United States Patent [19]

Peterson

[11] **3,717,793**

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[54] CIRCUIT PROTECTOR

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[52] **U.S. Cl.**.....**317/40 A**, 219/481, 219/517, 328/259

[51] **Int. Cl.**.....**H02h 5/04**

[58] **Field of Search**.....328/259, 262; 317/40 A; 219/481, 517

[56] **References Cited**

UNITED STATES PATENTS

1,968,198	7/1934	Gibbs	328/259
3,385,956	5/1968	Ohara et al.	219/481
3,396,342	8/1968	Feinberg	328/262
3,651,371	3/1972	Tingley	328/262 X

Primary Examiner—James D. Trammell
Attorney—Harold A. Murphy et al.

[57] **ABSTRACT**

An electrical circuit and means for protecting the high voltage supply of a microwave oven against faults, shorts or failures. Any failure in, for example, the magnetron energy generator, voltage rectifiers, capacitors or other components in the electrical circuit forming the secondary winding loop coupled to a high voltage step-up transformer, particularly, of the ferroresonant saturable core type results in the actuating of thermally controlled deenergizing means to decouple the oven from the line voltage source thereby preventing damage and/or unsafe operation.

6 Claims, 5 Drawing Figures

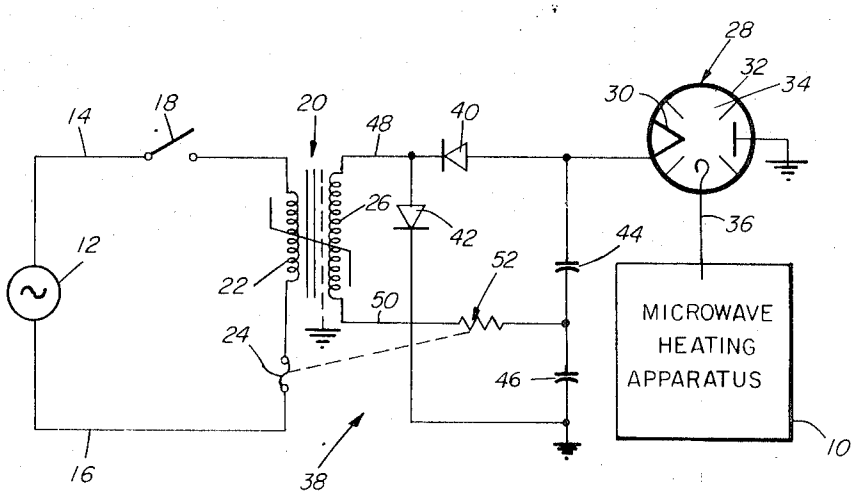
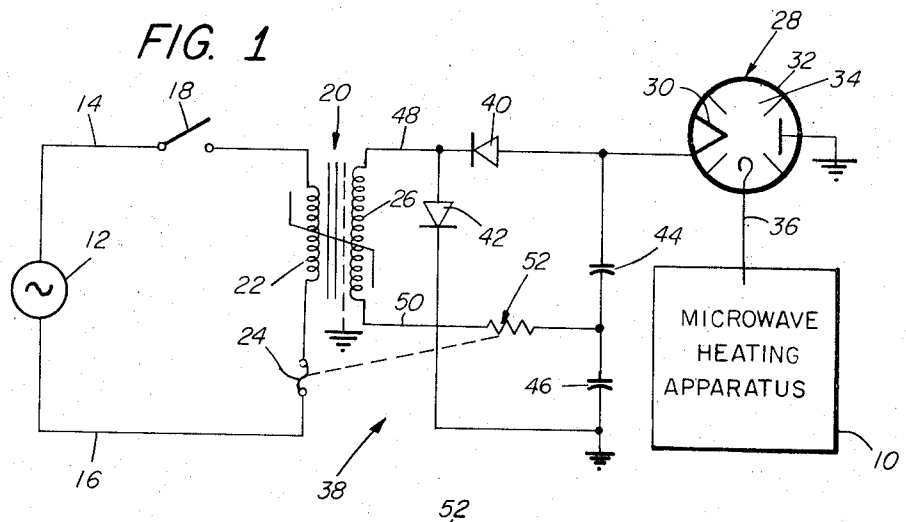


