

Sept. 16, 1969

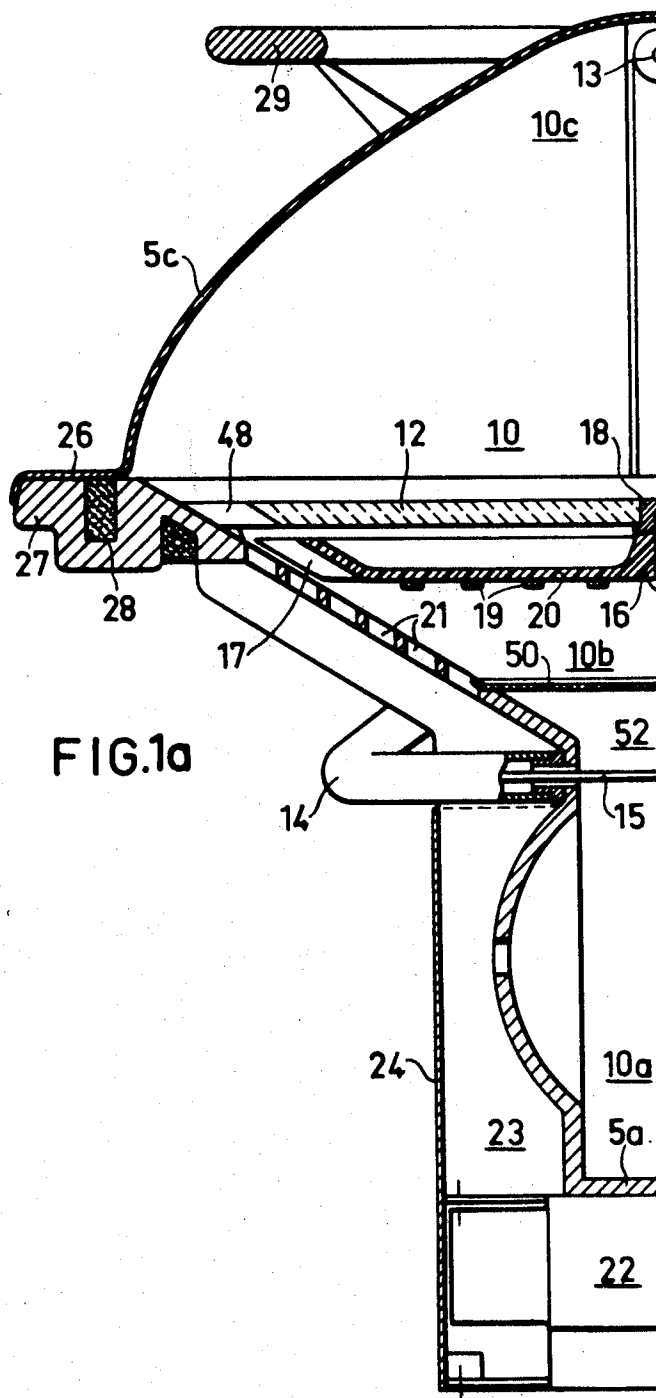
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3,467,803

