March 12, 1968 P. H. SMITH 3,373,259

ELECTRONIC OVEN

Filed March 26, 1965 2 Sheets-Sheet 1

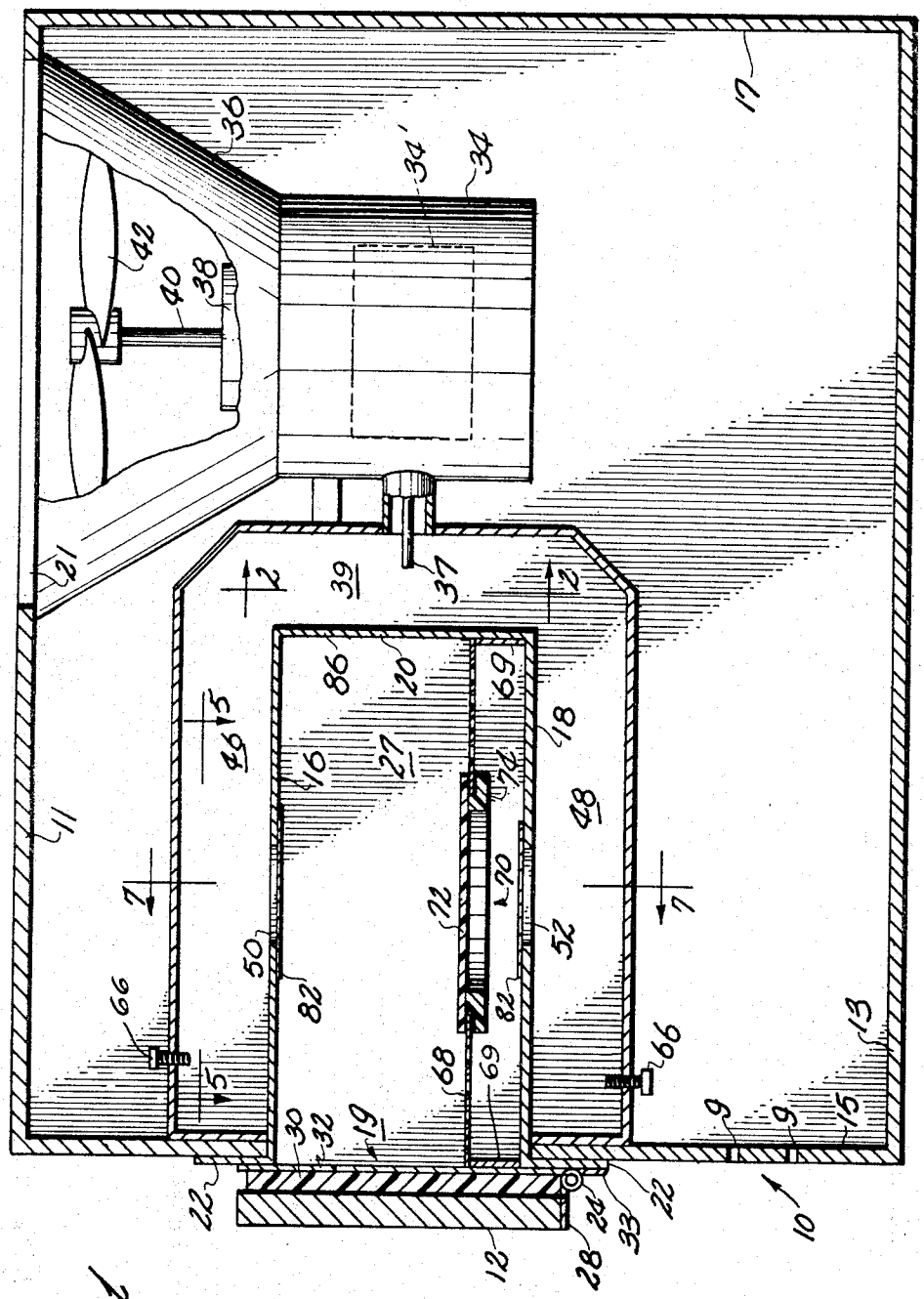


Fig. 1

INVENTOR.
Peter H. Smith
BY
Pendleton, Neuman, Seibold & Williams
Attorneys

March 12, 1968 P. H. SMITH 3,373,259

ELECTRONIC OVEN

Filed March 26, 1965 2 Sheets-Sheet 2

