May 16, 1967 H. BOEHM 3,320,396

ELECTRONIC OVEN

Filed June 18, 1964 2 Sheets-Sheet 1

Fig. 1

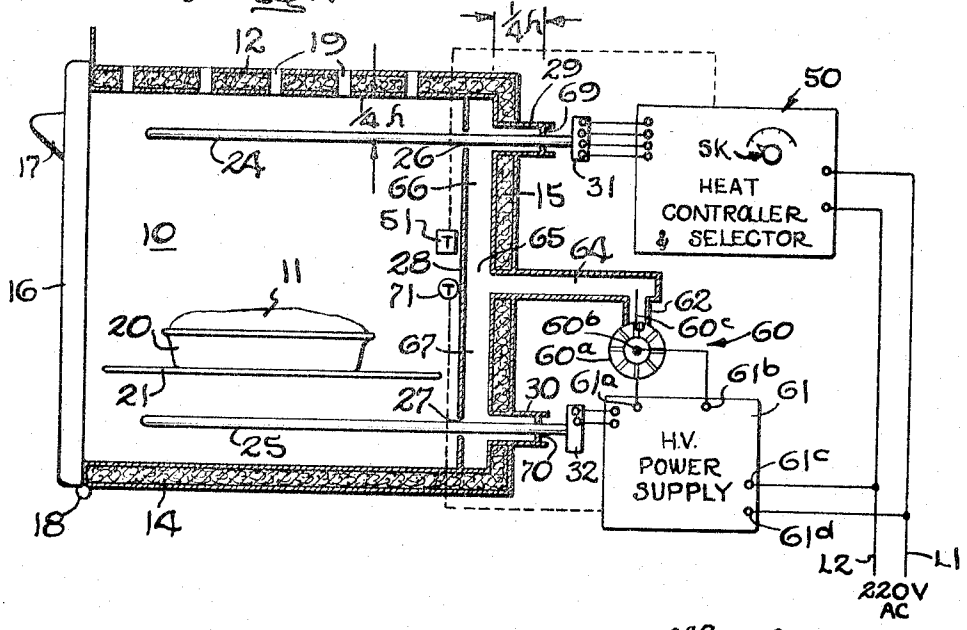
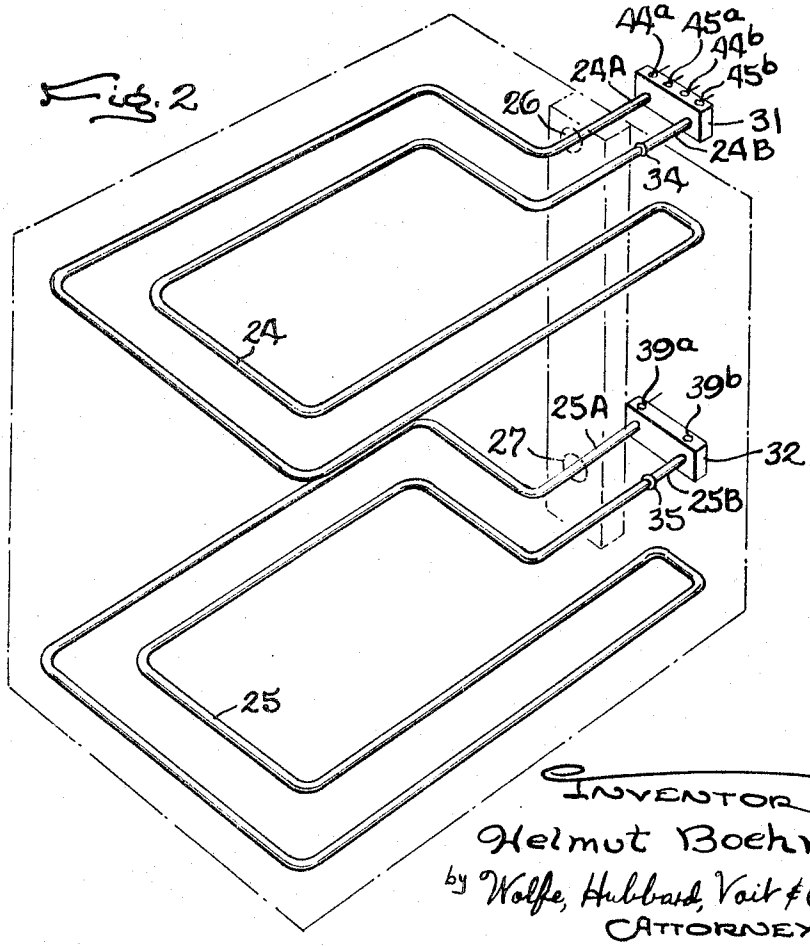


