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TRANSFORMER RESET CIRCUIT FOR MICROWAVE OVEN

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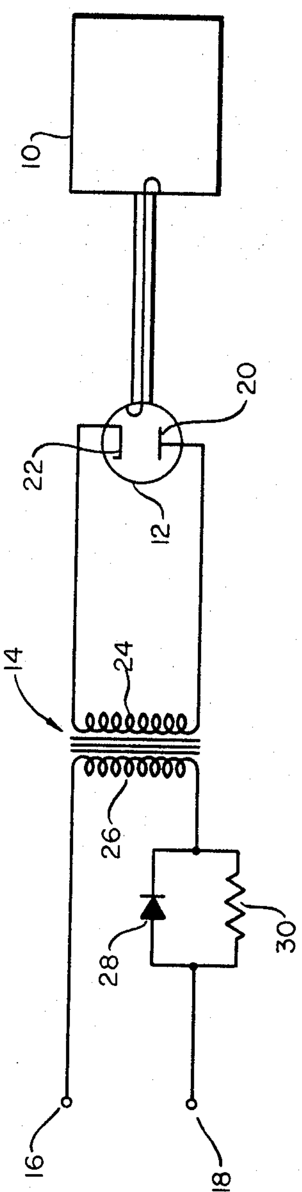

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TRANSFORMER RESET CIRCUIT FOR MICROWAVE OVEN

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ABSTRACT OF THE DISCLOSURE

A diode is connected in parallel with a resistor and both are connected in series with the primary winding of a transformer having a saturable core. Alternating current is applied to this series circuit to energize the primary winding and, hence, the secondary winding of the transformer. The polarity of the diode is such that current flows through the diode during the half cycle in each cycle of AC that a magnetron connected across the secondary winding is conducting. During the alternate half cycles, the diode blocks the passage of current and a limited amount of current flows through the resistor sufficient to unsaturate the transformer core, thereby resetting the transformer for unsaturated operation in the next conducting half cycle.

This invention relates to microwave ovens and, more particularly, to a circuit for reducing the input current and power to such an oven while maintaining the output microwave power constant.

In the microwave heating art it is quite common to provide microwave heating apparatus which utilizes a magnetron to supply electromagnetic wave energy to an enclosed cavity, a conveyorized tunnel or the like to heat objects in the cavity, or which may be passing through the tunnel. While such forms of microwave heating apparatus are gaining considerable acceptance in many areas, such as in the preparation of food, the relatively high initial cost of such equipment as compared to more conventional heating apparatus has drastically limited the scope of microwave heating apparatus in many areas.

One of the reasons for the high cost of microwave heating apparatus in the past has been the necessity for supplying some form of high voltage power supply circuit for the magnetron which generates the microwave frequency energy. It has been found that a relatively simple manner for supplying the high voltages required for the magnetron is to simply connect the cathode and anode of the magnetron directly across the secondary winding of a stepup transformer and to connect the primary winding of the transformer to a commercial electrical outlet such as a single phase, 60 cycle, 230 volt source. Since the magnetron is itself a diode, it half-wave rectifies the output current of the transformer, with the magnetron conducting on alternate half cycles of the input and blocking conduction on the intervening half cycles. However, it has been found that since a magnetron requires a relatively high plate voltage, typically several thousand volts, it is necessary to use a relatively large transformer to obtain the desired voltage stepup and still to handle the necessary power level which must be transformed. Further, it has been found that such transformers are quite expensive and it would be quite desirable if a smaller transformer could be used. However, as smaller transformers are employed in such circuits, it has been noticed that the input line current increases disproportionately, even though the output microwave power remains relatively constant, and also that heat losses in the transformer itself increase disproportionately. Investigation has revealed that this increase in line current and the resultant increase in transformer heating is caused by saturation of the core of the transformer during the half cycle that the magnetron is conducting. In the next "nonconducting" half cycle, the core is still saturated and presents a relatively large inductive load to the source. During this nonconducting half cycle, even though no current is being drawn in the secondary circuit, a substantial amount of out-of-phase current flows in the primary winding of the transformer which increases the I^2R losses in the transformer without contributing to any useful power output. Also, this out-of-phase current adversely affects the power factor of the overall heating circuit, thereby requiring higher line currents to be drawn to obtain the same level of microwave heating power.

