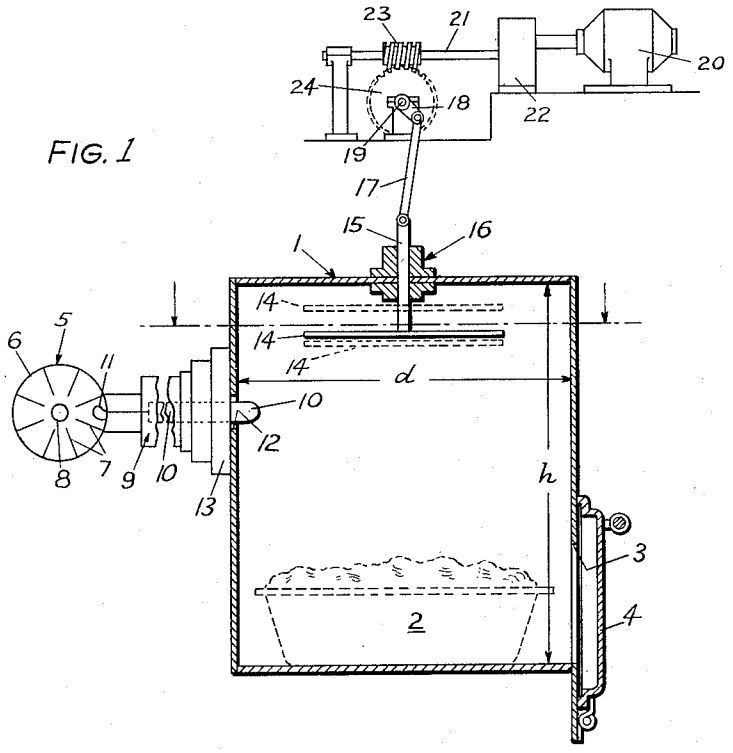
Sept. 4, 1956 W. M. HALL 2,761,942

HEATING APPARATUS

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FIG. 1



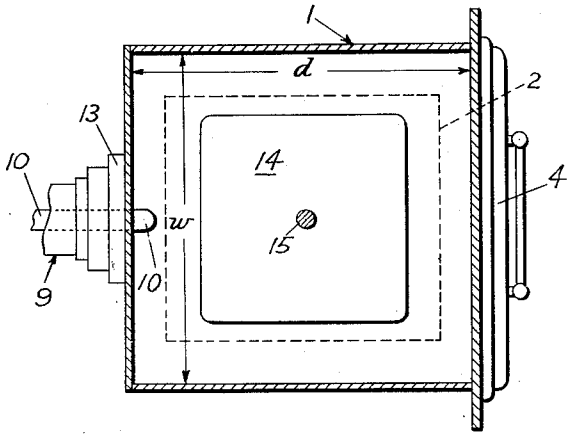


FIG. 2

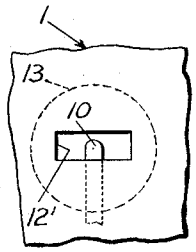


FIG. 5

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FIG. 3

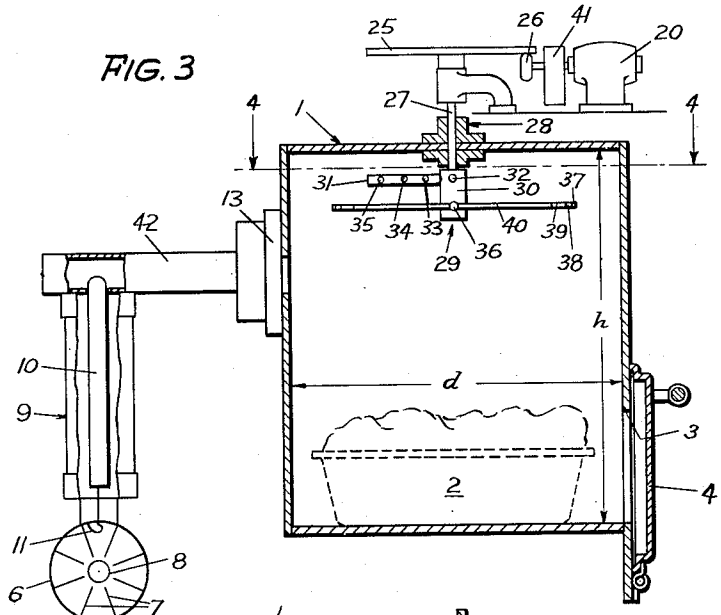
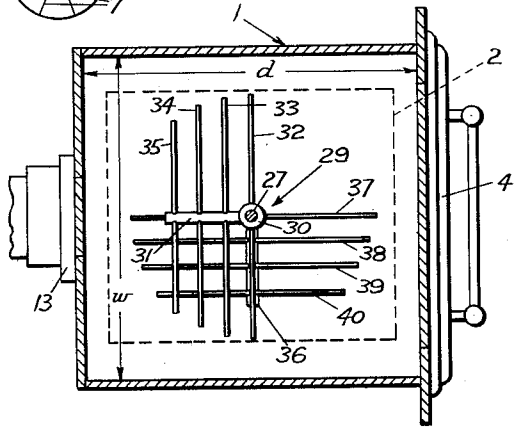