Fig. 2



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Fig. 3

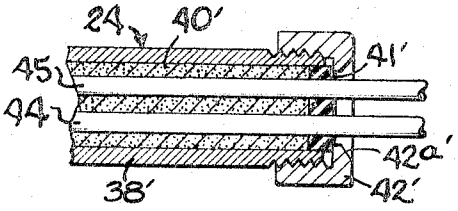


Fig. 4

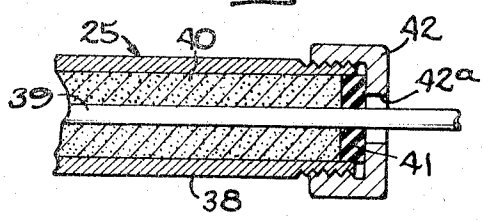


Fig. 6

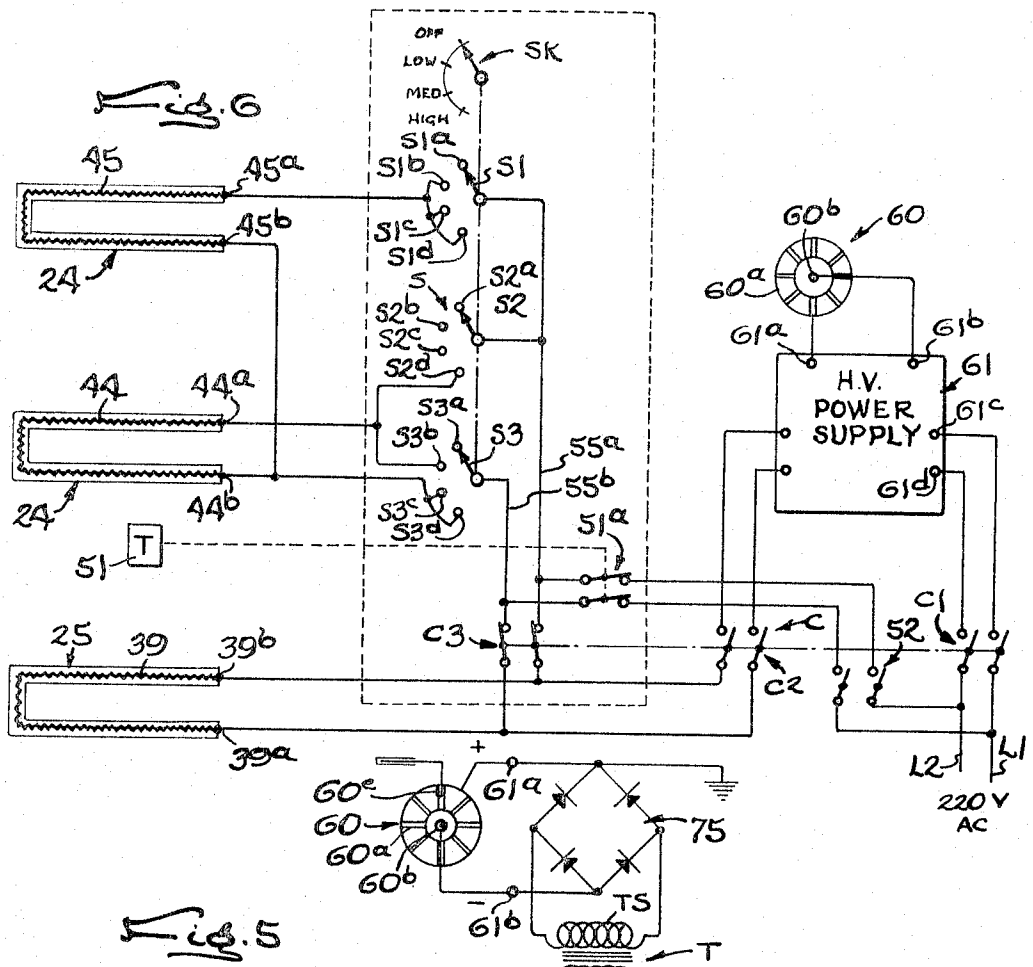
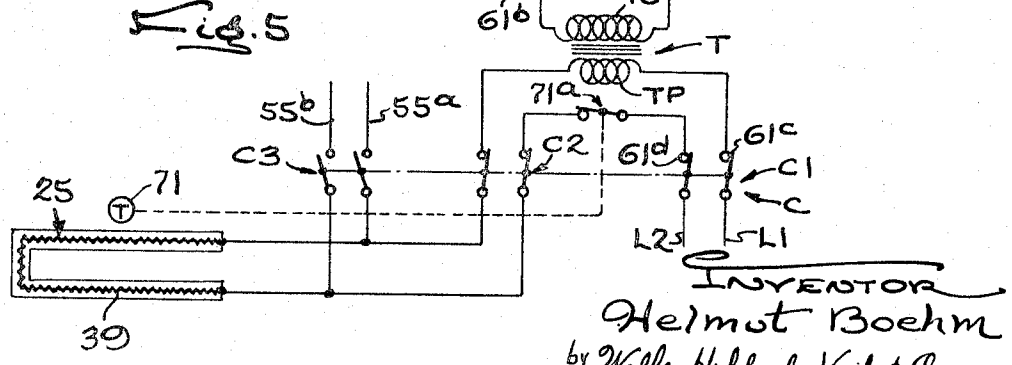


Fig. 5



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United States Patent Office 3,320,396
Patented May 16, 1967

3,320,396

ELECTRONIC OVEN

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Filed June 18, 1964, Ser. No. 376,185
17 Claims. (Cl. 219—10.55)

The present invention relates in general to ovens for heating objects placed therein, and in particular to ovens of the type which employ microwave energy for locally and internally heating objects containing appreciable amounts of moisture. While not so limited in its uses, the invention will find especially advantageous employment in connection with ovens utilizing microwave energy, together with more conventional low frequency heat energy, for cooking foods in homes, restaurants, and self-service cafeterias.

The general aim of the invention is to provide an oven for heating objects placed therein either by microwave energy or by more conventional lower frequency heat energy, or by both, and to accomplish this by the action of common elements which perform important functions in both types of heating.

It is a related object to achieve the foregoing while at the same time reducing the number and cost of components, and the space occupied by them, in an oven chamber.

More specifically, an important object of the invention is to provide an oven in which a single element serves both as an antenna for radiating microwave energy in the oven chamber and as a resistor type heater for creating heat within the oven chamber.

A related object is to provide such an oven in which a single element operates to heat the food or other object therein either by microwave energy action alone, by resistance heating action (I^2R dissipation) alone, or simultaneously by both such actions.

