Sept. 17, 1963 P. W. CRAPUCHETTES 3,104,303

MICROWAVE FREQUENCY HEATING APPARATUS

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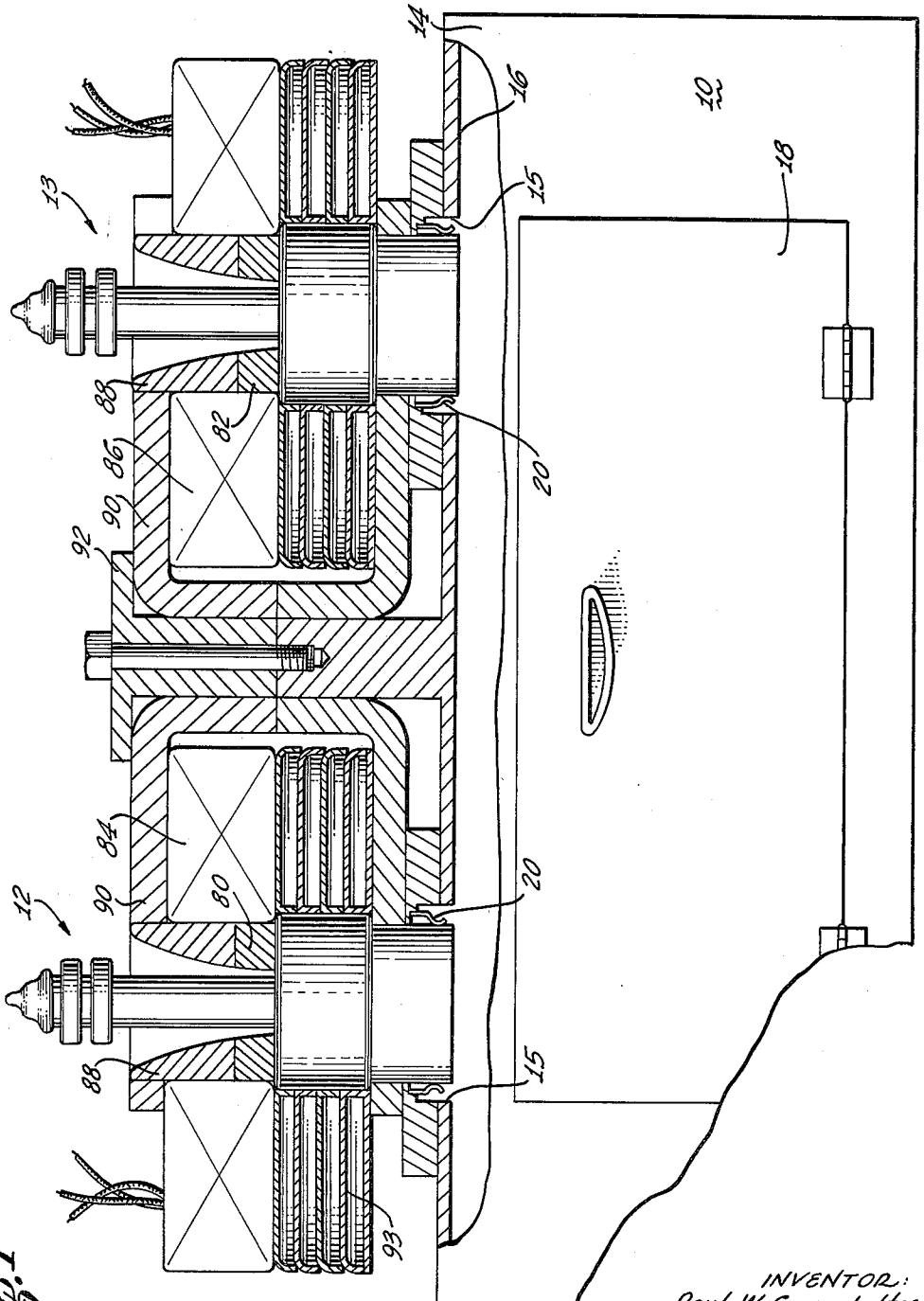


