March 31, 1964 S. H. KELLOUGH ETAL 3,127,494

MICROWAVE HEATING APPARATUS

Filed March 13, 1961 2 Sheets-Sheet 1

Fig. 1

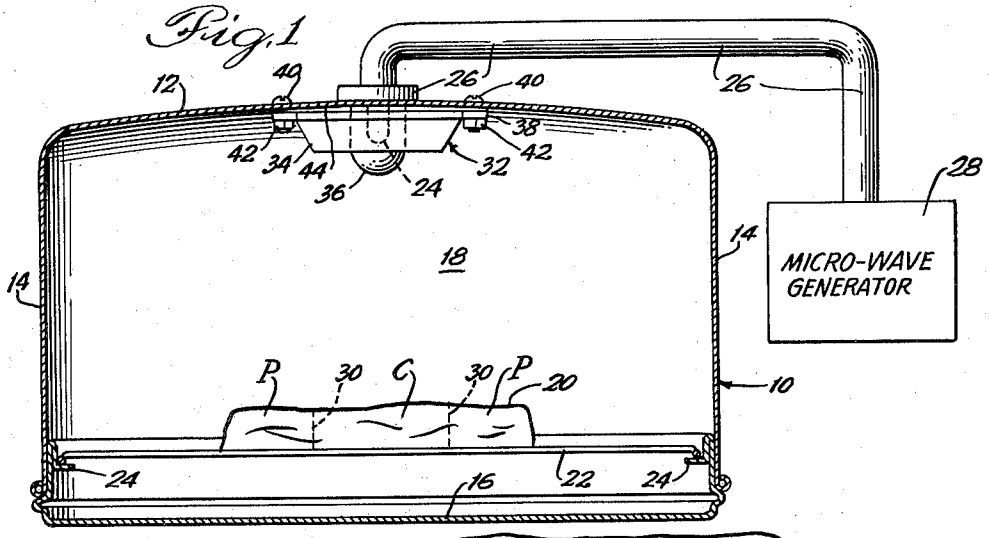


Fig. 2

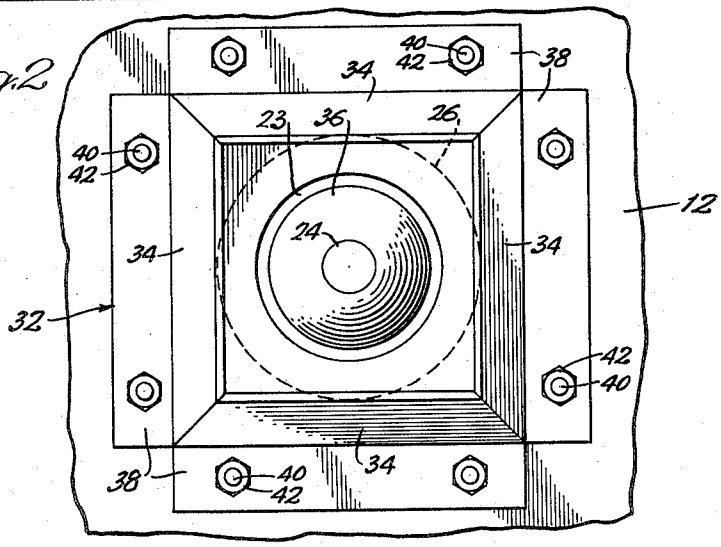
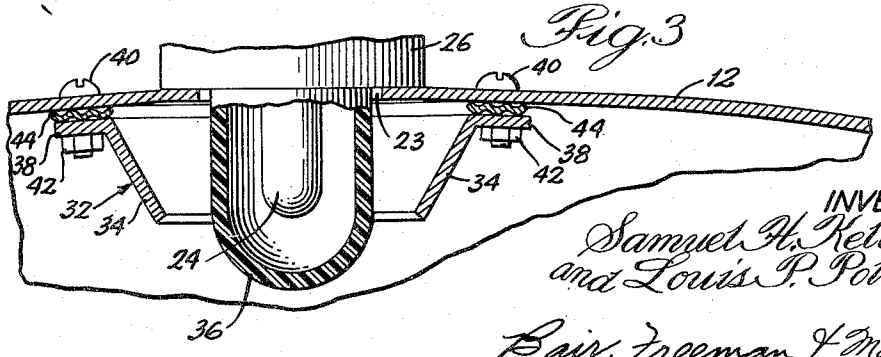