The obvious way to correct this problem is to provide capacitors in the primary transformer circuit to correct the power factor problems and to bring the line current and voltage back into phase, thereby permitting smaller line currents. However, it has been found that a typical installation may require several hundred microfarads of capacitance to correct the deficiency and that the cost of these capacitors more than offsets the savings obtained from using a smaller saturating transformer.

It is, accordingly, an object of the present invention to provide an improved power supply circuit for microwave heating equipment.

It is another object of the present invention to provide an improved power supply circuit for microwave heating equipment which utilizes a small saturating transformer while still maintaining the line current and voltage in phase.

It is yet another object of the present invention to provide an improved power supply circuit for microwave heating equipment which can be constructed from inexpensive components.

Briefly stated, and in accordance with one embodiment of the present invention, the above enumerated deficiencies in the prior art are overcome by providing a parallel circuit comprising a diode and a resistor in series with the primary winding of the transformer. The polarity of the diode is such that current flows through the diode during the half cycle the magnetron is conducting, with this current thereby bypassing the resistor. During the alternate half cycles, the diode blocks current passage therethrough, and a smaller amount of current flows through the resistor to unsaturate the transformer core, thereby resetting the transformer for unsaturated operation in the next conducting half cycle.

For a complete understanding of the invention, together with other objects and advantages thereof, reference may be had to the accompanying drawing, in which the sole figure schematically represents a self rectifying magnetron power supply for a microwave oven which incorporates the present invention.

Referring now to the drawing, therein is shown a microwave heating cavity **10** which receives electromagnetic wave energy from a magnetron **12** for heating objects in the cavity **10**. The magnetron **12** is connected directly to a power transformer **14** which is in turn energized through input terminals **16** and **18**, which terminals may be directly connected to a commercial electrical outlet such as a single phase, 230 volt, 60 cycle commercial outlet. The anode or plate **20** and cathode **22** of magnetron **12** are connected directly to the terminals of the secondary winding **24** of transformer **14**. One end of primary winding **26** of transformer **14** is connected directly to input terminal **16**, while the other end of primary winding **26** is connected to the other input terminal **18** through the parallel circuit of diode **28** and resistor **30**.

As was previously mentioned, the magnetron **12** requires a relatively high plate voltage, but can be used in a self half-wave rectifying configuration since the magnetron itself is a diode. For example, the L–3189 magnetron, manufactured by Litton Industries, Electron Tube Division of San Carlos, California, the most popularly used magnetron in the microwave heating field today, can be so operated off of a transformer **14** which provides a peak voltage in the output winding **24** of about 7000 volts, and which provides plate current of about 300 milliamps. Also, as was previously mentioned, it is economically desirable to use as small a transformer **14** as possible and, as a transformer is made smaller and smaller, the core of the transformer tends to saturate during the half cycle the magnetron **12** is conducting, and the core does not reset itself fast enough to so operate at a 60 cycle rate.

In accordance with the present invention, the parallel circuit of the diode **28** and resistor **30** is placed in series with the primary winding **26** of transformer **14**, with the polarity of diode **28** being chosen such that current passes through diode **28** in its forward direction during the half cycle that magnetron **12** is conducting.

The operation of the invention is as follows:

During the half cycles that magnetron **12** is conducting, line current passes through diode **28** in the forward direction and the circuit operates in a conventional manner. In the beginning of the next "nonconducting" half cycle, the core of transformer **14** is saturated as a result of the current flowing in the previous conducting half cycle. During this nonconducting half cycle, the polarity of diode **28** is such as to oppose conduction and current flows through the series circuit of primary winding **26** and resistor **30**. The value of resistor **30** is chosen to minimize the RMS value of current flowing in the primary circuit, at which time only enough current flows during the "nonconducting" half cycle to unsaturate the core of transformer **14** and reset the transformer for proper operation in the ensuing conducting half cycle.