Fig. 1

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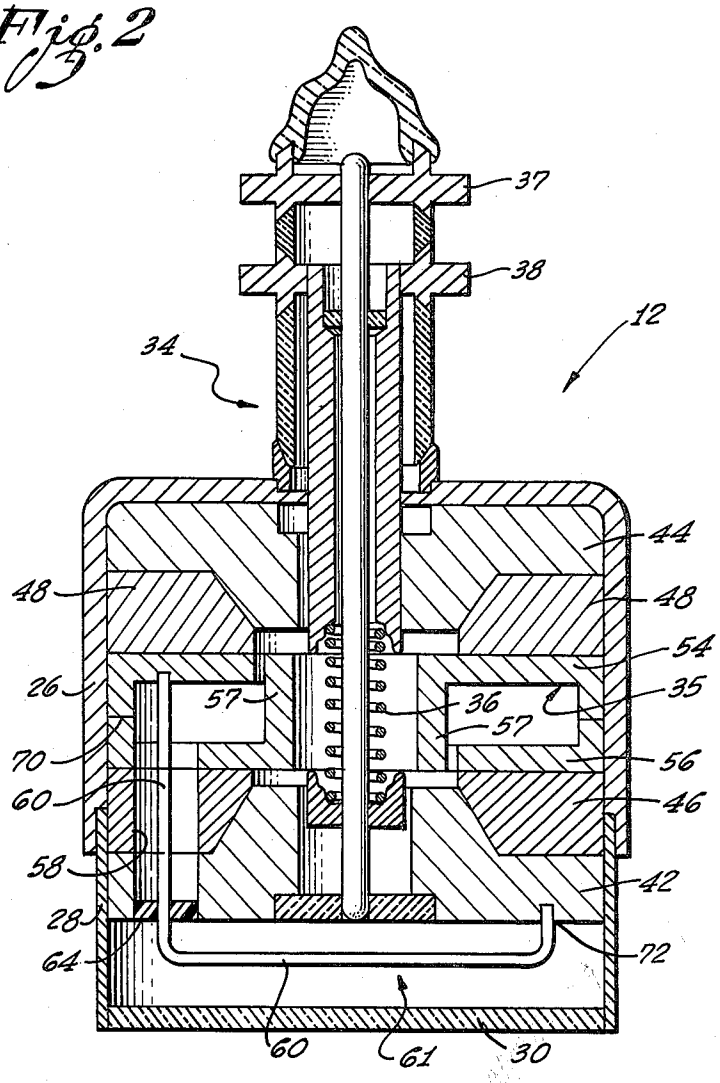
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MICROWAVE FREQUENCY HEATING APPARATUS

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Fig. 2



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MICROWAVE FREQUENCY HEATING APPARATUS

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Fig. 3

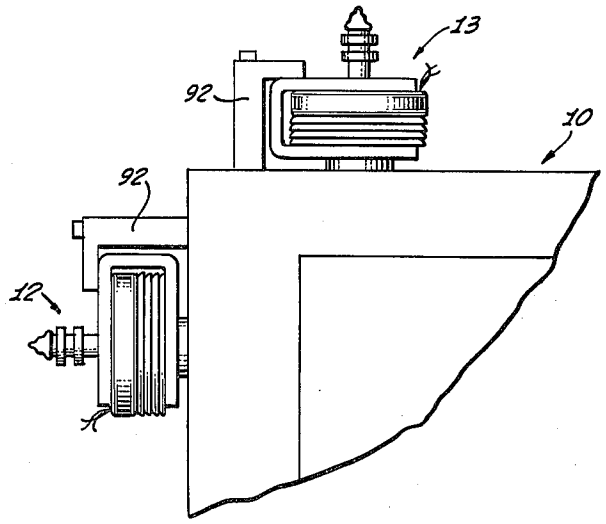
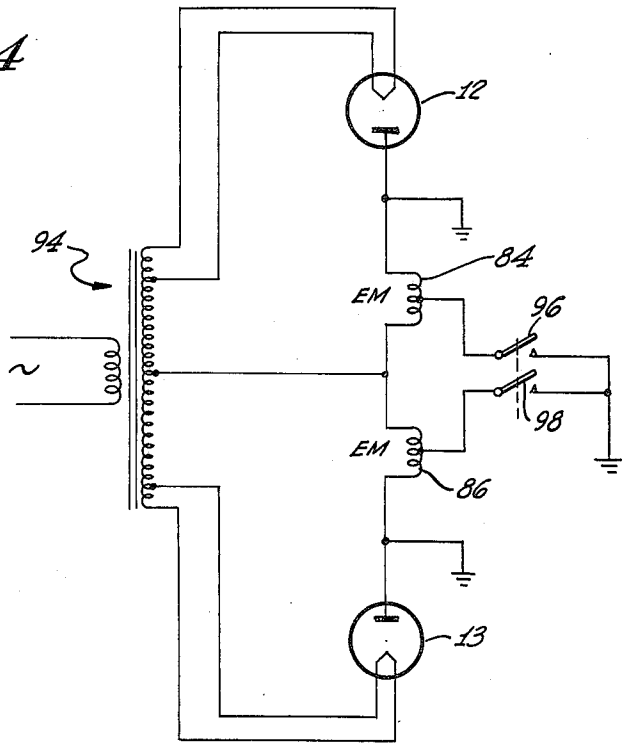


