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(54) MICROWAVE HEATING APPARATUS

(71) We, RAYTHEON COMPANY, a corporation organized under the laws of the State of Delaware, United States of America, of Lexington, County of Middlesex, State of Massachusetts, United States of America, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:–

The present invention relates to microwave heating apparatus.

Microwave ovens have used cavities containing mode stirring structures to provide varying electric field patterns in the cooking area of the oven. The microwave energy is introduced into a cavity, which generally has interior dimensions large with respect to a wavelength at the microwave frequency, and conductive elements are moved in the cavity to reflect the energy and vary the patterns so that points of maximum voltage gradients are continuously shifted in the cavity to more uniformly heat different sizes and shapes of bodies. Such as reflective mode stirrer, which is designed for one set of load conditions such as heating hamburgers or hot dogs, does not produce the same effectiveness in uniformly heating a large body such as a joint or a wide relatively flat body such as a pie.

Coaxial feeds of microwave energy into microwave heating cavities with mode stirrers rotating concentric with the feed have still provided that the mode stirring be by reflection from metal members moving with respect to the food body as shown, for example, in U.S. Patent No. 3 435 507.

According to the present invention, there is provided microwave heating apparatus comprising a conductive enclosure, a source of microwave energy outside the enclosure, a primary radiating structure supported in the enclosure by a conductive member extending into the enclosure through an aperture in a wall of the enclosure so as to form a coaxial transmission line which feeds energy from the source to the radiating structure, the primary radiating structure including a plurality of radiators which radiate simultaneous beams having differently orientated transverse polarization vectors, and means arranged to move the radiating structure and hence the beams of radiation.

The radiators can be radiating ports so arranged that the microwave energy pattern associated with each of the ports covers a region wherein the body to be heated is placed. The effect of the movement of the radiating structure is that a substantial portion of radiation is absorbed by the body to be heated without reflection from the enclosure walls. More specifically, the ports preferably rotate about a common axis at different distances from the axis, hence providing different annular regions of impingement on the body being heated. In addition, the radiating ports are preferably positioned along radii from the axis of rotation which are separated by substantially equal angles so that coupling and/or interference between the radiating beam patterns prior to impingement on reflecting walls of the enclosure is minimised. More specifically, the ports can be on radii from the axis which are spaced apart by 120 degrees to form a three-phase radiating system. In addition, the radiating ports are preferably oriented to produce substantial radiation parallel to the axis.

Additional heating elements such as resistance heaters or flame burner structures may be positioned in a region outside the radiating structure. More specifically, a resistance heating unit may be formed with a substantially arcuate shaped portion and be positioned around the radiating structure, having a radius of curvature larger than the maximum distance from the axis of rotation of the radiating structure to transfer heat by radiation and/or convection through the air to a body to be heated without interfering with the primary radiation patterns of the radiating structure.

Air may be circulated within the oven by a blower or fan action of the radiating structure to assist in the transfer of heat by convection through the air from the resistive heater and/or to assist in maintaining the over substantially free of surface wall deposits fron condensed gasses driven off from the body being heated.

The magnitude of the power radiated from each port is chosen by choosing the dimensions of the radiating ports, with the radiating ports being at different distances along said radii, whereby energy reflected from the surface returns to the coaxial radiator at different phases and amplitudes which substantially cancel.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a vertical sectional view taken along line 1-1 of Figure 2 of a microwave oven embodying the invention;

Figure 2 is a horizontal sectional view of the oven illustrated in Figure 1 taken along line 2-2 of Figure 1;

Figure 3 is an enlarged view of the mode stirrer section of Figure 1;

Figure 4 illustrates an enlarged detail of the mode stirrer section of Figure 2; and

Figure 5 illustrates a further embodiment of the invention.

Referring now to Figures 1 and 2, there is shown a microwave oven 10 comprising a cooking enclosure 12 formed of metal and having a door 14 which closes an access opening in the enclosure 12.

Positioned in oven 10 is a microwave energy feed structure 16 comprising a flat plate structure 18 having slots 20 therein through which microwave energy radiates into the interior of the oven. A microwave feed cavity formed by a plate 22 positioned below plate 18 and connected to plate 18 by an outer wall member 24 is supplied with microwave energy by a coaxial line 26 whose outer conductor 28 is fixed with respect to the oven and whose inner conductor 30 extends outside the oven to a motor 32 which rotates feed structure 16 about an axis concentric with coaxial feed 26.

