March 22, 1966 P. W. CRAPUCHETTES 3,242,303

MICROWAVE HEATING APPARATUS

Filed June 6, 1963

Fig. 1

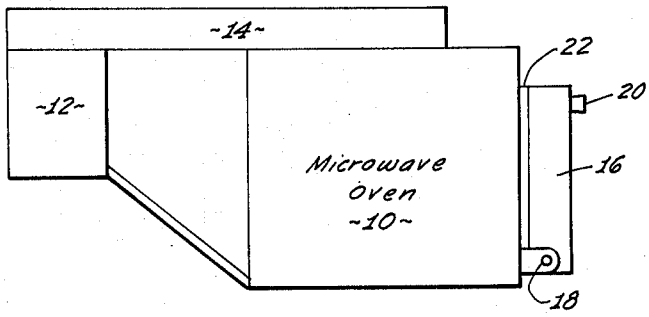


Fig. 2

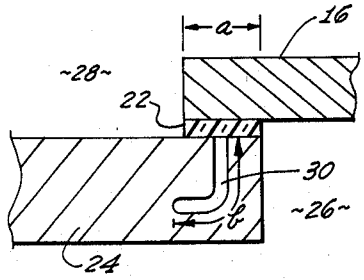
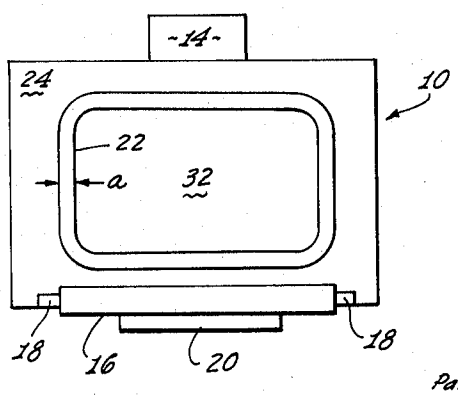


Fig. 3



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United States Patent Office 3,242,303
Patented Mar. 22, 1966

3,242,303

MICROWAVE HEATING APPARATUS

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Filed June 6, 1963, Ser. No. 286,117
4 Claims. (Cl. 219—10.55)

This invention relates to microwave heating apparatus, and more particularly to means for preventing the escape of electromagnetic wave energy from a microwave heating cavity.

It is well known that high frequency electromagnetic wave energy can be used to heat and cook foodstuff or other lossy dielectric materials. There are devices commercially available which utilize such electromagnetic wave energy to cook food. Such devices are known as microwave ovens. These ovens consist of a conductive cavity to which electromagnetic wave energy is applied from a suitable source, usually a magnetron. The cavity of necessity includes an opening to provide access to the interior for placing food in and removing food from the oven. A suitably movable door, such as a hinged or sliding door, is provided to cover the opening during the time the microwave energy is being supplied to the interior of the oven. The door serves both to complete the cavity to allow proper cooking and to prevent the escape of electromagnetic wave energy to the exterior of the oven.

The electromagnetic wave energy must be confined to the interior of the oven for two reasons. The first, and probably more obvious, of these reasons is to prevent the escape of harmful radiation which may injure persons near the oven. The second reason is to prevent the escape of electromagnetic wave radiations which may interfere with the operation of other devices, such as communication devices, which utilize electromagnetic wave energy. With regard to this second reason, the Federal Communications Commission has assigned specific frequencies and wave lengths for use in microwave ovens and the escape of energy of this frequency would not interfere with any other communication apparatus. However, second and third harmonic frequencies are usually present within an oven and the escape of radiation of these frequencies would interfere with the operation of devices which have been assigned these frequencies by the Federal Communications Commission.

In the prior art, various means have been tried to prevent the escape of electromagnetic wave energy from the interior of a microwave oven. For example, in United States Patent 2,888,543, issued on May 26, 1959 to D. B. Haagensen, it is proposed that the interior surface of the cavity be coated with a solid dielectric material, such as a vitreous ceramic, to provide a relatively large capacitance between the door and the interior surface of the cavity. This capacitance would appear as a low impedance to microwave frequency energy and would short any energy which tried to escape from the cavity at the junction of the door and the cavity. However, such an arrangement has not proven to be entirely satisfactory in preventing the escape of radiation from the interior of the oven.

It is accordingly the object of the present invention to provide an improved microwave oven.

It is a further object of the present invention to provide improved means for preventing the escape of electromagnetic wave energy from the interior of a microwave oven through the junction of the door and the oven walls.