FIG. 4



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FIG. 6

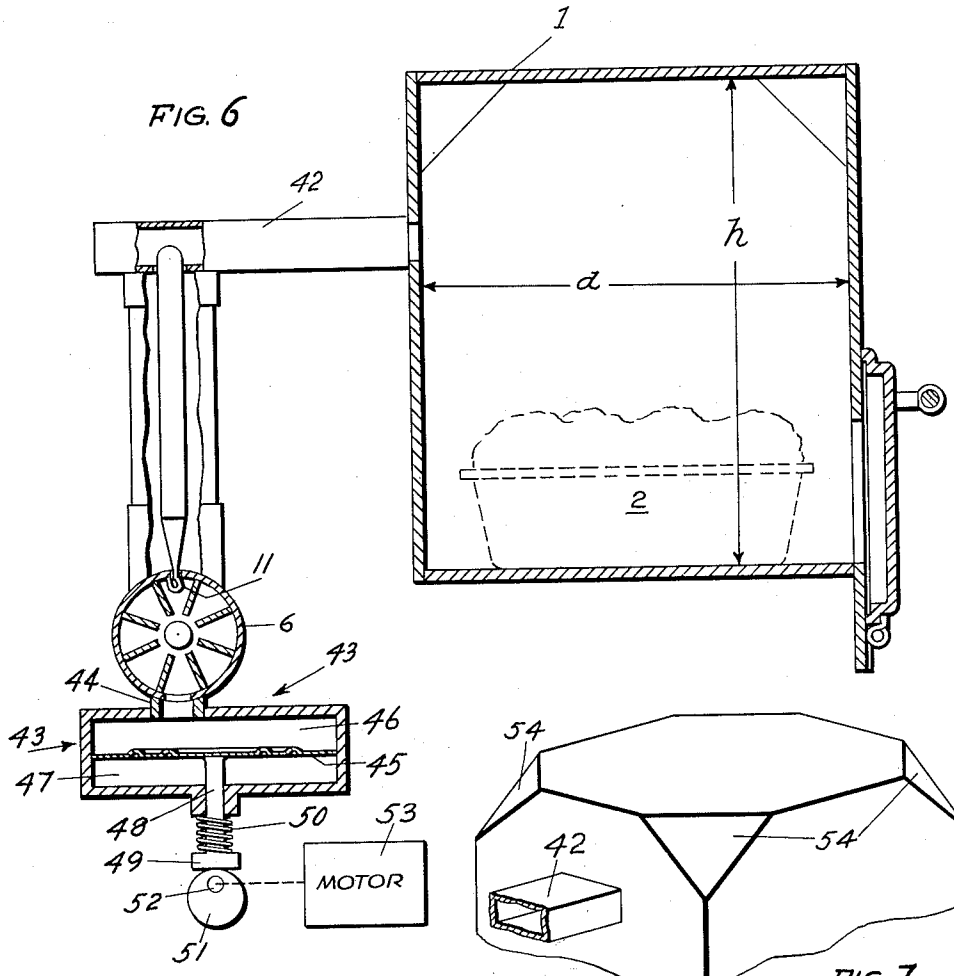


FIG. 7

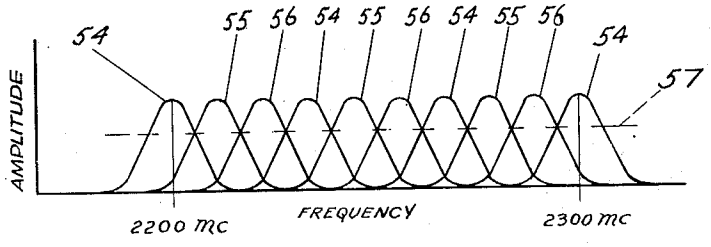


FIG. 8

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United States Patent Office 2,761,942
Patented Sept. 4, 1956

2,761,942

HEATING APPARATUS

William M. Hall, Lexington, Mass., assignor to Raytheon Manufacturing Company, Newton, Mass., a corporation of Delaware

Application June 6, 1952, Serial No. 292,087

5 Claims. (Cl. 219—10.55)

This application is a continuation in part of application, Serial No. 721,540, filed January 11, 1947, now Patent Number 2,618,735.

