United States Patent [19]

Corcoran et al.

[11] **3,872,276**

[45] **Mar. 18, 1975**

[54] **INCLUDING A SEMIRESONANT SLOTTED MODE STIRRER**

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[22] Filed: **Mar. 9, 1973**

[21] Appl. No.: **339,539**

[52] **U.S. Cl.** .... **219/10.55 H**
[51] **Int. Cl.** **H05b 9/06**
[58] **Field of Search** 219/10.55

[56] **References Cited**

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3,626,136	12/1971	Funahashi	219/10.55
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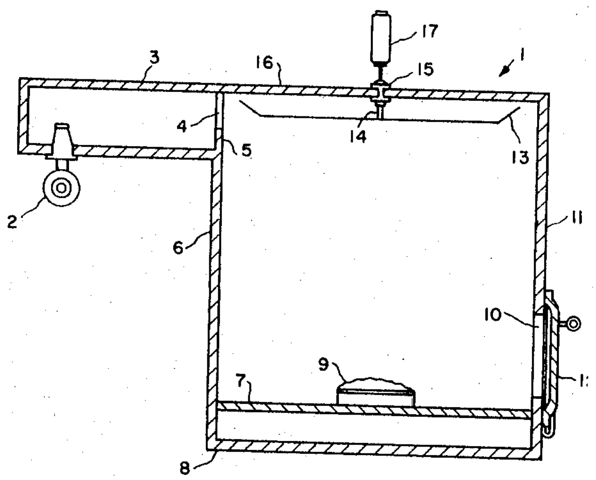
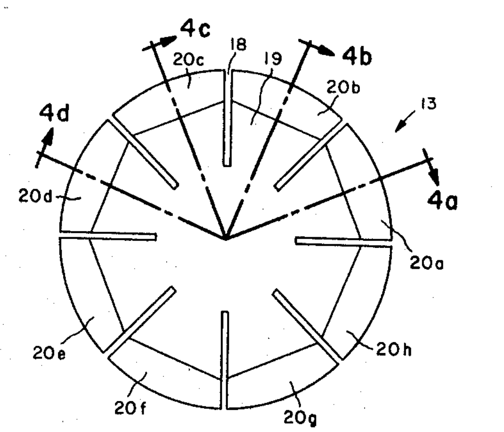
Primary Examiner—Bruce A. Reynolds
Attorney, Agent, or Firm—Frank R. Trifari; Bernard Franzblau

[57] **ABSTRACT**

A microwave oven having a field stirrer comprising a circular sheet metal disc having a plurality of radial slots arranged about its periphery. The ends of the segments thus formed are preferably bent at different angles. The slots and segments together form semiresonant elements to which the energy from the microwave generator couples directly and then is reradiated by the rotating disc which acts as a moving virtual energy source. The disc is rotated so that the segments pass by the microwave energy coupling aperture for the oven. The oven combination produces a more uniform microwave energy distribution within the oven cavity and also improves the matching of the microwave generator to the cavity load so that the generator operates in the load region most suitable to the application.