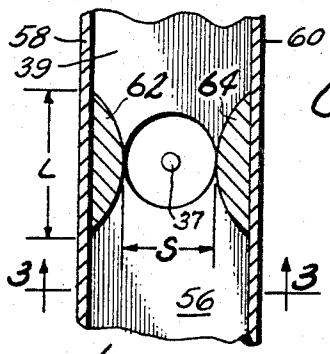


Fig. 2

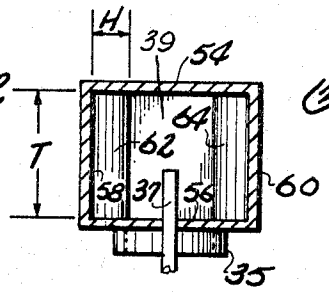


Fig. 3

Fig. 4

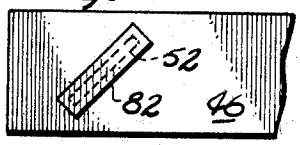


Fig. 5

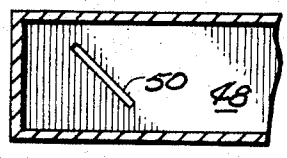


Fig. 6

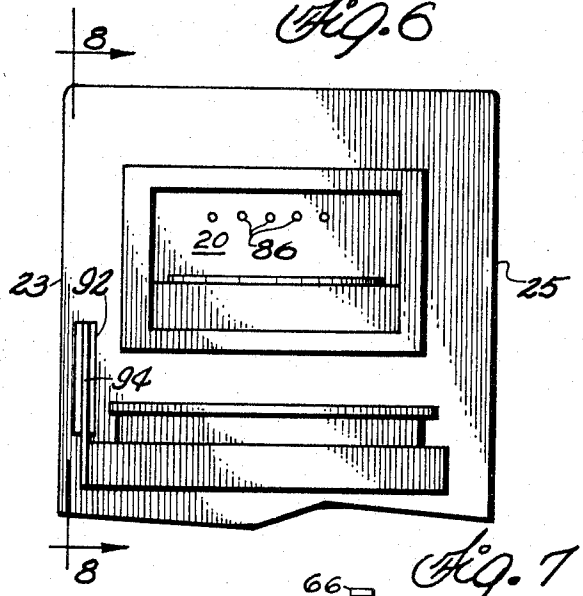


Fig. 7

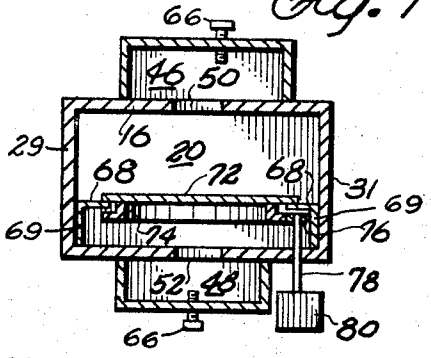
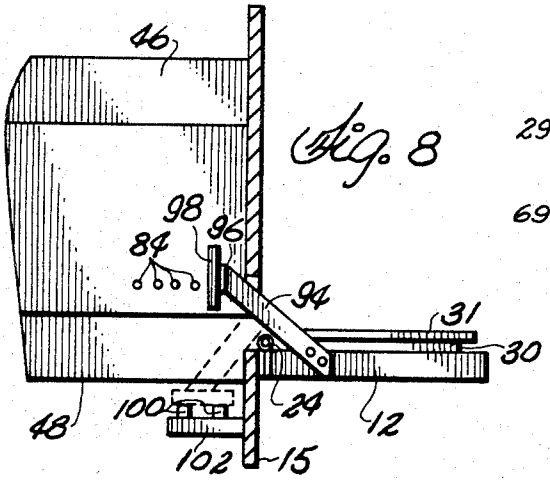