APPARATUS FOR DIELECTRIC HEATING

Filed Dec. 23, 1966

5 Sheets-Sheet 1



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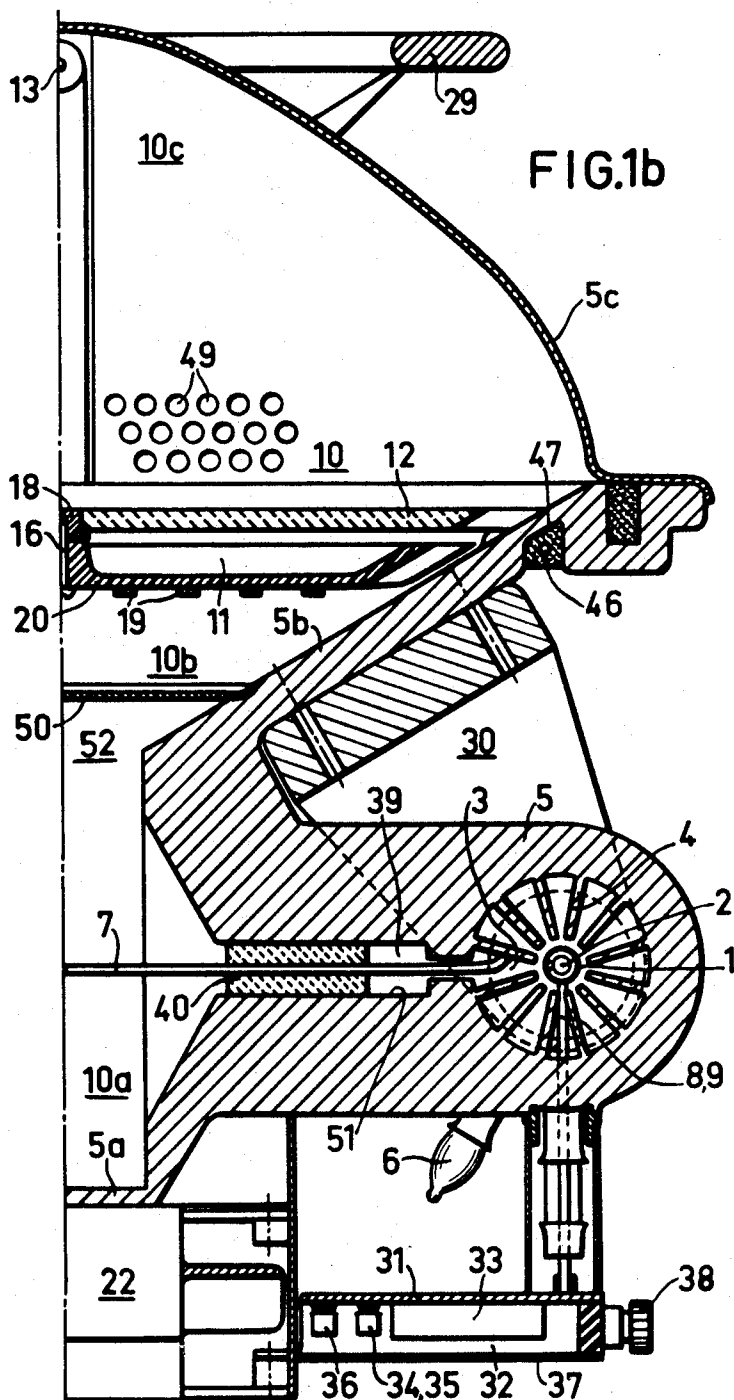
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5 Sheets-Sheet 2



In witness
 Whereof I set my hand and seal
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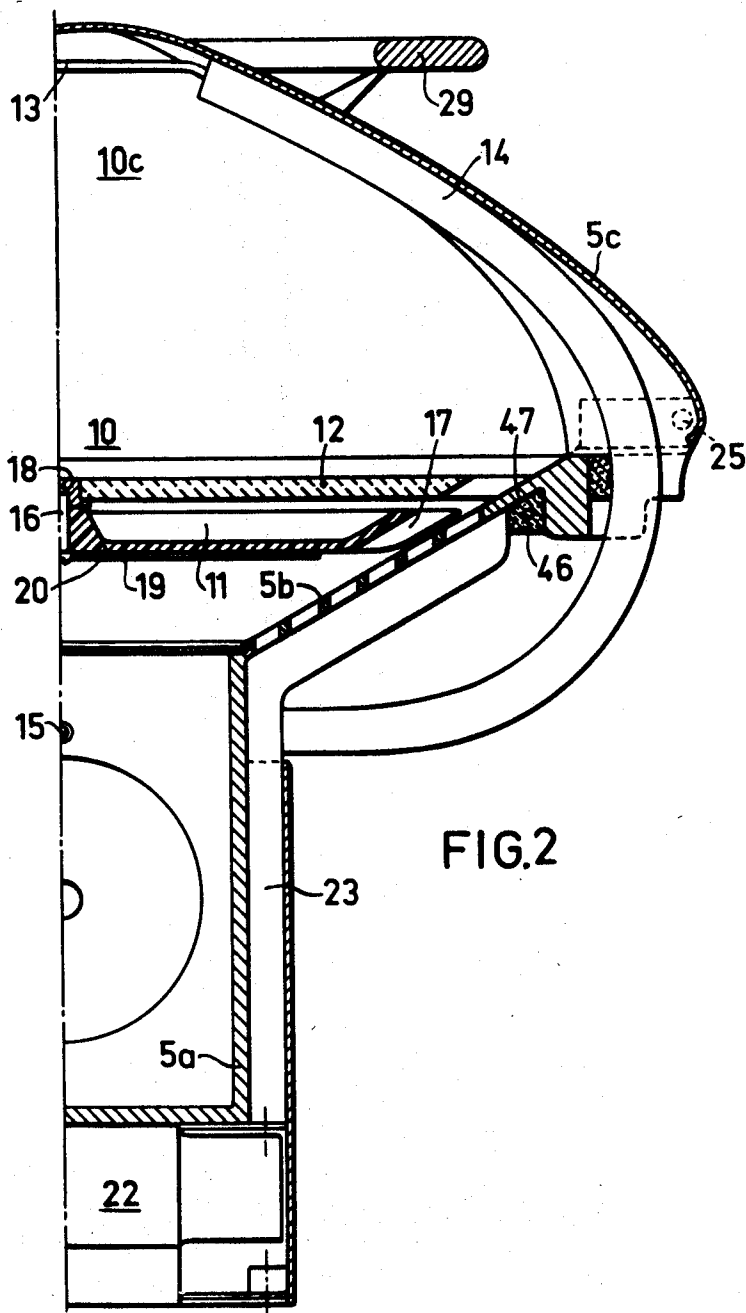


