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HIGH FREQUENCY HEATING APPARATUS

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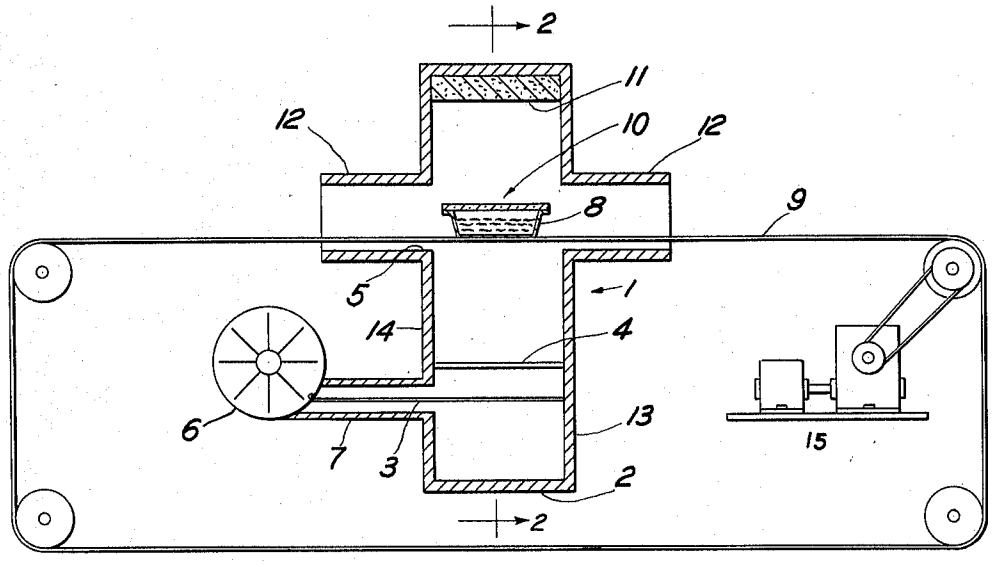


Fig. 1.

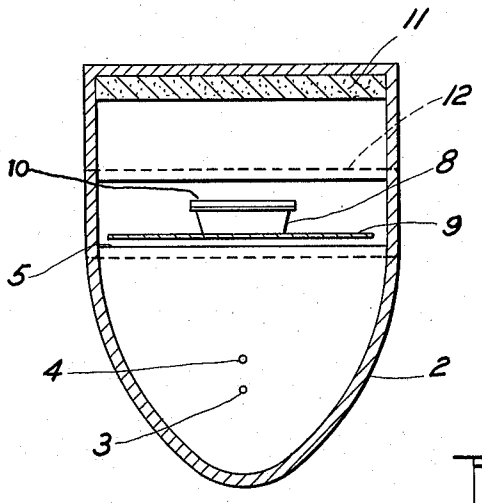


Fig. 2.

INVENTOR.
WALLACE C. HICKMAN

BY
Frank R. Trifari
AGENT

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HIGH FREQUENCY HEATING APPARATUS

Wallace C. Hickman, Wantagh, N.Y., assignor to North American Philips Co., Inc., New York, N.Y., a corporation of Delaware

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This invention relates to high frequency dielectric heating apparatus, and more particularly to apparatus for increasing the efficiency of microwave ovens.

In microwave ovens, the microwave energy is usually confined within the cooking compartment by means of metal walls or screens. The cooking compartment is generally a resonant cavity in which the object to be heated is placed, usually a foodstuff or other lossy dielectric substance, and wherein means are provided to couple microwave energy into the cavity. The heating of the food mass is accomplished by the penetration of microwave energy into the food mass and the resultant agitation of molecules within the food mass. The molecular friction produced results in the generation of heat that cooks the food in a relatively short time.

In most microwave ovens of the resonant cavity type, the microwave energy that penetrates the food is the result of direct radiation incident on the surface of the food mass and indirect energy reflected from the walls of the oven before striking the food. The resultant energy distribution makes it very difficult to produce a uniform field over any appreciable area within these ovens. Therefore, uniform heating of the substances placed in these ovens is usually difficult to attain. Another disadvantage of ovens of this type is that while generally they work satisfactorily as long as the lossy material to be heated is in the cavity, in the event the oven is operated while empty, very large reflections of microwave energy from the walls of the cavity result. These reflections may damage the microwave generator and therefore special precautions must usually be taken with ovens of this type.