Fig. 8



INVENTOR.
Peter H. Smith
BY
Pendleton, Neuman
Seibold & Williams
attorneys

United States Patent Office 3,373,259
Patented Mar. 12, 1968

3,373,259

ELECTRONIC OVEN

Peter H. Smith, Maidenhead, England, assignor to J. Lyons & Company, Limited, London, England, a corporation of England

Filed Mar. 26, 1965, Ser. No. 444,942
7 Claims. (Cl. 219—10.55)

ABSTRACT OF THE DISCLOSURE

This disclosure relates to microwave ovens of the type having apparatus for coupling two inputs of microwave energy into the heating compartment. A power divider having a pair of outputs and a single input matches the impedance of the coupling apparatus to a single microwave source. The two outputs of the power divider are at opposite ends of a length of wave guide, the cross-sectional area of which is reduced in the vicinity of the single input by inwardly bowed surfaces on two opposite walls of the waveguide.

This invention relates to electronic ovens and more particularly to such ovens which are adapted for cooking small prepackaged items such as sandwiches and the like.

It has been recognized in the prior art that the field intensity of wave energy within the cooking or heating chamber of an electronic oven is dependent not only upon the load represented by the food to be heated, but also by the physical size and shape of the heating chamber. Typically, variations in field intensity occur within the heating chamber, and are represented by locations within the heating chamber of relatively high field intensity, and other locations of relatively low field intensity. This variation in field strength within the heating chamber results in certain portions of the food being heated to a greater extent than others.

It has been recognized that one way of evening the field strength within the heating chamber is to provide two inputs or antennas where wave energy can enter the heating compartment. One difficulty with this approach is that some of the wave energy radiated by one antenna is received by the other, and transmitted back toward the wave energy source or sources. The result is a high standing wave ratio on the legs of the waveguide between the antennas and the wave energy sources.

When a single source is employed to drive both antennas, an additional problem arises from the division of power from a single source into two parts to drive the two antennas. In the prior art it has been impossible to make such a power division without reducing performance of the system in some way.

For example, in order to reduce the characteristic impedance of the waveguide legs connected to the two outputs of the power divider, it has been known to reduce the width of the narrower wall of the waveguide. However, this results in an increase in the electric field strength and may cause electrical flash over in the guide, especially at any bends in the wave guide. Flash over may also occur at the location of screws in the waveguide which are employed for tuning purposes. In electronic ovens it is important to have match impedances to maintain a low standing wave ratio, and moreover the match must exist over a relatively wide bandwidth. The frequency of oscillation of a magnetron, commonly used as the source of wave energy for such ovens, varies in response to changes in its load, and such load changes accompany the process of heating or cooking food. A high standing wave ratio is objectional not only because the energy reflected back to the source might damage the same, but also it is a characteristic of poor efficiency, since

all the available energy is not necessarily being absorbed by the food to be heated.

It has also been proposed to employ elliptically polarized wave energy to heat the food within the heating chamber, and one apparatus for performing this function is disclosed and claimed in copending Smith application Ser. No. 254,925, filed Jan. 30, 1963, now Patent No. 3,210,511. The present invention comprises in part an improvement of the apparatus there disclosed.

By use of the novel power divider of the present invention the energy output of a single magnetron may be coupled to a waveguide assembly terminating in a pair of antennas disposed on opposite sides of the heating chamber of the oven. The characteristic impedance of each of the legs of the waveguide assembly is the same as that of the magnetron, and matched impedance operation is provided over a relatively large range of frequencies, such as is encountered during typical operation of the electronic oven in which the magnetron is employed. In addition, the wave energy introduced into the heating chamber from the two antennas is 90° out of phase, to produce elliptically polarized energy within the chamber.