Fig. 3



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MICROWAVE HEATING APPARATUS

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Fig. 4

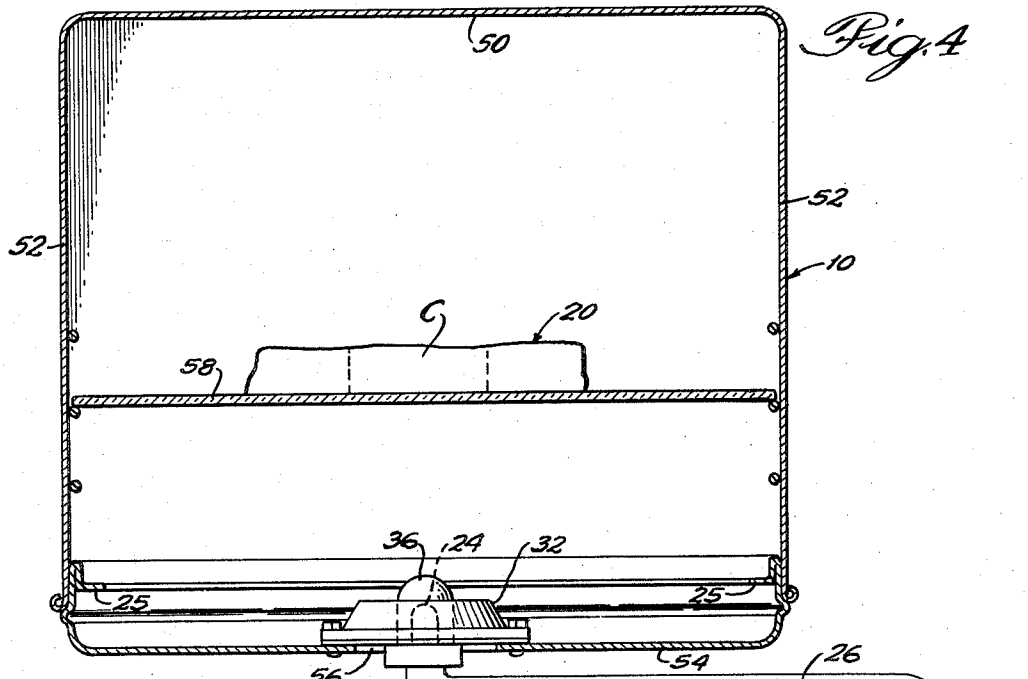
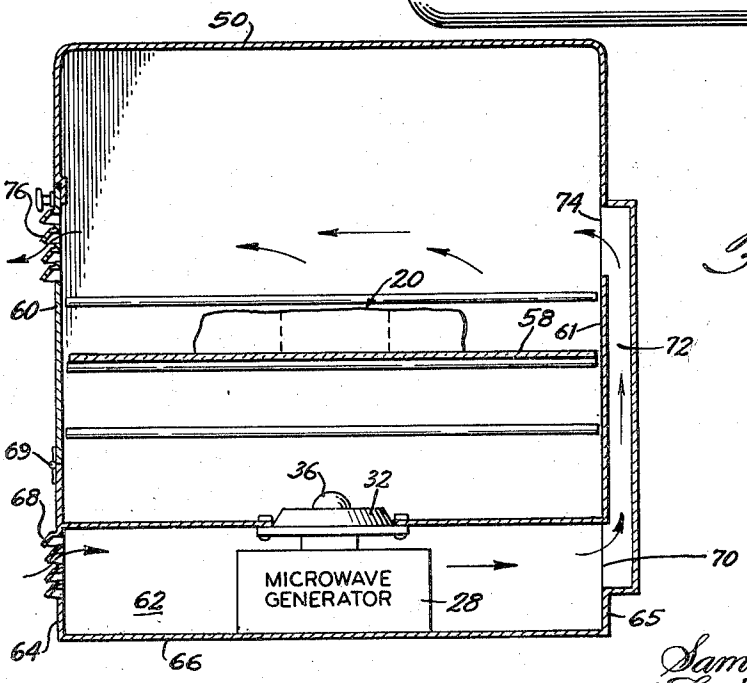


Fig. 5



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United States Patent Office 3,127,494 Patented Mar. 31, 1964

3,127,494

MICROWAVE HEATING APPARATUS

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Filed Mar. 13, 1961, Ser. No. 97,407
9 Claims. (Cl. 219—10.55)

This invention relates generally to microwave hearing apparatus and more particularly to new and improved means for properly concentrating the microwave energy within an oven to provide uniform heating of lossy dielectric articles therein.