Fig. 4



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United States Patent Office 3,104,303
Patented Sept. 17, 1963

3,104,303
MICROWAVE FREQUENCY HEATING APPARATUS

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13 Claims. (Cl. 219—10.55)

This invention relates to microwave frequency heating apparatus, and more particularly to an improved microwave frequency heating apparatus which employs a microwave oven which is excited in one or more predetermined modes by at least one magnetron oscillator mounted flush within the walls thereof, and to the magnetrons therefor.

In existing ovens of the type which operate at microwave frequencies the heating thereof is achieved through the use of one or more high frequency energy sources which communicate energy to the oven through the use of a transmission network such as coaxial line or waveguide. In the prior art it has been found preferable to use magnetrons almost exclusively as the source of energy for the illumination of the oven, the microwave energy being extracted from the magnetron usually by means of an output coupling antenna which then forms the inner conductor of the output transmission line. More specifically, the coupling antenna usually consists of a coupling loop which has one end connected to the wall of the magnetron's resonant system, while the other end extends from the loop externally through the side wall of the magnetron along a path perpendicular to the axis of the magnetron tube. The coaxial output line is then used to either illuminate the oven directly through the use of conventional coaxial probes inserted into the oven through openings provided in the walls thereof, or to excite a hollow waveguide connected to the oven walls at some specific location where openings are provided for physically terminating the waveguide.

While such prior art configurations will function to supply the required energy to the associated oven cavity, there are nevertheless several serious disadvantages attendant their use. Firstly, from an economic standpoint the magnetrons generally envisaged for use with microwave ovens are of the type formerly associated almost exclusively with military applications, and are therefore relatively expensive to fabricate. Moreover, the utilization of high power coaxial lines and waveguide runs for introducing energy into the oven provides an additional cost factor which must be considered and also introduces electrical losses and reflections which effectively decrease the amount of power deliverably to the oven from any given tube. Secondly, from an operational point of view these coaxial lines and waveguide runs are known to operate as a resonant load when connected between the magnetron and the oven cavity, thereby presenting mismatches or standing waves to the magnetron which may cause it to oscillate unstably at a plurality of output frequencies. As a consequence, the oven cavity is excited with a plurality of unpredictable mode patterns corresponding to the spurious frequencies at which the magnetron oscillates. Thirdly, the use of additional waveguide runs and transitions decreases substantially the volumetric efficiency of the overall oven while simultaneously adding to the weight thereof.

In the prior art it has also been found through experience that certain undesirable difficulties arise when a system of two or more magnetrons operating at substantially the same frequency are employed for exciting an oven, these difficulties arising from the fact that when such magnetron devices each have substantially the same

output frequency, one of the devices tends to act as a low impedance across the output of the other due to slight dissimilarities between them, so that one of the magnetrons tends to absorb the microwave power of the other, or stated differently, acts as an additional load across the other instead of supplying microwave power to the common load of the cavity.

In the prior art, attempts have been made to avoid this latter limitation by the use of magnetrons which produce output signals at appreciably different frequencies, the theory behind this concept being that the tendency of one of the magnetrons to absorb microwave power from the other may be reduced to a level that is inappreciable. Although this method has been used with minor success, it has proven impractical for many applications, and requires that two different tube types be manufactured and stocked to insure adequate servicing.

The present invention obviates the foregoing and other disadvantages of the prior art by providing a microwave oven which is excited by one or more magnetrons mounted at preselected points in the oven walls, each of the magnetrons having an output window disposed substantially flush with an oven wall for launching energy directly into the oven. More particularly, in accordance with one of the basic features of the invention there is provided a magnetron having a resonant system which exhibits substantially uniform impedance from tube to tube and whose output energy waves are transmitted from the magnetron through an axially positioned output window suitable for mounting in the oven walls to directly excite the oven cavity. Moreover, as will be disclosed in more detail hereinbelow, the advantages derived through the utilization of an axially mounted output window are obtained through the use of a relatively simple magnetron structure which should provide an economic impetus to the manufacture and sale of microwave ovens in general.

In accordance with another of the basic concepts of the invention, there is provided a microwave oven which is excited directly by a pair of magnetrons whose inputs to the oven are positioned relative to each other so as to illuminate the oven alternately in two different modes without appreciable intercoupling, thereby providing means for obtaining relatively uniform energy distribution throughout the oven while simultaneously permitting the magnetrons to function at the same or relatively close frequencies of operation.