FIG. 1



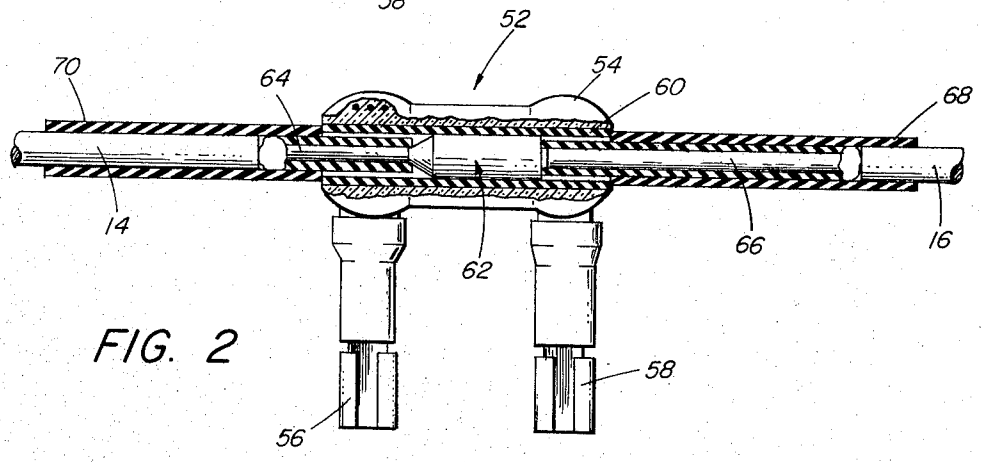


FIG. 2

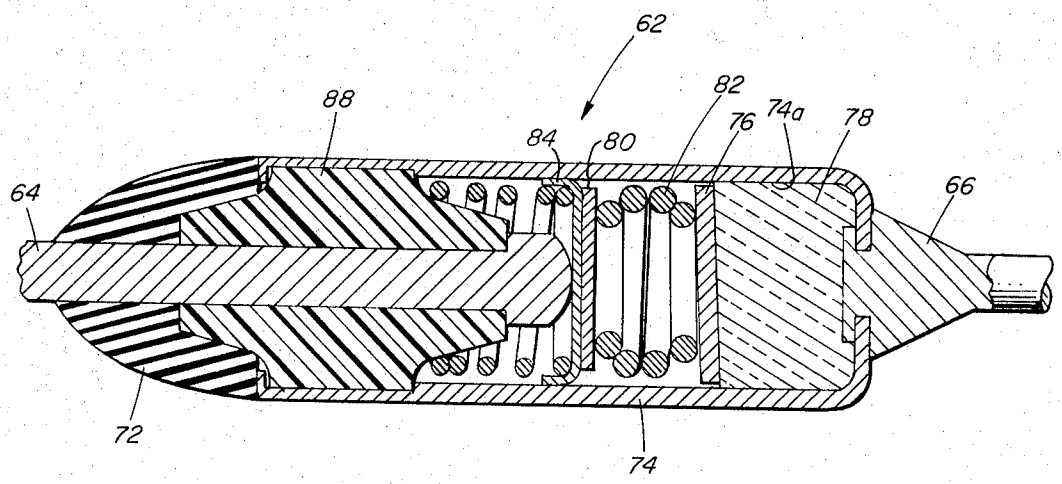


FIG. 4

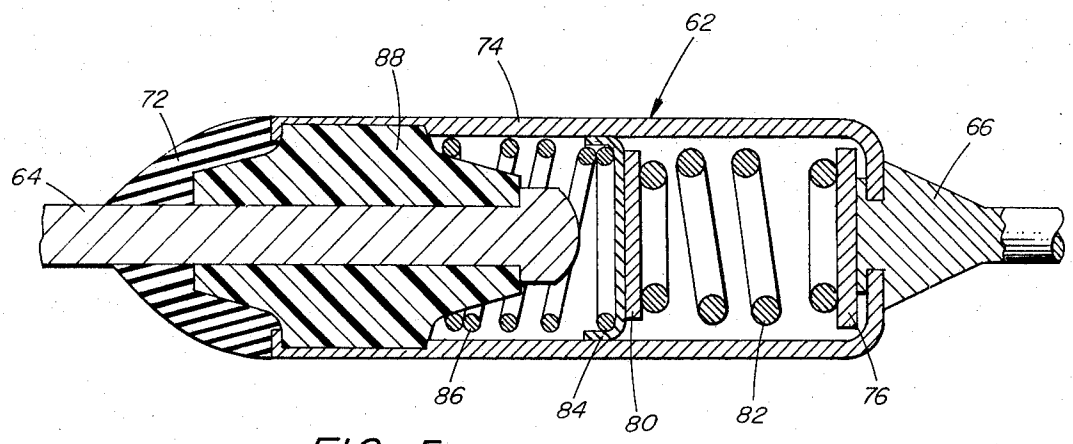


FIG. 5

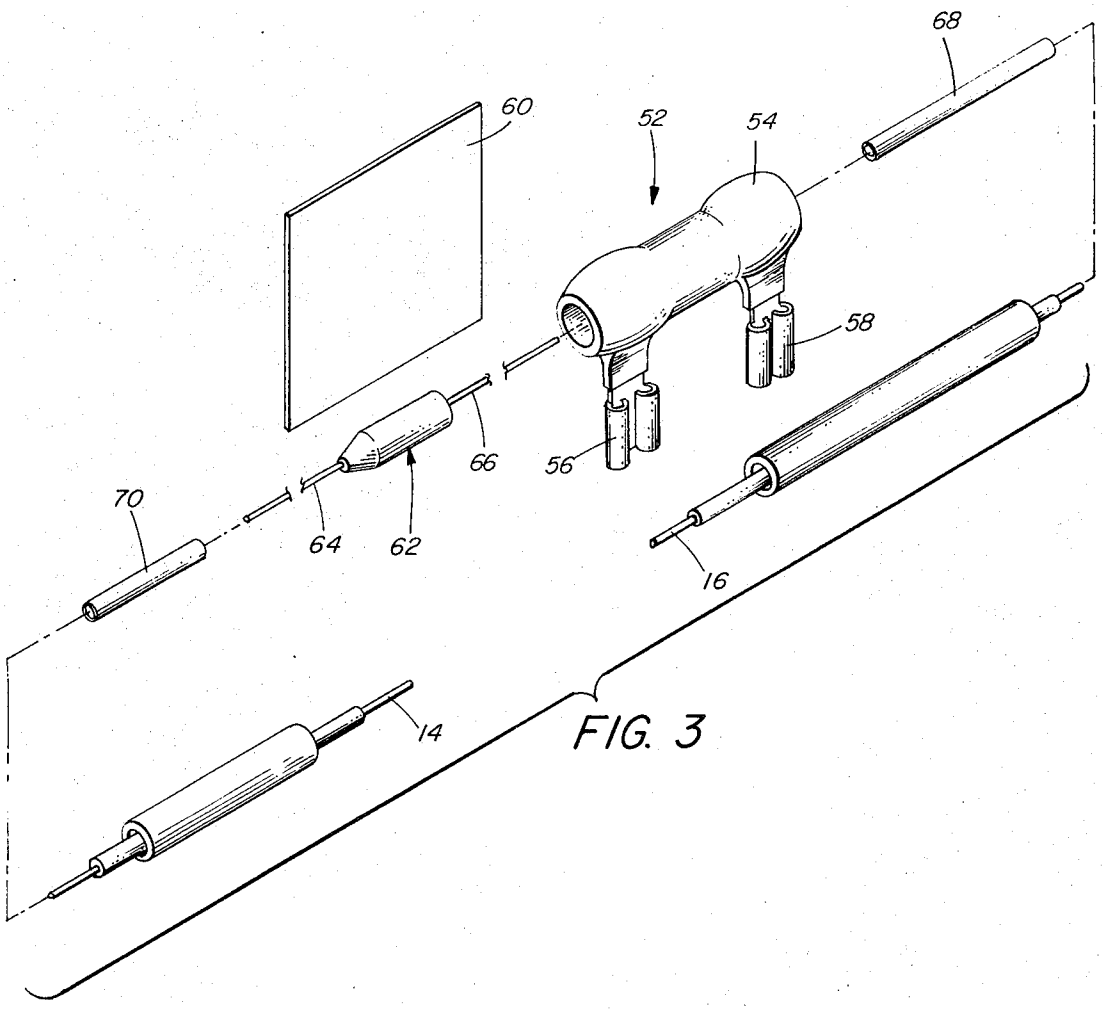


FIG. 3

CIRCUIT PROTECTOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to magnetron high voltage supply electrical circuits and, particularly, means for deenergizing the circuit upon the sensing of any component failure which causes an increase in current in any portion of the circuit.