Another advantage of the present invention pertains to the disposition of vapors generated in the heating chamber when the food within such chamber is being heated. It is desirable to prevent these vapors from entering the waveguide where they could damage the apparatus by causing corrosion, and the build up of moisture at a high voltage point along the waveguide which may cause arcing and damage the magnetron or the waveguide walls. It is also desirable to exhaust the vapors from the oven chamber to the atmosphere in order to prevent severe condensation within the chamber during the heating process.

During the operation of electronic ovens, it is necessary to insure that a dangerous amount of wave energy does not escape from the heating chamber. Prior ovens have been provided with interlock means comprising microswitches or the like, the contacts of which are adapted to open when the door of the heating chamber is opened. In the event that the contacts of such a switch might be welded shut, however, the opening of the door would be ineffective to shut off the power to the magnetron, and, in this event, a dangerous amount of wave energy could escape from the oven. It is therefore desirable to provide means to insure that this cannot happen. The present invention accomplishes this object by providing interlock means in the form of a switch which is adapted to prevent opening of the door in the event that the switch contacts are welded shut.

For the reasons discussed above, one object of the present invention is to provide an electronic oven having means adapted to present a uniform field intensity throughout the working area of the chamber.

Another object of the present invention is to provide a microwave oven having improved means for introducing elliptically polarized microwave energy into the heating chamber.

A further object of the present invention is to provide improved means for inserting wave energy into a heating chamber at oppositely disposed locations above and below the food to be heated.

Another object of the present invention is to provide a microwave oven having a waveguide assembly interconnecting a pair of antennas to a single source of wave energy, with means to provide a broad band impedance match.

A further object of the present invention is to provide a microwave oven having improved means for evacuating vapors from the heating chamber.

Another object of the present invention is to provide a microwave oven having means for preventing opening

of the door of the oven unless a pair of switch contacts are first opened.

These and other objects and advantages of the present invention will become manifest upon an examination of this specification and the accompanying drawings.

In one embodiment of the present invention, there is provided a microwave oven having a heating chamber and dielectric means within the heating chamber for supporting food to be cooked. Diametrically above and below the supporting means are disposed antenna means adapted to radiate wave energy with a relative radiation phase difference of 90°. Each of the antennas is fed by a single source of wave energy through a transmission line having power divider means adapted to provide a broad band impedance match between the magnetron and the load.

The heating chamber, the transmission line, and the wave energy source are contained within a housing, and means is provided to exhaust vapor generated in the heating chamber from the housing. The heating chamber is provided with an access door, and switch means is provided within the housing for preventing the door from opening unless the switch contacts are open.

Reference will now be made to the accompanying drawings in which:

FIG. 1 is a vertical cross-sectional view of an oven constructed in accordance with the present invention;

FIG. 2 is a cross-sectional view of a portion of the waveguide illustrated in FIG. 1, taken along the line 2—2;

FIG. 3 is a cross-sectional view of the apparatus of FIG. 2, taken along the line 3—3;

FIG. 4 is a plan view of a portion of the lower leg of the waveguide illlustrated in FIG. 1;

FIG. 5 is a cross-sectional view of a portion of the upper leg of the waveguide of FIG. 1, taken along the line 5—5;

FIG. 6 is a partial front elevation view of the oven of FIG. 1 with its door open;

FIG. 7 is a vertical cross-sectional view of a portion of the apparatus illustrated in FIG. 1, taken along the line 7—7; and

FIG. 8 is a vertical cross-sectional view of the apparatus of FIG. 6, taken along line 8—8.