It is, therefore, an object of the invention to provide an improved microwave heating apparatus which employs direct excitation of a microwave oven.

Another object of the invention is to provide a metallic microwave oven which is excited by one or more magnetrons mounted within the walls of the oven to provide direct microwave illumination of the oven.

A further object of the invention is to provide a magnetron tube from which energy is extracted through an output window in a direction parallel to the axis of the tube.

Still another object of the invention is to provide a magnetron which employs an output window mounted coaxially with respect to the axis of the magnetron to provide direct coupling between the magnetron and an associated microwave oven into a wall of which the magnetron is mounted.

A further object of the invention is to provide a microwave oven wherein energy is coupled into the cavity alternately from a pair of magnetrons operating at or near the same frequency and positioned to provide excitation in two different modes for producing a relatively uniform power density within the oven.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and

advantages thereof, will be better understood from the following description considered in connection with the accompanying drawings in which several embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are intended for the purpose of illustration and description only, and are not intended to limit the scope of the invention.

FIGURE 1 is a fragmentary view, partly in cross-section, of a microwave oven illustrating the manner in which a pair of magnetron oscillators constructed in accordance with the invention may be mounted within one wall of the oven to provide uniform excitation thereof;

FIGURE 2 is an enlarged cross-sectional view of one of the magnetron oscillators shown in FIGURE 1 illustrating the structural details thereof;

FIGURE 3 is a fragmentary view, partly in cross-section, of a microwave oven which includes two associated magnetrons mounted within different oven walls, in accordance with the present invention, to provide uniform excitation thereof; and

FIGURE 4 is a schematic diagram of one form of power supply unit which may be employed for exciting two magnetrons in accordance with the teachings of the present invention.

With reference now to the drawings, wherein like or corresponding parts are designated by the same reference characters throughout the several views, there is shown in FIGURE 1 a microwave oven, generally designated **10**, only a portion of which is shown, and a pair of associated magnetron oscillator tubes **12** and **13**, constructed in accordance with the teachings of the invention, which are mounted directly in the oven wall and energized alternately to provide microwave energy to heat any lossy dielectric body which may be placed within the oven. As shown in FIGURE 1, oven **10** comprises two basic elements, namely, a metallic conductive enclosure **14** having a pair of spaced apertures **15** passing through one wall **16** for permitting the magnetron oscillators to be mounted therein, and an enclosure door **18** to provide a communicating passage for placing objects within the oven or for removing objects previously placed therein. It will be seen from FIGURE 1 that the oven is illuminated directly from the magnetrons **12** and **13** without the use of any additional microwave transmission components.

Considering now the specific elements of the microwave oven of the invention, enclosure **10** is preferably rectangular in form comprising six metallic walls. In the specific embodiment of FIGURE 1 enclosure door **18** is located in one of the side walls, while the top wall **16** includes apertures **15**, the configuration of the apertures depending upon the outline of the magnetrons utilized therewith. In actual practice each aperture **15** has associated therewith a suitable grounding mechanism, such as a plurality of spring fingers **20**, to insure good electrical contact between the oven wall and the magnetron. It will be seen, therefore, that the boundary walls of the enclosure and enclosure door present to the magnetrons a cavity resonator which is capable of resonating in any one of a plurality of modes and at a plurality of microwave frequencies. As will be disclosed in more detail below, the oven may be made to support oscillations in preferred mode configurations through proper selection of the dimensions of the enclosure, the position of each magnetron in the oven wall, and the frequency of operation of the magnetrons.

Consider now the construction of the magnetrons mounted in the microwave oven of FIGURE 1 and the manner in which they function to provide flush mounting capabilities. Referring now to FIGURE 2, there is shown a detailed view of a magnetron oscillator constructed in accordance with the teachings of the present invention, which includes means for directly transferring microwave energy from the resonant system of the magnetron to the

oven along a path concentric with the axis of the magnetron. As shown in FIGURE 2, the magnetron includes two cylindrical housing members **26** and **28** forming a tubular envelope which is enclosed at one end by an output window **30** and at the other end by a cathode terminal assembly generally designated **34**. As further shown in FIGURE 2, mounted within the envelope is a cylindrical anode structure, generally designated **35**, which surrounds a cathode **36** which is in turn electrically and mechanically connected to a pair of terminal members **37** and **38** which form part of cathode assembly **34**. In addition, the magnetron includes a pair of pole pieces **42** and **44** which are disposed on opposite ends of the anode structure and are spaced therefrom by a pair of pole piece spacers **46** and **48** fabricated from a non-magnetic material, such as copper.