It is a further object to provide an oven employing a source of microwave energy together with a high voltage power supply therefor which employs a voltage regulating resistor, and to avoid the need to remove (for example, by a special cooling fan) substantial amounts of heat created in the resistor while at the same time effectively using such heat to good advantage in the oven chamber itself.

Another object is to achieve the foregoing by the use of a resistor which need not be especially and expensively constructed for high voltage operation, without the need for dangerous high voltage potentials and special insulators in the oven chamber, and in a manner which makes it possible to employ a smaller transformer in the high voltage supply circuit.

Still another object is to provide such an oven arrangement in which an element employed as a microwave radiating antenna in the oven chamber serves also as a voltage regulating resistor in the high voltage supply for the microwave source, that element thus contributing to the heating of an object in the oven by transferring microwave energy to the object and simultaneously radiating conventional lower frequency heat created by current flow through the element as an incident to its voltage regulating operation.

It is a related object to provide such an oven in which a voltage regulating resistor connected in the circuit of a high voltage supply for a microwave energy source is disposed in the oven chamber, and yet in which that resistor may be selectively connected to a conventional voltage source so as to heat the oven by direct action when the microwave source is not being used.

Stated another way, it is another object here to provide an oven in which a single element within the oven chamber

acts alternatively or simultaneously (a) to radiate microwave energy, (b) to perform an important voltage regulating function in a high voltage supply for a microwave generator, such as a magnetron, and (c) to generate heat by the action of current flowing through a resistance, the latter occurring either as an incident to operation of the high voltage supply circuit or as the result of current drawn from conventional A.C. power means.

Other objects and advantages will become apparent as the following description proceeds, taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a schematic illustration of an oven constituting an exemplary embodiment of the present invention, and showing in vertical section an oven chamber together with the heating means and controls therefor;

FIG. 2 is a perspective view showing the configuration of multi-purpose rod-like elements disposed in the oven chamber of FIG. 1;

FIGS. 3 and 4 are fragmentary sectional view respectively showing the construction details of the upper and lower rod-like elements;

FIG. 5 is a schematic diagram of a high voltage supply which creates and applies an operating voltage to a microwave energy source, e.g., a magnetron; and

FIG. 6 is a schematic circuit diagram, including the high voltage supply shown in block form, for the selector and control means associated with the oven.

While the invention has been shown and will be described in some detail with reference to a particular embodiment thereof, there is no intention that it thus be limited to such detail. On the contrary, it is intended here to cover all modifications, alternatives and equivalents falling within the spirit and scope of the invention as defined by the appended claims.

Referring now to FIG. 1, the oven here shown by way of example to illustrate one embodiment of the invention includes structural means for defining an oven chamber **10** which is adapted to receive and surround an object **11** to be heated. The chamber is formed by six walls disposed in box-like configuration, these including upper and lower walls **12** and **14**, a rear wall **15**, two side walls (not visible), and a front wall constituted by a door **16** provided with a handle **17** and pivoted at **18** to swing between open and closed positions. Each of these walls is preferably formed by spaced apart sheet metal panels, with insulating materials disposed between them. Preferably small openings are provided to permit limited circulation of air and the escape of water vapors from the chamber **10**, holes being illustrated at **19** and sized so that they do not permit escape of appreciable amounts of microwave energy from the chamber.

The object to be heated may be, for example, an item of food containing significant amounts of moisture. It is disposed in a non-metallic (e.g., paper, plastic, or glass) utensil **20** inserted through the door **16** and placed for support on an open framework metal shelf **21** which is formed to permit passage of microwave and heat energy therethrough.

In accordance with the present invention, a metal element is disposed within the chamber **10** and formed in the shape of an antenna for radiating microwave energy. That element includes, however, as an integral part thereof a resistive conductor adapted to have current at a frequency much lower than microwave frequencies (e.g. direct current or conventional 60 cycle A.C. current) passed therethrough and thus to dissipate heat energy according to the known relationship of current squared times resistance (I^2R) which determines the rate of heat generation in watts. Heating by current flow through a resistance will hereinafter be termed "resistance heating" or "I^2R dissiption," the heat energy so created within the oven chamber being at much lower

frequencies (longer wave lengths) than energy in the higher frequency, micro-wavelength range.

Two such elements **24** and **25** are employed in the present instance. They are preferably constituted as rod-like members folded back upon themselves to lie in upper and lower horizontal planes (FIGS. 1 and 2). Provision is made, as hereinafter described, to couple high frequency microwave electrical energy to the elements **24, 25** so that they act as antennas which radiate that energy into the oven chamber **10** where it is absorbed by and causes heating within the food item or object **11**. Additionally, however, means are provided to pass current through the resistive conductors of the elements **24, 25** so that the latter also contribute heat within the chamber **10** by a resistance heating mode of operation. This latter heat energy serves to heat the food item or object **11**, and indeed to produce a browning action on the surface thereof which is not normally produced by the action of microwave energy.

As will become apparent from the more detailed description which follows, the elements **24, 25** may function solely to radiate microwave energy, solely to produce resistance type heating action, or simultaneously to produce both microwave and resistance type heating actions.

As made clear by FIG. 1, the elements **24** and **25** are appropriately supported (by means not shown) within the chamber **10**, one extremity **24***a*, **25***a* of each passing in non-conducting relation through openings **26, 27** in a metal partition **28** and thence through elongated, metal walled passages **29, 30** formed in the rear wall **15** to terminal blocks **31** and **32**. The opposite extremities **24***b*, **25***b* of these elements pass through the rear wall **15** to the respective terminal blocks **31** and **32**, but are in electrical contact at points **34, 35** with the inner metal panel of that wall for reason to be more fully explained below.

