# United States Patent [19]

**Ohtani**

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


[54] **HYBRID MICROWAVE HEATING APPARATUS**


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[73] Assignee: **New Nippon Electric Co., Ltd.,** Shiga, Japan



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[30] **Foreign Application Priority Data**

Dec. 13, 1972 Japan ..... 47-143486

[52] **U.S. Cl.** ..... **219/10.55,** 219/10.55 B

[51] **Int. Cl.** ..... **H05b 9/06**

[58] **Field of Search** ... 219/10.55, 10.55 R, 10.55 B, 219/10.55 F; 331/107 R, 107 G



[56] **References Cited**

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*Primary Examiner*—Bruce A. Reynolds

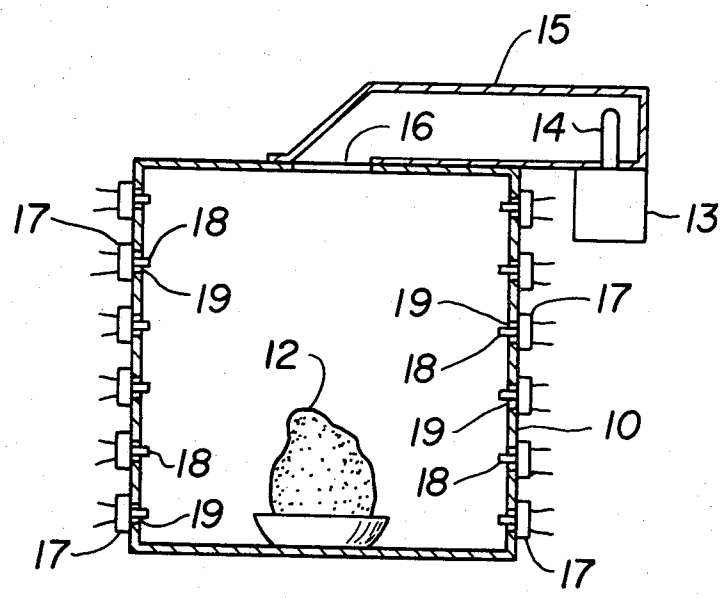
*Attorney, Agent, or Firm*—Wolfgang G. Fasse; Willard W. Roberts



[57] **ABSTRACT**

An apparatus for the treatment of materials by the application of heat for rapid drying, cooking, curing or the like of the materials, including an enclosure having microwave generators both of the magnetron type device and the solid state type oscillators. The magnetron device supplies a relatively large power constantly and each of the solid state oscillators supplies a small power, so that the combination of these different types of power generators in the microwave region provides the heating performance of continuously the output of the microwave power by selective operation of the solid state oscillators, or on-off operation of the magnetron device. For easy and continuous adjustment of the output microwave power in the apparatus, a plurality of solid state oscillators are arranged on several walls of the oven or are placed removably within the oven by means of a tray assembly. The apparatus is also provided with duct means for the solid state oscillators in order to maintain the high efficiency as well as to obtain a uniform heating effect.