2. Description of Prior Art

An energy generator widely used in microwave cooking is the magnetron. Such devices are energized by domestic low frequency, low voltage sources and high voltage supplies capable of generating rectified DC voltages at levels of, for example, 4,000 to 6,000 volts. In the magnetron electric and magnetic fields extend within an interaction region defined between a cathode and circumferentially disposed anode cavity resonators. The electrons are accelerated towards the cavity resonators and rotate in a substantially helical path to form a rotating spoke-like space charge and interact in energy exchanging relationship with the electric fields to generate microwave energy. The term "microwave" is defined as electromagnetic energy having wavelengths in the order of approximately 30 centimeters to 1 millimeter and frequencies in excess of 300 MHz. The starting voltages are applied between the anode and cathode by circuits coupled to the secondary winding of a high voltage step-up transformer. The magnetron is inherently a unidirectional device since oscillations are generated only when the anode is positive relative to the cathode on alternate half-cycles. Rectifying means are, therefore, employed in combination with the high voltage transformers to provide for continuous operation of the energy generator in microwave cooking. Full-wave or half-wave voltage doubler circuits are customarily employed for such rectification. Such circuits include numerous capacitors and semiconductor diodes.

A high voltage transformer which has evolved in the art to provide for controlled constant current in the pulses to energize the magnetron and thereby eliminate the effects of line voltage fluctuations is disclosed in U.S. Letters Pat. No. 3,396,342, issued Aug. 6, 1968, to A.E. Feinberg. Such transformers have the primary and secondary windings electrically isolated from one another and are coupled in a high leakage reactance operating relationship by means of a ferroresonant saturable core. Voltage variations in the primary winding loop, therefore, have very little effect on the magnetron current. Energy storage means are connected in the secondary winding loop and return paths for the current through such energy storage means on alternate half-cycles are provided. In the operation of such saturable core transformers with full-wave or half-wave voltage doubler circuits, a failure due to a fault in the energy generator or any of the circuit components normally causes an increase in current in the secondary loop. Due to the isolation of the secondary and primary windings such an increase in the current does not result in a corresponding increase in the current in the primary winding loop. It is customary in electrical circuits for operating microwave ovens to provide electrical circuit breakers in the line voltage circuit to handle component failures which could result in damage or unsafe operation. In saturable core transformers, however,

there is an absence of any protection from failures in the secondary winding loop to deenergize the oven. It is necessary, therefore, that suitable circuit protectors be provided, particularly, in microwave oven apparatus to prevent permanent damage to costly magnetrons, high voltage transformers and the components of the voltage rectification circuits as well as unsafe operation.

SUMMARY OF THE INVENTION

A high voltage supply electrical circuit is provided for a microwave oven apparatus including a step-up transformer having primary and secondary windings. Means are provided in the secondary winding loop to sense a predetermined rise in the secondary current. In an embodiment a resistor is serially connected in the secondary winding loop. Integral with the resistor is a thermally controlled deenergizing element in series with the primary winding loop and line voltage source.

Any equipment failure such as a shorted magnetron energy generator, inoperative diode rectifier, capacitor, or equivalent component fault which results in an increase in the secondary current will thermally actuate the protection means. Since the power dissipated by the resistor increases in proportion to the square of the current, a resistor of relatively low value, such as 4 ohms and 5 watts, can be employed. A sufficient rise in temperature will result to cause the adjacent thermally controlled element to disintegrate which will deenergize the overall microwave oven electrical circuit. Serious damage as well as unsafe operation is thereby avoided.

The invention is equally applicable to protect any circuits having high voltage transformers for such applications as radar, industrial microwave processing systems and communication equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

Details of an embodiment of the invention will be readily understood after consideration of the following description and reference to the accompanying drawings, wherein:

FIG. 1 is a schematic circuit diagram of the illustrative embodiment of the invention;

FIG. 2 is an elevation view, partially in section, of the sensing and thermally controlled deenergizing means embodying the invention;

FIG. 3 is an exploded elevation view of the principal components of the embodiment of the invention shown in FIG. 2;

FIG. 4 is a cross-sectional view of an exemplary thermally controlled element in the closed circuit position; and

