

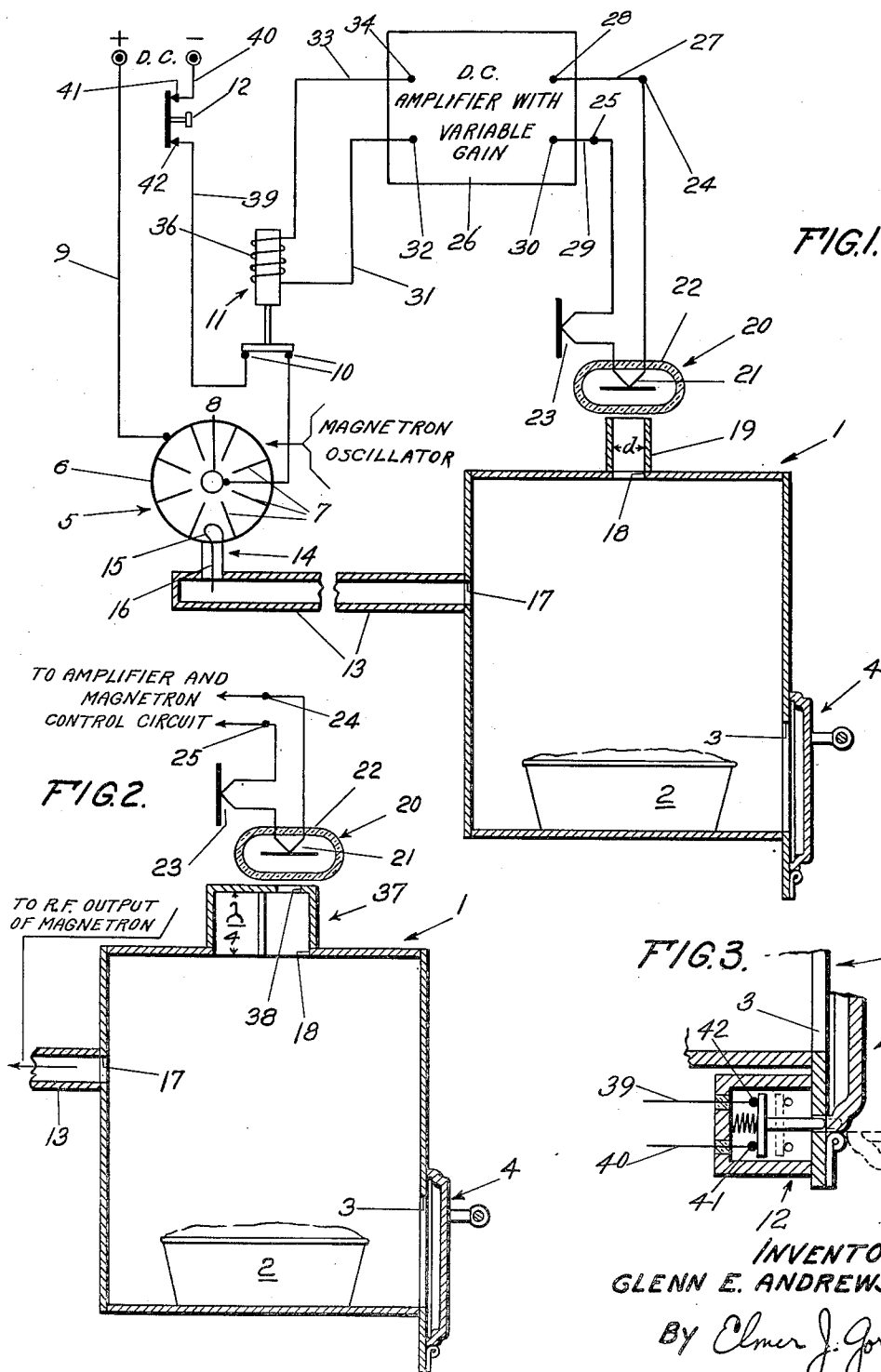
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HEATING APPARATUS

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HEATING APPARATUS

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1 Claim. (Cl. 219—47)

1

This invention relates to heating apparatus, and more particularly to a heat-responsive controlling means for a microwave heating or cooking device.