This application is a continuation-in-part of my copending application, Serial No. 49,627, filed August 15, 1960, now abandoned.

It is known to provide relatively fast heating of lossy dielectric articles by the use of high frequency energy in the microwave range. While microwave ovens have been made commercially available in the past, their acceptance by the public has been impeded for several different reasons.

One factor which has proved a problem area in the acceptance of prior art microwave ovens is the difficulty of obtaining proper energy distribution within the microwave oven so as to provide uniform heating and cooking of the lossy dielectric articles therein. Due to the characteristics of microwave energy, it has been found in the cooking of food articles, for example, that the peripheral portions of the food articles tend to be heated at a much higher rate than the center portions, with the result that the center portion is undercooked when the peripheral portion is properly cooked, or alternatively, the peripheral portion must be overcooked to obtain proper cooking of the center portion. In the past, various means have been proposed for evenly distributing microwave power in an empty cavity—such as reciprocating reflector plates, paddle wheel stirrers, etc.—but to date no truly satisfactory solution has been found to evenly distribute microwave energy within a lossy dielectric positioned for heating in the cavity.

Accordingly, it is a general object of this invention to provide new and improved microwave heating apparatus for achieving more uniform heating of lossy dielectric articles within an oven.

It is another object of this invention to provide new and improved microwave cooking apparatus, as above, having unique means for concentrating the microwave energy at a desired portion of the food articles to evenly distribute microwave power throughout the food articles and thereby obtain uniform cooking of such food articles.

In accordance with a feature of one illustrative embodiment of this invention, the oven comprises a nonresonant cavity defined by a plurality of walls of electrically conductive material forming a heating chamber and having a door through which the articles of food or other lossy dielectrics to be heated are placed in the chamber. Microwave frequency electromagnetic fields are provided in the heating chamber for cooking the food articles by means of any suitable high frequency generator coupled to the oven.

Advantageously, the high frequency generator may take the form of a microwave tube having a tubular output probe radiator. The output probe is enclosed in glass or other low loss insulating material and extends into the heating chamber to radiate microwave energy therewithin. Alternatively, the high frequency generator may be coupled to a waveguide which terminates in a microwave radiator inserted in the oven heating chamber through an aperture formed in one of the chamber walls. Preferably, the microwave radiator would be enclosed by a suitable corrosion resistant low loss dielectric housing, such as some types of glass or plastic, to afford protection of the radiator from adverse effects which may arise during the operation of the cooking apparatus.

It is a salient feature of this invention that the microwave energy output from the radiator be concentrated in a particular manner to provide uniform heating of the articles within the oven so as to eliminate the undesirable results of the peripheral heating characteristic of the prior art devices. This highly desirable end is achieved by means of a unique concentrating device positioned about the microwave radiator and its housing.

In accordance with one illustrative embodiment of the invention, the concentrating device comprises an integrally formed tapered concentrator having an opening of relatively large diameter which tapers inwardly from the wall of the oven to an opening of smaller diameter positioned near the output end of the microwave radiator. In the operation of the invention, this tapered concentrator causes the load—such as the food articles to be cooked—to be heated in a uniform manner throughout its bulk.

In accordance with a further feature of the invention, the tapered concentrator advantageously may be formed of plastic coated silver plated brass and is secured to the oven wall by welding or by means of corrugated copper foil so as to insure maximum electrical conductivity and contact for optimum efficiency.

Thus, it is a further object of this invention to provide new and improved microwave cooking apparatus which comprises a tapered concentrator positioned around and operatively associated with a microwave radiator within an oven for achieving uniform heating of an article of food within the oven.