FIG. 2

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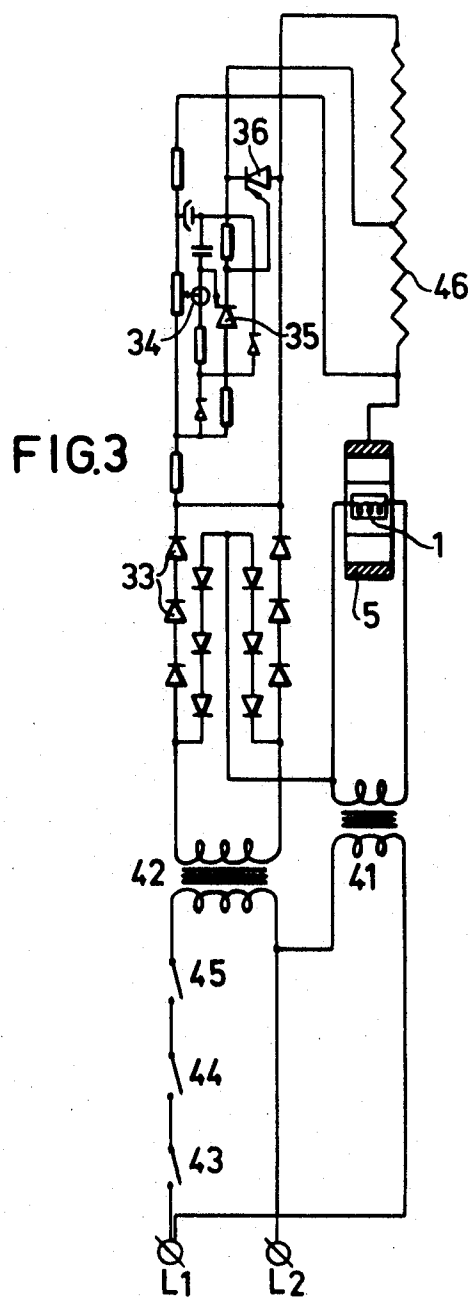
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FIG. 4

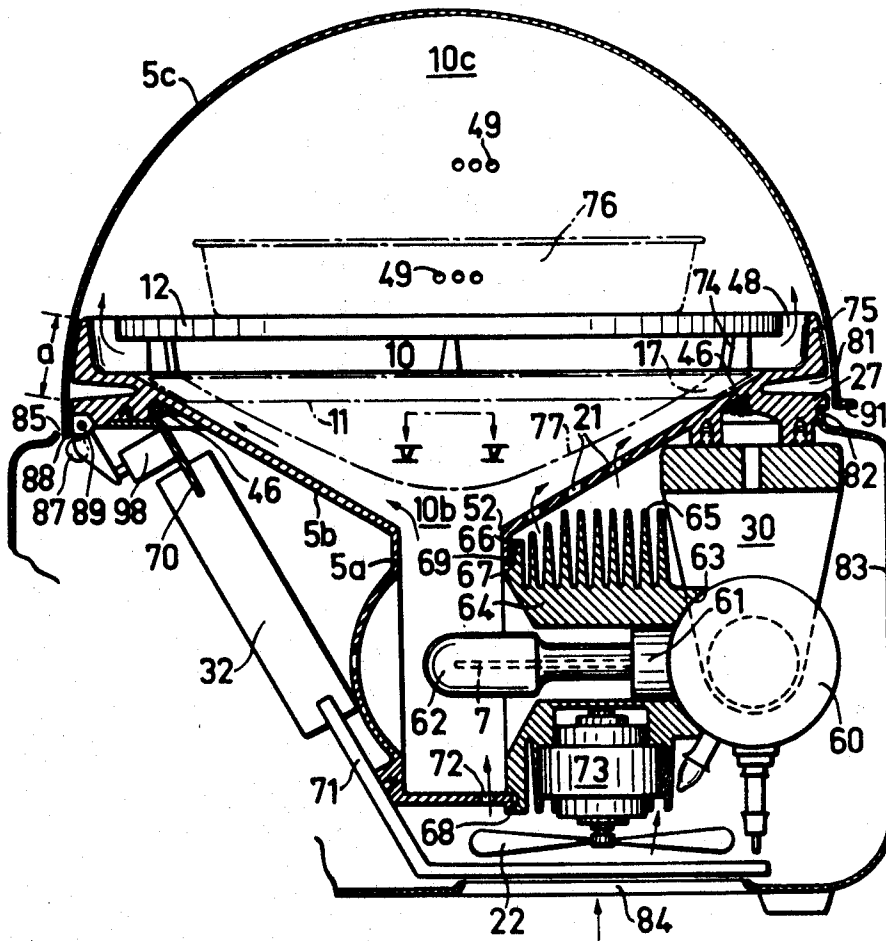
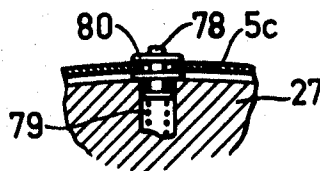