An object of this invention is to provide a means, useful in conjunction with apparatus for heating dielectric bodies by alternating electrical energy, for automatically controlling the supply of energy to the body being heated.

Another object is to devise a means for automatically cutting off the supply of alternating electrical energy to a dielectric body being heated, when said body reaches a predetermined temperature.

A further object is to provide a device for microwave cookers which automatically shuts off the microwave generator when the food being cooked reaches a predetermined temperature, this device being capable of manual adjustment to vary said predetermined temperature.

A still further object is to devise a controlling means whereby dielectric bodies being heated may be brought to a certain predetermined end or final temperature, after which the energy is automatically decoupled from said body, this end temperature being attained regardless of the initial temperature of the body, the size of the body, or the rate of energy absorption of the body.

An additional object is to provide an automatic body-heat-responsive, microwave-energy-controlling means for a microwave heating apparatus, which will not interfere with the absorption of microwave energy by the body being heated and will not be affected by said microwave energy.

The foregoing and other objects of the invention will be best understood from the following description of some exemplifications thereof, reference being had to the accompanying drawing, wherein:

Fig. 1 is a schematic illustration of an arrangement whereby the invention may be carried out;

Fig. 2 is a schematic illustration of a modified arrangement; and

Fig. 3 is a partial view, on an enlarged scale, showing a detail.

Now referring to Fig. 1, a hollow rectangular prismoidal enclosure or cavity 1 is made of a suitable metal and has rather thin walls as shown; enclosure 1 is adapted to serve as the oven of the heating or cooking apparatus. A dielectric body 2 to be heated, which may be a container of food for example, is positioned in enclosure 1, said body resting on the bottom wall

2

of the oven while the body is being heated. In order to allow access to the interior of the oven for placing the body 2 therein and for removing said body therefrom, an opening 3 is provided in the front wall of the oven 1, this opening being closable by means of a hinged metal door 4. When door 4 is closed, the enclosure 1 is entirely closed, except for the openings 17 and 18 to be described hereinafter.

Numerals 5 generally designates an electron-discharge device of the magnetron type, which includes, for example, an evacuated envelope 6, made of highly conductive material, such as copper, and provided with a plurality of inwardly-directed, radially-disposed anode vanes 7. The arrangement is such that each pair of adjacent anode vanes forms, together with that portion of the envelope lying therebetween, a cavity resonator whose natural resonant frequency is, as is well known to those skilled in the art, a function of the geometry of the physical elements making up the same. For an oven as above described, it is desirable that the dimensions of each such cavity resonator be such that the predetermined wavelength of the electrical oscillations adapted to be generated therein has a value which lies in the microwave region of the frequency spectrum. However, this invention is equally applicable in heating apparatus utilizing alternating electrical energy of any frequency useful for heating dielectric bodies by electrical energy.

Centrally located in envelope 6 is a highly electron-emissive cathode member 8, for example, of the well-known alkaline-earth metal-oxide type, said cathode member being provided with conventional means (not shown) for raising the temperature thereof to a level sufficient for thermionic emission.

The electron-discharge device or magnetron oscillator or radio-frequency oscillator 5 is completed by magnetic means (not shown) for establishing a magnetic field in a direction transversely of the electron path between the cathode and anode members thereof.

Anode or envelope 6 of the oscillator is connected, by a conductor 9, directly to the positive terminal of a suitable power source or direct current supply, while cathode 8 of the oscillator is connected, in series with the normally-closed contacts 10 of a relay 11, by a conductor 39, to one contact 42 of a switch 12, the other contact 41 of said switch being connected by a conductor 40 to the negative terminal of said power source; switch 12 is normally closed to connect contacts

41 and 42, as will be later described. It will be seen that, normally, oscillator 5 is connected to be energized from the power source, and that by the opening of contacts 10 or the opening of contacts 41—42 the oscillator will be disconnected from the power source and thereby deenergized.