It is a still further object of this invention to provide such a tapered concentrator for a microwave radiator in a microwave oven which is secured to the oven wall by welding or by means of corrugated copper foil so as to assure maximum contact and optimum efficiency of the apparatus.

It is still another object of this invention to provide uniform cooking within a microwave oven by means of a tapered concentrator which is characterized by its relatively low cost of manufacture and its relatively high efficiency of use.

It is a still further object of this invention to provide new and improved microwave cooking apparatus having means for removing steam from the heating chambers, as it is given off by the cooked food articles, through the utilization of a stream of high temperature, low velocity air which has already served to cool the heating components of the oven.

The novel features which are characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following description taken in conjunction with the accompanying drawing in which:

FIGURE 1 is a front elevational view, partly in cross-section, and partly in block diagram form, of a microwave oven incorporating the invention;

FIGURE 2 is a top plan view of one illustrative embodiment of tapered microwave concentrator constructed in accordance with the invention;

FIGURE 3 is a side elevational view, partly broken and partly in cross-section, showing the details of an illustrative embodiment of tapered microwave concentrator in accordance with the invention;

FIGURE 4 is an illustrative view of another alternative embodiment of a microwave oven having a tapered

microwave concentrator positioned at the bottom center wall of the heating chamber; and

FIGURE 5 is a view illustrating the method of removing steam from the heating chamber by utilizing a stream of high temperature low velocity air which has already served to cool the heating components of the oven.

Referring now to the drawing, and more particularly to FIGURE 1, thereof, there is shown one preferable embodiment of microwave oven **10** which for purposes of illustration is depicted with an article of food **20** positioned for cooking therein. Advantageously, the microwave oven **10** comprises a shaped top wall **12**, side walls **14**, and a bottom wall **16**, all of which define a heating chamber **18** therewithin. The particular construction of the oven **10** may take any suitable form or shape as will be apparent to those skilled in the art. In accordance with customary practice, the oven **10** will have a door provided in the front wall thereof for enabling the articles of food **20** to be inserted in cooking position therein.

As shown in FIGURE 1, the oven **10** is provided with a suitable shelf **22** which is supported by the flanges **25** extending along the side walls **14** of the oven **10**. If desired, the height of shelf **22** may be adjustable, as by providing additional flanges **25** on side walls **14**, to enable the articles to be cooked to be positioned at any suitable height, provided the shape of the microwave concentrator is properly related to the selected height to provide uniform cooking of the food articles on the shelf **22**.

Advantageously, the top wall **12** of oven **10** is formed with an opening **23**, shown in FIGURE 3, through which a microwave energy probe or radiator **24** enclosed within a suitable protective housing **36** is inserted. As known to those skilled in the art, the microwave energy probe **24** may be the output probe of a microwave tube suitably enclosed in a glass, or low loss insulating material housing, or alternatively, the probe **24** may be coupled, by means of a waveguide **26**, to a source of microwave energy, such as the microwave generator **28**. The details of the microwave generator have not been shown herein since the generator is of a conventional type and may employ any suitable source of microwave energy, such as the magnetron tube or the like.

An article of food to be cooked, such as the lossy dielectric article **20**, is adapted to be supported by the shelf **22** within the oven **10**. Those skilled in the art will appreciate that due to the inherent characteristics of microwave energy, the articles **20** normally will not be heated in a uniform manner. Rather, there will be a tendency for the peripheral portions of the article **20** to be heated at a much higher rate than the center portion of the article **20** to the end that the peripheral portion of the article **20** will be cooked before its center portion will be cooked.

This is illustrated in FIGURE 1 of the drawing, wherein the article **20** is divided by the dotted lines **30** into a peripheral portion P and a center portion C. In practice, it has been found that the portion P will be heated almost exclusively and the portion C will be raw or greatly undercooked at the time when the portion P is sufficiently cooked or heated.

This highly undesirable result is eliminated in accordance with a novel feature of this invention by the provision of a unique tapered concentrator **32** positioned about the microwave energy probe **24**. As shown in greater detail in FIGURES 2 and 3 of the drawing, the tapered concentrator **32** comprises a plurality of tapered walls which are joined to form a rigid unitized assembly. The walls **34** of the concentrator **32** taper downwardly and inwardly from an opening of relatively large cross-section at the upper portion of the concentrator **32** to an opening of small cross-section at the lower portion of the concentrator **32**.