This invention relates to heating apparatus, and more particularly to a microwave heater including a microwave-energy-filled region of space which is of substantial size as compared to the wavelength of the microwave energy.

One object of this invention is to devise apparatus for improving the efficiency and uniformity of the distribution of microwave energy in a cooking device.

A second object is to devise apparatus for producing a substantially uniform integrated radio-frequency heat pattern in a cooking device.

Another object is to devise apparatus for cooking large volumes of food with the expenditure of a minimum amount of input power.

A further object is to devise means for producing periodic changes in the field distribution in a radio-frequency cavity, whereby the integrated heating effect of the field is made substantially uniform.

A still further object is to devise means for continuously changing the mode of the waves in a radio-frequency cavity, whereby the changing complex modes produce a substantially uniform overall heating effect therein.

An additional object is to provide a microwave cooking device in which food masses, whose linear dimensions are large compared to the wavelength of the microwave energy used, may be cooked in a substantially uniform manner.

Still another object is to accomplish the above objects in a simple yet effective manner.

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 drawings, wherein:

Fig. 1 is a vertical cross-sectional view of a microwave cooker embodying this invention;

Fig. 2 is a section taken along line 2—2 of Fig. 1 and looking in the direction of the arrows;

Fig. 3 is a view similar to Fig. 1 of a modified cooker;

Fig. 4 is a section taken along line 4—4 of Fig. 3;

Fig. 5 is an elevation looking at the rear wall of the oven of Figs. 3 and 4 from the inside thereof;

Fig. 6 is a vertical cross-sectional view of a further embodiment of the invention;

Fig. 7 is an isometric view of a detail of the device shown in Fig. 6; and

Fig. 8 illustrates a graph indicating the relationship between frequency and the resonant modes in the microwave cooker illustrated in Figs. 1 and 2.

In microwave cooking devices, the problem arises of cooking foodstuffs having a rather large total area or volume. In order to accomplish this result, it is necessary to energize large regions of space with microwave energy, and for proper cooking this energization should be substantially uniform throughout the space. Also, it

is desirable to accomplish such energization with a minimum expenditure of power.

In such a space, the wavelength of the microwave energy is small in comparison to the linear dimensions of the oven, or in comparison to the linear dimensions of the food mass to be cooked or heated.

At any single frequency, there can be only one distribution of regions of high electric field intensity and regions of high magnetic intensity. Unless the walls are made highly absorbing, so that substantially all incident radiation is absorbed, the differences in field intensity will be very great. The problem presented, therefore, is to minimize or eliminate the effect that such field distribution may have on the heating of the material to be cooked.

The electrical load which is presented to the source will, in general, change if this field distribution changes. This will occur if the frequency of the source is changed or if the quantity or nature of the food which is being heated is changed.

This invention utilizes the fact that different modes of propagation can exist at closely adjacent frequencies along different axes of the cavity. By the use of a coupling structure which is, for example, placed nonsymmetrically with respect to one or more axes of the cavity, modes existing along any of the axes of the cavity may be effectively coupled to the source. Therefore, by making the dimensions of the cavity different from each other along each of the axes, three times as many possible resonant modes may be excited in the cavity by the nonsymmetrical coupling means over a given frequency range as would be possible in a cavity whose dimensions were all the same, or which was symmetrically coupled to the source. It has been found that, with such a cavity operating in the microwave region, the resonant modes in the cavity will have frequency resonance characteristics which overlap. As a result, the source will be effectively coupled to the cavity substantially independent of the frequency of the source over a relatively wide range of frequencies. This eliminates the need for careful matching of the frequency of the source to a particular resonant frequency of the cavity. Moreover, the introduction of material to be heated into the cavity causes a shifting of the resonance frequencies within the cavity such that, even if the frequency of the source were matched to the resonant frequency of the cavity, introduction of material to be heated into the cavity would detune the cavity. Thus it may be seen that, by the use of an oven which is large with respect to a wave length, which has different dimensions for the respective axes thereof, and which is coupled nonsymmetrically to the source, a wide range of frequencies of the source and a wide range of dielectric constants in the loads introduced into the cavity may be utilized while still maintaining a relatively good impedance match between the source and the cavity.