Although the specific structure of the elements **24** and **25** may vary, and indeed both the radiating antenna function and the resistance heating function may be accomplished by a single metal piece, preferred forms thereof are shown by FIGS. 3 and 4, respectively. As shown in FIG. 4, the lower element **25** is constituted by an outer metal sheath **38** which surrounds and is spaced or insulated from an inner resistive conductor **39** made of any suitable high resistivity metal such as nickel-chromium alloys, molybdenum, or other resistance heater materials well known in the art. The inner resistive conductor **39**, although shown in the form of simply a straight wire, constitutes a heater type resistor which generates substantial low frequency heat and energy in response to the passage of energizing current therethrough. The space between the sheath **38** and the resistive conductor **39** may be filled with a heat-resistant, inert insulating powder **40** so that the rod-like element after initial manufacture can be bent or otherwise formed into a folded-back or serpentine configuration such as that illustrated in FIG. 2.

One product available on the market and which may readily be employed as the element **25** is known by the trademark Calrod. Such Calrod units will serve satisfactorily, but it is preferred that the outer sheath **38** thereof be made of a low resistivity metal which tolerates high temperatures, so as to present low resistance to current which may flow therethrough at microwave frequencies as an incident to radiation of microwave energy.

In or near the junction block **32** the tips of the element **25** are terminated by an insulating disc **41** pressed into the sheath **38** and retained in place by a nut **42** threaded onto the sheath. The resistive conductor or resistor wire **39** extends through the insulating disc **41** and passes with clearance through an oversize opening **42***a* in the nut so as to remain insulated from the sheath. The projecting portion of the resistor wire **39** then extends into connector sockets carried by the terminal block **32** and electrically connected with terminal screws shown on the upper surface of the block.

The rod-like element **24** is here shown as being identical in every way with the element **25**, except that the former contains two separate and spaced-apart inner resistive conductors **44** and **45**. Accordingly, the individual components of the element **24** shown in FIG. 3 are identified by the same reference characters employed in FIG. 4, except for the distinguishing addition of prime symbols. Whereas the opposite ends of the resistor wire **39** lead to terminals **39***a*, **39***b* on the terminal block **32** (FIG. 2), the terminal block **31** has four connection points, its first two terminals **44***a*, **44***b* being connected to the opposite ends of the resistor wire **44** and its second two terminals **45***a*, **45***b* connecting with the opposite ends of the resistor wire **45**.

In keeping with the invention, the resistive conductors **44** and **45** are adapted for connection to a conventional voltage source so that they may create heat by I^2R dissipation within the chamber **10**. Such connection is established, for example, through a heat controller and selector **50** (FIG. 1) to conventional 220 volt A.C. power mains **L1, L2** and controlled in response to oven temperature as sensed by a thermostatic unit **51** disposed in the chamber **10**.

The controller and selector **50** is shown in somewhat more detail by FIG. 6. A main selector switch **52**, closed when resistance heating action is desired, leads from the lines **L1, L2** through thermostatic switch contacts **51***a* to the input terminals **55***a*, **55***b* of a selector switch S having ganged switch arms **S1, S2, S3** set to any one of four associated contact points *a, b, c, d*, by manual adjustment of a selector knob S*k*. Assuming that the main switch **52** is closed, and the oven temperature is below a desired value so that the thermostatically controlled switch **51***a* is also closed, then neither the heater resistor **45** nor the heater resistor **44** will be energized when the selector knob S*k* is in the "off" position. If that knob is turned to the "low" position, a circuit is established from line **L1** through contacts **S1**, **S1***b*, the resistor **45**, the resistor **44**, and contacts **S3***b*, **S3** to line **L2**. In this way, the two resistive conductors **44, 45** are connected in series across the 220 volt power source. If, on the other hand, the knob S*k* is set to the "medium" position, a circuit will be established from line **L1** through contacts **S1**, **S1***c*, resistor **45**, and contacts **S3***b*, **S3** to line **L2**. This applies 220 volts to the heater resistor **45**, but leaves the second heater resistor **44** in the element **24** de-energized. Finally, if the knob S*k* is set in the "high" position, a circuit is established from the line **L1** through the contacts **S1**, **S1***d*, through the resistor **45**, and thence through the contacts **S3***d*, **S3** to the line **L2**; while a similar circuit is established from the line **L1** through the contacts **S2**, **S2***d* through the resistor **44** and the contacts **S3***d*, **S3** to the line **L2**. Thus, the two resistors **44** and **45** are connected in parallel across the 220 volt power source so both receive relatively large energizing currents and generate heat at a high rate.

The selector switch S, therefore, permits the conductive resistances **44** and **45** of the element **24**, to produce either a low, medium or high rate of heating in the chamber **10** by resistance heating action. This heating of the chamber **10** may, if desired, be controlled by the thermostatic unit **51** which operates to open or close the switch **51***a* as the temperature within the chamber rises above or falls below some predetermined and selected value. It will be apparent from FIG. 6 that as the contacts **51***a* open or close, the energizing circuit or the selected combination of the heater resistors **44** and **45** is broken or completed. In keeping with another aspect of the invention, however, means are also provided to couple high frequency microwave electric energy to the elements **24** and **25** so that they serve

the additional function of radiating microwave energy throughout the chamber **10** and toward the object **11** to be heated To accomplish this, a suitable source of microwave energy has its output coupled by high frequency energy-transmitting means to the rod-like elements **24–25**. While the microwave energy source may take various forms such as high frequency triode oscillators or klystron tubes, that here shown in FIG. 1 is a magnetron **60** schematically illustrated as comprising a multi-cavity anode **60***a* surrounding a cathode **60***b*. The magnet and the cathode heater normally associated with such a magnetron are not illustrated, inasmuch as there components are well known to those skilled in the art of magnetrons and microwave heating. The operating energy for the magnetron **60** is supplied to it in the form of a relatively high direct voltage applied between its anode and cathode, and for this purpose a high voltage power supply **61** is here shown as having its output terminals **61***a* and **61***b* connected respectively to the anode **60***a* and the cathode **60***b*. The input terminals **61***c* and **61***d* are adapted for connection to a conventional voltage source, here represented by the 220 volt A.C. power main L1, L2.