It should be noted at this point that the configuration of housing element **26** and the placement of the various structural elements therein, in accordance with the invention, greatly facilitates construction and assembly of the magnetron. More specifically, it will be noted that housing member **26** has a general cup shaped configuration with an aperture for receiving the cathode assembly. In assembling the magnetron, therefore, there are successively placed within the housing **26** the pole piece **44**, spacer **48**, anode **35**, spacer **46** and pole piece **42**, thereby providing a sandwich type construction.

Considering now in more detail the construction of anode **35**, it will be noted that the anode is basically a hybrid form of interdigital structure comprising a pair of cup-like conjugate members which when placed together form a cavity enclosed at its ends by a pair of conductive end plates **54** and **56** positioned adjacent the opposite ends of the cathode **36** and perpendicular to the axis thereof. Each of the end plates has an aperture **55** in the central region thereof coaxial with the cathode, and a group of anode fingers **57** mounted about this aperture at uniformly spaced points and extending perpendicular from the plane of the associated end plate toward the other end plate. As further shown in FIGURE 2, the two cup-like anode members are positioned with respect to each other so that the two groups of anode fingers respectively associated with the two end plates are interleaved to form the anode inter-action structure of the interdigital anode **35**.

Considering now the novel output structure employed in the magnetron of this invention, energy is extracted from the magnetron's resonant system through a communicating passage **58** which extends through end plate **56**, spacer **46**, and pole piece **42** into the region **61** between pole piece **42** and output window **30**. More particularly, as viewed in FIGURE 2, the communicating passage is formed by an aperture eccentrically located in each of the foregoing elements, the apertures being drilled or otherwise formed to register with each other and thereby provide a passage substantially parallel with the tube axis, which extends from the inductive region of the magnetron anode to the region of the output window.

It should be noted at this point, that if desired, energy may be extracted directly from the magnetron through passage **58** by using the passage as a cylindrical waveguide into which the output energy propagates. However, in accordance with the preferred embodiment of the invention the output structure further comprises a conductor **60** which extends from the anode resonator, through passage **58** and into the region **61** adjacent output window **30** whereat it is terminated at a point **72** on the pole piece **42** to provide an output antenna for radiating energy through the output window. The other end of conductor **60**, on the other hand, is affixed to anode end plate **54** and functions as an energy pick-up or receiving antenna in the inductive region of the cavity resonator, the output energy thus produced being transmitted to the output antenna by the coaxial link formed by passage **58** and the central region of the conductor **60**. It will

be understood, of course, that if desired the central region of conductor **60** may be further supported within passage **58** through the use of a suitable insulating spacer, such as the spacer designated **64** in FIGURE 2.

In the operation of the magnetron the RF electric field set up in the resonant system functions to generate a current in conductor **60**, and energy is extracted through the coaxial link formed by passage **58** and is presented to the output antenna portion of conductor **60** in the region **61**. At this point, therefore, the conductor **60** functions in conjunction with the reflective back surface of pole piece **42** to produre a radiated field in response to the current flowing in the conductor. It should be noted, incidentally, that the process by which microwave oscillations are generated in the magnetron of the present device is substantially the same as that of conventional magnetrons, and therefore further discussions of the phenomena occurring in the electron inter-action gap is considered unnecessary.

Consider now the advantages of the construction of the magnetron of FIGURE 2 with respect to its use in magnetron ovens and the manner in which it provides flush mounting capabilities. In accordance with the invention the microwave energy generated within each magnetron is oriented uniquely by the antenna-like conductor **60** in such a manner that it may be launched in an output wave through the output window along a path which is coaxial with the axis of the magnetron. This novel feature of orientating the output energy wave differs substantially from that of the prior art devices and is utilized advantageously as described herein, to permit the magnetron to be mounted in the walls of the oven, thus eliminating the need for conventional lossy and inefficient transmission circuits and microwave plumbing traditionally associated with the microwave ovens of the prior art. A further advantage is derived from the fact that the novel construction of the magnetron output structure functions to permit the magnetron to be placed readily in any one of various locations within the oven walls to produce whatever mode pattern has been selected for the operation of the oven.

Returning now to the description of FIGURE 1, the static magnetic field requisite for magnetron operation is provided in part by a pair of annular permanent magnets **80** and **82** respectively associated with magnetrons **12** and **13**, and in part by a pair of electromagnets comprising two electromagnet coils **84** and **86** and associated magnetic return structures. It will be noted that each of the magnetic return structures includes an annular member **88** which engages the associated permanent magnet, and a yoke **90** which communicates magnetically with the opposite ends of the evacuated envelope of the associated magnetron, the yokes **90** further providing a surface for fastening the magnetrons in position with a suitable clamp **92**.