When energized, radio-frequency oscillator 5 delivers radio-frequency energy to a hollow metallic waveguide 13 through a coaxial transmission line 14 which is coupled to oscillator 5 by a loop 15. The central conductor 16 of line 14 extends into the interior of waveguide 13 near one end thereof, through an opening provided in the wall thereof, to serve as an exciting rod or exciting probe for said guide.

The end of guide 13 nearest this exciting rod is closed, while the opposite end of said guide is fastened to the rear wall of enclosure 1 and is open. The interior of guide 13 is placed in energy-transmitting relationship with the interior of the cavity 1 by means of an aperture 17 provided in the rear wall of said cavity, this aperture being of the same size and configuration as the interior of guide 13 and being aligned with said guide to place the interior of said guide in communication with the interior of cavity 1.

When magnetron oscillator 5 is energized, the radio-frequency or microwave energy produced thereby is propagated down waveguide 13 and emanates from the open end thereof into the interior of enclosure 1. This energy impinges on the body 2 and is in effect absorbed thereby, resulting in heating or raising the temperature of said body.

Pursuant to this invention, an aperture 18 is provided in the top wall of enclosure or oven 1, this aperture preferably being located in the center of said wall, being circular, for example, and having a diameter d . Extending outwardly or upwardly from the top wall of oven 1, at right angles thereto, and aligned with aperture 18, is a hollow metallic tube 19 which has an internal diameter equal to d . The diameter d of aperture 18 and of tube 19 is made such that for the wave mode present in enclosure 1, the cutoff wavelength of tube 19, considered as a hollow waveguide, is below the wavelength of the oscillations generated by oscillator 5. The cutoff wavelength for hollow waveguides depends on the cross-sectional dimensions of such guides, as is well-known to those skilled in the art.

Mounted adjacent the outer end of tube 19 is a heat-responsive or heat-sensitive device 20, which may be, for example, a sensitive bank or series of thermocouples in a vacuum. Device 20 is here represented as including a bimetallic "hot" junction 21 enclosed in an evacuated envelope 22, and a bimetallic "cold" junction 23. The arrangement of tube 19 and device 20 with respect to body 2 is such that junction 21 is exposed to the heat radiated from said body. In other words, the axis of tube 19 is pointed at the body and the inner end of the tube is exposed to the body, so that thermocouple device 20 in effect "looks" at the body. Junction 23 is maintained at a so-called fixed or reference temperature, and when the temperature of junction 21 is raised above that of junction 23, a thermal electromotive force, direct in nature, is produced between the output terminals 24 and 25 of the device 20.

As used herein, the phrase "thermal electromotive force" has the meaning commonly associated with it by those skilled in the science of physics. A current flows in a circuit composed

of two metallic conductors of different materials if the temperatures of the two junctions are different; in such a circuit there is an electromotive force dependent on thermal conditions and called a "thermal electromotive force."

The electromotive force thus produced between terminals 24 and 25 is connected as the input voltage of a direct current vacuum-tube amplifier 26, and to this end terminal 24 is connected by means of a lead 27 to one of the input terminals 28 of said amplifier, and terminal 25 is connected by means of a lead 29 to the other input terminal 30 of said amplifier. A lead 31 connects one end of the operating winding 36 of relay 11 to one of the output terminals 32 of amplifier 26, while a lead 33 connects the other end of said winding to the other output terminal 34 of said amplifier.

Amplifier 26 has a variable gain, and this gain is such that normally the output of said amplifier is insufficient to energize relay 11; as a result said relay is unenergized and contacts 10 are closed.