Outer conductor 28 of coaxial line 26 is connected to waveguide 34 while inner conductor 30 extends through the waveguide 34 to feed microwave energy from the waveguide 34 through the feed structure 16 into the enclosure 12. Waveguide 34 is supplied with m microwave energy from a magnetron 36 in accordance with well-known practice.

As shown in detail in Figures 3 and 4 impedance matching structures 38 and 40 around coaxial feed 30 provide transitional impedance matching between the waveguide 34 and the coaxial line 26 and between the coaxial line 26 and the microwave feed structure 16. Structure 38 also acts with conductor 30 as a choke to prevent microwave energy from leaking out toward motor 32.

The openings 20 are radiating antennae, also referred to as radiating ports, positioned at different distances from the axis of rotation of the structure 16 and are shown, for example, as three openings oreinted about said axis at 120-degree angles with respect to each other. The ports 20 are spaced from the axis of rotation 42, for example, by different distances.

While distances of ports 20 from said axis may be other than those shown, such distances preferably differ by amounts which cause energy reflected from the opposite oven wall to cancel in the stirrer feed acvity due to out of phase summation at the centre conductor 30. In addition, the apertures 20 are preferably spaced at right angles to radii of the axis of rotation as elongated slots perpendicular to said radii, with the length of said slots being on the order of a wavelength of the energy and the width of the slots being less than a quarter wavelength of the energy so that the radiation from the slots will be in the TEM mode with the electric lines parallel to the radii through the axis of rotation of the structure. As is apparent from Figure 4, the transverse polarization vectors of the beams all have different orientations.

The power radiated from each port 20 is dependent on the width of that port, and any desired pattern can be achieved by selecting the port width. However, the radiating port furthest from the axis of rotation preferably radiates the most power. Also, the distance from the axis of rotation to the centre of the innermost slot at the end of the slot is preferably nearly as great as the distance radially from the axis of rotation to the centre of the closest portion of the next slot and, similarly, the distance of the end portions of the middle slot are less than the distance from the axis of rotation to the closest point of said further slot so that when the structuer 16 rotates, the areas of the slots sweep out overlapping cylindrical regions.

A wire grille 46 having opening dimensions greater than a wavelength of said radiation is positioned above the radiating structure 16. The position of grille 46 is adjustable by the structure 46 being slid in and out between bumps 48 and the side walls of the enclosure 12.

Positioned on support rack 46 is a dielectric plate 50 of, for example, pyroceram having a dielectric constant at the microwave frequency which is greater than unity and may be, for example, on the order of ten depending on the particular ceramic. Due to the difference in dielectric constant, the field pattern radiated from the slots 20 is caused to converge slightly into a food body 52 supported thereon; the food body may be a joint of meat.

Positioned around the outside of rotating feed 16 are resistive heating elements 56 and 58 which may be used before, after, or during the application of microwave energy to the food body 52. Elements 56 and 58 may, for example, in a typical oven have a resistive heating capacity of one kilowatt per element and heat the oven and the body by radiation as well as by convection.

The motor 32 and waveguide 34 are positioned outside the enclosure 12 whose outside is preferably insulated, for example, by insulation 60 held in place by an outer oven skin 62. Therefore the waveguide structure 43 and coaxial oven feed are not overheated when the resistance heating elements are operating. In addition, cooling air is supplied by a blower 64 driven by an electric motor 66 which cools the anode of magnetron 36 by blowing air past fins on the magnetron and cools waveguide structure 34 by blowing air into waveguide structure 34 through apertures 68 in the waveguide structure 34. A portion of the air is blown through the coaxial feed 26 and out into the oven through ports 20 to aid in circulation of the heat in the oven and to exhaust cooking gases through apertures 70 in the enclosure 12, such vapours being processed in a canister 72 in accordance with well-known practice so that the air exhausted from canister 72 may be exhausted directly into the kitchen.

Referring now to Figure 5, there is shown a modified embodiment of the invention wherein two rotary feed mode stirring structures are positioned in a microwave heating cavity 80 More specifically, microwave heating cavity 80 has a mode stirring structure 82 positioned in the bottom thereof fed through the floor of the cavity by a coaxial line 84 and rotated by a central conductor 86 of the coaxial line driven by a motor 88 through a belt 90. An upper mode stirring structure 92 is similarly fed with microwave energy through a coaxial line 94 and rotated by central conductor 96 of coaxial line 94 which is driven by a motor 98 through a belt 100.