An object of this invention is to provide apparatus for a microwave oven which substantially eliminates the above disadvantages of the prior art ovens.

Another object of the invention is to provide apparatus for increasing the efficiency of microwave ovens.

A further object of the invention is to provide means for more uniformly heating a dielectric body by means of radio-frequency energy.

In accordance with the invention, the foodstuff to be heated is placed in a container in which the bottom surface or the bottom surface and side walls are composed of a material substantially transparent to microwave energy. The efficiency with which the radiated energy is coupled into the body to be heated is materially improved by introducing said energy at a point below said body. The top of the container is covered with a metallic cover or other energy reflecting material. The microwave energy passes through the material to be heated and is reflected and diffused back into said material upon striking the reflective cover. The microwave energy is thereby caused to pass through the material to be processed a second time, resulting in a more efficient utilization of the available energy. In addition, since the cover provides a reflective surface for the incident microwave energy, there is no need to rely on the walls of the oven, particularly in an oven of the non-resonant type, to provide additional indirect energy for heating purposes. Therefore, this construction is particularly adapted to the inclusion of a lossy dielectric material within the cavity which will load the cavity at all times. This material will absorb sufficient microwave energy in the absence of the food to be heated to prevent damage to the high

frequency energy generator by reducing the reflected energy to acceptable levels. The cover also serves to retain the heat developed and any vapors released during the heating process. The distribution of the heat and hot vapors within the container provides a more uniform heating of the material as well as an increase in the efficiency of the heating process.

The invention is not limited to use with microwave ovens of the resonant cavity type. The invention is also well suited for use in a conveyor belt system of the type disclosed in United States Patent 3,027,442, entitled "High-Frequency Furnaces."

Further objects and advantages of the invention will become apparent from the following description taken in conjunction with the accompanying drawing, wherein:

FIG. 1 illustrates a preferred embodiment of the invention in cross-section; and

FIG. 2 shows the device of FIG. 1 in cross-section taken along the lines 2—2 of FIG. 1.

Referring to FIGS. 1 and 2 in which like elements are indicated by the same reference numerals, there is shown by way of illustration a modified form of conveyor belt system as disclosed in U.S. Patent 3,027,442 suitable for use with this invention. The microwave oven comprises a hollow waveguide system **1** comprising a parabolic planar reflecting surface **2** bounded by a pair of parallel monoplanar conducting surfaces **13, 14** which are normal to the focal line of the parabolic plane of the reflecting surface **2**. A linear radiating element **3** is arranged on the focal line of the parabolic planar surface **2**. Between the radiating element **3** and the open end of the parabolic surface, a reflector means **4** is provided to reflect the direct radiation of the linear radiator back towards the parabolic planar surface. Reflector means **4** may comprise one or more rods arranged parallel to the linear radiator **3**. As is described more fully in the aforementioned U.S. Patent 3,027,442, the combination of the linear radiating element **3**, reflector means **4**, and the waveguide system provide a radiation pattern along the surface **5** of the waveguide system whereby there is obtained substantially uniform heating of objects placed thereat with a minimum of stray radiation. Microwave energy of the desired frequency is supplied to the system by means of a magnetron generator **6** and any suitable coupling arrangement **7**, for example, a coaxial cable or waveguide, and linear radiating element **3**. Microwave energy having a wavelength in the vicinity of **12** centimeters has been found to produce good results in microwave ovens.

A container **8** of food or other suitable substance to be heated is disposed on a conveyor belt **9** which is moved continuously by suitable driving means **15** through the waveguide system **1**. Both the container **8** and conveyor belt **9** are preferably composed of a low-loss dielectric material, for example, plastic or silicone impregnated fiber glass, which is substantially transparent to microwave energy. Covering the top of the container is a metallic cover **10** which is arranged to reflect the microwave energy passing up through the container **8** and the mass of food located therein. At the far end of the waveguide system there is mounted an energy absorbent material **11** which will absorb any energy emitted by the linear radiator **4** which is not absorbed by the food in container **8**. The absorbent material **11** protects the magnetron generator **6** from damage due to dangerously high amounts of reflected energy, even in the absence of a container of food in the path of the microwave energy. A suitable lossy dielectric material for this purpose is carbon. Entrance and exit passages **12** serve to reduce any stray radiation into the surrounding areas.