Referring now to FIG. 1, there is illustrated an electronic oven including a housing 10 having top and bottom walls 11 and 13, respectively, a pair of end walls 15 and 17 enclosing the separate parts of the oven, except for a rectangular aperture 19 in the end wall 15 and an aperture 21 in the top wall 11. A pair of side walls 23 and 25 (FIG. 6) interconnected the sides edges of the walls 11, 13, 15 and 17, to close the housing 10.

Within the housing 10 there is disposed a metallic heating chamber 27 having top and bottom walls 16 and 18, respectively, and an end wall 20, and side walls 29 and 31 (FIG. 7). The heating chamber 27 is open on its side opposite the end wall 20, and is provided with an outwardly extending peripheral flange 22 at its open end. The flange 22 overlaps and is secured to portions of the end wall 15 of the housing 10 surrounding the rectangular aperture 19.

A door 12 is hinged to the end wall 15 by a hinge 24 which has one leaf 33 secured to the end wall 15, and its other leaf 28 secured to the lower surface of the door 12.

A pad 30 formed of resilient plastic foam or the like is secured to the inside surface of the door 12, a thin flexible metallic sheet 32 is supported by the pad 30. The sheet 32 is adapted to be pressed into tight fitting engagement with the flange 22 when the door 12 is in its closed position.

Also within the housing 10 is provided a magnetron 34' schematically shown in FIG. 1, surrounded by a casing 34. The casing 34 is in the form of a hollow circular cylinder, open at its ends, and is connected at its upper end to a conically-shaped channel 36 which extends between the casing 34 and the aperture 21. Within the channel 36 a fan 42 is connected to the shaft 40 of a motor 38 supported within the casing 34 by means not shown. When the fan 42 is rotated by the motor 38, air is drawn upwardly through the open lower end of the casing 34 past the magnetron 34' to air-cool the same.

The magnetron 34' is connected to a hollow circular mounting flange 35, and the magnetron antenna 37 extends through the mounting flange 35 into a vertical waveguide leg 39, which is secured to the end wall 20, the end wall 20 forming one of the walls of the vertical waveguide leg 39. The vertical waveguide leg 39 is connected at its upper end to an upper waveguide leg 46 and at its lower end to a lower waveguide leg 48. The upper waveguide leg 46 is secured to the upper wall 16 of the heating chamber 27, and is adapted to radiate wave energy into the heating chamber 27 through an antenna slot 50 disposed in the upper wall 16. Similarly, the lower waveguide leg 48 is disposed adjacent the lower wall 18 of the heating chamber 27, and radiates energy into the heating chamber 27 through an antenna slot 52. As illustrated in FIGS. 1 and 7, the upper wall 16 of the heating chamber 27 forms the lower wall of the upper waveguide leg 46, and the lower wall 18 forms the upper wall of the lower waveguide leg 48.

Both the upper and lower waveguide legs 46 and 48 include a bend in a vertical plane, adjacent the edges of the rear wall 20, and extend for the length of the upper and lower walls 16 and 18. The vertical waveguide leg 39 and the upper and lower waveguide legs 46 and 48 present a symmetrical waveguide assembly, with the power input at the midpoint of the assembly. The antenna slots 50 and 52 are each located at the same distance from the antenna 37, and are disposed opposite each other substantially at the center of the heating chamber 27.

It is more clearly seen in FIGS. 2 and 3 the magnetron output is coaxial, and the power input to the vertical waveguide leg 39 comprises the antenna 37 and the mounting flange 35. The vertical waveguide leg has a rectangular cross section with oppositely disposed relatively wider walls 54 and 56, and oppositely disposed relatively narrower walls 58 and 60. The coaxial output of the magnetron is connected in alignment with a circular aperture in the wall 56. A pair of segmental members 62 and 64 composed of conductive material are disposed opposite the aperture. The members 62 and 64 each have a length L approximately equal to the dimension of the width of walls 54 and 56, a thickness T equal to the width of walls 58 and 60, and an arcuate interior contour. The spacing S between the crests of the members 62 and 64 determines the characteristic impedance of the waveguide assembly as seen by the magnetron.