Mode stirring radiating structures 82 and 92 which are similar to structure 16 are rotated about a common axis in opposite directions so that the field patterns radiating from the ports 20 in the faces 18 of the mode stirrers cross each other as the mode stirrers rotate thereby creating additional pattern variation. The port sizes and structures for the mode stirrer may be, for example, like those disclosed for Figures 1, 2, 3 and 4. However, other sizes and shapes may be used.

Bodies to be heated 102 are preferably supported on a shelf 104 which is transparent to the radiated energy from stirrer 82 so that the bodies 102 are positioned substantially equidistant between the radiating mode stirrers 82 and 92, the bodies 102 being inserted or removed from the cavity 80 through a door 106 having a microwave seal 108 between the periphery of the door and the adjacent wall.

Microwave energy radiated into cavity 80 may be in the frequency range having a free space wavelength from one to 100 centimeters. For the batch processor shown herein, 915 megahertz is preferable while for smaller bodies 52, 2450 megahertz may be preferable. The microwave energy is supplied to upper and lower coaxial lines 94 and 84 through waveguide sections 110 and 112, respectively, which are fed from a common microwave source 114, such as a magnetron, through a waveguide 116 and a T-section 118. In such a structure, microwave energy radiated, for example, from the upper mode stirring radiator 92 has a portion which passes through food bodies 102 without absorption to impinge on lower radiator 82 and a portion thereof is coupled back through coaxial line 84 to the waveguide 110. However, since such energy on reaching the T section 118 will have only a fraction thereof coupled back to the magnetron 114 with the rest being coupled to the waveguide portion 110 and back to the mode stirring radiator 92, the isolation of the magnetron 111 from energy fed back from the cavity is greater than that which would occur if only one of the mode stirring radiators 82 and 92 were used. For this reason, the magnetron 114 may have its output coupled closer to the waveguide 116 and hence closer to its maximum efficiency operating conditions without changes in the energy absorption produced by different loads, causing excess reflection of power to the magnetron 114 which could damage the magnetron by overheating.

While the magnetron 114 is shown herein as cooled by air from a blower 120, a water cooled magnetron could be used and, in any event, some of the air from the blower 10 is preferably coupled into the waveguide 116 through ports, as indicated by arrows 122, to be directed through the waveguides 110 and 112 and the coaxial lines 84 and 94 into the cavity 80 to carry away gases produced by the heating which are exhausted through an outlet canister 124.

This completes the description of the embodiments of the invention illustrated herein. However, many modifications may be made within the scope of the claims. For example, the mode stirring radiators could be moved in paths other than circular, and the structure could be used in continuous processing applications in which a conveyor belt moves bodies to be heated past the rotary mode stirring radiators.

WHAT WE CLAIM IS:

1. Microwave heating apparatus comprising a conductive enclosure, a source of microwave energy outside the enclosure, a primary radiating structure supported in the enclosure by a conductive member extending into the enclosure through an aperture in a wall of the enclosure so as to form a coaxial transmission line which feeds energy from the source to the radiating structure, the primary radiating structure including a plurality of radiators which radiate simultaneous beams having differently orientated transverse polarization vectors, and means arranged to move the radiating structure and hence the beams of radiation.

2. Apparatus in accordance with Claim 1, wherein the radiating structure is a rotary structure.

3. Apparatus in accordance with Claim 2, wherein the conductive member is a rod and the radiating structure rotates baout the axis of the rod.

4. Apparatus in accordance with Claim 3, wherein the moving means rotate the rod and hence the radiating structure which is fixed to

the rod.

5. Apparatus in accordance with Claim 2, 3 or 4, wherein the radiators are radiating ports.

6. Apparatus in accordance with Claim 5, wherein the ports radiate substantial energy parallel to the axis of rotation.

7. Apparatus according to Claim 5 or 6, wherein the radiating ports are positioned at different distances from the axis of rotation of the rotary radiating structure.

8. Apparatus according to any of Claims 1 to 7, wherein the radiators are spaced from a reflecting surface by substantially equal distances and the electrical distances of the radiators from the source are different and produce substantial cancellation of energy refelcted from the reflecting surface to the source.

9. Microwave heating apparatus substantially as hereinbefore described and illustrated in any of Figures 1 to 4 of the accompanying drawings.

10. Microwave heating apparatus substantially as hereinbefore described and illustrated in Figure 5 of the accompanying drawings.