It is well known that a magnetron when so supplied with an operating voltage serves as an oscillator which generates very high frequency electrical energy. By appropriate design or adjustment of the magnetron, it can be made to produce microwave energy in the ultra-high frequency range of 2,000 to 3,000 megacycles, the most commonly employed microwave cooking frequency being about 2,450 megacycles.

For the purpose of transmitting the microwave energy output of the magnetron **60** to the elements **24** and **25**, a coupler in the form of a probe **60***c* is disposed in one anode cavity and projects through a coaxial sheath **62** into a metal wave guide **64**. Microwave energy is thus transmitted and reflected through the wave guide **64** to a T junction **65** where it divides and passes upwardly and downwardly through wave guides **66** and **67** defined in part by the metal partition **28** and the inner metal panel of the wall **15**. For efficient transfer of energy passing through the wave guides **66** and **67** to the elements **24** and **25**, the latter are disposed with a spacing equal to a quarter wave length at the magnetron frequency from the upper and lower extremities of the wave guides.

The metal walled passages **29** and **30** through the wall **15** are closed by annular metal plates **69** and **70** spaced approximately one quarter wave length from the inner panel of the wall, thus minimizing the escape of microwave energy toward the terminal blocks **31** and **32**. These quarter wave length shorted "stubs" appear as very high impedances, and thus cause the microwave energy to be transferred to the elements **24** and **25** which have their opposite ends electrically connected at **34** and **35** to the inner metal panel of the wall **15**.

With this arrangement, microwave energy generated by the magnetron **60** passes through the wave guide **64**. divides and passes through the upper and lower wave guides **66** and **67**, and is then coupled to the elements **24** and **25** so that the metallic sheaths **38'** and **38** thereof act as radiating antennas which distribute the microwave energy within the chamber **10**. Thus, it may be said in the parlance of electrical engineers that elements **24** and **25** are "driven" by microwave energy coupled to them from the microwave generator, and they act as driven antennas which radiate such microwave energy into the oven chamber. As is known in the art of microwave heating, this energy will be reflected from the internal metal surfaces which define the chamber **10**, will pass without substantial attenuation or loss through nonconductive materials having negligible dielectric losses (such as paper, glass or certain plastics), and will be absorbed in dielectric materials such as moisture-containing food items **11** disposed in the utensil **20**. The microwave energy is effective in heating the moisture-containing object **11** substantially uniformly both at its outer surface and in its center portion, and it acts with great speed in raising the temperature of the object to a relatively high level. Thus, it is possible to heat the object **11** and quickly to cook it if it is an item of food, simply by the microwave energy generated in the magnetron **60** and radiated by the elements **24** and **25** acting as antennas.

As mentioned above, the microwave generator or magnetron **60** receives a high operating voltage from the voltage supply **61** having its input terminals **61***c*, **61***d* adapted for connection to the A.C. power source lines L1,, L2. The high voltage supply may be controlled by a second thermostatic sensor **71** disposed in or near the object **11** so as to indicate directly or indirectly the temperature of the latter. The sensor **71** controls a switch which renders the power supply **61** effective or ineffective, thereby turning the microwave generator on or off as the sensed temperature falls below or rises above a desired value.

In accordance with another feature of the invention, the power supply **61** is so constructed as to include the element **25**, or more properly the resistive conductor **39** forming a part thereof, as one component which performs an important voltage regulating function. As an incident to that function, however, the resistive conductor generates a considerable amount of heat, and the present system not only avoids the necessity of dissipating such heat by a special cooling fan or the like, but also makes advantageous use of such heat by causing it to be distributed within the oven chamber **10** where it contributes to the warming of the object **11**.

As shown in greater detail by FIG. 5, the high voltage supply **61** has its input terminals **61***c*, **61***d* adapted for connection to the voltage source lines L1, L2 through contacts C1 of a control switch C. The switch C is shown in FIG. 6 in its normal position to which it is set when heating by microwave energy is not desired, and it is shown in FIG. 5 in the actuated position to render the power supply **61** and the magnetron **60** effective. The switch C has normally open contacts C1, normally closed contacts C2, and normally open contacts C3. With these contacts actuated (FIG. 5), the high voltage supply **61** includes an input series circuit from the line L1 through the primary winding T*p* of a step-up transformer T, through one side of the contacts C2 to the terminal **39***b*, through the resistor **39** to the terminal **39***a*, through the other side of the contacts C2, and thence through contacts **71***a* (controlled by the thermostatic sensor **71**) to the line L2 The secondary winding T*s* of the transformer T is connected to the input of a full wave rectifier **75**, the output of the latter being connected through the terminals **61***a*, **61***b* to the anode **60***a* and cathode **60***b* with a polarity to make the anode positive relative to the cathode.

With the power supply energized by the switch C set to the position shown in FIG. 5, successive pulses of very high voltage are applied to the anode **60***a* by virtue of the full wave rectified output of the step-up transformer T. These pulses will have a repetition rate of 120 c.p.s. if the frequency of the A.C. source voltage on lines L1, L2 is 60 c.p.s. As each such pulse of anode voltage rises above a certain level, the magnetron is triggered into oscillation, and generates energy at a frequency of about 2,450 megacycles per second until the anode voltage pulse again falls below a cutoff level. In the exemplary arrangement, therefore, the magnetron **60** does not continuously oscillate, but rather produces short bursts of microwave energy, each such burst being at a frequency of 2,450 megacycles, and with the bursts recurring at a repetition rate of 120 c.p.s.