This invention further discloses that the mode pattern within the cavity may be stirred or varied to produce uniform heating of material in the cavity by cyclically varying the frequency of the source.

Referring now to the drawings, and more particularly to Figs. 1 and 2 thereof, 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 container 2 of food may be placed inside oven 1, said container resting on the bottom wall of the oven or being placed in any other suitable position therein while the food is being cooked. In order to allow access to the interior of the oven for placing the food therein and for removing the food therefrom, a rectangular 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 an opening 12 for the exciting means to be described hereinafter. Cavity 1 has an internal width *w*, an internal height *h*, and an internal depth *d*.

Numeral 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 7 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 the purposes of the present invention it is desirable that the dimensions of each such cavity resonator be such that the wavelength of the electrical oscillations adapted to be generated therein has a predetermined value, for example, of the order of ten centimeters. Wavelengths of this order lie in the microwave region of the frequency spectrum. However, this invention is equally applicable to radio-frequency energy of longer or shorter wavelengths within or without the microwave region.

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 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.

Magnetron 5 is energized from any suitable source (not shown) and when so energized delivers high-frequency electromagnetic energy having a predetermined wavelength to a coaxial transmission line 9, the inner conductor 10 of which is coupled to oscillator 5 by a loop 11 and the outer conductor of which is connected to envelope 6. The inner conductor 10 of line 9 extends directly into the interior of oven 1 through a suitable opening 12 provided in the rear wall thereof, while the outer conductor of said line is connected to the rear wall of the oven 1 by a suitable fastening means 13.

By making the height *h*, width *w*, and depth *d* of the oven space different from each other, for example, by one quarter wavelength, and feeding power into the oven at a point displaced slightly from the center of one surface, the number of different modes which will exist in a given range of frequencies can be made somewhat greater than it would be if the oven were entirely symmetrical. This will tend to make the operation of the oven more uniform if the source is to operate at different frequencies. The dimensions *w*, *h*, and *d* of enclosure or cavity 1 are all large compared to the wavelength of the oscillations of oscillator 5, as stated above, and are all different. For example, *w* may be 13 inches, *d* may be 14 inches, and *h* may be 15 inches.

For any given frequency of operation, however, the unique distribution of field maxima and minima still exists. Making the oven irregular in shape does not change this condition and therefore some other means must be resorted to. Moreover, it has been found that great irregularities of the surfaces of the oven, for example, deep corrugations, tend to increase the difficulty of providing uniform heating of food samples.

In order to provide uniform heating in the oven, it has been found satisfactory to move the food about in the oven so that all parts of the food are exposed to many different regions in the oven and the effects of the different field intensities are averaged out. It is within the scope of this invention to provide uniform heating of a body in the oven by moving said body with respect to the oven.

Another expedient which has been found satisfactory is to change the boundary conditions of the oven, thereby changing the field distribution. This can be accomplished without moving the side walls by introducing into the oven an additional reflecting or dielectric object which can then be moved about, causing a change in field distribution within the confined space.

One possible type of reflecting object is shown in Figs. 1 and 2. A thin metallic plate member 14, which may have substantially square upper and lower faces, as shown in Fig. 2, is mounted horizontally inside cavity 1 near the upper end thereof. The dimensions of the faces of this plate member are somwhat smaller than the corresponding dimensions *d* and *w* of the oven, but the face dimensions of the plate are each a substantial proportion of the corresponding oven dimensions, such as on the order of three-fourths thereof, for example. Plate 14 is affixed to a shaft 15 which extends through the upper wall of oven 1 by means of a hole in the central area thereof. Shaft 15 is mounted, for vertical reciprocation with respect to oven 1, in a suitable bearing 16 fixed to the top wall of said oven.

Shaft 15 is adapted to be continuously reciprocated vertically, thereby continuously reciprocating or moving plate 14 between the upper and lower dotted-line positions shown in Fig. 1. In order to reciprocate shaft 15 vertically, one end of a link 17 is pinned to the upper end of said shaft, the other end of said link being similarly pinned to the outer end of a crank arm 18 which is keyed to a shaft 19. A motor 20 rotates a shaft 21 through a speed-reducing mechanism 22. A worm 23 is keyed to shaft 21 and drives a worm wheel 24 keyed to shaft 19 to rotate said latter shaft and vertically reciprocate shaft 15 and plate 14 at any desired relatively slow rate of reciprocation. This rate may be on the order of 75 oscillations per minute, for example.