It will be further noted from FIG. 1 that in addition to the elements described previously, each of the magnetrons further comprises a plurality of annular cooling fins **93** which are preferably formed of a good heat conductor, such as copper, the fins being stacked together and affixed to the tubular body portion **26** of each of the magnetrons. While an air cooled system of this nature will be found satisfactory in most applications, it will of course be appreciated by those skilled in the art that an equivalent liquid cooling system could be employed with the basic magnetron construction shown in FIG. 2 without departing from the basic concept of the invention.

Consider now the factors which determine the position of the magnetrons in the oven wall **16** as shown in FIGURE 1. It will be recognized by those familiar with resonator design that the dimensions of the oven and the frequency of operation of the magnetrons both contribute to establish the number of mode patterns of the type TE_{lwh} which may be excited in the oven, and that the excitation of a preselected mode within the oven by a

particular magnetron is also dependent upon the excitation energy therefrom being introduced into the oven at a given point such that it has a particular space relationship to the fields of the mode pattern to be excited. Furthermore, it may be demonstrated that to achieve a relatively uniform power density throughout the oven it is preferable to excite the oven alternatively in two different modes whose field configurations overlap, and that to minimize any coupling between the two magnetrons each of the tubes should be located preferably at a point in the oven wall which appears substantially as a null in the mode pattern produced by the other tube.

In general the frequency range in which frequency of operation of the magnetrons must fall is preordained by the Federal Communications Commission. Accordingly, after the specific frequency at or around which the magnetrons will operate has been selected, it is only necessary to select two mode configurations for exciting the oven which are consistent with the criteria outlined above and which provide overall oven dimensions compatible with the size of conventional ovens for use in environments similar to that for which the microwave oven is intended. In additon, once the mode patterns of the type TE_{lwh} which are to be utilized in the oven are selected, the locations for placement of the magnetrons can be determined, and the magnetrons placed in spaced relationship to the fields of the mode to provide proper excitation of the oven. Since there are many possible modes in which the oven may operate for a given frequency, it is important that placement of the magnetrons be relatively accurate to insure proper coupling to the oven so that excitation occurs in the particular modes selected to provide uniform heating within the oven. Thus, as an added feature of the invention, the use of flush mounted magnetrons as shown in FIG. 1 facilitates placement of the magnetrons for coupling energy into the oven directly at the desired points through the use of the apertures **15** described hereinabove.

It is to be expressly understood, of course, that the invention may be practiced in manners other than that shown in the embodiment of FIGURE 1 by employing a plurality of magnetrons of the general form shown in FIGURE 2. With reference now to FIGURE 3, for example, there is shown a microwave cooker in accordance with the invention which includes an oven **10** and two magnetrons **12** and **13** for the illumination thereof, the magnetrons being positioned in adjacent walls of the oven. In this embodiment of the invention the magnetrons function in substantially the same manner and provide the same advantages as in the embodiment of FIGURE 1, one further advantage of the invention illustrated in FIGURE 3 being that the magnetrons may be placed in the various walls of the oven for special applications.

It will be recognized, of course, that numerous electrical circuits may be devised for energizing magnetrons **12** and **13** alternatively in time. With reference to FIGURE 4, for example, there is shown a magnetron power supply which comprises a power transformer **94** having a center-tapped secondary which is connected to the anodes of magnetrons **12** and **13** through a pair of respectively associated electromagnet windings **84** and **86**. The cathodes of the magnetrons, in turn, are each connected to the ends of the transformer secondary by a pair of asosciated conductors, the ends of the secondary further providing filament transformers for energizing the magnetron cathodes. In addition, as shown in FIGURE 4, the circuit further includes a pair of switch contacts **96** and **98** which are selectively operable in unison to short circuit a portion of electromagnet coils **84** and **86** to thereby provide means for varying the output power presented by the magnetrons through variation of the magnetic field applied to the associated tubes. It will be recognized by those skilled in the art that maximum power will be presented when the switches are in the small coil position since the transverse magnetic field in the tubes is

then held to a specified minimum, whereas a smaller amount of power will be presented when the full transverse magnetic field is applied to the tubes.