The power or wattage of microwave energy drawn from the magnetron **60** depends upon the quality and quantity of the energy absorptive material (such as the object **11**) in the chamber **10**, and upon the impedance matching back through the wave guides **66**, **67**, **64** to the output coupling

loop in the magnetron. It is characteristic of magnetrons and other similar microwave generators that the cathode-anode current varies not only with the output power coupled to the load, but also with the anode-cathode voltage. While a relatively high anode voltage is required to initiate high frequency oscillations, once they have been started any further increase in anode voltage causes a severely and disproportionate increase in cathode current. Unless some provision is made to regulate and limit the anode voltage, the current flow may become so high as to damage or destroy the magnetron, for example, by injuring the electron-emissive material on the cathode or overheating of structural parts.

This characteristic of magnetrons is well known, and it has been dealt with in the past by providing a voltage regulator in the form of a feedback-controlled saturable reactor or the like connected in series with the primary winding of the step-up transformer. In the practice of the present invention, however, the cathode current of the magnetron **60** is safely limited by virtue of the resistive conductor **39** connected in series with the input winding T*p* of the transformer T. As a positive voltage pulse applied to the anode **60***a* initially rises, the magnetron is non-oscillatory and causes no appreciable current through the transformer T. Accordingly, there is substantially no voltage drop across the resistor **39**, and the high voltage applied to the magnetron anode reaches a critical "firing" value early in the sinusoidally shaped rising voltage pulse. As soon as the magnetron "fires," however, and thus tends to draw substantial current from the secondary winding T*s*, corresponding current flows through the circuit for the primary winding T*p*, thereby creating a substantial voltage drop across the resistor **39**. Such voltage drop reduces the voltage effectively applied to the primary winding T*p*, and so correspondingly reduces the output voltage of the secondary winding T*s*, thus reducing output voltage of the rectifier **75**.

In this way, the anode voltage of the magnetron **60** is reduced as its cathode current increases by virtue of the resistor **39** connected in the low voltage side of the supply circuit, and excessive cathode currents are prevented by this voltage regulating action. Yet, the current which flows through the resistor **39** as an incident to this voltage regulation function creates a considerable amount of heat by I^2R dissipation in that resistor. Because the resistor **39** constitutes a part of the element **25** disposed inside the chamber **10**, there is no need to provide special cooling fins or fans to dissipate that heat, and indeed such heat is distributed within the oven chamber **10** to assist in heating the object **11**. Because the resistor **39** is connected in the primary circuit of the voltage step-up transformer T, it operates at a relatively low voltage level (e.g., 220 or 110 volts as compared to 1500 volts in the secondary circuit of the transformer). Thus, the resistor **39** need not be especially and expensively constructed for high voltage operation, and at the same time the danger of such high voltages, and the necessity for special high voltage insulators, in the oven structure are avoided.

From FIGS. 5 and 6, it will now be seen that when microwave heating of the object **11** is desired, it is only necessary to actuate the control switch C, thereby closing the contacts C1, C2 and opening the contacts C3 (FIG. 5). The magnetron **60** is thus supplied with a high pulsating D.C. operating voltage between its anode and cathode, and produces repeated bursts of microwave energy. Such energy is coupled to the element **25** (as well as to the element **24**) and radiated by the latter in the oven chamber **10** where it is absorbed by the object **11** to cause heating throughout the latter. At the same time, however, considerable energy in the form of heat is dissipated by current flow through the resistor **39** while the latter is performing its voltage-regulating function, but this heat is produced in the oven chamber by the element **25** while that element is simultaneously radiating microwave energy. Such I^2R dissipation in the resistance **39** is thus caused advantageously to contribute to the heating or cooking of the object **11**. The thermostatic sensor **71**, if employed, will open its associated contacts **71***a* when the temperature of the object **11** is above a predetermined value, thus stopping the generation and radiation of microwave energy and also stopping the associated resistance heating contributed by the element **25**.

The single element **25**, therefore, performs three distinct functions, viz. (a) it radiates microwave energy, (b) it serves to regulate the high voltage supply **61** so that the cathode current of the magnetron does not become excessive, and (c) it creates useful heat by resistance heating action inside the chamber **10**. In addition to these functions, means are provided selectively to connect the element **25** to a conventional voltage source so that it may heat the oven by resistance heating action when not being used with the microwave generator. This is here accomplished by the contacts C2 and C3 of the control switch C. When the latter is set to the position shown by FIG. 6, the contacts C1 are open so that the magnetron is ineffective, as previously described. The contacts C2 are also open to disconnect the resistor **39** from the high voltage supply **61**, and the contacts C3 are closed to connect the resistor **39** across the input terminals **55***a*, **55***b* of the selector switch S. Thus, if resistance heating of the oven chamber is now effected by closure of the main switch **52** (and assuming the thermostat contacts **51***a* to be closed), the resistor **39** is energized by a direct connection across the 220 volt A.C. supply lines L1, L2. The element **25** under these conditions generates heat by resistance heating action, and thus by itself or in conjunction with the resistors **44** and **45** in the element **24** (depending upon the position of the selector knob S*k*) warms the chamber **10** and any object **11** therein.

The apparatus here disclosed is highly flexible in its possible modes of operation, despite the fact that only two relatively simple and compact elements **24** and **25** are disposed within the oven chamber. By way of summary, the several possible modes of operation may be tabulated as follows:

Mode 1

Resistance heating.—Switch C is left in its normal position (FIG. 6), switch **52** is closed, and selector knob S*k* is set in the "off" position. The chamber **10** is now warmed by resistance heating of element **25** with its resistive conductor **39** connected across voltage source lines L1, L2.