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1591140 COMPLETE SPECIFICATION

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Sheet 1

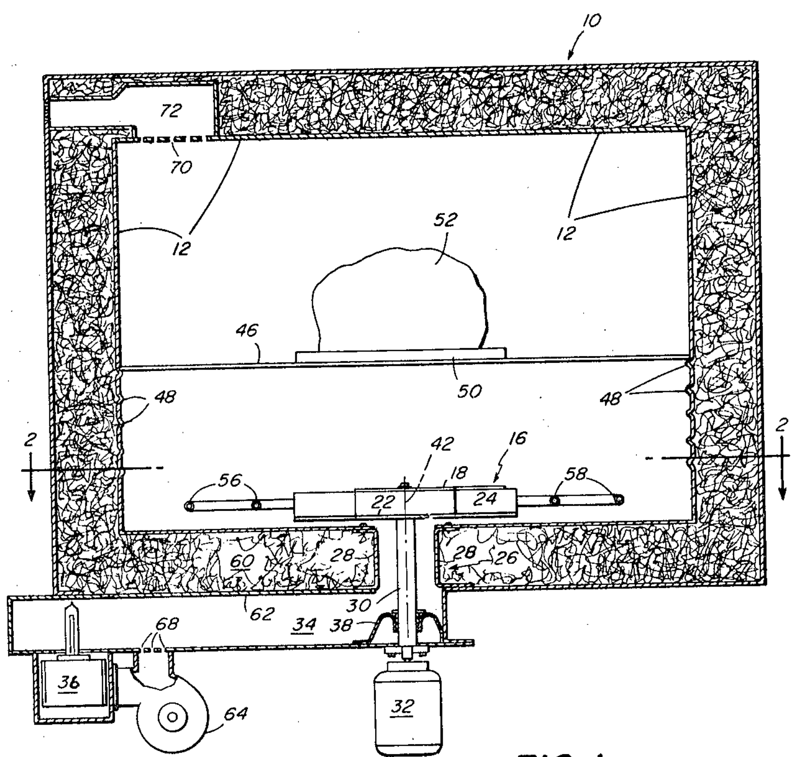

FIG. 1

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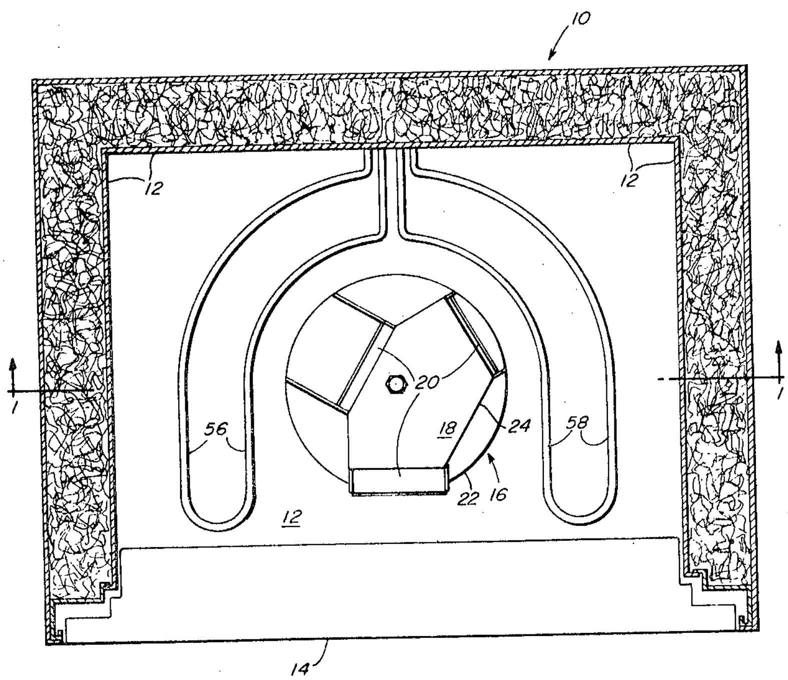

FIG. 2

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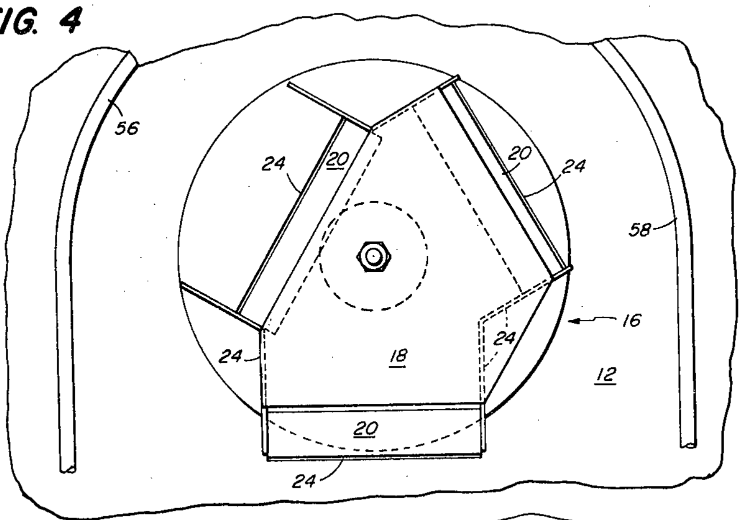
FIG. 4