16 Claims, 10 Drawing Figures





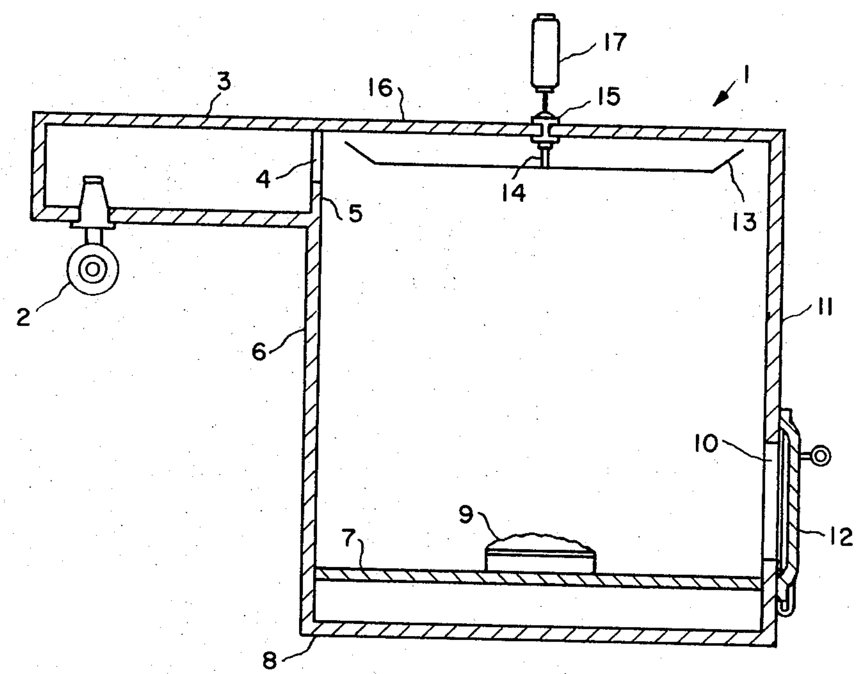


Fig. 1

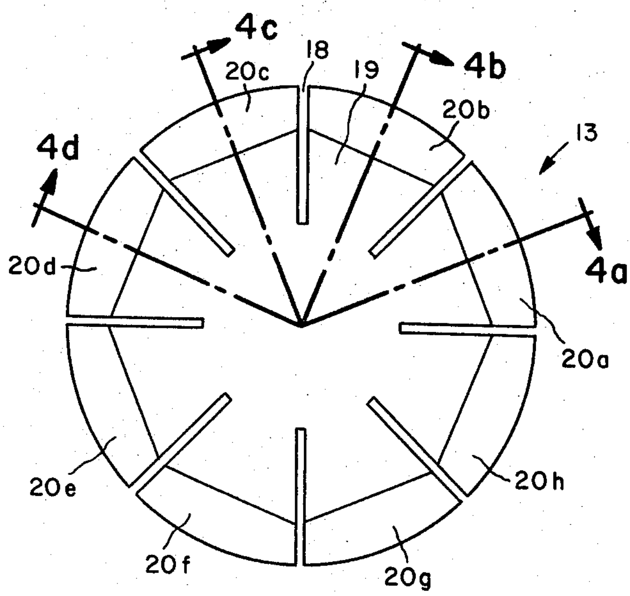


Fig. 2

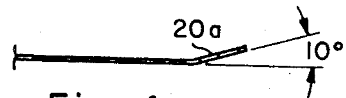


Fig. 4a

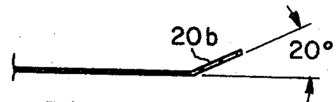


Fig. 4b

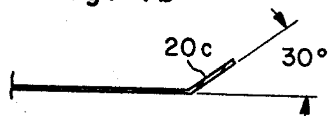


Fig. 4c

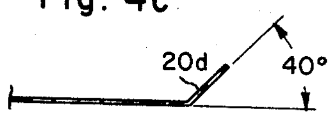


Fig. 4d

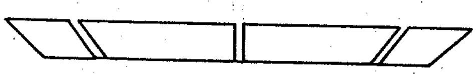


Fig. 3

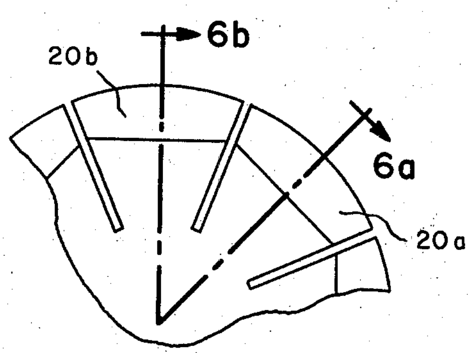


Fig. 5

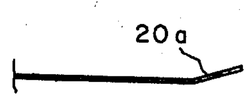


Fig. 6a

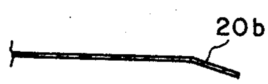


Fig. 6b

INCLUDING A SEMIRESONANT SLOTTED MODE STIRRER

BACKGROUND OF THE INVENTION

This invention relates to a microwave oven and more particularly to a microwave oven having an improved field stirrer which produces a more uniform distribution of microwave energy within the oven enclosure.

It is well known that microwave energy can be used successfully for heating or cooking various dielectric materials, especially for cooking foodstuffs in a rapid and economical manner. The amount of heat developed in the work material is a function of the intensity and frequency of the electromagnetic field and the electrical properties of the material. A suitably dimensioned closed metal cavity into which microwave energy can be introduced makes a good microwave oven. Microwave energy coupled into the cavity produces a pattern of standing waves. A problem inherent in this type of oven is that the intensity of the electric field is not constant throughout the cavity. This may give rise to an unequal distribution of heat within the work material. In order to overcome this problem, the cavity can be dimensioned for a so-called multi-mode operation and the field patterns within the cavity can be periodically shifted in position so that a more uniform distribution of heat is achieved in the work material. If the cavity is properly dimensioned, a small change in the microwave generator frequency can cause a change-over to a different mode or field pattern in the cavity. A change in the shape of the cavity, or a change in boundary effects, also can be used to switch modes in the cavity.