It has been found that the provision of the segmental members 62 and 64 provide substantially matched impedance operation over a wide band of frequencies, with a relatively low standing wave ratio.

In one embodiment of the present invention, designed to operate at a nominal frequency of 2450 megacycles, the interior dimensions of all the waveguide legs were 86 mm. by 43 mm., and the segmental members 62 and 64 were 86 mm. long, with a height H of 11.5 mm. The measured standing wave ratio was 1.13 at 2400 mc., 1.02 at 2450 mc., and 1.12 at 2500 mc.

Each of the upper and lower waveguide legs 46 and 48 is provided with a tuning screw 66 by which the waveguide legs may be tuned to the proper operating condition.

Within the heating chamber 27 is disposed a platform 68 comprising a piece of sheet metal formed with folded down side walls 69 which rest on the bottom wall 18 of the heating chamber 27. A relatively large aperture 70 is provided in the central portion of sheet 68, and a dielectric turntable 72 is mounted in the aperture 70, over-

lapping with portions of the sheet **68** adjacent the aperture **70**, and having its lower side connected to a gear **74**. The gear **74** is provided with a boss which projects through the aperture **70** and connects with the turntable **72**, thereby spacing the turntable **72** and the gear **74** apart by a distance which is greater than the thickness of the sheet **68**.

Apparatus is provided for driving the gear **74**, including a drive gear **76** mounted on a shaft **78** (FIG. 8). One end of the shaft **78** is journaled in an aperture in sheet **68**, and the other end of the shaft **78** is connected to a motor **80**. The motor **80** is preferably mounted by a bracket (not shown) on the front wall **15** of the housing **10**. The drive gear **76** is in mesh with the gear **74** so that energization of the motor **80** is adapted to rotate the platform **72** within the heating chamber **15**.

Each of the antenna slots **50** and **52** of the upper and lower legs **46** and **48** are disposed at a 45° angle relative to the longitudinal dimension of their respective waveguides as illustrated in FIGS. 4 and 5, and are disposed at 90° with respect to each other. This causes the wave energy inserted into the heating chamber **27** from the two antennas to have a relative radiation phase difference of 90°. As a consequence, the electromagnetic field within the heating chamber **27** is elliptically polarized, containing E vectors at right angles to each other. This has been found to render the field distribution within the heating chamber **27** substantially more uniform than if the wave energy were polarized in a single dimension. In addition, the antenna slots **50** and **52** are disposed in opposite walls of the heating chamber **27**, which also helps to make the field distribution within the heating chamber more uniform.

With the waveguide dimensions and operating frequency as described above, slots about 61 mm. long and 3 mm. wide have been found to operate very satisfactorily.

The sheet **68**, in addition to supporting the platform **72** within the heating chamber, also functions to space it upwardly from the bottom wall **18** of the heating chamber **27** so that the food disposed thereon is generally in the central portion of the heating chamber **27**. Thus the food disposed on the platform **72** is centrally located within the heating chamber **27**, where the intensity of the radiation emanating from each of the two antennas **50** and **52** is substantially equal, thereby heating the food substantially uniformly.

The platform **72** is formed from a low-loss dielectric material such that there is little attenuation of the radiation emanating from the slot antenna **52** passing upwardly through the platform **72**.

Each of the slot antennas **50** and **52** are covered with a piece of low-loss dielectric tape **82**, so that the radiation emanating from the antennas may pass therethrough substantially unattenuated. The tape presents a vapor barrier between the heating chamber **27** and the waveguide, so that no vapors or moisture from the heating chamber **27** may pass into the waveguide.