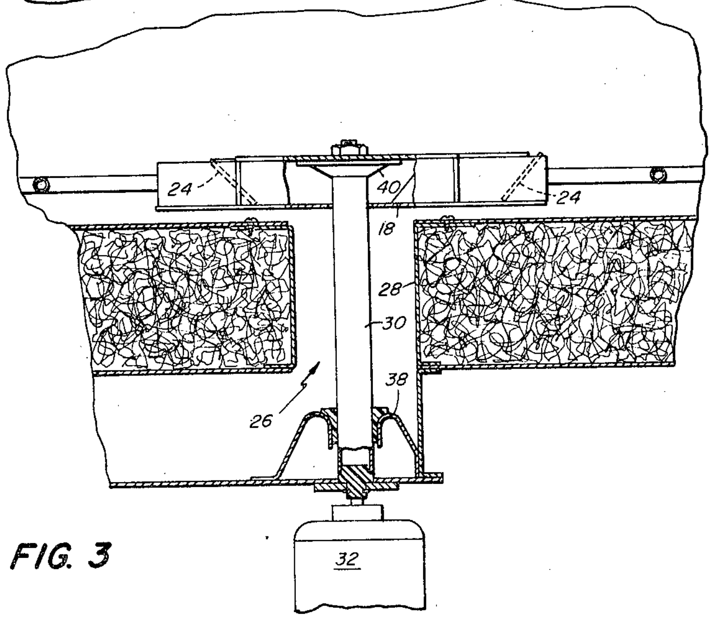


FIG. 3

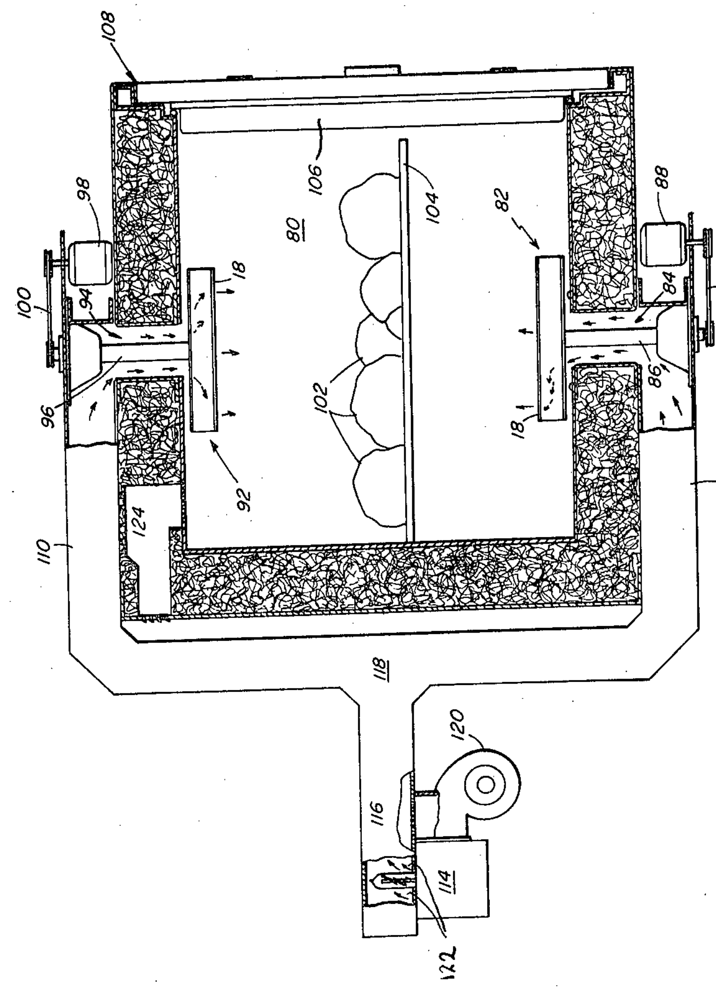

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FIG. 5