One commonly used device for effecting a change in the boundary effects is a field stirrer. The stirrer is generally a propeller - type fan having a plurality of radially disposed metal fan blades which are rotated by a motor. The stirrer fan is mounted within the oven cavity so as to intercept a substantial portion of the microwave energy radiated from the generator and to deflect the energy impinging upon the fan blades towards the oven load. The blade rotation influences the generator frequency and also changes the mode pattern within the cavity by changing the boundary effects. One such field stirrer is described in U.S. Pat. No. 2,813,185. Although the use of known field stirrers improves the energy distribution within the cavity, there is still room for further improvement, especially in ovens designed to accomodate a wide variety of load materials and of widely varying shape and size.

It is therefore an object of the present invention to provide a microwave oven which will uniformly heat or cook foodstuffs or other suitable load materials.

Another object of the invention is to provide a new and improved form of field stirrer for use in a microwave oven to produce a more uniform distribution of the electromagnetic energy in the oven cavity.

A further object of the invention is to provide a microwave oven with a field stirrer that can be readily adjusted to match a wide variety of oven loads.

SUMMARY OF THE INVENTION

The microwave oven of the subject invention includes a novel field stirrer arrangement that comprises a circular sheet metal disc having a plurality of radially extending slots arranged around its periphery. The ends of the segments formed by the slots can be bent at the

same or different angles. The disc is mounted directly on a revolving metal or dielectric shaft or by means of dielectric spacers on a revolving shaft so that the segments pass in front of a coupling aperture in the oven by means of which the microwave energy is introduced into the oven cavity.

As they revolve past the coupling aperture, the bent ends of the segments formed by the slots reflect the microwave energy coming from said aperture at different angles depending upon the degree of bend in the different segments. The angle of bend also is used to perform a secondary function in that it influences the matching of the microwave generator, for example, a magnetron, to the load, i.e. the microwave oven cavity.

The slots in the disc also serve a dual function in that when cut to the proper depth, the slots and the segments produced thereby form semiresonant elements which couple to the microwave fields in the cavity and reradiate some of the energy in various directions in the oven cavity. The slots, or semiresonant elements, are analagous to short circuited sections of two wire transmission lines in which the metal surrounding the slot constitutes the inductance and the opposite walls of the slots act as the plates of a capacitor. Surface currents are induced in the metal disc which causes coupling between the various slots. By varying the degree of bend and the slot dimensions, the rotating stirrer interacts with fields of different frequencies to a greater or lesser extent. The rotating stirrer thus provides an active function because of the direct interaction of the fields and the semiresonant elements. At the same time, the slots and the segments formed thereby also affect the matching of the microwave generator to the load. Since the disc is made of sheet metal, it is possible to readily adjust or vary the number of slots, the width and the depth of the slots, the angle of bend in the ends of the segments, the position of the stirrer, etc. so that the microwave generator can be made to operate in the most advantageous region (sink region) of its load (Reike) diagram, thus producing the greatest overall efficiency of operation for the entire microwave oven system. Alternately, the microwave generator may be operated away from the sink region to gain additional stability of operation in those applications where the generator is consistently lightly loaded.

The distribution of microwave energy to the load obtained with the oven of the present invention has been found to be substantially uniform. The stirrer used herein also serves to excite several modes in the oven. By periodically changing the field distribution or mode pattern inside the oven, the energy distribution is made uniform throughout the oven thereby producing uniform heating in all parts of the oven.

BRIEF DESCRIPTION OF THE DRAWING

The foregoing and other objects and advantages of the invention will become apparent from the following description of a preferred embodiment of the invention taken in connection with the accompanying drawing in which:

FIG. 1 illustrates a sectional view of a preferred embodiment of a microwave oven according to the invention,

FIGS. 2 and 3 together illustrate the details of the new and improved field stirrer construction,

FIGS. 4A–7D are sectional view of the field stirrer of FIG. 2,

FIG. 5 shows a portion of a second embodiment of the field stirrer, and

FIGS. 6A and 6B are sectional views of the stirrer of FIG. 5 that help to illustrate the construction thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1 of the drawing, a hollow rectangular thin walled metallic enclosure or cavity 1 is adapted to serve as a microwave oven for heating or cooking foodstuffs, or the like. The dimensions of the oven are preferably large compared with the wavelength of the microwave energy supplied by a magnetron 2 to the oven cavity. The microwave energy generated by the magnetron is coupled into the oven cavity by means of a waveguide section 3 and a rectangular or other suitable coupling aperture 4 formed in a metal wall 5. The microwave energy is supplied to the oven cavity through the back wall 6 of the oven.