**6 Claims, 10 Drawing Figures**



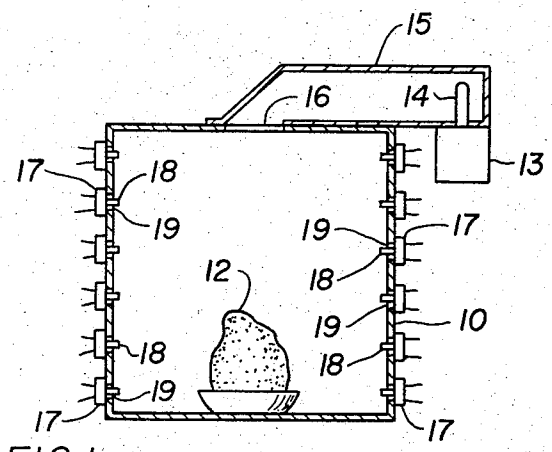



FIG.1

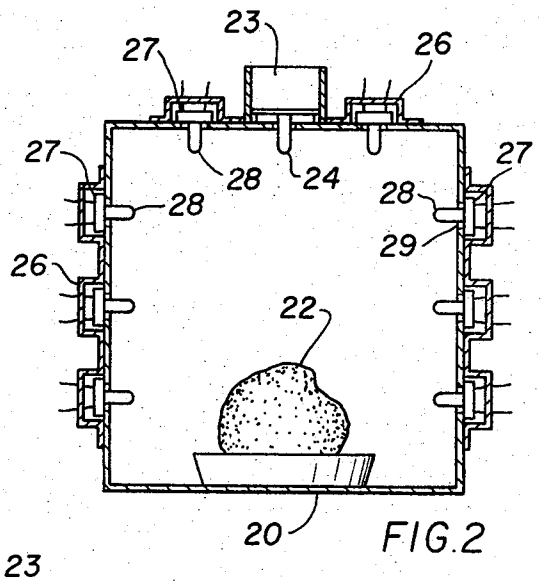



FIG.2

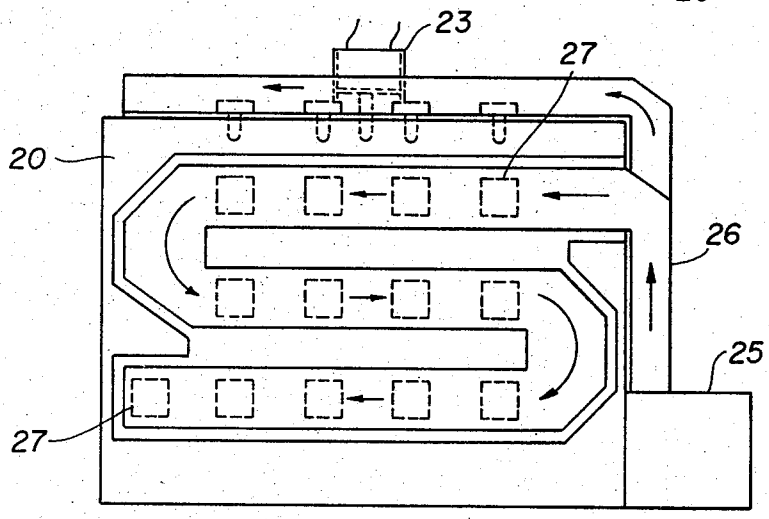



FIG.3

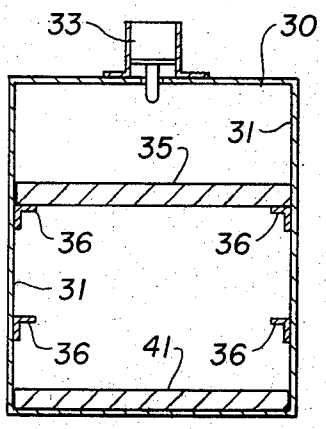



FIG.4

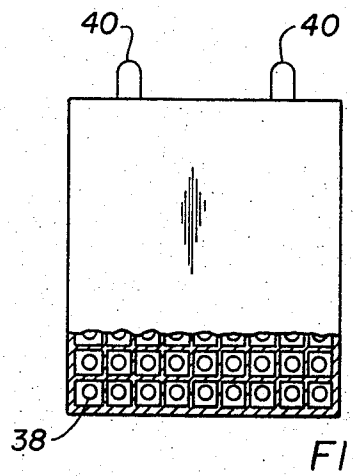



FIG.5

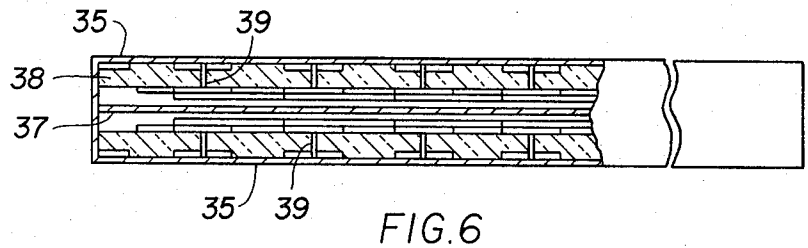



FIG.6

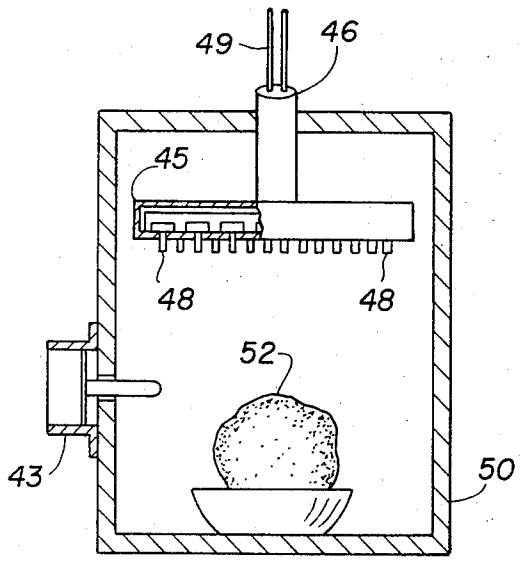



FIG.7

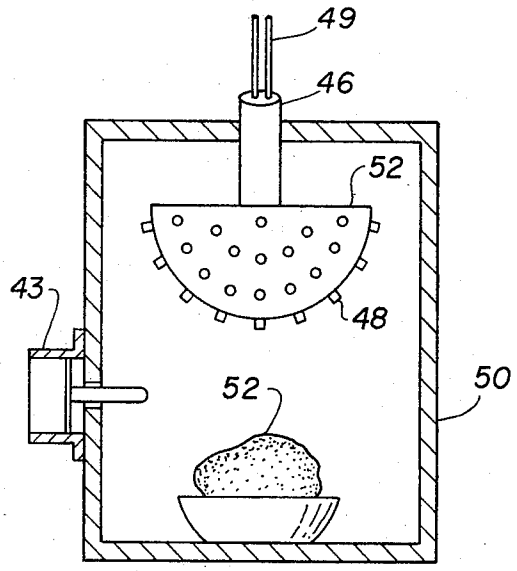



FIG.8