It is a further specific object of the present invention to provide such an improved means which also prevents the escape of electromagnetic wave energy of any harmonic frequencies of the energy supplied to the microwave oven.

Briefly stated, and in accordance with an illustrative embodiment of the invention, a microwave oven is provided which includes an opening and a movably mounted door for closing the opening. When closed, the door is in spaced relation with an area of the outer wall of the oven. The dimensions of the opening and the door are chosen such that the area has a width of one quarter wave length of the second harmonic frequency of the electromagnetic wave energy supplied to the oven. A groove is provided in the area which has a depth of one quarter wave length of the fundamental frequency of the electromagnetic wave energy supplied to the oven. A resilient solid dielectric member is attached to the area to occupy the space between the outer wall and the door when the door is in its closed position. Two transmission lines are thereby formed, the first being the groove and the second being the parallel surfaces of the outer wall and the door. The first transmission line forms a quarter wave length choke for the fundamental frequency and all odd harmonic frequencies thereof and the second forms a quarter wave length choke for all even harmonic frequencies of the electromagnetic wave energy supplied to the oven.

For a complete understanding of the invention, together with other objects and advantages thereof, reference may be had to the attached drawings, in which;

FIGURE 1 shows a side view of a microwave oven in which the door is in its closed position;

FIGURE 2 shows a sectional view of a portion of the oven of FIGURE 1; and

FIGURE 3 shows a front view of the oven of FIGURE 1 with the door in its opened position.

In the following description of the figures, like reference numerals are used to designate the same component in the different views wherever practical.

FIGURE 1 shows the side view of a microwave oven **10** to which electromagnetic wave energy from a suitable source **12**, such as a magnetron and associated power supply, is furnished through a wave guide **14**. The structure and operation of these devices are well known to those skilled in the art, and since they form no part of the present invention, no further description of them is given. The oven **10** includes a suitable opening (not shown in this view) through which access is available to the interior, and a door **16** pivoted on hinges **18** is provided to close this opening whenever the oven **10** is utilized. The door **16** includes a handle **20**. FIGURE 1 also shows a solid dielectric member **22** positioned between the door **16** and the front of oven **10** when door **16** is in its closed position. Member **22** may be constructed from any suitable solid dielectric material which can withstand the cooking temperatures, such as tetrafluoroethylene, readily available under the trade name Teflon. The purposes and advantages of dielectric member **22** will become apparent from the following description.

FIGURE 2 shows a sectional view of a portion of the oven of FIGURE 1. Shown therein is a portion of the door **16**, dielectric member **22** and the front wall **24** of the oven **10**. Door **16** is shown in its closed position to prevent the escape of electromagnetic wave energy from the interior **26** of oven **10** to the exterior **28** thereof.

As is shown in FIGURE 2, the boundary of the door **16** overlaps an area of front wall **24** when the door **16** is in its closed position. In the preferred form of the present invention, the width *a* of this area is made equal to a quarter wave length of the second harmonic frequency of the electromagnetic wave energy supplied to oven **10** from source **12**.

In accordance with another feature of the preferred embodiment of the present invention, an L-shaped groove **30** is provided in front wall **24** which opens into the area of front wall **24** which is overlapped by the boundary of door **16** when door **16** is in its closed position. The

total depth *b* of groove **30** is made equal to a quarter wave length of the fundamental frequency of the electromagnetic wave energy provided to oven **10** from source **12** and is thus also equal to three quarters wave length of the third harmonic frequency of this electromagnetic wave energy, five quarters wave length of the fifth harmonic frequency, and so forth for higher odd harmonic frequencies.

Dielectric member **22** is attached to the outer surface of front wall **24** to completely cover the area which is overlapped by door **16** when it is in its closed position. Thus, as will be readily appreciated by those skilled in the art, the adjacent conducting surfaces of door **16** and front wall **24** and the dielectric member **22** form a first parallel strip transmission line having a length *a* which is equal to a quarter wave length of the second harmonic frequency of the electromagnetic wave energy being supplied to the oven while the groove **30** forms a second parallel strip transmission line having a length *b* equal to a quarter wave length of the fundamental frequency of the electromagnetic wave energy being supplied to the oven and having a length equal to three quarters wave length of the third harmonic frequency of this electromagnetic wave energy, and so forth for higher odd harmonic frequencies.