A shelf 7 is secured to the oven walls and is located near the bottom wall 8 of the oven. The shelf is made of any material that is transparent or semi-transparent to microwave energy and is adapted to support a heating load 9, e.g., an article of food to be cooked. The shelf may be partially composed of a lossy dielectric material to insure that the cavity has some load in the event that the oven is operated without its normal load. This serves to protect the magnetron from damage due to excessive amounts of reflected microwave energy. In order to gain access to the oven interior, an opening 10 is provided in the front wall 11 of the oven. The opening 10 is covered by a hinged metal door 12 having means, not shown, for sealing the opening against the leakage of microwave energy when the door is closed. When the door is closed, the oven cavity is entirely closed except for the coupling aperture 4 through which the microwave heating energy enters the cavity.

A field stirrer 13, shown in greater detail in FIGS. 2–4, is mounted on a vertical extending shaft 14 made of a metal or a dielectric material. The shaft 14 is mounted for rotation in a bearing 15 secured in the top wall 16 of the oven. The shaft and stirrer are rotated by means of a motor 17 to which the shaft is coupled. Obviously, suitable means for sealing the shaft opening in top wall 16 against energy leakage must be provided, such sealing techniques being known in the art. The shaft and stirrer are preferably symmetrically located in the top wall 16 of the oven. As the stirrer is rotated by the motor the end segments or fins pass in front of the coupling aperture 4 to provide the above described desirable "stirring" action on the microwave field within the oven cavity.

Turning now to FIGS. 2–4 there is shown, in detail, the novel field stirrer 13 of the microwave oven described with reference to FIG. 1. The stirrer 13 is a thin circular sheet metal disc having a plurality of radially extending slots 18 symmetrically arranged about the periphery of the disc to form a plurality of segments 19. The ends 20 of the segments can all be bent up or down at the same angle. Preferably, the fins or segment ends 20 are bent at different angles. In one embodiment of the invention the fin 20_a was bent up at an angle of 10°, fin 20_b was bent up at a 20° angle, and fins 20_c and 20_d were bent up at angles of 30° and 40°, respectively. Fin 20_e, radially opposite fin 20_a, also was bent up at an angle of 10°. Fins 20_f, 20_g and 20_h were bent up at angles of 20°, 30° and 40°, respectively. It is also possible to bend all of the fins downward at the same angle or at different angles. It is furthermore possible to bend some of the fins up and others down. This feature of the invention is best illustrated in FIGS. 5 and 6 wherein the end segment 20_a is bent up and the end segment 20_b is bent down. The optimum configuration of the fins will vary with the dimensions and shape of the various oven cavities. Since the stirrer is made of a thin sheet metal, the best configuration of the fins can be readily adjusted by test or service personnel for each individual oven. The height of the shaft 14 (FIG. 1) also can be adjusted to provide optimum performance of any given oven cavity. Furthermore, it is feasible to vary the number of slots and the width and the depth of the slots to provide optimum oven heating performance. As discussed above, the slots and segments form semiresonant elements to which some of the energy from the microwave generator couples directly, as well as coupling to fields in the oven cavity. This coupled energy is then reradiated from the rotating stirrer which acts as a moving virtual source to improve the energy distribution in the oven cavity.

It will be clear from the above that the invention provides a large degree of design flexibility for the designer of microwave ovens. In addition, as discussed above, the invention produces a more uniform energy distribution pattern in the oven cavity and improves the matching of the microwave generator to the cavity load. Thus, the novel stirrer makes it possible to load the magnetron tube near its sink region, a very desirable feature from the viewpoint of overall system efficiency.

One embodiment of the invention which was tested and found to produce good overall results had the following approximate dimensions. The diameter of the stirrer disc was 13 inches and it was 0.04 inches thick. The radial distance from the center of the disc to the interior end of the slot was 2 ¾ inches and to the fin it was 5 inches. The slot was 3 ¾ inches long and ¼ inch wide. The shaft 14 extended ¾ of an inch down from the top wall 16 of the oven. The oven was 14 inches high, 15 inches deep and 16 inches wide. The coupling aperture was a rectangular opening 1 inch by 4 inches symmetrically located at the top of the back wall and equally distant from the ovenside walls. The waveguide section was 2 inches high, 4 inches wide and 6 inches long.