FIG. 5



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Int. Cl. H05b 9/06

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20 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to an apparatus for dielectric heating, particularly of deep-frozen food, by means of microwaves. The apparatus comprises a magnetron and a treatment cavity to which the magnetron is coupled by means of a coaxial line and a wave-guide in such a way, that primary electromagnetic radiation is radiated upwards into said treatment cavity from below. The treatment cavity is defined by a perforated metal casing which contains at least one secondary antenna which is coupled to the wave-guide for providing a microwave field having a polarization direction differing from that of the primary radiation.

This invention refers to heat treatment apparatus of the kind set forth in the preamble of claim 1. In such apparatus the casing of the treatment cavity and the wave-guide are commonly of sheet iron. In the past it has proved difficult to attain accuracy with respect of the measures of the said parts of the apparatus, even when their temperature has been raised by the magnetron by an amount sufficient for obtaining a high efficiency and other favourable operating conditions, particularly since the treatment cavity is ordinarily made relatively large for providing uniform heating of the article to be treated, and the wave-guide is ordinarily made comparatively long, e.g. for providing a space saving arrangement of the magnetron under the casing.

These drawbacks are eliminated in an apparatus having the characteristics set forth in the characterizing clause of claim 1. Such an apparatus also is simple and cheap in construction and may be made very compact. The rigid form body guarantees measure constancy and may to advantage be die cast and will thereby attain a sufficient accuracy in measures without machining. The radiation which reaches the treatment cavity from below through the central opening furthers uniform heating of the article horizontally and also vertically, in that part of the heat, most of which is certainly developed in the lower portions of the article, tends to rise upwards. Because of the secondary antenna arrangement the operating cavity and accordingly also the concave lower portion of the casing may be made relatively small, which furthers the abovementioned advantageous design of the form body and incoming radiation from below. Preferably, a horizontally rotating secondary radiator is utilized which is arranged below the support means and creates a rotating proximity or vicinity field in an article resting upon the support means and is driven by an air current which is blown into the form body past cooling flanges thereupon by a blower, is subsequently conducted along the inside of the casing and finally leaves the operating cavity through perforations in the upper member or portion thereof after its evacuation of the cavity. The lower portion or member is preferably countersunk in the upper side of an outer housing or in a stove top, which may possibly be provided with ordinary cooking

plates, the upper member then being a risable cover pivoted to the lower member.

The invention will be more particularly described with reference to the accompanying drawings, in which:

FIGURES 1a and 1b placed with FIGURE 1a to the left of FIGURE 1b form a vertical cross sectional view of an apparatus according to the invention;

FIGURE 2 is a vertical cross sectional view of the apparatus but taken at right angles with respect to the view according to FIGURES 1a and 1b;

FIGURE 3 is the wiring diagram of the apparatus;

FIGURE 4 is a vertical cross sectional view corresponding to FIGURE 1 and illustrating a modification of the apparatus;

FIGURE 5 is a cross sectional view on the line V—V in FIGURE 4 on a larger scale;