It will be apparent that, as metallic plate 14 is vertically reciprocated, in effect the internal height *h* of cavity 1 is continuously and periodically varied to a predetermined extent, since metallic plate 14 "looks" like the upper wall of enclosure 1 to the high-frequency electromagnetic waves inside the cavity.

Microwave energy is fed by coaxial line 9 and exciting probe or rod 10 from magnetron oscillator 5 to the interior of oven 1. It has been found that a large oven of the above-described type, containing such a moving plate-like member therein and excited by microwave energy from source 5 in the above-described manner, produces a very uniform overall or integrated radio-frequency heat pattern throughout the entire interior of enclosure 1. It is not known exactly how or why this result is accomplished, but our present understanding of the theory of operation is substantially as follows.

Due to the relatively large dimensions of cavity 1 with respect to the wavelength of the radio-frequency energy, such energy supplied to the interior of the cavity is reflected back and forth in various directions by the inner walls thereof to establish a complex-mode radio-frequency field pattern in the cavity or enclosure. Because of the large dimensions of the cavity with respect to the wavelength of the energy supplied, a plurality of nodes and loops appear in the standing-wave system set up within the cavity, producing a high-order mode or complex-mode pattern in said cavity, said pattern filling the entire volume of the enclosure in a more or less uniform manner. The cavity 1, due to its substantial dimensions with respect to the wave length, is a high-Q cavity, which means that there is a large amount of circulating (reactive) power within the cavity, setting up a high standing wave ratio in the oven which utilizes the expended power in a very efficient manner for heating purposes.

The effective dimension *h* is periodically varied by the movements of plate 14, as described above. Due to these periodic changes of the effective internal dimensions

of cavity 1, the field distribution therein is changed periodically because of the change in the distance which must be travelled by the waves before reflection from plate member 14. The radio-frequency field pattern or field distribution in the cavity is therefore changed periodically; in other words, the mode present in the cavity is changed periodically with the periodic reciprocation of plate member 14, thus in effect "stirring up" the microwave energy in the cavity. Therefore the device may be termed a "stirrer" or "mode changer."

Since the field distribution, or the mode pattern, inside the cavity is periodically changing, and since there is a complex mode pattern inside the cavity, the total or integrated heat provided in any one area of the cavity during a period of time will be substantially the same as that provided in any other equal area of the cavity during the same time, no matter where in the cavity the two comparable areas are located. Due to this heat uniformity, the oven is made very effective for cooking purposes.

It is also within the scope of this invention to change the field distribution in the cavity 1 by frequency-modulating the output of magnetron 5, thus changing the wave mode in the cavity by effectively changing the dimensions of the cavity with respect to the wavelength of the oscillations supplied thereto.

Now referring to Figs. 3–5, these figures show a modified reflecting-object type of mode changer or stirrer or field-distribution-changer, together with a modified feed line between the magnetron and the cavity. In Figs. 3–5, the same reference numerals are used for elements corresponding to those of Figs. 1–2.

In this modification, magnetron 5 when energized delivers high-frequency electromagnetic waves to a hollow rectangular wave guide 42 through a coaxial transmission line 9 which is coupled to oscillator 5 by loop 11. The central conductor 10 of line 9 extends into the interior of waveguide 42 near one end thereof, through an opening provided in the center of the longer side of said guide, to serve as an exciting rod or exciting probe for said guide.

The end of guide 42 nearest this exciting rod is closed, while the opposite end of said guide is fastened to the rear wall of enclosure 1 by fastening means 13 and is open. The interior of guide 42 is placed in energy-transmitting relationship with the interior of the cavity 1 by means of a rectangular aperture 12′ provided in the rear wall of said cavity, this aperture being of the same size and configuration as the interior of guide 42 and being aligned with said guide to place the interior of said guide in communication with the interior of cavity 1. Aperture 12′ is located in a central position with respect to the vertical side walls of oven 1, and is preferably located above the horizontal midplane of oven 1.

If desired, the interior of wave guide 42 may be sealed off or masked from the interior of oven 1 by means of a plate of a material which is transparent to microwave energy but is not transparent to solids, liquids, or gases, such as "Pyrex" or quartz, for example, in accordance with the principles disclosed in the patent to Norman R. Wild, Serial No. 709,987, filed November 15, 1946, and issued June 3, 1952 under Patent No. 2,599,033. Such a plate could be placed in a position covering and sealing the open (oven) end of guide 42 to keep undesirable food vapors and steam out of said guide, as explained in said Wild patent.