In the side walls **29** and **31** of the heating chamber **27**, a plurality of apertures **84** are provided, opening into the interior of the casing **10**, so that air may pass from the interior of the housing **10** into the heating chamber **27**. The end wall **20** of the heating chamber is provided with a plurality of apertures **86** so that the air within the heating chamber **27** may pass out of the heating chamber **27**, carrying with it any vapors which are generated by the heating process. From the apertures **86**, the air is drawn through the open end of the casing **34** by the fan **42**. This air is entrained in the stream of air cooling the magnetron **34'**, and the result is that any vapors generated within the heating chamber **27** are exhausted through the aperture **21** in the top wall **11** of the casing **10**. The stream of air passing from the apertures **9** in the end wall **15** of the casing **10** to the open end of the casing **34** is sufficient to maintain the circulation just described through the heating chamber **27**.

Referring now to FIGS. 6 and 8, positive interlock means is illustrated, by which operation of the magnetron **34'** is inhibited, unless the door **12** is in its closed position. A slot **92** is disposed in the front wall of the housing **10**, aligned with one of the side edges of the door **12**, and an arm **94** is secured to the side of the door **12** and extends through the slot **92** into the interior of the housing **10** but outside of the heating chamber **27**. An insulating member **96** is connected to the end of the arm **94** within the casing **10**, and the member **96** supports a conductive switch member **98**. When the door is in open position, as illustrated in FIG. 8, the switch member **98** is disposed in spaced relation with a pair of contact elements **100** which are supported by an insulating member **102** secured to the end **15** of the casing **10**. When the door **12** is in closed position, however, the arm **94** and the switch member **98** rotate about the hinge **24** into the position illustrated in dashed lines in FIG. 8, where the conductive switch member **98** is brought into engagement with the cotnacts **100** and establishes an electrical connection therebetween. Wires **104** are connected to the contacts **100** and are incorporated in the control circuit for the magnetron so that the operation of the magnetron is inhibited unless the switch member **98** is in its lower position interconnecting the contacts **100**. Such a control system is well known in the art and therefore need not be specifically described.

In the operation of the interlock formed by the arm **94** and its associated parts, the door **12** is inhibited from opening if, by some malfunction of the electrical system, the switch member **98** becomes welded to its contacts **102**. It is therefore impossible to open the door **12** into the position illustrated in FIG. 8 unless the circuit including the contacts **100** has first been broken.

From the foregoing the present invention has been described with such particularity that others skilled in the art may make and use the same, and by employing common knowledge adapt the same for use under varying conditions of service without departing from the essential features of novelty thereof which are intended to be defined and secured by the appending claims.

What is claimed is.

1. A power divider for connecting a source of wave energy to first and second waveguide legs each having the same characteristic impedance as said source, comprising a relatively straight rectangular waveguide leg connected with said first and second legs, coaxial means for transmitting wave energy from said source into an intermediate portion of said straight leg through one wall of said waveguide, and a pair of segmental members disposed on first and second opposite walls of said waveguide on opposite sides of said coaxial means to reduce the internal dimension of said straight leg in the vicinity of said coaxial means, said segmental members being equal in width to the width of said first and second walls and the central portions of said members bowing inwardly toward each other and away from said first and second walls.

2. A power divider comprising a length of rectangular cross-section waveguide having a characteristic impedance Z, coaxial means connected to one of the wider walls of said waveguide for transmitting wave energy into said waveguide in opposite directions along the longitudinal dimension of said waveguide, said coaxial means having a characteristic impedance Z, and first and second curved surfaces on opposite ones of the narrower walls of said waveguide with said coaxial means disposed centrally between them, said surfaces being equal in width to the width of said narrower walls and the central portions of said surfaces bowing inwardly toward each other and away from said narrower walls, thereby lessening the wider dimension of said waveguide in the vicinity of said coaxial means.

3. A power divider for effecting a broad band impedance match between a first coaxial waveguide, and second and third rectangular waveguides having oppositely disposed wider and narrower sides, each of said three waveguides having the same characteristic impedance,

comprising means for connecting an end of said second waveguide in common with an end of said third waveguide, means for connecting said first waveguide with one of said wider sides of said second and third waveguides where said second and third waveguides are connected in common, and a pair of cylindrical surfaces juxtaposed with said narrower sides in facing relationship for narrowing the internal dimension of said second and third waveguides parallel to said wider sides in the vicinity of said first waveguide, said cylindrical surfaces extending for a distance equal to one-fourth of the cutoff wavelength of said second and third waveguides longitudinally down said second and third waveguides from said first waveguide.