The apparatus according to FIGURES 1 and 2 comprises a block or form body of light metal which forms a hollow anode body 5, an outer coaxial conductor 51, a wave-guide 5a and a lower member 5b comprised in a casing defining a heat treatment cavity 10. The hollow anode body 5 contains a cathode 1 which is provided with a helical incandescent wire or filament 2 and is coated with barium oxide or a similar emissive metal compound. The cathode is surrounded by a circular delay line in the form of chambers 3 and partition walls 4 which are provided in the block or form body 5 and have their surface coated with vacuum copper or silver which forms a coating of such a thickness, that the space around the cathode may be evacuated from gas until an absolute pressure of 10^{-5} mm. mercury has been attained. For the evacuation there is provided a tube 6 which is sealed by melting after the removal of the gas. A filamentary antenna 7 is brazed or soldered to a wall of one of the chambers 3 and therefrom extends through a channel 39 in the block portions 5, 51 and through an insulator 40 of glass or ceramics which is sealed vacuum tight to the block and the antenna. In a similar way two filamentary supporting and connecting members 8, 9 for the cathode and its coiled filament are insulatingly and vacuum tight passed through the wall of the evacuated anode cavity. A member or portion 5b of the block and a separate metallic upper member 5c form parts of the treatment cavity 10. In the block portion 5b there is provided a carrier plate 12 for food or another loss creating substance. The carrier plate is provided with apertures 48 at its circumference. The antenna 7 extends horizontally into the wave-guide 5a and terminates blindly in the cavity 10a. The cavity 10a has a substantially rectangular cross section in a horizontal plane (43 x 86 mm. at a wave length of 12 cm.) and forms on account of its dimensioning, a high pass filter for electromagnetic radiation from the antenna 7 through a central opening 52 in the member 5b. The portion 10b of the cavity 10 is funnelled in such a way that the impedance of the high pass filter is matched to the impedance of the article to become treated which is placed upon the plate 12 in combination with that of a rotary secondary antenna 11. The upper portion 10c of the cavity 10 has a parabolic or another suitable shape, and the portion 10b has a corresponding shape. The upper portion 10c is at its top provided with an antenna 13 which through a flexible coaxial cable 14 is connected to the portion 10a of the cavity by a coupling plug 15. The portion 10c also is shaped for matching or transforming the impedance, i.e. the impedance of the antenna 13. The two antennas 7, 13 are mutually so arranged that their longitudinal axes form an angle of 90° which is important with regard to their cooperation. The secondary antenna 11 preferably has the form of a plurality of parallel copper rods or slabs 19, and it is located on the surface of an

insulating disk 20 which is rotatably suspended on a shaft 16 and is provided with oblique blades 17 along its circumference. The shaft 16 has the shape of a bolt which is threaded from below into a bushing 18 which is moulded into the plate 12. The material of the plate 12 is steatite which has proved to possess characteristics which are of value in respect of the coupling of the microwave field to the smooth underside of a food portion, probably on account of a suitable dielectric constant. The disk 20 is made of a light material with a small loss angle at microwave frequencies and a great temperature tenacity as related to such materials, preferably polypropylene.

The members 5b, 5c are perforated with rings of orifices 21 and 49 respectively. Of the orifices 49 only a few are shown in the lower portion of the member 5c in FIGURE 1. The diameter or width of the orifices is about 8 mm. which is a sufficiently minute dimension to prevent the passing through of too great an extent of electro-magnetic fields having a wavelength of 12 cm. The orifices define a path for a current of air which is provided by a turbine blower 22 which is driven by an electric motor. The air current cools the block 5 by sweeping its surfaces, which are extended by fins or flanges 23 (FIGURE 2), makes the disk 20 rotate and evacuates steam and smell of roasting meat from the cavity 10. In order to enhance this action the blower 22 and the fins 23 are surrounded by a cylindrical baffle plate 24 (FIGURES 1a and 1b). In the lower portion of the member 5b there is pressed in a slab 50 of a low loss material which prevents moisture and rests of food from reaching the cavity 10a. The members 5b and 5c abut against each other with circumferential flanges 26, 27 and are through a pivotal connection 25 (FIGURE 2) so connected to each other that the upper member 5c by means of a handle 29 can be swung up for introducing and removing food portions or the like. Sealing between the members 5b and 5c is provided by the capacitance between their abutting flanges 26, 27 in combination with the reactance of a groove 28 in the member 5b. For hygienic reasons the groove 28 is filled with a non-metallic substance, which in addition thereto may have great losses at the frequency in question, for instance graphite.