FIG. 5 is a cross-sectional view of the element shown in FIG. 4 in the break of open circuit position for deenergizing the overall electrical circuit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, FIG. 1 is a schematic circuit diagram illustrative of the embodiment of the invention used in combination with microwave heating apparatus 10. The high voltage supply circuit is coupled to a domestic or industrial low frequency, low voltage source 12 by means of leads 14 and 16 through

a manually operated stop-start switch 18. A saturable core transformer 20 having a high leakage reactance of the type disclosed in the afore-referenced U.S. Pat. No. 3,396,342 has primary winding 22 connected to the line leads 14 and 16. The thermally controlled deenergizing element 24 of the invention is serially connected in the primary winding circuit.

Secondary winding 26 which is electrically isolated from the primary winding has, illustratively, a turns ratio of 40–50:1 to provide the high voltages to energize the magnetron energy generator 28. The energy generator is of the well-known type having a cathode 30 generally of the oxide-coated type with a directly heated filament and an anode 32 defining a plurality of cavity resonators 34 circumferentially disposed about the cathode 30. The high frequency microwave energy generated by magnetron 28 is coupled by an antenna loop member 36 through conventional waveguide means to the oven enclosure defined by the conductive walls of microwave heating apparatus 10 in a manner well known in the art. Means may also be provided for distributing the energy, such as stirrers.

The high voltage rectification means comprise a full-wave voltage doubler circuit 38 coupled to the secondary winding 26. The circuit includes semiconductor diodes 40 and 42, electrically biased in the manner shown in the illustration. Capacitors 44 and 46 are also connected in the circuit. In operation, when the end of secondary winding 26 connected to lead 48 is poled positive, the current flows through semiconductor diode 42 to charge capacitor 46 to the predetermined voltage. Semiconductor diode 40 in this portion of the cycle remains nonconductive.

On the next half-cycle, lead 50 becomes poled positive and the current flows through diode 40 to charge capacitor 44. In this portion of the cycle diode 42 remains nonconductive. The total rectified voltage applied between the anode and cathode of the magnetron energy generator 28 is the sum of the voltages or approximately twice the voltage applied across each capacitor 44 and 46. Other high voltage rectifying means may be employed in the practice of the invention such as half-wave voltage doubler circuits, voltage triplers or quadruplers.

In view of the electrical isolation of the secondary winding and accompanying loop circuit from the primary winding of the transformer any failures in the components, such as a shorted magnetron energy generator, faulty diodes or capacitors which could result in damage or unsafe operation would not cause an increase in the primary voltage current to trip a conventional circuit breaker or fuse at the source. A fault in the secondary circuit, however, does cause an increase in current. It is this current rise which is utilized in the invention by means of a sensing element serially connected in the secondary winding loop circuit to actuate the thermally controlled deenergizing element 24 in the primary winding circuit.

Referring now to FIGS. 2 and 3, an exemplary embodiment 52 of the invention, comprises a wirewound resistor 54 having terminals 56 and 58 for serially connecting to the secondary winding loop circuit. An increase in the secondary current increases the power dissipated by the resistor 54 in proportion to the square of the current. A source of thermal energy is thereby provided which is utilized to actuate the thermally controlled element 24. In an exemplary embodiment a wirewound resistor 54 having a value of 4 ohms and power dissipation of 5 watts was found to function satisfactorily The resistor circuit normally carries a current of 1.0 amperes R.M.S. and is at approximately 8,000 volts potential.

An exemplary thermally controlled element 62 is integrally mounted adjacent to the resistor and is isolated by means of insulating tape 60. The element 62 is selected to operate with a temperature rise of approximately 358° F. A thermal limiter, available under the trade name "Micro Temp," comprises a nonconductive material which rapidly changes from a solid to a liquid state at a predetermined temperature to actuate a spring-loaded contact and open an accompanying electrical circuit. Insulating tape 60 is wound around the element 62 to electrically isolate it from the secondary winding circuit. Leads 64 and 66 together with sleeve insulators 68 and 70 provide for connecting the thermal element 62 to the primary circuit through leads 14 and 16. The primary circuit connected through the thermal element handles a current of approximately 20 amperes R.M.S. during normal operation.