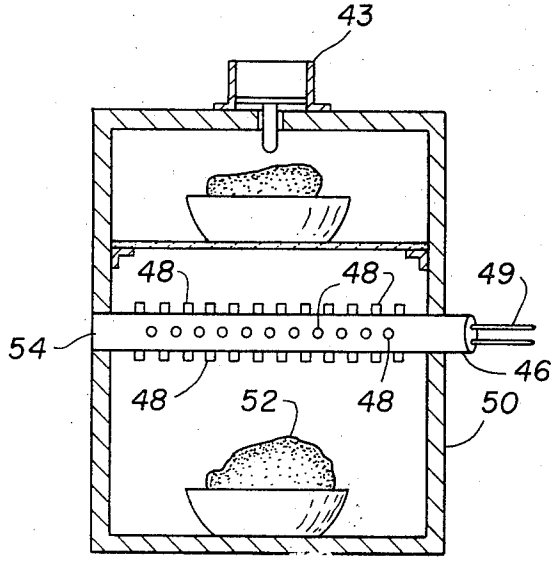



FIG.9

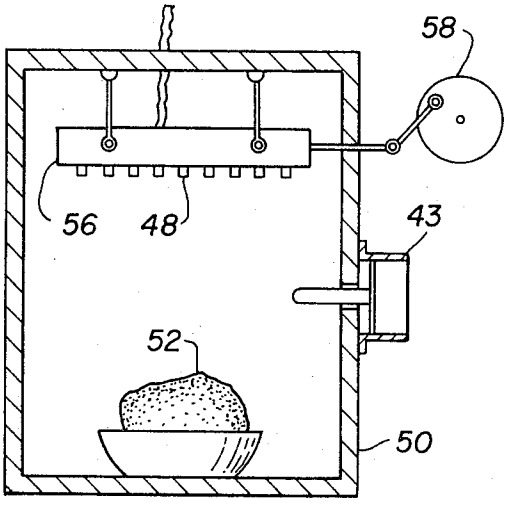



FIG.10

# HYBRID MICROWAVE HEATING APPARATUS

## BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates, in general, to a microwave heating apparatus and more particularly to an apparatus wherein a body located within the oven is heated by microwave power generated by a single magnetron device and a plurality of solid state oscillators.