The anode block 5 of the magnetron is surrounded by the shanks of a horseshoe magnet 30 having such a location that an axially extending magnetic field is created around the cathode 1. To provide an electric field which is perpendicular to the magnetic field, the connecting means 8 of the cathode is connected to a unit 32 built together upon a circuit board 31 and comprising rectifiers 33 and transistors 34, 35 and a thyristor 36. The unit 32 is together with the connecting means 8, 9 encapsulated in a metal casing 37 which prevents disturbing radiation and protects against touch. In an insulating wall of the unit 32 there are provided four terminals 38 for connection of two transformers 41 and 42 (FIGURE 3) having as their object to supply from the terminals L1, L2 of a main alternating current system suitably transformed filament current to the magnetron and a suitably high voltage to the unit 32 respectively, in dependence of the manipulation of switches 43, 44. Since the dynamic internal resistance of the magnetron is low, the transistors 34, 35 and the thyristor 36 are adapted to maintain the current from the structure 32 constant by the shunting of a resistor 46 inversely proportional to the voltage of the main supply system. To permit utilisation of the heat developed in the resistor 46 to maintain the flanges 26 and 27 dry, this resistor is embedded in an insulating mass in a groove 47 in the member 5b. The transformers 41, 42 and the switches 43, 44 are included herein solely to facilitate the explanation of the mode of operation of the apparatus, which is as follows:

From the terminals L1, L2 of the mains the current

is supplied to the coiled filament 2 through the transformer 41 and thus heats the cathode 1. At the same time a bimetallic element or the like in the switch 43 is heated, so that it is closed when the cathode has reached its operating temperature. If meanwhile a food portion has been introduced into the cavity 10 and the latter has then been closed, the switch 44, too, is closed. If subsequently also the switch 45, which may be set to become automatically opened after a selectable interval, the transformer 42 starts supplying high voltage alternating current to the unit 32. The alternating current is rectified by the unit 32 and is applied, through the resistor 46 and the thyristor 36, to the anode-cathode path of the magnetron. This then starts oscillating at the resonance frequency of the chambers 3. The oscillations are fed through the antenna 7 into the cavity 10, where its energy content is transformed to heat in the food portion. The incoming primary radiation of microwave energy also from above, which is provided by means of the cable 14 and has a polarisation of 90° with respect to the radiation coming in from below, is of great importance to the uniformity of the heating and the ability of thawing deep-frozen food. The secondary antenna 11, which is rotated through the action of the cooling air current upon the disk 11 and on account of its rotation alternately intensifies the field from the upper and the lower primary antenna, respectively, contributes to a great extent to the said uniformity. The heat treatment continues normally until the switch 45 after the lapse of its set time interval interrupts the current to the transformer 42, but the heating operation may also be interrupted by opening the cavity 10, whereby the switch 44 is opened and interrupts the current.

The apparatus described is primarily intended to be built in by being countersunk into the top of a cooking stove, a work-bench or an individual casing. The two transformers may then be located at an arbitrary distance from the magnetron. A plurality of such apparatus may be arranged in a file in a common, low, lengthened housing adapted to be placed upon a table for simultaneous heating of several food portions.

Other embodiments are also possible within the scope of the claims. Instead of being provided directly in the block 5, the chambers 3 and the walls 4 may thus be formed in a separate copper cylinder, which is fitted and soldered into a coppered, cylindrical recess 53 in the anode block or body 5.

The apparatus may also to advantage have a separate conventional hollow anode body of copper. In the modification illustrated in FIGURE 4 such an anode body 60 having a cylindrical coaxial conductor collar 61 and a glass bulb 62 which encloses the antenna 7 are through soldering or the like connected to a member or portion 63 of a die cast outer coaxial conductor 64 which surrounds the collar 61 and is provided with cooling flanges 65 and an attachment flange 66 extending circumferentially around an end portion 67 which fits in a lateral opening in the wave-guide 5a which here has a flange 68 bolted to the flange 66. A groove or channel 69 in the flange 66 contains a flexible metal tube (not shown), preferably a tube which comprises a silicone rubber core and is spun of a metal wire, and is compressed between the bottom of the channel and the flange 68 to form an effective seal against stray radiation. The encapsulated unit 32 is by means of a bracket 70 and a metal sheath tube 71 attached to the underside of the flange 27 and the wave-guide 5a, respectively. The latter has in its bottom a group of circular apertures 72 and the lower member 5b is, at least over the cooling fins 65, provided with a group of circular perforations 21. The blower projects in under the group of apertures 72 and the cooling fins 65, and has an electric drive motor 73 which is secured in a recess in the member 64. The carrier plate 12 is supported and maintained horizontal by six shoulders 74 provided at uniform circumferential distances on the inside of an up-