A motor 20, through a speed reducer 41, drives a disk 25 by means of a friction wheel 26. Disk 25 is keyed to a shaft 27, which extends through a suitable bearing 28, in which said shaft is journaled for rotation into the interior of oven 1 through an aperture provided centrally in the top wall of said oven. Shaft 27 is continuously rotated by motor 20 through the above-described mechanism.

Fastened to the lower end of shaft 27 is a metallic grid-like stirrer structure indicated generally by 29. A sleeve 30 is fastened to the lower end of shaft 27. An upper support rod 31 is integral with sleeve 30 and the axis of said rod extends radially from sleeve 30, so that said rod is horizontal. Four parallel rods 32, 33, 34 and 35, of smaller diameter than rod 31, have their parallel axes lying in the same horizontal plane and perpendicular to the axis of rod 31. The longest rod 32 of these four rods is integral with sleeve 30 and represents the diameter of a semi-circle, said diameter being on the order of ten inches, for example; the other rods 33–35 are integral with rod 31 and have lengths corresponding to chords of said semi-circle; the axis of rod 31 is collinear with a radius of said semi-circle. The axis of rod 31, as well as the axes of rods 32–35, are preferably spaced a distance on the order of a quarter to a half wavelength from the top wall of the cavity 1. The axes of rods 31–35 lie in a common horizontal plane. The above-described rods 31–35 constitute the upper half or upper grid of stirrer structure 29.

The lower half or lower grid of said stirrer structure is exactly like the upper half previously described, and consists of support rod 36, four chordal rods 37–40 whose axes are perpendicular to the axis of rod 36, the axes of all the rods 36–40 being horizontal but the axes of rods 37–40 being perpendicular to the axis of rod 36. The only difference between the upper and lower halves of structure 29 is that the lower half 36–40 is displaced 90° in azimuth with respect to the upper half, so that the axes of rods 31 and 36 lie at right angles to each other, and the axes of rods 37–40 lie at right angles to the axes of rods 32–35.

The axes of the rods 36–40 of the lower half of the stirrer structure 29 lie in a common horizontal plane, this plane being spaced approximately a quarter-wavelength below the horizontal plane in which the axes of rods 31–35 lie.

The exciting rod of guide 42 is arranged to set up $TE_{0,1}$ mode waves therein, as will be apparent to those skilled in the art. These waves propagate down the waveguide and emanate from the open end thereof into the cavity 1. It has been found that a large oven of the above-described type, containing therein such a rotating grid-like "stirrer structure" and excited by microwave energy from source 5 in the above-described manner, produces a very uniform overall or integrated radio-frequency heat pattern throughout the entire interior of enclosure 1, due to its "stirring" action. It is not known exactly how or why this result is accomplished, but our present understanding of the theory of operation of this modification is substantially as follows.

Cavity 1, as in the previous embodiment, has linear dimensions which are large compared to the wavelength of the radio-frequency energy, so that a complex-mode radio-frequency field pattern is established in the enclosure or cavity, said pattern filling the entire volume of the enclosure in a more or less uniform manner, said cavity utilizing the input power thereto very efficiently because of the high Q thereof.

Considering the stirrer structure 29 in the particular momentary position of Fig. 4, in the first quadrant (algebraically speaking) there are no conducting rods whatever, so that in this area both horizontal polarization components of the radio-frequency waves pass beyond the stirrer structure to the top wall of the oven and are reflected therefrom. In the second quadrant there are the conducting rods 32–35 extending from side to side of the oven parallel to dimension *w*, which rods act as a polarizer, permitting only the horizontal polarization component of the waves which is perpendicular to said rods (or parallel to dimensions *d*) to pass through the stirrer structure in this area and reflecting from the stirrer structure the horizontal polarization component which is parallel to said rods (or parallel to dimension

w). In the third quadrant, there are the conducting rods 37–40 extending from front to rear of the oven parallel to dimension d and also the conducting rods 32–35 extending parallel to dimension w, the two sets of rods being spaced from each other. This structure causes both horizontal polarization components (that is, the one parallel to dimension w and the one parallel to dimension d) to be reflected from the stirrer structure in this quadrant, permitting neither of these components to pass therethrough. Rods 32–35 reflect the component parallel to dimension w, while rods 37–40 reflect the component parallel to dimension d. In the fourth quadrant, there are the conducting rods 37–40 extending parallel to dimension d, which act to permit only the horizontal polarization component of the waves which is perpendicular to said rods (or parallel to dimension w) to pass through the stirrer structure in this area and to reflect from the stirrer structure the horizontal polarization component which is parallel to said rods (or parallel to dimension d).