Mode 2

Resistance heating.—Same as mode 1, but knob S*k* is set to its "low" position. The chamber **10** is heated at a low rate by resistance heating of resistors **44** and **45** in element **24** connected in series across voltage source lines L1, L2 and by resistor **39** connected across lines L1, L2.

Mode 3

Resistance heating.—Same as mode 2, except that knob S*k* is set to its "medium" position. The resistive conductor **45** is connected across lines L1, L2; and the resistive conductor **39** is connected across lines L1, L2, so that the chamber **10** is heated at a medium rate.

Mode 4

Resistance heating.—Same as mode 3, except that the knob S*k* is set to the "high" position, so that the conductive resistors **39**, **44**, **45** are all connected individually across lines L1, L2 to provide a high heating rate.

Mode 5

Microwave heating.—Switch C is set to the actuated position (FIG. 5) and main switch **52** is opened. The power supply **61** and the magnetron **60** are effective, so that elements **24** and **25** radiate microwave energy in the chamber **10**. The resistive conductor **39** in element **25** regulates the magnetron operating voltage, and the heat

generated therein as a result of such regulation contributes to warming of the object **11**.

Modes 6, 7 and 8

Microwave plus resistance heating.—Same as mode 5, except that main switch **52** is closed and knob *Sk* is set to the "low," "medium," or "high" positions, respectively, so that elements **24** and **25** both radiate microwave energy and simultaneously add heat to the chamber **10** by resistance heating action.

By virtue of the present invention it is possible to cook objects which contain no appreciable amounts of moisture by a resistance heating action produced by the same elements which serve an important function in microwave heating. This can be done either with or without simultaneous microwave heating of moisture-containing objects disposed in the oven chamber. Moreover, moisture-containing food can be internally heated and cooked by microwave action and simultaneously surface browned by resistance type heating or broiling action. And, whenever the microwave heating mode is to be used, heat generated as an incident to voltage regulation in the high voltage supply is advantageously utilized simultaneously to assist in warming any objects in the chamber.

I claim as my invention:

1. In an oven, the combination comprising means defining an oven chamber, a metal element disposed in said chamber, means for supplying microwave electrical energy to said element to cause such element to act as a driven antenna radiating microwave energy therefrom and into the chamber, and means for passing current other than at microwave frequencies through said element to generate heat by I^2R dissipation therein.

2. In an oven, the combination comprising means defining an oven chamber adapted to receive an object to be heated, a metal element disposed in said chamber and including a resistive conductor, means for supplying microwave electrical energy to said element to cause such element to act as a driven antenna radiating microwave energy therefrom and into the chamber, and means for passing current at a frequency lower than microwave frequencies through said resistive conductor to generate heat in the oven by I^2R dissipation in conductor.

3. In an oven, the combination comprising means defining an oven chamber adapted to receive an object to be heated, a rod-like element disposed in said chamber and including an outer metal sheath surrounding and insulated from a resistive conductor, a source of microwave electrical energy, means for coupling said source to said sheath to cause the latter to act as a driven antenna radiating microwave energy within said chamber, and means for passing current of a frequency substantially lower than the microwave frequency range through said resistive conductor to heat the oven by I^2R dissipation in the conductor.

4. In an oven, the combination comprising structural means defining an oven chamber adapted to receive an object to be heated, a metal element disposed in said chamber, a source of microwave electrical energy, means for coupling said source to said element so that the latter serves as a driven radiating antenna for distributing microwave energy in said chamber, said element including an electrical resistance, and means for supplying current through such resistance from a conventional electrical power source.

5. In an oven, the combination comprising structural means defining an oven chamber adapted to receive and contain an object to be heated, rod-like element disposed in said chamber and including a metal sheath surrounding but insulated from a resistive conductor, a source of microwave electrical energy, means for coupling said source to said element so that the latter serves as a driven radiating microwave antenna, and means adapting said resistive conductor to be connected to a conventional electrical power source so that resistance heating action is produced in such conductor.

6. In an oven, the combination comprising means defining an oven chamber adapted to receive an object to be heated, a metal element disposed in said chamber to act as a radiating antenna and including a resistive conductor, first selector means for supplying microwave electrical energy to said elements to drive the latter as an antenna so that the object is heated by microwave radiation from the element, and second selector means for connecting said resistive conductor to a conventional electrical power source so that said chamber and any object therein are heated by resistance heating action.

7. In an oven, the combination comprising structural means defining an oven chamber adapted to receive an object to be heated, a metal element disposed in said chamber to act as a radiating antenna and including a resistive conductor, first means for heating the object by microwave energy comprising a source of electrical microwave energy and means coupling the same to drive said element so that it radiates microwave energy into the chamber, second means for heating the object comprising means for connecting said resistive conductor to a conventional electrical energy source, and selector means for (a) rendering said first means effective by itself, (b) rendering said second means effective by itself, or (c) rendering both said first and second means effective.

8. In an oven, the combination comprising means defining an oven chamber adapted to receive an object to be heated, a rod-like element disposed in said chamber and including an outer metal sheath surrounding and insulated from an inner resistive conductor, a magnetron microwave generator having an output coupler, means coupling said output coupler to said sheath for driving the latter as an antenna so that it radiates into said chamber microwave energy generated by said magnetron, and means adapted to selectively connect said resistive conductor to a conventional electrical power source to generate heat in said chamber by I^2R dissipation in said conductor.