The upper and lower openings defined by the concentrator walls **34** advantageously are coaxially aligned and the protective housing **36** for the microwave energy probe **24** is positioned through said openings. In the operation of the invention, the tapered concentrator **32** serves to focus or concentrate the microwave energy output of the radiator probe **24** towards the center portion C of the article of food **20**, thereby compensating for the normal faster heating rate at the peripheral portion P thereof. As a result, the heat distribution is uniform throughout the article **20** and it will be cooked in an even and uniform manner.

It is important that the microwave energy tapered concentrator **32** be made rigid and highly conductive. To this end, in one illustrative embodiment of the invention, the walls of the tapered concentrator **32** are formed of silverplated brass and the concentrator is secured or mounted to the upper wall **12** of the oven **10** in a manner to provide maximum contact between the concentrator **32** and the oven. Since the surface of the silverplated brass concentrator may tarnish and alter the heating pattern, it advantageously may be encased in a low loss, electrically transparent plastic material.

In accordance with a feature of this invention, each of the tapered walls **34** of the concentrator **32** is provided with a horizontally extending flange **38** which is fastened to the upper wall **12** of the oven **10** as by means of a suitable fastener such as the threaded bolts **40** and nuts **42** associated with each flange **38**.

The contact between the flanges **38** of the tapered concentrator and the wall **12** of the oven **10** advantageously is optimized by means of welding or alternatively by means of a corrugated metal sheet material, such as the copper foil **44**, which is positioned between each flange **38** and the wall **12** of the oven **10**.

It will be appreciated by those skilled in the art that normally the junction of the flanges **38** and the oven wall **12** will not necessarily assure maximum contact therebetween due to bends, imperfections, indentations and the like which may be present in the structures. Thus, it is useful to either weld the flanges to the oven wall or to provide corrugated copper foil between the flanges **38** and the wall **12**, which foil will be compressed when the bolts **40** and nuts **42** are tightened to provide maximum contact between the flanges and the oven wall.

In addition to the above features, it is contemplated that the loading adjustment or the microwave generator to load coupling may be varied by properly selecting the cross-section of the tapered concentrator **32**. If the transverse cross-section of the tapered concentrator **32** is adjusted so that the tapered walls **34** are either nearer to or further from the input probe **24**, the tube-to-load coupling may be varied, thereby varying the microwave power input to the load.

In one particular embodiment of microwave concentrator which has been constructed and operated successfully in a microwave oven, microwave energy at a frequency of 2,450 megacycles was supplied from the microwave generator source and the concentrator to deliver about 1,000 watts of power to the load, and approximately four times as much power/cubic inch was delivered to the center volume C of the food article **20** as was delivered to the peripheral portion P thereof. This served to compensate for the inherent tendency of the microwave oven to heat the peripheral portion at a faster rate, and uniform cooking of the article of food **20** was achieved.

In a particular illustrative embodiment, wherein the tapered concentrator comprised tapered walls **34** of approximately one inch in length and wherein the bottom opening of the concentrator measured approximately 3¼ inches across, and wherein the angle of taper was approximately 25 degrees, a piece of meat approximately 6 inches by 8 inches in area was cooked in uniform manner with the power energy output being concentrated at a 3½ inch square central portion thereof.

Those skilled in the art now will appreciate that the microwave concentrator may be shaped in a manner other than as illustrated herein in accordance with the principles

of the invention. Thus, a microwave concentrator of parabolic or modified parabolic form might be used to provide the uniform heating results described above.

It further will be appreciated by those skilled in the art that the microwave concentrator may be positioned in walls of the oven other than the top wall installation shown in the illustrative embodiment of FIGURE 1. Thus, FIGURE 4 of the drawing is an illustrative view of another alternative embodiment of the invention having the novel tapered concentrator described hereinabove positioned at the bottom wall of the heating chamber.

This bottom mounted embodiment is of particular advantage in certain microwave oven constructions where a top wall installation may result in a degree of power concentration which is highly sensitive to the dimensions and taper of the concentrating wave guide. In accordance with a feature of this invention, this sensitivity and any undesirable effects resulting therefrom are avoided by locating the microwave input probe and tapered concentrator walls at the bottom of the heating chamber.