The operation of the invention is as follows: The second harmonic electromagnetic wave energy on the interior **26** of the cavity sees a parallel strip transmission line having a length equal to one quarter of its wave length and which is terminated in an open circuit. As is well known, an open circuit when viewed from a quarter wave length away appears to be a short circuit and thus the second harmonic energy sees a short circuit between door **16** and wall **24** and no energy of this frequency escapes between door **16** and front wall **24**. This first parallel strip transmission line thus forms an open circuited choke for electromagnetic wave energy of this second harmonic frequency.

The same operation occurs for what may be termed the "odd" even harmonic frequencies, the sixth, tenth, and so forth harmonic frequencies. For these frequencies, this transmission line is an odd multiple of a quarter wave length long and thus the open circuited termination appears to be a short circuit on the interior side of the joint. However, what may be termed the "even" even harmonic frequencies, the fourth, eighth, and so forth, harmonic frequencies, the transmission line appears to be a multiple of a half wave length long and thus, as is well known to those skilled in the art, the open circuited termination also appears to be an open circuit preventing the transmission of these "even" even harmonic frequencies. This transmission line thus forms a choke for all even harmonic frequencies of the electromagnetic wave energy supplied to oven **10**.

However, dielectric member **22** is transparent to electromagnetic wave energy and since the resulting parallel strip transmission line is not a quarter wave length of the primary or third harmonic frequency of the electromagnetic wave energy, energy of these frequencies can escape from the interior **26** and enter the transmission line. However, when this energy reaches the point at which groove **30** emerges from front wall **24**, it sees the second parallel strip transmission line which is either a quarter wave length or three quarters wave length long and which is terminated in a short circuit. As is well known to those skilled in the art, a transmission line having a length of a quarter wave length, or any odd multiple thereof, which is terminated in a short circuit appears to be an open circuit from the input end. Thus, any energy of the primary or third harmonic frequency which reaches this point sees in series therewith what appears to be an open circuit and the energy is blocked and prevented from being further transmitted to the exterior **28** of oven **10**. Groove **30** thus forms a second parallel strip transmission line which is a short circuited choke for electromagnetic wave energy of the fundamental or any odd harmonic frequency thereof.

FIGURE 3 shows a front view of oven **10** with the door **16** in its open position and shows the opening **32** through which access is had to the interior of oven **10**. FIGURE 3 also shows dielectric member **22** completely surrounding opening **32**. Not shown in the figure is groove **30** which is covered by dielectric member **22**. Groove **30** also completely surrounds opening **32**. The dimensions of opening **32** and door **16** are chosen such that the boundary of door **16** overlaps opening **32** over an area having the width *a* completely around the periphery of opening **32**, and this area is completely covered by dielectric member **22**, which is attached to front wall **24** of oven **10**.

It is readily apparent to those skilled in the art that the dimensions *a* and *b* could be interchanged and that the resultant structure would still retain microwave energy on the interior **26** of oven **10**. However, in practice it has been found that a short circuited choke such as groove **30** is a more efficient means of stopping electromagnetic wave energy than is the open circuited choke consisting of the parallel surfaces of door **16** and front wall **24** and dielectric member **22**, and since the intensity of the primary frequency and third harmonic frequency is much greater than the second harmonic frequency, the preferred form of the present invention utilizes the more efficient short circuited choke to trap these components and the less efficient open circuited choke to trap the second harmonic frequency component of the electromagnetic wave energy.

In practice, it has also been found that the short circuited choke, groove **30**, loses some of its effectiveness against higher odd harmonic frequencies because of the capacitance appearing across the opening in the groove **30**. However, this same capacitance appears as a low impedance to these same higher odd harmonics and prevents their escape to the exterior of the oven, and thus the object of the invention is still satisfied.

In addition to retaining electromagnetic wave energy within the interior **26** of oven **10**, there are several other advantages realized in the practice of the present invention. For example, dielectric member **22** maintains a uniform separation between door **16** and front wall **24** of oven **10**. Thus, in addition to forming the above described transmission line, dielectric member **22** also prevents arcing between door **16** and front wall **24**, such as has been experienced in oven in which the door makes a metal-to-metal contact with the remainder of the cavity. Also, dielectric member **22** completely covers groove **30** and thus prevents any food particles from becoming trapped in groove **30**. Dielectric member **22** thus renders the oven easier to clean and gives a more attractive appearance to the oven. Also, dielectric member **22** acts as a muffler to cushion any noise from door **16** being closed too hard against oven **10**.