Referring now to FIGS. 4 and 5, thermally controlled element 62 is illustrated in greater detail. Such thermal devices which have evolved in the commercial market are capable of being miniaturized so that in an embodiment for protection of a microwave oven circuit an element having a length of typically 1⅜ inches can be employed with a wirewound resistor 54 having an inner diameter of approximately three-sixteenths of an inch. In FIG. 4 the element is shown in the closed circuit position. Wire lead 64 is encased in a sealing compound 72 secured at one end of case 74 while lead 66 is disposed at the opposing end and is conductively secured to the case 74. A pellet 78 of a nonconductive material which rapidly changes from a solid to a liquid state at a predetermined temperature is disposed in contact with disc member 76 to urge spring 82 against disc member 80. Metallic star contact member 84 is in contiguous relationship with disc member 80 and the interior walls of the conductive case 74 as well as the inner end of lead 64. A trip spring 86 urges the contact member 84 in the opposite direction and is maintained in position by ceramic bushing 88 through which the lead 64 extends. In normal operation, with the thermal element 62 carrying the normal primary winding current, lead 64 provides a current path through star contact member 84 and the inner walls 74*a* of the case 74 adjacent pellet 78. The current path is completed through the opposing lead 66.

In FIG. 5 the thermal element 62 is shown in the open circuit position deenergizing the primary winding circuit upon the sensing of a fault in the secondary winding loop by the resistor 54. Upon reaching the illustrative threshold temperature of 358° F the pellet 78 will disintegrate. The circuit will be broken when lead 64 no longer contacts star contact member 84 to provide positive protection. Deenergizing of the overall microwave oven electrical circuit will prevent serious equipment damage as well as unsafe operation. It will be noted that spring 82 has been fully extended with disc member 76 positioned against the interior of lead 66.

There is thus disclosed an efficient and positive operating circuit protector for sensing faults in components coupled to the secondary winding loop of a high voltage core transformer. A rise in temperature due to an increase in secondary current deenergizes the primary winding circuit. In the operative position the thermal deenergizing element is not required to carry the high secondary voltages which in the case of microwave oven apparatus can be many thousands of volts. The circuit is unique in that equipment failure results in complete decoupling of the high voltage supply circuit from the line voltage source. The oven can be operated again only after qualified service personnel have replaced the faulty component and inserted a new circuit protector.

Numerous modifications, variations or alterations may be practiced by those skilled in the art. It is intended, therefore, that the foregoing illustrative embodiment and detail description be considered in its broadest aspects and not in a limiting sense.

I claim:

1. In combination:
a voltage source;
high voltage transformer means having primary and secondary windings with said primary winding connected to said voltage source;
an electrical circuit connected to said secondary winding to generate high output voltages;
a circuit protector including means for sensing a predetermined current increase due to circuit faults operatively associated with said secondary winding circuit; and
deenergizing circuit means operatively associated with said primary winding and disposed adjacent to said sensing means;
said deenergizing means being electrically isolated from said sensing means.

2. The combination according to claim 1 wherein said sensing means comprise a resistor.

3. The combination according to claim 1 wherein said deenergizing means are thermally actuated.

4. In combination:
a voltage source;
high voltage transformer means having electrically isolated primary and secondary windings with said primary winding connected to said source;
an electrical circuit connected to said said secondary winding including components for voltage storage, rectification and generation of high output voltages;
a circuit protector including means for sensing a predetermined current increase due to component failure in said secondary winding circuit; and
thermally actuated deenergizing means operatively associated with said primary winding and disposed adjacent to said sensing means.

5. In combination:
a voltage source;
an energy generator;
an electrical circuit including high voltage transformer means having primary and secondary windings with said primary winding connected to said voltage source and a circuit loop including voltage rectification means connected to said secondary winding to generate high voltages to operate said energy generator;
a circuit protector including means for sensing a predetermined current increase in said secondary winding circuit loop; and
deenergizing circuit means disposed in thermal contact with said sensing means;
said deenergizing circuit means being electrically isolated from said sensing means.

6. Microwave heating apparatus comprising:
an oven enclosure;
an electromagnetic microwave energy generator;
means for radiating said microwave energy within said enclosure;
electrical circuit means for energizing said generator including a voltage source, transformer means having primary and secondary windings and high voltage rectification means;
a circuit protector having means for sensing a predetermined current increase due to operative failure in said high voltage rectification means and energy generator; and
deenergizing circuit means thermally associated with said sensing means;
said deenergizing means being electrically isolated from said sensing means.

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