary side of the transformer 2 for the highly frequent repetitive operation can be reduced. Consequently, the voltage drops at the portions of the circuit where the power capacity is small can be prevented and the detrimental effects on other electric equipment can be alleviated. In the embodiments of FIGS. 1 and 2, the high voltage-control switch can be inserted between $d-e'$ or between $h-d'$. However, with the switch inserted at the position shown, the current passes in the high voltage-control switch 6 at the interruption of oscillation of the magnetron only in the period T_1 in FIG. 5, in case of the embodiment of FIG. 1 and only in the period of T_2 in case of the embodiment of FIG. 2, and the time T_2 is zero in the embodiment of FIG. 1 and the time T_1 is zero in the embodiment of FIG. 2. If the high voltage-control switch 6 is inserted between $d-e'$ or between $h-d'$, the current will flow in

the circuit throughout the period T_0 in FIG. 5, and in this case, discharge such as an arc discharge will occur almost certainly across the contacts of the switch when said switch is opened. In the circuit arrangement of the invention, the current flows in the high voltage-control switch only for the period T_1 or T_2 and the percentage of occurrence of discharge such as an arc across the contacts of the switch 6 is T_1/T_0 in case of the embodiment of FIG. 1 and is T_2/T_0 in case of the embodiment of FIG. 2. When the switch 6 is opened in the period T_2 in FIG. 1 or in the period of T_1 in FIG. 2, the current can be interrupted without the occurrence of discharge and the voltage impressed across the contacts of the switch is substantially equal to zero, and thus the switch can be opened positively. The low percentage of occurrence of discharge at the opening of the switch 6 as stated above is advantageous in respect of the wear and tear of the contacts of said switch and other detrimental effects, and ensures positive opening operation of the switch. It will be understood from the foregoing description that according to the circuit arrangement of the invention comprising the high voltage-control switch, it is possible to reduce the surge current, to prolong the service life of the switch and the interruption of oscillation of the magnetron can be achieved positively with high reliability. It is also possible to incorporate the magnetron cathode heating transformer in the main transformer 2 and thereby to simplify the construction and reduce the cost of electronic oven as compared with the conventional ovens having an additional transformer for the magnetron cathode heater.

The same effects as obtainable from the arrangement of FIG. 1 can be obtained by inserting the high voltage-control switch between $h'-f'$ and substantially the same effects as obtainable from the arrangement of FIG. 2 can be obtained by inserting said switch between h and the anode of the magnetron 3.

In the embodiment of FIG. 2, when the high voltage-resistant switch 6 is closed, the capacitor 4 has already been charged and the surge current occurring on the low voltage side is substantially equal to the current in the normal operation. Namely, the effect of reducing the surge current occurring on the low voltage side is more remarkable.

What is claimed is:

1. In an electronic oven, a circuit comprising:

- a. a transformer having primary and secondary windings, said primary winding being coupled to a power source,
- b. a magnetron including a heater, a cathode and an anode, said anode being connected to a first terminal of the secondary winding of said transformer,
- c. a capacitor connected between a second terminal of said secondary winding and the cathode of said magnetron,
- d. a rectifier having an anode and a cathode,
- e. a high voltage-control switch connected in series with said rectifier, said series-connected high voltage-control switch and rectifier being connected across the cathode and anode of said magnetron, the polarity of said rectifier being such that current is conducted from the connection of said series-connected circuit to the cathode of said magnetron to the connection of said circuit to the anode of said magnetron, and
- f. means operating said high voltage-control switch to open said rectifier circuit during a first predeter-

mined time interval and close said rectifier circuit during a second predetermined time interval while said electronic oven is being used for cooking, said magnetron oscillating when said voltage-control switch is closed and not oscillating when said voltage-control switch is open.

2. A circuit defined by claim 1 wherein said high voltage-control switch is connected between said rectifier and the anode of said magnetron.

3. The circuit defined by claim 1 wherein said transformer is provided with a second secondary winding and the heater of said magnetron is coupled across said second secondary winding.

4. In an electronic oven, a circuit comprising:

a. a transformer having primary and secondary windings, said primary winding being coupled to a power source,

b. a magnetron including a heater, a cathode and an anode, said anode being connected to a first terminal of the secondary winding of said transformer,

c. a capacitor having one end connected to a second terminal of the secondary winding of said transformer,

d. a rectifier having an anode and a cathode, the anode of said rectifier being connected to the other end of said capacitor and the cathode of said rectifier being connected to the anode of said magnetron,

e. a high voltage-control switch connected between the capacitor-rectifier junction and the cathode of said magnetron, and

f. means operating said high voltage-control switch to connect said rectifier across the cathode and anode of said magnetron during a first predetermined time interval and disconnect said rectifier during a second predetermined time interval while said electronic oven is being used for cooking, said magnetron oscillating when said voltage-control switch is closed and not oscillating when said voltage-control switch is open.

5. The circuit defined by claim 4 wherein said transformer is provided with a second secondary winding and the heater of said magnetron is coupled across said second secondary winding.

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