It is to be understood that the above described arrangements are illustrative of the application of the principles of the present invention. Numerous other arrangements within the scope of the invention may be devised by those skilled in the art. Thus, by way of example, but not of limitation, groove **30** could instead be provided in door **16** rather than in front wall **24**, in which case dielectric member **22** would be attached to door **16** to cover groove **30**. The electrical properties of the resultant structure would be identical with the above disclosed arrangement when door **16** is in its closed position. Also, the shape of groove **30** need not be L-shaped, but might be any shape which provides the necessary length. Accordingly, from the foregoing, it is evident that various changes may be made in the present invention without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. Microwave heating apparatus comprising, a heating cavity, means for supplying electromagnetic wave energy of a predetermined wave length and frequency to said cavity, said cavity having an opening therein for access to the interior thereof, a conductive surface extending away from the exterior side of said opening, a movably mounted door for closing said opening whenever said heating apparatus is to be used, the boundary of said door being positioned in spaced relation with an area of said conductive surface when said door is in its closed position, the width of said area being a first predetermined dimension with respect to said predetermined wave length, a groove formed in one of said area and said boundary, the depth of said groove being a second predetermined dimension with respect to said predetermined wave length, a solid dielectric member attached to said one of said area and said boundary, thereby covering the opening of said groove and occupying the space between said area and said boundary when said door is in its closed position, said area, boundary and dielectric member forming a first parallel strip transmission having a length equal to said first predetermined dimension, said groove forming a second parallel strip transmission line having a length equal to said second predetermined dimension.

2. Microwave heating apparatus comprising, a heating cavity, means for supplying electromagnetic wave energy of a predetermined wave length and frequency to said cavity, said cavity having an opening therein for access to the interior thereof, a conductive surface extending away from the exterior side of said opening, a movably mounted door for closing said opening whenever said heating apparatus is to be used, the boundary of said door being positioned in spaced relation with an area of said conductive surface when said door is in its closed position, the width of said area being one quarter wave length of the second harmonic of said predetermined frequency, a groove formed in one of said area and said boundary, the depth of said groove being equal to one quarter of said predetermined wave length, and a solid dielectric member attached to said one of said area and said boundary, thereby covering the opening of said groove and occupying the space between said area and said boundary when said door is in its closed position, said area, boundary, and dielectric member forming a first parallel strip transmission line having a length equal to one quarter wave length of the second harmonic of said predetermined frequency, thereby forming an open circuited choke for said second harmonic, said groove forming a second parallel strip transmission line having a length equal to one quarter of said predetermined wave length, thereby forming a short circuited choke for said predetermined frequency and the odd harmonic frequencies thereof.

3. Microwave heating apparatus comprising, a heating cavity, means for supplying electromagnetic wave energy of a predetermined wave length and frequency to said cavity, said cavity having an opening therein for access to the interior thereof, a conductive surface extending away from the exterior side of said opening, a movably mounted door for closing said opening whenever said heating apparatus is to be used, the boundary of said door being positioned in spaced relation with an area of said conductive surface when said door is in its closed position, the width of said area being a first predetermined dimension with respect to said predetermined wave length, a groove formed in said area, the depth of said groove being a second predetermined dimension with respect to said predetermined wave length, and a solid dielectric member attached to said area, thereby covering the opening of said groove and occupying the space between said area and boundary when said door is in its closed position, said area, boundary, and dielectric member forming a first parallel strip transmission line having a length equal to said first predetermined dimension, said groove forming a second parallel strip transmission line having a length equal to said second predetermined dimension.

4. Microwave heating apparatus comprising, a heating cavity, means for supplying electromagnetic wave energy of a predetermined wave length and frequency to said cavity, said cavity having an opening therein for access to the interior thereof, a conductive surface extending away from the exterior side of said opening, a movably mounted door for closing said opening whenever said heating apparatus is to be used, the boundary of said door being positioned in spaced relation with an area of said conductive surface when said door is in its closed position, the width of said area being equal to a quarter wave length of the second harmonic of said predetermined frequency, a groove formed in said area and completely surrounding said opening, the depth of said groove being equal to one quarter of said predetermined wave length, and a solid dielectric member attached to said area, thereby covering the opening of said groove and occupying the space between said area and boundary when said door is in its closed position, said area, boundary and dielectric member forming a first parallel strip transmission line having a length equal to a quarter wave length of the second harmonic of said predetermined frequency, thereby forming an open circuited quarter wave length choke for said second harmonic, said groove forming a second parallel strip transmission line having a length equal to one quarter of said predetermined wave length, thereby forming a short circuited quarter wave length choke for said predetermined frequency and the odd harmonic frequencies thereof.

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