wards facing portion 75 of the flange 27. The article to be treated may be a layer of food, suitably not exceeding 3 cm. in thickness, in a bowl of plastics 76 having a plane bottom. The antenna disk 20 is shown in dash-dot lines but may also be located closer to the carrier plate, together with which it is removable. It may on its lower side have a thin-walled, substantially calotte-shaped air-guide 77 of the same material as the disk 20 for guiding air, which is blown in through the orifices or apertures 21, 72, towards the circumference of the disk 20 which is provided with blades, the antenna rods then being arranged on the upper side of the disk. The secondary antenna 13 and the disk 50 are not included. The cover 5c is semi-spherical and at least along half of its circumference provided with a reinforcing flange 91 which also serves as a handle. The cover 5c is journaled on two diametrically opposite pivot pins 78 which are slidably arranged in the flange 27 as is most clearly shown in FIGURE 5. Each of the pivot pins 78 engages, under the influence of the pressure of a spring 79, in a bushing 80 which is preferably of plastics and is provided in the cover 5c. When closed, the cover forms an annular air slit of uniform thickness in cooperation with the partially spherical outside of the flange 27, 75, which has a circumferential groove 81. The depth of the groove 81 is, like the distance *a* between the lower edge of the groove and the upper edge of the flange 75, equal to $\frac{1}{4}$ of a wavelength. On account hereof, there is created in the slit a "current-free plane" which affords sealing against stray radiation. For hygienic reasons the groove 81 may be filled with plastics or covered by a film of plastics.

Along half of its circumference the flange 27 rests upon and is bolted to the collared rim 82 of a circular opening in the upper side of a grounded outer housing 83 of sheet iron which has an air inlet 84 directly in front of the blower 22 and which may also accommodate the transformers 41, 42. Along the other half of the circumference shown to the left in FIGURE 5 there is a slit 85 which permits the cover 5c to be partially swung down into the outer housing 83. An arm 86 carrying a roller 87 located in the path of movement of the downwards pivotable edge 88 of the cover is pivotable around a pivot pin 89 which is provided on the flange 27 and is parallel to the pivot pins 78 of the cover 5c. The arm 86 is adapted to maintain a switch 98, which is secured to the bracket 70, corresponds to the switch 44 and has an automatic spring-operated return movement, in its open position when the cover 5c is not shut or almost in its closed position. The roller 87 may be adapted to maintain, by engaging the edge 88 of the cover 5c, the latter in its closed position, and it may also thanks to its friction against the inside of the cover 5c maintain it in its open position. The heat developed by the resistor 46 counteracts condensation in the air slit between the cover 5c and the flange 27. In the closed position of the cover its perforations 49 are located on a higher level than the upper edge of the flange 27. On account of the pressure created in the outer housing 83 by the blower 22, air inlets 21 may to advantage be provided also in the left hand half of the lower member 5b in FIGURE 4. The fact that the air, which flows from below through the interspace 48 surrounding the carrier plate 12, is guided along the inside of the cover 5c makes the evacuation of the treatment or operation cavity particularly effective.

When the pivot pins 78 have been pressed in, the cover 5c may easily be removed for the purpose of cleaning the apparatus. In other respects not discussed above the apparatus according to FIGURE 4 may agree to the embodiment illustrated in FIGURES 1-3.

What I claim is:

1. Apparatus for dielectric heating by means of microwaves, particularly of deep-frozen food, comprising:

a metal casing (5b, 5c) having a concave bottom member (5b) and a separate, perforated upper member (5c);

a microwave-guide (5a) coupled to said metal casing

but apart therefrom being closed in respect of electromagnetic fields of operation frequency and defining a treatment cavity (10) in which articles to be treated may be introduced;

a magnetron (5, 30) having a hollow anode body (5) and a primary antenna (7) which extends from said hollow anode body into said microwave-guide; and an outer coaxial conductor (51) which surrounds said antenna and extends between said hollow anode body and said microwave-guide which is coupled to said treatment cavity for radiating electromagnetic radiation upwards, into said treatment cavity through an opening (52) substantially at the center of said concave bottom member (5b) which is provided with a substantially horizontal, non-metallic carrier means (12) for an article to be treated and is at its top connected to said perforated upper member (5c);

characterized in that said bottom member forms together with said microwave-guide a rigid form body which carries said magnetron (5, 30);

and in that said upper member (5c) contains at least one secondary antenna (13) which is arranged in the upper portion of said upper member (5c) perpendicularly to said primary antenna and is through a coaxial line connected to a coupling pin (15) in said wave-guide (5a), and said upper member being furthermore shaped for matching the impedance of said secondary antenna to that of an average article on said carrier means (12).