2. Description of the Prior Art

Microwave heating is usually achieved by the use of magnetron devices, however, the output of microwave power in such devices is generally determined by its rated factors such as anode current. Changing the anode current of the magnetron, which is varied by switching the capacitors in the operating circuit, controls the output within a particular range, for example, operation at 250 milliampares of anode current provides 600 watts output, and at 200 milliampares provides 400 watts output. Control of the output in such a manner, however, causes unstable operation of the magnetron and results in undesired effects with respect to operation and economic aspects. It is well known that the current operation of the magnetron in the circuit of a leakage transformer is better for the stable operation and optimum efficiency in the microwave oven.

Further, a microwave oven employing only magnetrons has the following disadvantages:

1. A magnetron has a relatively short life span, such as in the order of 500 to 1,000 hours, due to operation with a high anode current.
2. It is necessary to consider means for the isolation of the high voltage of 3 to 4 kilovolts required for magnetron operation. This is an important problem in the manufacture and use of the heating apparatus.
3. A high voltage transformer having a weight is above the order of 10 kilograms, must be used for operation of the heating apparatus using only a magnetron, so that reducing the weight of the apparatus is difficult in this arrangement.
4. In consideration of economic and space problems, the cavity or oven configuration in the magnetron type apparatus is limited to a cube or rectangular parallelepiped, due to the loading and heat distribution characteristics of microwave energy.
5. Uneven distribution of heat is obtained by loading the apparatus with a lot of materials to be heated.
6. As to continuous variation of the output microwave energy during normal operation, it is difficult to change the microwave power with a single magnetron.
7. For preventing undesired radiation over the broad region generated from the magnetron device such as a door, oven and other components in the apparatus, it is necessary to provide means for preventing such radiation.
8. In an apparatus using a magnetron device, the cavity or oven must be made of non-magnetic materials, such as stainless steel, aluminum, etc., because a magnet is assembled in the magnetron device. Also it is necessary to space the two parts of the apparatus sufficiently for isolation of the magnetic field produced by the magnet of the magnetron device.

For the solution of the above problems, it has been proposed to provide a heating apparatus employing a plurality of solid state oscillators generating signals at microwave frequencies. Such solid state microwave heating apparatus are disclosed in U.S. Pat. No. 3,557,333 and 3,691,338, in which the above disadvantages will be substantially eliminated.



However, the output of the single solid state oscillator is very small and its cost is high, so an all solid state type heating apparatus also has practical and economic disadvantages. Further, an apparatus having a continuously controlled microwave energy output, is desired in such as the application of heat for cooking rice or medical treatment of neuritis.

Accordingly, an object of this invention is to provide a microwave heating apparatus employing hybrid microwave power sources of the magnetron type device and solid state type microwave oscillators. It is another object to provide a microwave oven, in which the output microwave power can be controlled at user's option by using a magnetron which supplies a relatively large power and a number of solid state oscillators, each of which supplies a small power with respect to the power of the magnetron. In other words, microwave energy for heating materials in the oven is controlled by selective operation of each of the solid state oscillators and/or the magnetron.

## SUMMARY OF THE INVENTION

In accordance with the invention, a microwave heating apparatus comprises an enclosure, a magnetron device and a plurality of solid state oscillators. Solid state oscillators are mounted on the enclosure, preferably by using means of tray or supporting plate to form several blocks, each block is individually operated to control the microwave power. The output of the apparatus of this invention is continuously controlled so that the particular heating program is applied for heat treatment, such as cooking rice.