From the above discussion, we see that there is a different polarization-reflection characteristic in each of the four quadrants of the stirrer structure—that is, in the first no waves are reflected by or from the stirrer stucture, in the second the horizontal polarization component parallel to dimension w is reflected by the stirrer structure, in the third both horizontal polarization components are reflected by the stirrer structure, and in the fourth the horizontal polarization component parallel to dimension d is reflected by the stirrer structure. Of course, those components not reflected by or from the stirrer structure pass on therethrough and are reflected from the top wall of the oven. Therefore, a wave having both horizontal components of polarization will be differentially reflected by the stirrer structure in each of the four quadrants.

As the stirrer structure is rotated by motor 20, these different polarization-reflection characteristics will, of course, be varied or interchanged accordingly. Therefore, there will be continuously-varying polarization-reflection characteristics in each of the four quadrants, resulting in a continuous effective changing of the wave modes present in the enclosure, or a changing of the field distribution which is the "stirring" action. The integrated heat is thereby made substantially uniform throughout the cavity. This can be appreciated from the fact that waves, which travel entirely through the stirrer structure before reflection, travel distances which are different from those travelled by the waves which are reflected from and by the stirrer structure.

Referring now to Figs. 6 and 7, there is shown a still further modification of the invention wherein the stirring is accomplished by frequency modulating the source of energy. The cavity and coupling structure are similar to that of the species shown in Figs. 3 and 4 with similar parts being designated by the same numbers. The devices of Figs. 6 and 7 do not have, however, the mode stirring structure 29, nor the drive motor 20 and the attendant mechanical driving structure. Rather the anode structure 6 of the magnetron has associated therewith means for cyclically varying the frequency of the magnetron. To accomplish this there is coupled to the magnetron anode structure 6 a cavity 43 by means of a wave guide 44 positioned, for example, on the opposite side of the anode structure from the coupling loop 11. Positioned within the cavity 43 is a diaphragm 45 which separates the cavity into two portions, one of the portions 46 being the effective electrical cavity which is coupled to the magnetron anode structure; the other portion 47 of the cavity 43 contains an actuating rod 48, one end of which is rigidly connected to the center of the diaphragm 45, and the other end of which extends out through the wall of the cavity 43 and terminates in a flange 49. A spiral spring 50 is positioned around the rod 48 outside the cavity 43 with one end of the spring engaging the flange 49 attached to rod 48 and the other end of the spring engaging the outside of the cavity 43, whereby the actuating rod 48 is urged out of the cavity 43. This causes the diaphragm 46 to move toward the cavity portion 47 and away from the cavity portion 46, thereby causing the portion 46 to attain its maximum size, and, as a result, tunes the magnetron anode structure 6 to its lowest operating frequency.

A cam 51 rotating on a shaft 52 engages the surface of flange 49, thereby causing the rod 48 to move periodically into the cavity 43. The cam 51 is driven by a motor 53. Due to the fact that the coupling means 42 enters the cavity 1 off-center, coupling is possible to modes whose electrostatic lines are perpendicular to any of the conductive wall surfaces of the cavity. This effect may be further improved by cutting off the corners of the cavity as at 54. Therefore, the frequency of the anode structure 6 may be varied over a wide range, while still coupling to any of the modes which exist in the cavity at any particular frequency.