2. Apparatus according to claim 1, characterized in that said body is of die-cast metal and has at least two of its said three members (51, 5a, 5b) made integral with one another.

3. Apparatus according to claim 1, characterized in that said form body is provided with inlet openings (21, 72) for evacuation air under said non-metallic carrier means (12) which is a plate surrounded by an annular opening (48) for directing said air towards said upper member (5c) and its perforations.

4. Apparatus according to claim 1, characterized by the provision of cooling fins (23, 65) on the outside of said form body, and a blower (22) which is adapted to force said evacuation air to sweep said cooling fins before entering into said form body.

5. Apparatus according to claim 4, characterized in that said form body carries said blower (22) including an electric drive motor (73) therefore.

6. Apparatus according to claim 1, characterized by the provision of a unit (32) for the supply of anode current to said magnetron, said unit being connected to a transformer (42) and built up on a circuit board (31), and of a rectifier (33) and transistors (34, 35) comprised in said unit.

7. Apparatus according to claim 1, characterized in that said upper member (5c) of the casing is comprised of a vertically pivotable cover, which is pivoted on an upper circumferential flange (27) on said lower member (5b) and which in its closed position covers an arrangement (28, 76, 81) for sealing against stray radiation on said flange.

8. Apparatus according to claim 4, characterized by the provision of a horizontally disposed secondary antenna (11), which is arranged close below said carrier means (12) and is adapted to rotate on a vertical, central axis and in so doing create a rotating proximate field in an article carried by said carrier means, said lower member having such a funnel-shape, that the impedance of a high pass filter formed by said wave-guide (5a) matches the impedance of said secondary antenna (11) and an average article located on said carrier means (12).

9. Apparatus according to claim 8, characterized in that said secondary antenna (11) comprises mutually parallel metal rods (19) on a light material disk (20), which is rotatably suspended in said carrier means (12),

has a small loss angle at microwave frequency and is provided, circumferentially, with oblique blades (17) located close to the inside of the lower member (5b) of said casing for becoming rotated by air blown in by said blower (22).

10. Apparatus according to claim 1, characterized by the provision of a secondary antenna (13) which is arranged in the upper portion of said upper member (5c) perpendicularly to said primary antenna and is through a coaxial line connected to a coupling pin (15) in said wave-guide (5a), said upper member (5c) being shaped for matching the impedance of said secondary antenna to that of an average article on said carrier means (12).

11. Apparatus according to claim 1, characterized in that said carrier means (12) is comprised of a plate, which rests in the upper portion of said lower member (5b) of the casing and consists of a material with substantially the same dielectric constant as steatite.

12. Apparatus according to claim 7, characterized by the provision of an electric resistor (46), which is embedded in insulation mass in a groove (47) in said circumferential flange of said lower member for heating said flange and maintaining its said sealing arrangement dry.

13. Apparatus according to claim 1, characterized by the provision of an outer housing (83), in which said form body (5-5b) is counter-sunk.

14. Apparatus according to claim 13, characterized in that said form body by means of its circumferential flange (27) rests upon the edge (82) of an opening in an upper wall of said outer housing (83), which encloses said form body and elements secured thereto below said flange (27), preferably also transformers (41, 42) for the supply of current to said magnetron, and is provided with an air inlet (84) at its bottom.

15. Apparatus according to claim 14, characterized in that said cover (5c) has substantially semi-spherical shape and is partially pivotable downwards into said

outer housing (83) on two diametrically opposite pivot pins (78) through a slot (85) between an edge of said housing and said circumferential flange (27).

16. Apparatus according to claim 15, characterized in that said pivot pin connection (78) between said cover (50) and said circumferential flange (27) is easily releasable.

17. Apparatus according to claim 15, characterized by the provision of a spring operated low voltage switch (98) for the switching on and off of said magnetron, which is adapted to be maintained open, as long as said cover is not substantially closed by a portion of said cover (5c) swung down into said outer housing (83).

18. Apparatus according to claim 4, characterized by apertures (72) in said wave-guide (5a) and cooling fins (65) on said coaxial conductor (64) and wherein said blower (23) has propeller blades having their path of movement located under said apertures (72) and under said cooling fins (65).

19. Apparatus according to claim 2, characterized in that said hollow anode body (5) is also of die cast metal and has an internal coating of a metal having at least the same electric conductivity as copper.

20. Apparatus according to claim 19, characterized by a cylinder recess (53) in said hollow anode body and by the provision of a delay line in the form of chambers (3) and partition walls (4), which is provided in a separate copper cylinder, which is pressed into and soldered to said recess (53).

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