In a typical embodiment of the present invention, an L–3189 magnetron has been used to deliver about 1 kilowatt of microwave energy to the cavity of a microwave oven for cooking food or the like. A Utrad Transformer No. 3965 has been connected in the manner shown in the drawing, with the value of resistor **30** being 15 ohms. It has been found that the inclusion of the invention reduces the line current in the input circuit from a value of about 25 amperes RMS to about 16 amperes RMS, with a resultant considerable reduction in losses in the transformer, even though a relatively smaller saturating transformer is being utilized.

It is to be understood that the above described arrangements are illustrative of the principles of the present invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention. Thus, by way of example and not limitation, the invention may be used in any type of device which uses a magnetron as a source of electromagnetic wave energy, and is not limited to use in microwave heating equipment. Also, the invention could be used to reduce the input current to any type of circuit in which the load is inherently half wave rectifying, whether a magnetron or not. Accordingly, it is to be understood that the present invention is limited only by the spirit and scope of the appended claims.

What is claimed is:

1. A power supply for a magnetron heating system delivering power in the kilowatt range and greater comprising: a magnetron having an anode and cathode, a step-up power transformer having a saturating core, an input winding energizeable by a low voltage, high current alternating current voltage, and a power output winding interconnected to energize the anode-cathode of the magnetron with a high alternating current voltage and a large current that is an appreciable portion of an ampere and greater, means for reducing the electrical current heating loses in the power transformer and correspondingly enabling a reduction in the size and heat dissipating capacity of the transformer, said transformer being capable of drawing substantially full primary current on both half cycles of the alternating current source when coupled to the magnetron resulting from saturation of the core during a conducting half cycle of the magnetron resulting in a low impedance to the power source during the nonconducting half cycle of the magnetron, said reducing means comprising a low impedance undirectional coupling means interconnecting a primary winding with the alternating current power source enabling full current flow during conducting half cycles of the magnetron, and impedance means shunting said undirectional conducting means for providing a reduced current flow to said primary winding during nonconducting half cycles of the magnetron, said impedance means limiting said current flow during nonconducting half cycles to an amplitude sufficient to desaturate said transformer core during said nonconducting half cycles.

2. In the power supply of claim **1**, said unidirectional conducting means comprising a diode and said impedance means comprising a resistor.

3. In a microwave heating device, a saturating transformer having a primary winding, a secondary winding, and a saturating core, a magnetron having an anode and a cathode, means for connecting said anode to one of the terminals of said secondary winding and said cathode to the other terminal of said secondary winding, said magnetron conducting current only during one-half cycle of each cycle of alternating current, said saturating transformer being capable of drawing substantially a full primary current or both half cycles of each cycle of alternating current when coupled to said magnetron, a diode connecting said primary winding to a source of alternating current for enabling full current flow in said primary winding only during the conducting half cycle of said magnetron to magnetically set said saturating core and couple electrical energy to said secondary winding and a resistor connected in parallel with said diode for providing a limited current flow in said primary winding during the non-conducting half cycle of said magnetron for resetting said saturating core, whereby a full current flow otherwise appearing in said primary winding during the non-conducting half cycle of said magnetron is prevented, and means for applying the output energy of said magnetron to an object to be heated.

4. A power supply for a magnetron comprising, a saturating transformer having a primary winding, a secondary winding, and a saturating core, a magnetron having an anode and a cathode, means for connecting said anode to one of the terminals of said secondary winding and said cathode to the other terminal of said secondary winding, said magnetron conducting current only during one-half cycle of each cycle of alternating current, said saturating transformer being capable of drawing substantially a full primary current on both half cycles of each cycle of alternating current when coupled to said magnetron, a diode connecting said primary winding to a source of alternating current for enabling full current flow in said primary winding only during the conducting half cycle of said magnetron to magnetically set said saturating core and couple electrical energy to said secondary winding, and a resistor connected in parallel with said diode for providing a limited current flow in said primary winding during the non-conducting half cycle of said magnetron for resetting said saturating core, whereby a full current flow otherwise appearing in said primary winding during the non-conducting half cycle of said magnetron is prevented.

References Cited

UNITED STATES PATENTS

2,008,496	7/1935	Garretson	315—206
3,168,637	2/1965	Lamb	219—10.55
3,265,850	8/1966	Crapuchettes	219—10.55
2,568,757	9/1951	Mesh	307—101 X

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