As shown in FIGURE 4 of the drawing, the microwave oven **10** is formed with the top wall **50** and side walls **52**, with no openings in top wall **50** of the type shown in the previous figures. However, the bottom wall **54** of the oven is formed with an opening **56** through which a microwave energy probe **24**, enclosed within a suitable protective housing **36**, is inserted. In the manner set forth in detail hereinabove, the microwave energy probe **24** and its housing **36** are enclosed by a tapered concentrator **32** to focus or concentrate the microwave energy output of the probe **24** towards the center portion C of the article **20** to be heated within the oven chamber. Due to the advantageous characteristics of the concentrator **32**, as explained above, the heat distribution throughout the article **20** is uniform and the article **20** will be cooked in an even and rapid manner.

Advantageously, the microwave oven may be provided with support rods **59** which extend longitudinally along the side walls **52** of the oven for supporting a suitable shelf **58**, formed of Pyrex or the like, upon which the article of food **20** is positioned. Manifestly, the height of the shelf **58** may be adjustable, as by providing a plurality of spaced support rods **59** on the side walls **52**, to enable the articles of food to be positioned at a desired height relative to the microwave concentrator and probe assembly.

In the actual manufacture and use of microwave ovens constructed in accordance with the illustrative embodiment of FIGURE 4, it has been found that the degree of power concentration is not as sensitive to the dimensions and taper of the concentrating wave guide as that which may be present in some top wall concentrator mountings. As a result, the manufacturing tolerances of the microwave concentrator are not particularly critical and the microwave oven is not limited to any particular dimensions and taper of the concentrator, or to any particular dimensions and slope of the oven cavity walls.

In accordance with a still further feature of this invention, the microwave oven may be constructed in such a manner as to permit the steam given off by the cooked articles to be removed from the cavity in a highly efficient and economical manner. Thus, as shown in FIGURE 5 of the drawing, the microwave oven may take the form generally described hereinabove with respect to the prior embodiments wherein the oven is formed by a top wall **50**, side walls **60** and **61** and bottom wall **54**. In this case, side wall **60** may be the front wall of the oven which is selectively operable, as at the hinged connection **69**. Bottom wall **54** is formed with a suitable opening **56** through wihch a microwave energy concentrator **32** is positioned. The microwave radiating probe is coupled to a suitable microwave generator **28** for enabling microwave energy to be distributed in an advantageous manner in the microwave oven for uniform cooking of the article **20** supported on the shelf **58**.

In this embodiment, it will be noted that the microwave generator **28** is positioned within a lower components chamber **62** defined by the walls **64**, **65** and **66** beneath the heating cavity of the microwave oven. An air intake opening **68** is provided in the front side wall **64** and an air outlet opening **70** is provided in the rear side wall **65**. The air outlet opening **70** is coupled by means of a suitable conduit **72** to an opening **74** in the microwave oven chamber. In addition, the front wall **60** of the microwave oven chamber is provided with an air outlet opening **76** to define an air flow path through the lower chamber past the microwave generator **28**, up through the conduit **72** and across the microwave oven cavity for exit at the opening **76**.

In the operation of this particular embodiment of the invention, the air taken in through the opening **68** in the components chamber **62** passes the microwave generator **28** and its associated components to cool the latter and to reduce the heat generated thereat. This stream of low velocity, low temperature air becomes a stream of low velocity, high temperature air in cooling the microwave generator components, and further serves to remove the steam given off by the cooked objects within the microwave oven cavity as the air stream passes through the latter.

Thus, the high humidity air normally present in the heating cavity during the cooking operation is constantly removed by an air stream which has already served to cool the microwave generator components.

It has been found that a microwave oven constructed in accordance with this particular embodiment materially alleviates the problem of water condensation within the microwave oven cavity by the use of the high temperature, low relative humidity, low velocity air stream which sweeps the steam out the front of the oven.

While there has been shown and described a specific illustrative embodiment of the present invention, it will of course, be understood that various modifications and alternative constructions may be made without departing from the true spirit and scope of the invention. Therefore, it is intended to cover by the appended claims all such modifications and alternative constructions as fall within their true spirit and scope.