9. In an oven, the combination comprising means defining an oven chamber adapted to receive an object to be heated, a resistor disposed in said chamber, a magnetron for generating microwave electrical energy, means for coupling the output of said magnetron into said chamber to produce microwave heating action in the object, a high voltage supply for applying an operating voltage to said magnetron, said high voltage supply including input terminals adapted to be connected to a conventional A.C. power source and means including said resistor interposed between said input terminals and said magnetron for supplying the latter with a high operating voltage, whereby heat dissipated in said resistor contributes to the heating of the object.

10. In an oven, the combination comprising means defining an oven chamber, a heater-type resistor disposed in said chamber, a magnetron having an anode and a cathode for generating microwave electrical energy, a high voltage supply for said magnetron including input terminals adapted for connection to an A.C. voltage source, a step-up transformer having a primary and a secondary winding, means connecting said resistor in series with said primary winding across said input terminals, a rectifier having its input connected to said secondary winding and its output connected to said anode and cathode, and means for coupling microwave energy from said magnetron into said chamber, whereby microwave heating occurs in the chamber and energy dissipated in said resistor as a result of current flow therethrough appears in the form of heat within the chamber.

11. In an oven, the combination comprising means defining an oven chamber adapted to receive an object to be heated, a resistor disposed in said chamber, a magnetron for generating microwave electrical energy, means for coupling the output of said magnetron into said chamber to produce microwave heating action in the object, a high voltage supply for applying an operating voltage to said

magnetron, said high voltage supply including input terminals adapted to be connected to a conventional A.C. power source and means including said resistor interposed between said input terminals and said magnetron for supplying the latter with a high operating voltage, whereby heat dissipated in said resistor contributes to the heating of the object, and selector means for disconnecting said resistor from said voltage supply and connecting it instead to a conventional electrical power source.

12. In an oven, the combination comprising means defining an oven chamber, a metal element disposed in said chamber and including a resistive conductor, an electrical microwave generator, a high voltage supply for said generator adapted for connection to a conventional electrical energy source, said voltage supply including voltage regulating means constituted by said resistive conductor connected therein, and means coupling said microwave generator to said element so that the latter is driven as an antenna to radiate microwave energy in said chamber while heat dissipated in said resistive conductor as an incident to its voltage regulating function heats said chamber.

13. In an oven, the combination comprising means defining an oven chamber, a metal element disposed in said chamber and including a resistive conductor, a magnetron for generating microwave electrical energy, a high voltage supply for said magnetron including means adapted for connection to a conventional electrical voltage source and a resistor effectively connected between the source and the magnetron to transmit current to the latter and to decrease the magnetron supply voltage as the magnetron current increases, said resistor being constituted by said resistive conductor so that heat dissipated therein as an incident to operation of said high voltage supply heats said chamber, and means for coupling the output of said magnetron to drive said element as an antenna so that the latter radiates microwave energy in said chamber.

14. In an oven, the combination comprising means defining an oven chamber, a rod-like element disposed in said chamber and including a metal sheath surrounding and insulated from a resistive conductor, a magnetron having an anode and a cathode for generating microwave electrical energy, a high voltage power supply for applying a high D.C. operating voltage between the anode and cathode of said magnetron, said power supply including means effectively connecting said resistive conductor to carry current corresponding to the current flow between said anode and cathode for reducing the anode-cathode voltage in response to an increase in the anode-cathode current, and means for coupling the microwave output of said magnetron to said sheath so that the latter acts as a driven antenna radiating microwave energy in said chamber.

15. In an oven, the combination comprising means defining an oven chamber adapted to receive an object to be heated, a metal element disposed in said chamber and including a resistive conductor; a magnetron having an anode and a cathode for generating microwave energy; a power supply for applying a high D.C. operating voltage between said anode and cathode; said power supply comprising input terminals adapted for connection to an A.C. voltage source, a step-up transformer having an input winding and an output winding, means connecting said input winding and said resistive conductor in series across said input terminals, and a rectifier having an input connected across said output winding and an output connected across said anode and cathode; and means coupling the microwave output of said magnetron to said element so that the latter acts as a driven antenna radiating microwave energy in said chamber while the I^2R dissipation in said resistive conductor heats said chamber.

16. In an oven, the combination comprising means defining an oven chamber, a metal element disposed in said chamber and including a resistive conductor, a source of microwave electric energy means for coupling the output of said microwave source to drive said element as a radiating antenna, a normally ineffective high voltage supply for said microwave source including means for coacting with a resistor connectable in circuit therewith to regulate the magnitude of the high voltage while dissipating heat in the resistor, and selector means for optionally (a) connecting said resistive conductor to a conventional voltage source so as to cause the conductor to dissipate heat in said chamber or (b) rendering said high voltage supply effective and connecting said resistive conductor in circuit with said high voltage supply as the resistor referred to above, so that said element both radiates microwave energy in said chamber and contributes heat in the chamber by the dissipation which occurs in said resistive conductor as an incident to operation of the high voltage supply.

17. In an oven, the combination comprising means defining an oven chamber, a metal element disposed in said chamber, said metal element being shaped in the form of a radiating antenna and including as an integral part thereof a resistive conductor, a magnetron for generating microwave electrical energy when supplied with an operating voltage, means coupling the microwave output of said magnetron to said element to cause the latter to act as a driven antenna radiating microwave energy into said chamber, a high voltage supply for said magnetron including input terminals adapted to be connected to a conventional voltage source, first selector means for selectively connecting said resistive conductor to a conventional voltage source, and second selector means for selectively connecting said input terminals to a conventional voltage source and simultaneously connecting said resistive conductor in circuit with said high voltage power supply to perform a voltage dropping function, whereby operation of said first selector means causes said element to create I^2R heat in said chamber, and operation of said second selector means causes said element to radiate microwave energy in said chamber while simultaneously creating I^2R heat as an incident to its voltage dropping function.

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