In operation, containers of foodstuff are placed on the conveyor **9** and transported through the microwave

heating system 1. Microwave energy emitted by the linear radiator 3 and reflected by reflecting rod 4 and the parabolic reflecting surface 2 produce a substantially uniform electromagnetic field along the surface 5. This energy passes through container 8, some of this energy being absorbed by the foodstuff therein to rapidly heat it. The energy which is not absorbed in passing through the material to be heated in container 8 is reflected and diffused back into said material upon striking the metallic cover 10. As mentioned above, the microwave energy reflected by the cover is thus caused to pass through the material to be heated a second time, thereby resulting in a more efficient utilization of the available energy. If the material to be heated in the container contains a relatively high water content, steam vapor may be released during the heating process. The cover 10 then serves the additional function of confining the vapor in the container. Since the vapor is hot, the redistribution of the hot vapor formed and any hot condensed liquid over the substance to be heated further improves the efficiency of the heating process, as well as providing a more uniform distribution of the heat throughout the material being processed. While it is preferable to maintain a space between the material to be heated and the metallic cover, such a space is not essential and efficient heating of the material may be obtained in cases where there is actual physical contact between the two. Furthermore, if it is found desirable to equalize the pressure within the container, the cover 10 may be loosely fixed to the container 8. Alternatively, a small pinhole or other means may be provided in the cover for equalizing the pressure. If the system is accidentally operated without the material to be heated in the oven, absorbent material 11 absorbs most of the energy radiated, thereby preventing damage to the magnetron generator 6 as a result of energy reflected off of the conductive walls, as sometimes occurs in the closed resonant cavity systems.

The food container 8 and the cover 10 may be supplied with handles composed of low loss materials, thereby facilitating the handling of same after the heating operation is completed. While the invention has been described with reference to one particular embodiment, a conveyor belt system, it will be obvious that this invention may also be used in the resonant cavity type system and in other microwave ovens. Therefore, since many modifications of the invention disclosed will be apparent to those skilled in the art without departing from the spirit and scope of this invention, it is understood that applicant does not wish to be limited to the specific details disclosed herein.

What is claimed is:

1. Radio frequency heating apparatus comprising a metallic enclosure, means for radiating radio frequency energy into the interior of said enclosure, a low-loss dielectric container substantially transparent to radio frequency energy located within said enclosure at a point spaced from said energy radiating means and containing therein a lossy substance to be heated, a conductive member covering said container, said container and the substance to be heated therein being interposed in the path of the directly radiated energy and between said radio frequency radiating means and said conductive member so that said directly radiated energy must first pass said point before it reaches said conductive member.

2. Apparatus for heating a substance by means of microwave energy, comprising a metallic enclosure, means for radiating microwave energy into said enclosure, said radiating means being located near one end of said enclosure, microwave energy absorbing means located within said enclosure and spaced apart from said radiating means and in the path of said radiated energy, a low-loss dielectric container within said enclosure and interposed between said energy radiating means and said energy absorbing means, said container holding a lossy substance to be heated and having a conductive shield covering said container, said container and the substance to be heated therein being interposed between said microwave energy radiating means and said conductive shield.

3. Microwave heating apparatus comprising a metallic enclosure having an inlet port and an outlet port, conveyor means passing through said ports and said enclosure and arranged to transport a low-loss dielectric container containing a lossy substance to be heated, a metallic shield covering said container, means for radiating microwave energy into said enclosure from below said conveyor means, and a radiation energy absorbing body located within said enclosure above said conveyor means in the path of the radiated microwave energy.

4. Apparatus as described in claim 3 wherein said conveyor means is composed of a low-loss material substantially transparent to microwave energy.

5. Microwave heating apparatus comprising a metallic enclosure having an inlet port and an outlet port, conveyor means composed of a low-loss dielectric material, said conveyor means passing through said ports and said enclosure and arranged to transport a low-loss dielectric container containing a lossy substance to be heated, a metallic shield covering said container, means for radiating microwave energy into said enclosure from below said conveyor means, and a radiation absorbing body located within and near the upper end of said enclosure and above said conveyor means, said absorbing body being arranged in the path of said radiated energy so as to absorb substantially all of the radiated energy impinging thereon.

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RICHARD M. WOOD, *Primary Examiner.*