It is well known that for good cooking of rice controlling of the heating temperature of the treatment is required with time programmed steps comprising a first step of heating at a smoothly rising temperature, a second step of heating at a constant moderate temperature, a third step of heating at a constant high temperature, and a final step of heating at sharply decreasing temperature.

For the above treatment, the heating apparatus of this invention is effectively applied, because of selective operation of a plurality of solid state oscillators and magnetron under optimum conditions.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross sectional view of a microwave heating apparatus of an embodiment according to this invention;

FIG. **2** is a modification of the arrangement of the solid state oscillators of the FIG. **1**, wherein the efficiency of each oscillator is improved by cooling;

FIG. **3** is a side view of FIG. **2**;

FIG. **4** is a cross sectional view of another embodiment in which solid state oscillators are assembled on a tray;

FIG. **5** is a plane partially sectional view of the tray of FIG. **4**;

FIG. **6** is an enlarged side, partially sectional view of FIG. **5**;

FIGS. **7** to **10** show other modifications of the tray assembly of FIG. **4**, in which a sub-assembled tray of

various types is used as the plug-in unit or the movable tray within the microwave oven.

## DETAILED DESCRIPTION OF THE EMBODIMENTS

Referring now to the drawings, embodiments of this invention are explained.

In FIG. **1**, there is illustrated a cooking apparatus having an enclosure **10** wherein a body **12** of such a material as rice located within the enclosure **10** is heated by microwave power from a magnetron device **13** which is the first type of microwave energy source employed in the apparatus. Microwave power from an antenna **14** of the magnetron device **13** is conducted through the wave guide **15** and iris **16** which is located on the top wall of the enclosure **10** of the apparatus.

A plurality of solid state microwave oscillators **17** which are the second employed in the apparatus type microwave energy source are fixed to each side walls of the enclosure **10.** The output of each solid state oscillator **17** is also supplied to the enclosure **10** from the respective antennas **18** of the solid state oscillator **17** through a plurality of small holes **19** drilled in the walls of the enclosure **10.**

In a 600 watt rated heating apparatus, the output of 300 watts is supplied from the first microwave energy source of the magnetron device **13** and the rest of the 300 watts are supplied from the second microwave energy source of the solid state oscillators **17.**

Therefore, the total output of 600 watts can be controlled by the selection of the power supplied at the input side.

It is the most practical and effective way to provide a fixed power of 300 watts with the magnetron device **13** in normal operation and to vary the microwave power with solid state oscillators **17** only, because microwave power below 300 watts as the minimum power output is not desired in the 600 watts rated apparatus. If necessary, the solid state oscillators may control the output in the range of zero to **300** watts when the magnetron device is cut off.

As mentioned above, this invention can provide a comparatively inexpensive microwave heating apparatus of which the microwave power can be controlled by the solid state microwave oscillators **17** at user's option. While in the case of conventional microwave oven using the magnetron only, there is the limit on the distribution of heat through the body placed in the oven to be heated, the present invention improves the distribution of heat by the combination of magnetron device and solid state microwave oscillators as the microwave part thereof. That is, proper arrangement of the solid state oscillators provides a desired temperature distribution within the enclosure.

In FIGS. **2** and **3** an improved arrangement of solid state oscillators is illustrated, in which the operation of each oscillator is maintained stable with high efficiency. The improvement of the above is achieved by adding cooling means for each oscillator, since the radiation of heat from the oscillators during operation causes a temperature rise of the oscillators. As shown in FIG. **2,** the heating apparatus comprises an enclosure **20** having a single magnetron device **23** directly fixed on the top wall and a plurality of solid state oscillators **27** as illustrated in FIG. **1.** The outside of the enclosure **20,** however, provides a blower **25** and a zig-zag shaped air duct **26** following along the positions of the oscillators **27.** This duct **26** is made of metal or ferrite rubber materials, and covers the oscillators **27** to form an air path. Thus, the air blowing from the blower **25** acts as cooling means for each oscillator **27** by flowing air within the duct **26.** The air heated from the oscillators is conducted into the enclosure **20** through holes **29** so that the air circulation within the enclosure **20** may be done effectively. Wet air from the body **22** within the oven may be alternated with the dry air flowing in the duct **26** as shown in FIG. **3.**

It is an advantage that the duct **26** covering the holes **29** of the enclosure **20** serves as a shield for undesired radiation.