What is claimed as the invention is:

1. In microwave heating apparatus, the improvement of means for providing uniform heating of articles within a heating chamber comprising a microwave oven formed of a plurality of walls defining a heating chamber, shelf means positioned within said heating chamber for receiving articles of food to be cooked, a probe receiving opening formed in one of said walls, a source of microwave energy, a microwave energy radiating probe coupled to said source of microwave energy and positioned through said opening so as to extend into said heating chamber in heating relationship with the articles of food upon said shelf means, a microwave energy concentrating means positioned within said heating chamber and around said probe for concentrating the energy radiated therefrom to provide uniform cooking of said articles of food, said concentrating means comprising a plurality of tapered walls assembled into a rigid, unitary structure, said tapered walls defining an opening of relatively large cross-section adjacent a wall of the oven and tapering inwardly to an opening of relatively smaller cross-section adjacent the innermost end of said probe, and means for rigidly securing said concentrating means to a wall of said oven.

2. In microwave heating apparatus, the improvement of means for providing uniform heating of articles within a heating chamber comprising a microwave oven formed of a plurality of walls defining a heating chamber; shelf means positioned within said heating chamber for receiving articles of food to be cooked, a probe receiving opening formed in one of said walls, a source of microwave energy, a microwave energy radiating probe coupled to said source of microwave energy and positioned

through said opening so as to extend into said heating chamber in heating relationship with the articles of food upon said shelf means, microwave energy concentrating means positioned around said probe for concentrating the energy radiated therefrom to provide uniform cooking of said articles of food, said concentrating means comprising a plurality of tapered walls assembled into a rigid, unitary structure, said tapered walls defining an opening of relatively large cross-section adjacent a wall of the oven and tapering inwardly to an opening of relatively smaller cross-section adjacent the innermost end of said probe, means for rigidly securing said concentrating means to a wall of said oven, and means for providing optimum contact between said concentrating means and said oven comprising a layer of corrugated copper foil positioned therebetween.

3. In microwave heating apparatus, the improvement of means for providing uniform heating of articles within a heating chamber comprising a microwave oven formed of a plurality of side walls, a bottom wall and a shaped top wall, said walls defining a heating chamber, shelf means positioned within said heating chamber for receiving articles of food to be cooked, a probe receiving opening formed in one of said walls, a source of microwave energy, a microwave energy radiating probe coupled to said source of microwave energy and positioned through said opening so as to extend into said heating chamber in heating relationship with the articles of food upon said shelf means; microwave energy concentrating means positioned around said probe for concentrating the energy radiated therefrom to provide uniform cooking of said articles of food, said concentrating means comprising a plurality of tapered walls assembled into a rigid, unitary structure, said tapered walls defining an opening of relatively large cross-section adjacent a wall of the oven and tapering inwardly to an opening of relatively smaller cross-section adjacent the innermost end of said probe, whereby the cross-section of said concentrating means decreases as a linear function of its height from said relatively large opening to said relatively small opening, means for rigidly securing said concentrating means to a wall of said oven comprising a flange member connected to each of said tapered walls, and fastening means attaching said flange members to the oven walls, and means for providing optimum contact between said concentrating means and said oven comprising a layer of corrugated copper foil positioned between each flange member and the oven wall.

4. In microwave heating apparatus, the improvement of means for providing uniform heating of articles within a heating chamber comprising a microwave oven formed of a plurality of walls defining a heating chamber, shelf means positioned within said heating chamber for receiving articles of food to be cooked, a probe receiving opening formed in one of said walls, a source of microwave energy, a microwave energy radiating probe coupled to said source of microwave energy and positioned through said opening so as to extend into said heating chamber in heating relationship with the articles of food upon said shelf means, microwave energy concentrating means positioned around said probe for concentrating the energy radiated therefrom to provide uniform cooking of said articles of food, said concentrating means comprising a plurality of inwardly tapered walls assembled into a rigid, unitary structure, means for rigidly securing said concentrating means to a wall of said oven comprising a flange member connected to each of said tapered walls, and fastening means attaching said flange means to the oven wall, and means for providing optimum contact between said concentrating means and said oven comprising a thin flexible metal sheet positioned between each flange member and the oven wall.