Although a particular embodiment of the invention has been described above it is to be understood that the invention is not limited to the particular details so described, as many equivalents will suggest themselves to those skilled in the art. Furthermore, many modifications thereof will become apparent to those skilled in the art without departing from the spirit and scope of this invention. In view of the foregoing, we do not wish to be limited to the details of the invention disclosed herein except as defined by the appended claims.

We claim:

1. A microwave oven comprising a substantially closed metallic cavity adapted to hold an energy absorbing load, an aperture in a wall of said oven for coupling microwave energy into the oven cavity, means for generating and coupling microwave energy to said aperture, a field stirrer rotatably mounted in the cavity and comprising a thin metal disc having a plurality of radial slots arranged about its periphery to form a plurality of segments with the outer ends of at least some of said segments being bent out of the plane of the disc

whereby said slots and segments form semiresonant elements which couple to the R.F. fields in the oven and reradiate the energy in various directions, and means for rotating said disc so that the bent ends pass near said aperture to intercept and reflect the microwave energy entering through the aperture so as to periodically change the mode pattern within the oven cavity.

2. A microwave oven as claimed in claim **1** wherein the bent ends of said disc segments are inclined at different angles to the plane of the disc.

3. A microwave oven as claimed in claim **2** wherein diametrically opposed pairs of end segments of the discs are inclined at the same angle to the plane of the disc.

4. A mircowave oven as claimed in claim **2** wherein the bending angle of the end segments varies progressively about the disc periphery.

5. A microwave oven as claimed in claim **1** wherein some of the disc end segments are inclined upward from the plane of the disc and other ones of said end segments are inclined downward from the plane of the disc.

6. A microwave oven as claimed in claim **1** wherein the disc is composed of sheet metal of a thickness which allows it to be easily bent to form different adjustable angles of inclination to the plane of the disc.

7. A microwave oven as claimed in claim **1** wherein said aperture is located in a side wall of the cavity near the top wall and said stirrer is mounted on a vertical shaft extending from said cavity top wall.

8. A microwave oven as claimed in claim **1** wherein at least one diametrically opposed pair of end segments are inclined in the same direction to and at the same angle to the plane of the disc.

9. A microwave oven comprising a substantially closed metallic cavity adapted to hold an energy absorbing load, means for supplying microwave energy into the oven cavity, a field stirrer rotatably mounted within the cavity and comprising a thin metal circular disc having a plurality of radial slots therein to form radial fins arranged about the disc periphery with at least some of the fins inclined in a direction at an angle to the plane of the disc, at least a part of said slots lying in the plane of the disc to function as semiresonant elements, and means for rotating said disc to intercept and interact with the energy supplied to the oven cavity thereby to produce a cyclically repetitive distribution of energy within the cavity which is substantially uniform in the region of the cavity to be occupied by the load.

10. A microwave oven as claimed in claim **9** wherein said fins are uniformly disposed about the disc periphery and at least some of which are inclined at different angles to the plane of the disc.

11. A microwave oven comprising a substantially closed metallic cavity adapted to hold an energy absorbing load, means for supplying microwave energy into the oven cavity, a field stirrer rotatably mounted in the cavity and comprising a thin metal circular disc having a plurality of radial slots symmetrically arranged about its periphery to form a plurality of segments with the outer ends of at least some of said segments being bent out of the plane of the disc, said slots being dimensioned so as to form semiresonant elements to which energy from said energy supplying means is coupled directly and then is reradiated to the oven cavity, and means for rotating said disc so as to intercept and interact with the energy from said energy supplying means and the energy within the fields in the oven cavity thereby to improve the energy distribution within said cavity.

12. A microwave oven as claimed in claim **11** wherein the bent ends of at least some of said disc segments are inclined at different angles to the plane of the disc.

13. A microwave oven as claimed in claim **12** wherein at least one diametrically opposed pair of end segments are inclined in the same direction to and at the same angle to the plane of the disc.

14. A microwave oven as claimed in claim **13** wherein the bending angle of the end segments varies progressively about the disc periphery.

15. A microwave oven as claimed in claim **12** wherein some of the disc end segments are inclined upward from the plane of the disc and other ones of said end segments are inclined downward from the plane of the disc.

16. A microwave oven as claimed in claim **11** wherein the width of the slots is relatively narrow with respect to the width of the segment area between adjacent slots in the plane of the disc.

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