It is to be understood, of course, that alterations and modifications may be made in the structure and circuits shown without departing from the spirit and scope of the invention. For example, it is clear that the concepts disclosed herein are equally applicable for use with a pair of magnetrons placed in opposite walls of the oven, for operation of the magnetrons at substantially different frequencies, or for the use of more than two magnetrons as an energy source. It should be emphasized, therefore, that the spirit and scope of the invention is to be limited only by the spirit and scope of the appended claims.

What is claimed as new is:

1. The combination of a microwave oven and a plurality of magnetron oscillators to drive said oven in a plurality of respective modes each having at least one null point, said combination comprising: a microwave oven having a plurality of metallic walls defining a cavity resonator; a first magnetron oscillator for illuminating said oven with microwave energy, said magnetron including a substantially cylindrical housing member having an axis and first and second ends, a cathode, means enclosing said first end of said housing member for mounting said cathode in said member concentric with said axis, an anode member defining a resonator system concentrically surrounding said cathode, said resonator system including at least one cavity resonator means including an output window transparent to microwave energy enclosing said second end of said housing member, and means for extracting microwave energy from said anode member and launching said energy in an output wave through said output window; and means positioned at a null point of a resonant mode of a second magnetron oscillator for mounting the first magnetron in one of said walls of the oven with said output window substantially flush with said one wall whereby said oven is excited in a mode of preselected orientation relative to the resonant mode of said second magnetron oscillator.

2. The combination defined in claim 1 which further includes a second magnetron oscillator having an output window, and second means positioned along one of said metallic walls at a null point of said resonant mode of said first magnetron oscillator for mounting said second magnetron therein whereby said oven is excited in a second mode of preselected orientation.

3. The combination defined in claim 2 wherein said magnetron oscillators are positioned relative to each other and to said oven walls to energize said oven in two different modes, and which further includes means for energizing said magnetron oscillators alternately in time.

4. The combination comprising: a metallic enclosure whose interior boundary walls define a cavity resonator resonant at microwave frequencies and in a plurality of modes, in which a lossy dielectric body may be placed to be heated, a magnetron for generating microwave energy, said magnetron having an axis and including an axially mounted cathode, an anode structure positioned concentrically around said cathode, said anode defining at least one cavity resonator, means including a substantially flat output window coaxial with said cathode for extracting the microwave energy from said anode resonator, and means for mounting said flat magnetron output window with its exposed surface substantially flush with one wall of said cavity resonator in a preselected location to provide direct coupling of the microwave energy into the interior of said metallic enclosure and to excite a preselected mode therein.

5. The combination comprising: a microwave oven having a plurality of boundary walls defining a cavity resonator resonant in a plurality of modes; a plurality of magnetron oscillators each having an interdigital anode structure for generating microwave energy, each oscillator cooperating with said cavity to provide a different output mode from each of said oscillators; means for energizing said oscillators alternately; and means for mounting said oscillators flush within the oven walls at two different places for coupling the microwave energy of said oscillators directly into the interior of the oven to excite the same in at least two of said modes and to prevent substantially the exchange of energy between said magnetron oscillators, said oscillators transmitting microwave energy to the interior of said area alternately during different periods to provide uniform average energy at substantially all points within the oven, such that said microwave oven is excited in at least two different modes of the form TE_{lwh} during said different periods, where l, w and h are integers of predetermined values.

6. The combination comprising: a microwave oven having a plurality of boundary walls defining a cavity resonator resonant in a plurality of modes; a plurality of magnetron oscillators each having an interdigital anode structure for generating microwave energy, each oscillator cooperating with said cavity to provide a different output mode from each of said oscillators; means for energizing said oscillators alternately; and means for mounting said oscillators flush within the oven walls at two different places for coupling the microwave energy of said oscillators directly into the interior of the oven to excite the same in at least two of said modes and to prevent substantially the exchange of energy between said magnetron oscillators, said oscillators transmitting microwave energy to the interior of said area alternately during different periods to provide uniform average energy at substantially all points within the oven, the dimensions of said oven, the position of said magnetrons in said oven walls, and the frequency of operation of said magnetrons being chosen to provide excitation of said oven in the TE_{lwh} mode by one of said magnetrons and in the $TE_{l'w'h'}$ mode by the other of said magnetrons, where the terms l, l', w, w', h and h' are integers and at least two of said terms l, w and h have different integer values than the corresponding two prime terms.

7. In a magnetron oscillator, the combination comprising: a substantially cylindrical housing member having an axis; a cathode; mounted in said member concentric with said axis; an anode member mounted within said housing member concentric with said cathode, said anode member defining at least one cavity resonator; means including an output window transparent to microwave energy enclosing one end of said housing member; and means including a transmission iris and a continuous passage extending from within said cavity resonator and parallel to said axis for extracting microwave energy from said anode member and axially launching said energy in an output wave through said output window.