Switch 12, as shown in Fig. 3, may be mounted on the rear face of the depending portion of the front wall of enclosure 1, adjacent to the hinge of door 4. The actuating rod of switch 12 is spring-biased to the position indicated in dotted lines in Fig. 3, in which position the contacts 41 and 42 of said switch are not connected to each other or are open. The switch actuating rod is arranged to be forced, by the movement of door 4 from its dotted-line open position to its solid-line closed position, against the bias of the spring, to the position indicated in solid lines in Fig. 3, in which the contacts 41 and 42 of the switch are closed or connected to each other. When door 4 is opened, the pressure on the switch actuating rod is released, so that said actuating rod is moved to the right by the spring to open the contacts 41 and 42. Thus, when door 4 is closed, after body 2 is placed inside the oven 1, the contacts 41—42 of switch 12 will be closed, and when door 4 is opened to remove body 2 said contacts will be opened.

Assume, now, that a dielectric body 2, which is at some initial temperature and which is desired to be heated to a predetermined final temperature, is placed in enclosure 1 and door 4 is closed. Switch 12 is closed by the closing of said door and, since junctions 21 and 23 are at the same temperature, device 20 produces no thermal electromotive force and conditions are normal, being such that relay 11 is unenergized and contacts 10 are closed. Therefore, the controllable circuit which connects oscillator 5 to the power source is completed, and said oscillator, being energized, produces radio-frequency energy which is supplied to the interior of enclosure 1, where it impinges on dielectric body 2 to heat the same. As body 2 is heated or as it rises in temperature, it radiates heat. This radiant energy in the form of heat falls on junction 21 (since junction 21 is exposed to this radiant heat energy of body 2), producing a rise in temperature at said junction and consequently a direct thermal electromotive force between terminals 24 and 25. This electromotive force is applied to the input of amplifier 26, in such a direction as to tend to increase the output of said amplifier. This thermal electromotive force is proportional to the temperature of junction 21, and, when it reaches a definite predetermined value, will cause the output of amplifier 26 to increase to a level sufficient to energize relay 11, opening its contacts 10, thus

5

deenergizing oscillator 5, thereby stopping the supply of radio-frequency energy to enclosure 1 and body 2. The aforesaid definite value of thermal electromotive force necessary to produce energization of relay 11 is variable at will by varying the gain of amplifier 26, thereby varying the output level of the amplifier relative to the input level thereof. The heat energy radiated from body 2 is proportional to the temperature of said body, and the temperature of junction 21 is proportional to the radiant heat energy falling thereon, so that the thermal electromotive force produced between terminals 24 and 25 is proportional to the temperature of body 2. Thus, when body 2 reaches a predetermined temperature, oscillator 5 is automatically deenergized and the supply of radio-frequency energy to said body thereby stopped.

When magnetron oscillator 5 has been so deenergized, the door 4 may be opened and the body 2 removed. Opening of said door causes the contacts of switch 12 to be opened, so that even though body 2, which is now a source of radiant heat, be removed from the oven, thereby also removing the thermal electromotive force from amplifier 26 and deenergizing relay 11 to reclose contacts 10, oscillator 5 will not be reenergized unnecessarily, because of the series connection of the contacts of switch 12 and of contacts 10. The contacts of switch 12 are reclosed by the reclosure of door 4 after another body 2 has been placed in the oven 1, to energize the oscillator 5 for the next heating cycle, contacts 10 of relay 11 being closed at this time because of the absence of a thermal electromotive force from thermocouple 20.

As explained above, the definite value of thermal electromotive force (and therefore also the temperature of junction 21 and the temperature of body 2) at which relay 11 is energized to deenergize oscillator 5 is variable by varying the gain of amplifier 26. Therefore, when body 2 is food, the food can be heated to various selected temperatures by appropriately varying the amplifier gain. For instance, the food could be cooked rare, medium, or well done.

The microwave energy of oscillator 5 is automatically cut off when and only when body 2 reaches a predetermined temperature. This means that, when body 2 is food, such food is by this invention heated until it reaches the temperature at which it is cooked, regardless of its initial temperature, its size, or its rate of energy absorption. If a preset timing device were used to control the application of radio-frequency energy to the dielectric body, rather than the device of this invention, various different initial temperatures of the bodies, different sizes of the bodies, or different rates of energy absorption of the bodies might result in underheating or overheating of the bodies. However, with the system of the invention, such possible undesired end results are eliminated.