4. In an electronic oven having a heating chamber, means for introducing wave energy into said heating chamber comprising a U-shaped waveguide disposed adjacent said heating chamber on three sides thereof and having a central leg and two terminal legs, each of said terminal legs having means to transmit energy from said waveguide into said heating chamber, a source of wave energy having a coaxial waveguide output, said coaxial waveguide having the same characteristic impedance as each of said terminal legs, means for connecting said coaxial waveguide to said central leg, and a pair of inwardly bowed cylindrical surfaces juxtaposed with the interior of said central leg in diametric relation with coaxial waveguide for reducing an internal dimension of said central leg in the vicinity of said coaxial waveguide, said internal dimension being perpendicular to the axis of said coaxial waveguide.

5. In an electronic oven having a heating chamber, means for introducing wave energy into said heating chamber comprising a waveguide having a central leg having first and second ends, a first terminal leg having one end closed and the other end connected to said first end of said central leg, and a second terminal leg having one end closed and the other end connected to said second end of said central leg, said first and second terminal ends being juxtaposed with first and second opposing walls of said heating chamber, said first and second walls each having a slot therein for admitting wave energy from said first and second terminal legs into said heating chamber, said slots being disposed at 90° to each other, a source of wave energy having an output waveguide, means connecting said output waveguide to said central leg, and a pair of inwardly bowed cylindrical surfaces juxtaposed with the interior of said central leg in diametric relation with said output waveguide for reducing an internal dimension of said central leg in the vicinity of said output waveguide, said internal dimension being perpendicular to the longitudinal dimension of said output waveguide.

6. An electronic oven comprising a heating chamber, means for supporting food to be heated within said heating chamber, a waveguide having a central waveguide leg and first and second terminal waveguide legs connected to opposite ends of said central leg, said terminal legs being juxtaposed with opposing walls of said heating chamber, said terminal waveguide legs having a U-shaped cross section with portions of said opposing walls closing one side of said terminal waveguide legs, a pair of slots oppositely disposed in said opposing walls substantially in the center of said heating chamber, said slots being disposed at 90° with respect to each other, a source of wave energy having an output waveguide, means connecting said output waveguide to said central waveguide leg, and a pair of inwardly bowed cylindrical surfaces juxtaposed with the interior of said central leg in diametric relation with said output waveguide reducing an internal dimension of said central leg in the vicinity of said output waveguide, said dimension being transverse to the longitudinal dimension of said output waveguide.

7. A power divider comprising a length of rectangular waveguide and an input waveguide elment coupled to the central portion of said rectangular waveguide, the wider walls of said central portion having a reduced width with said width increasing progressively outwardly from said central portion toward the ends of rectangular waveguide so as to provide reduced reflection of power when the input element is connected to a wave energy source and the ends of said rectangular waveguide are connected to matched terminations.

References Cited

UNITED STATES PATENTS

2,532,817	12/1950	Lafferty et al.	333—7 X
2,593,120	4/1952	Dicke	333—7 X
2,632,838	3/1953	Schroeder	219—10.55 X
2,744,990	5/1956	Schroeder	219—10.55
2,929,905	3/1960	Hahn	219—10.55
2,993,973	7/1961	Johnson et al.	219—10.55
3,182,166	5/1965	Bohn et al.	219—10.55
3,188,441	6/1965	Ojelid	219—10.55
3,210,511	10/1965	Smith	219—10.55
3,300,615	1/1967	Smith	219—10.55

RICHARD M. WOOD, *Primary Examiner.*

L. H. BENDER, *Assistant Examiner.*