8. In a magnetron the combination comprising: a cylindrical cathode structure, an anode defining a resonant cavity concentrically surrounding said cathode structure to form a cylindrical interaction space between said anode and cathode, a pair of magnetic pole-pieces, one adjacent each end of said interaction space and forming parts of a magnetic circuit adapted to provide a magnetic field substantially parallel to said cathode structure, one of said pole-pieces having a microwave energy transmission aperture passing therethrough eccentric with respect to said cathode and forming a section of a continuous transmission line passage extending parallel to said magnetic field and longitudinally of said cathode structure from within said resonant cavity to provide a communicating opening for extracting microwave energy from said resonant cavity and longitudinally of said cathode structure.

9. A magnetron comprising: a vacuum envelope, said envelope including a cylindrical housing member having first and second ends, an output window electrically transparent to microwave energy hermetically enclosing said first end of said housing member, and a cathode terminal assembly hermetically enclosing said second end of said housing member; a cathode mounted axially within said

cylindrical housing member by said terminal assembly; a cylindrical anode structure defining a resonant cavity for generating microwave energy, said anode having an inductive portion and first and second ends parallel to said output window and being positioned within said housing member to concentrically surround said cathode for providing an interaction space between said cathode and anode; a pair of magnetic pole-pieces one adjacent each end of said anode structure and coaxial with said cathode, one of said pole-pieces separating said anode structure and said window and being spaced from said window, said one pole-piece having an aperture therethrough extending between said anode structure and the volume between said window and said one pole piece to form a continuous transmission passage extending longitudinally of said cathode and from within said resonant cavity for extracting energy from said anode structure and longitudinally launching said energy through said output window.

10. The magnetron defined in claim 9 which further includes a conductor extending from said inductive portion of said anode resonant cavity, through said aperture in said one pole-piece, and into said volume between said one pole-piece and said window, said conductor functioning as an inductive receiving antenna for extracting energy from within said anode cavity and as a transmitting antenna for radiating the extracted energy through said output window.

11. A magnetron comprising: a vacuum envelope including a cylindrical housing member having first and second ends, an output window electrically transparent to microwave energy hermetically enclosing said first end of said housing; a cathode mounted axially within said cylindrical housing member; an interdigital anode structure concentrically surrounding said cathode and coaxial therewith for generating microwave energy within said magnetron, said anode structure including a pair of conductive end plates mounted within said housing member adjacent the opposite ends of said cathode and perpendicular to the axis thereof, each of said end plates having a first aperture in the central region thereof, coaxial with said cathode a first group of anode fingers mounted at uniformly spaced points to one of said plates adjacent said first aperture and extending toward the other of said plates, parallel with said cathode a second group of anode fingers, said second group of anode fingers being mounted at uniformly spaced points to said other plate adjacent said first aperture and extending toward said plate parallel with said cathode, said first and second groups of fingers being interleaved to provide an interdigital anode structure, said interdigital anode structure forming a radial transmission line having a capacitive portion adjacent said cathode and an inductive portion remote from said cathode, the end plate nearest to said output window having a second aperture passing therethrough eccentric with respect to said cathode to provide inductive coupling means for extracting microwave energy generated within said anode structure; a pair of magnetic pole-pieces one adjacent each end of said anode structure and coaxial with said cathode, one of said pole-pieces separating said anode structure and said window and being spaced from said window, said one pole-piece having an aperture therethrough extending between said anode structure and the volume between said window and said one pole-piece for extracting energy from said anode structure and launching said energy through said window.

12. The magnetron defined in claim 11, which further includes a conductor extending from the inductive portion of said interdigital anode structure, through said second aperture in said end plate and said aperture in said one pole-piece, and into said volume between said one pole-piece and said window, said conductor functioning as a receiving antenna for extracting energy from said anode structure and as a transmitting antenna for radiating the extracted energy through said output window.

13. The combination comprising: a metallic enclosure whose interior boundary walls define a cavity resonator resonant at microwave frequencies and in a plurality of modes, in which a lossy dielectric body may be placed to be heated, a magnetron for generating microwave energy, said magnetron having an axis and including an axially mounted cathode, an anode structure positioned concentrically around said cathode, said anode defining at least one cavity resonator, means including a substantially flat output window for extracting the microwave energy from said anode resonator, and means for mounting said flat magnetron output window with its exposed surface substantially flush with one wall of said cavity resonator in a preselected location to provide direct coupling of the microwave energy into the interior of said metallic enclosure and to excite a preselected mode therein.

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