Since tube 19 is designed to make its cutoff wavelength below the wavelength of the radio-frequency oscillations of source 5, such oscillations will not propagate down said tube as a hollow waveguide. Therefore, radio-frequency energy will not be transmitted away from the interior of enclosure 1 to be lost for purposes of heating body 2, so that the means of this invention will not interfere with the absorption of energy by the body being heated. Also, since radio-frequency energy is not transmitted down tube 19, the heat-responsive device 20 will not be

6

actuated or affected by such energy, but will be actuated by or sensitive to only the radiant heat energy of body 2.

In ovens or enclosures of the above-described type, the air within the enclosure is not heated appreciably by the radio-frequency energy, so that device 20 is not affected by the temperature of the atmosphere surrounding the dielectric body, as would be the case with an ordinary oven which relies on heat transmission by conduction of heat energy through the atmosphere from the heat source to the body.

It is within the scope of this invention to make the aperture 18 of any convenient shape, element 19 having an opening therethrough of a corresponding configuration. For example, aperture 18 may be rectangular and element 19 may have a hollow rectangular cross-section, in which case the cutoff wavelength formulae for rectangular hollow waveguides would be used to calculate the internal dimensions of portion 19 so as to make the cutoff wavelength of waveguide portion 19 less than the wavelength of the oscillations of oscillator 5.

Now referring to Fig. 2, in which similar elements are denoted by the same reference numerals as in Fig. 1, a modified structure for coupling the heat-responsive device or thermocouple 20 to the enclosure 1 is disclosed. In this modification, a coaxial stub 37 is provided, said stub being a quarter-wavelength long and having an open lower end and a short-circuited upper end. The open lower end of stub 37 is aligned with enclosure aperture 18, with the axis of the stub pointed at body 2 and with the open end of the stub exposed to said body.

The shorted end of stub 37 has a relatively small aperture 38 therein, and the junction 21 of thermocouple 20 is placed directly above this aperture, so that the thermocouple junction 21 is exposed to the heat radiated from body 2, the thermocouple thereby in effect "looking" at the body 2.

Since junction 21 is exposed to the heat radiated from body 2, a thermal electromotive force will be produced between terminals 24 and 25 of the thermocouple as body 2 heats, and this electromotive force may be utilized, as in Fig. 1, to control the radio-frequency oscillator in such a way as to stop the supply of energy to body 2 when the same reaches a predetermined temperature.

Due to the utilization of the shorted quarter-wavelength coaxial stub 37 in the above-described manner, no radio-frequency load additional to that of the body 2 is imposed on the radio-frequency source, so that no radio-frequency energy is abstracted away from the dielectric body 2 and, in addition, the thermocouple is effectively isolated from the intense radio-frequency radiations, so that the heat-responsive device or thermocouple 20 will not be actuated or affected by such radio-frequency energy.

Of course, it is to be understood that this invention is not limited to the particular details as described above, as many equivalents will suggest themselves to those skilled in the art. For example, it may in most cases be preferable to put the thermocouple tube or stub in the side wall of the oven, rather than in the top wall as shown, in order to prevent the entrance of cooking vapors, steam, etc. into the tube or line leading to the thermocouple. Various other variations will suggest themselves. It is accordingly desired that the appended claims be given a broad inter-

7

pretation commensurate with the scope of this invention within the art.

What is claimed is:

In combination, a metallic enclosure adapted to serve as an oven, an oscillator for supplying electromagnetic wave energy to the interior of said enclosure to heat a dielectric body positioned in said enclosure, a controllable circuit for energizing said oscillator from a power source, means for generating a thermal electromotive force, said means being exposed to the heat radiated from said body and being coupled to said oven in such a way that said means is isolated from said wave energy, and means for utilizing said electromotive force to control said circuit to de-energize said oscillator when said body reaches a predetermined temperature.

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