Referring now to Fig. 8, there is shown an illustrative diagram indicating the advantages attendant upon coupling to all the possible modes in the cavity 1 over a range of frequencies. The advantage of the coupling structure is similar for all the species of the invention illustrated herein. The graph on Fig. 8 discloses a plot between frequency along the axis of abscissae and relative amplitude of the field inside the cavity plotted along the axis of ordinates. For a particular family of modes excited within the cavity within a band of say, 2200 megacycles to 2300 megacycles, there may be, for example, four resonant modes along the axes perpendicular to the floor of the oven as indicated by the curves 54. Along the axis of the cavity perpendicular to the wall of the cavity containing the door 4, there may be three resonant modes 55 possible, while along the axes parallel to the floor of the cavity and the wall containing the door, there may be three possible resonant modes 56. It has been found that the adjacent resonant areas of modes 54, 55 and 56, respectively, do not substantially overlap. However, when it is possible to couple to any of the modes 54, 55 or 56, it has been found that with a lossy load in the cavity, such as the food body 2, the modes 54 overlap the modes 55 and 56, and the modes 55 similarly overlap the modes 56. Thus, as is indicated by the line 57, the intensity of a field in the cavity will not be less than the value indicated by line 57 which intersects the points of overlapping of the various modes, no matter what frequency within the range of 2200 to 2300 megacycles is applied to the cavity 1. Since this intensity of field in the cavity is a measure of the impedance match of the cavity to the source, the fact that the intensity is relatively high at all frequencies indicates that a good impedance match may be achieved between the cavity and the source substantially independent of frequency. As a result, the source need not be tuned to the cavity and indeed, as is illustrated in Figs. 6, 7 and 8, the source may be varied in frequency to stir or vary the mode pattern in the cavity 1. Thus it may be seen that in any of the species of the invention the magnetron source may be replaced upon its failure for any other reason by another magnetron source which is different in frequency without adjusting the coupling or tuning of the cavity 1. Similarly, a large variety of food materials may be placed in the cavity, said food materials having different loss factors and differing dielectric constants without requiring variation of the tuning of the source or adjustment of the coupling structure. This completes the description of the species of the invention illustrated herein.

However, many modifications thereof will be apparent to persons skilled in the art without departing from the spirit and scope of this invention. For example, various other types of structures could be used to produce the asymmetrical or off-center coupling required to couple to all the modes in the cavity, other means could be used

to frequency modulate the source, such as an electrical tunable magnetron or a vibrating reed inside the magnetron structure, and other shapes and sizes of the cavity 1 could be used. Accordingly, it is desired that this invention be not limited to the particular details of the species illustrated herein, except as defined by the dependent claims.

What is claimed is:

1. High frequency heating apparatus comprising a source of high frequency energy, a substantially closed metallic cavity, means effectively coupling said source to a plurality of mode patterns existing in said cavity over a range of frequencies, said cavity having dimensions which are substantially greater than the wavelength of said high frequency energy supplied by said source, a body to be heated resting in said cavity, and means for varying said plurality of mode patterns existing in said cavity for obtaining uniform heat distribution in said cavity comprising means for cyclically varying the frequency of said energy supplied by said source.

2. Microwave heating apparatus comprising a source of microwave energy, a substantially closed metallic cavity, means effectively coupling said source to a plurality of mode patterns existing in said cavity over a range of frequencies, said cavity having dimensions which are substantially greater than the wavelength of said microwave heating apparatus supplied by said source, a body to be heated resting in said cavity, and means for varying said plurality of mode patterns existing in said cavity for obtaining uniform heat distribution in said cavity comprising means for cyclically varying the frequency of said energy supplied by said source.

3. High frequency heating apparatus comprising a source of high frequency energy, a substantially closed metallic cavity, means effectively coupling said source to a plurality of mode patterns existing in said cavity over a range of frequencies, said cavity having dimensions which are substantially greater than the wavelength of said high frequency energy supplied by said source, the dimensions of said cavity also being substantially different along different mutually perpendicular axes thereof whereby said plurality of mode patterns thereby caused to exist in said cavity may be effectively coupled to said source independent of the frequency of said source, a body to be heated resting in said cavity, and means for varying said mode patterns for obtaining uniform heat distribution in said cavity comprising means for cyclically varying the frequency of said course.

4. High frequency heating apparatus comprising a source of high frequency energy, a substantially closed metallic cavity, said cavity having dimensions which are substantially greater than the wavelength of said source, the dimensions of said cavity also being substantially different along different mutually perpendicular axes thereof whereby a plurality of mode patterns may be effectively coupled to said source independent of the frequency of said source, means for coupling and radiating energy from said source into said cavity to excite modes along any of the mutually perpendicular axes of said cavity, a body to be heated resting in said cavity, and means for varying said mode patterns for obtaining uniform heat distribution in said cavity comprising means for cyclically varying the frequency of said energy supplied by said source.

5. Microwave heating apparatus comprising a source of microwave energy, a substantially closed metallic cavity, said cavity having dimensions which are substantially greater than the wavelength of said energy supplied by said source, the dimensions of said cavity also being substantially different along different mutually perpendicular axes thereof whereby a plurality of mode patterns thereby caused to exist in said cavity may be effectively coupled to said source independent of the frequency of said source, means for coupling and radiating energy from said source into said cavity to excite modes along any of the mutually perpendicular axes of said cavity, said cavity including means for placing a body to be heated in said cavity, a body to be heated resting in said cavity, and means for varying said mode patterns for obtaining uniform heat distribution comprising means for cyclically varying the frequency of said source.

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