FIGS. **4** to **6** show another embodiment in which the solid state oscillators are assembled on a plate or tray **35** within the oven **30,** wherein the heating apparatus has a single magnetron device **33.**

A pair of side walls **31** are provided with L-shaped metals **36** for supporting a tray **35** made of microwave transmitting materials. This tray **35** is placed removably on the pair of L-shaped metals **36** and comprises a compartment within which a partition wall **37** establishes upper and lower partitions. Both partitions have a plurality of parting strips **37** to form a number of partitioned rooms for containing solid state oscillators **38** as shown in FIGS. **5** and **6.** Electric power is supplied to each oscillator **38** from the terminals **40** affixed to the tray **35.** A magnetron device **33** is directly fixed to the top wall of the oven **30.** Also a tray **41** having a pluraltiy of solid state oscillators **38** arranged on the one side only is placed at the bottom of the oven **30.**

FIGS. **7** to **10** are other modifications of the arrangement of solid state oscillators, in which different types of tray assemblies are shown for improving distribution of temperature characteristics. In FIG. **7,** a movable tray **45** having solid state oscillators **48** mounted thereon is supported by the rotating shaft **46.** The apparatus includes the magnetron device **43** and the movable tray **45** provided with a pair of power supplying feeders **49** within the oven **50.**

As shown in FIGS. **8** to **10,** the shape and configuration of the movable tray can be modified in the form of a hemisphere, a polyhedron or a tubular member. FIG. **8** shows a hemispheric type tray **52** provided with solid state oscillators **48** and FIG. **9** shows a tubular type tray **54.** In FIG. **10,** a further modification of the movable tray **56** is shown, in which the tray **56** is hung freely within the oven **50,** and is shaken by means of crank and rotating wheel **58,** so as to distribute microwave energy uniformly.

What is claimed is:

**1.** A microwave heating apparatus comprising an enclosure, a magnetron mounted on said enclosure for directing microwave energy into said enclosure, and a plurality of solid state oscillators mounted to direct microwave energy into said enclosure, whereby the microwave power and the distribution of temperature in said apparatus may be readily controlled.

**2.** The apparatus of claim **1,** wherein said solid state oscillators are mounted on at least one wall of said apparatus, further comprising air duct means externally covering said oscillators, and means directing cooling air through said air duct means for cooling said oscillators, whereby the efficiency of operation of said oscillators is increased.

**3.** The apparatus of claim **1,** further comprising support means within said enclosure, said solid state oscil-

lators being mounted on said supporting means, said supporting means being movably mounted within said enclosure.

**4.** The microwave heating apparatus of claim **1**, further comprising a rotatable support mounted within said enclosure, said solid state oscillators being mounted on said rotatable support, wherein said rotatable support comprises a hemispherical body so as to distribute microwave energy uniformly by using reflection from walls of the enclosure.

**5.** The microwave heating apparatus of claim **1**, further comprising a rotatable support mounted within the central portion partitioning said enclosure, said solid-state oscillator being mounted on said rotatable support, wherein said rotatable support comprises a tubular member mounted for rotation about its axis so as to distribute microwave energy uniformly within each partition of the enclosure.

**6.** The microwave heating apparatus of claim **1**, further comprising a movable tray freely hung within said apparatus, said solid state oscillators being mounted on said tray, and means fixed on the outside of said enclosure for moving said tray, wherein said tray is so shaken in at least one direction that the microwave energy is distributed uniformly in said apparatus.

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