5. Microwave heating apparatus in accordance with claim 4 wherein said thin metal sheet comprises corrugated copper foil.

6. In microwave heating apparatus, the improvement of means for providing uniform heating of articles within a heating chamber comprising a microwave oven formed of a plurality of walls defining a heating chamber, shelf means positioned within said heating chamber for receiving articles of food to be cooked, a probe receiving opening formed in one of said walls, a source of microwave energy, a microwave energy radiating probe coupled to said source of microwave energy and positioned through said opening so as to extend into said heating chamber in energy heating relationship with the articles of food upon said shelf means, a protective housing of energy transparent material positioned around said probe within the heating chamber, microwave energy concentrating means positioned around said probe and said protective housing for concentrating the energy radiated therefrom to provide uniform cooking of said articles of food, said concentrating means comprising a plurality of tapered walls defining an opening of relatively large cross-section and tapering inwardly to an opening of relatively smaller cross-section whereby the cross-section of said concentrating means decreases as a linear function of its height from said relatively large opening to said relatively small opening, means for rigidly securing said concentrating means to a wall of said oven, and means for providing optimum contact between said concentrating means and said oven comprising a layer of flexible conductive material positioned therebetween.

7. In microwave heating apparatus, the improvement of means for providing uniform heating of articles within a heating chamber comprising a microwave oven having top, bottom and side walls defining a heating cavity, shelf means positioned within said oven for receiving articles of food to be cooked, a probe receiving opening formed in a wall of said oven, a source of microwave energy, a microwave energy radiating probe coupled to said source of microwave energy and positioned through said opening, microwave energy concentrating means positioned within said heating chamber and around said probe for concentrating the energy radiated therefrom to provide uniform cooking of said articles of food, said concentrating means comprising a plurality of tapered walls defining an opening of relatively large cross-section and tapered inwardly to an opening of relatively smaller cross-section, and means for rigidly securing said concentrating means to a wall of said oven.

8. In microwave heating apparatus, the improvement of means for providing uniform heating of articles within a heating chamber comprising a microwave oven formed of a plurality of top, bottom and side walls defining a heating chamber, shelf means positioned within said heating chamber for receiving articles of food to be cooked, a probe receiving opening formed in a bottom wall of said heating chamber, a components chamber positioned below said bottom wall, a source of microwave energy within said components chamber, a microwave energy radiating probe coupled to said source of microwave energy and positioned through said opening so as to extend into said heating chamber in energy heating relationship with the articles of food upon said shelf means, a protective housing of energy transparent material positioned around said probe within the heating chamber, microwave energy concentrating means positioned around said probe and said protective housing for concentrating the energy radiated therefrom to provide uniform cooking of said articles of food, means for rigidly securing said concentrating means to a wall of said oven, said means providing optimum contact between said concentrating means and said oven, and means for first passing a stream of low velocity, low humidity air through said components chamber to cool the microwave energy source therein and for then passing the stream of air through said heating chamber to remove the steam therefrom.

9. In microwave heating apparatus, the improvement of means for providing uniform heating of articles within a heating chamber comprising a microwave oven formed

of a plurality of top, bottom and side walls defining a heating chamber, shelf means positioned within said heating chamber for receiving articles of food to be cooked, a probe receiving opening formed in a wall of said heating chamber, a components chamber positioned adjacent said heating chamber, a source of microwave energy within said components chamber, a microwave energy radiating probe coupled to said source of microwave energy and positioned through said opening so as to extend into said heating chamber in energy heating relationship with the articles of food upon said shelf means, a protective housing of energy transparent material positioned around said probe within the heating chamber, microwave energy concentrating means positioned around said probe and said protective housing for concentrating the energy radiated therefrom to provide uniform cooking of said articles of food, means for rigidly securing said concentrating means to a wall of said oven, said means providing optimum contact between said concentrating means and said oven, an air stream intake opening in said components chamber, an air stream exit opening in said heating chamber, and air conduit means connecting said components chamber with said heating chamber for enabling a stream of low velocity, low humidity air to be passed first through said components chamber for cooling the microwave energy source and then through said heating chamber for removing any steam therein.

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