

- [54] SEAL MEANS FOR PREVENTING THE LEAKAGE OF MICROWAVE ENERGY FROM MICROWAVE HEATING OVEN
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- [22] Filed: Nov. 21, 1973
- [21] Appl. No.: 418,047

Related U.S. Application Data

- [63] Continuation of Ser. No. 259,755, June 5, 1972, abandoned, which is a continuation-in-part of Ser. No. 48,137, June 22, 1970, Pat. No. 3,742,176.

Foreign Application Priority Data

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Jan. 21, 1970 Japan..... 45-5098
- [52] U.S. Cl..... 219/10.55 D

- [51] Int. Cl. H05b 9/06
- [58] Field of Search..... 219/10.55

References Cited

UNITED STATES PATENTS

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|-----------|---------|------------------|-----------|
| 2,956,143 | 10/1960 | Schall | 219/10.55 |
| 3,249,731 | 5/1966 | Johnson | 219/10.55 |
| 3,525,841 | 8/1970 | Haagensen et al. | 219/10.55 |

Primary Examiner—Bruce A. Reynolds

[57] ABSTRACT

A microwave oven having prevention material for microwave leakage located in the path formed by a gap between the oven door and the oven body. The prevention means may comprise several seals and includes ferromagnetic material as one of the seals. Another seal may be a volumetric resonant cavity, and a metal spring can be provided to minimize the gap.

6 Claims, 11 Drawing Figures

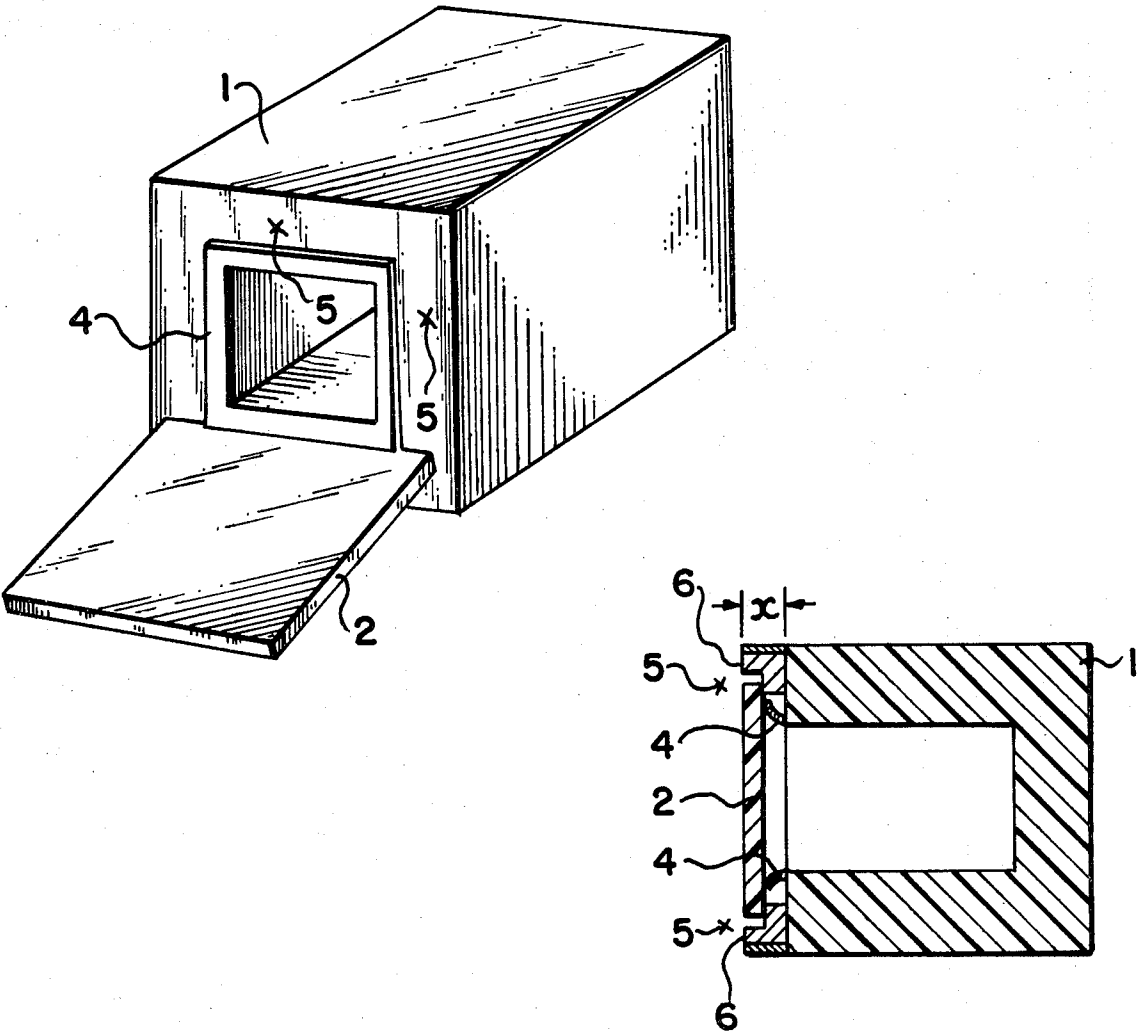


FIG. 1

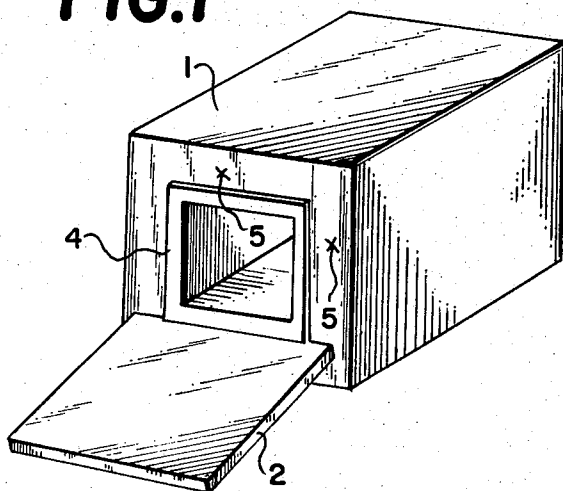


FIG. 2

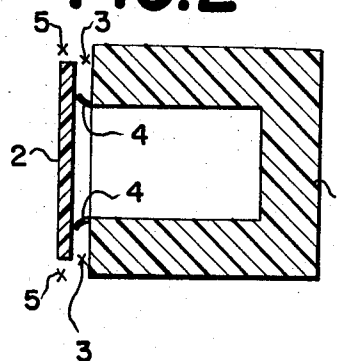


FIG. 3

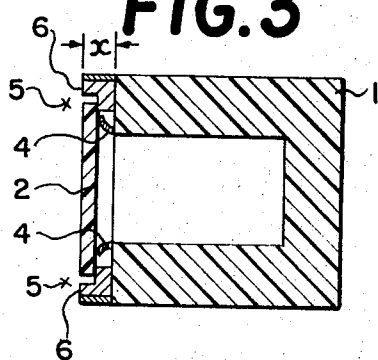


FIG. 4

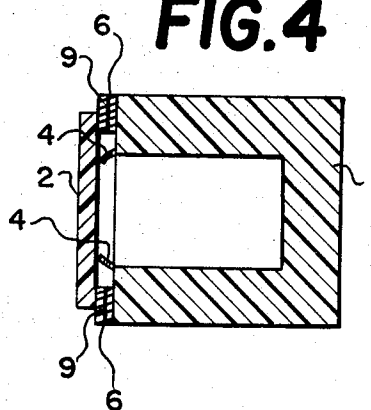


FIG. 5

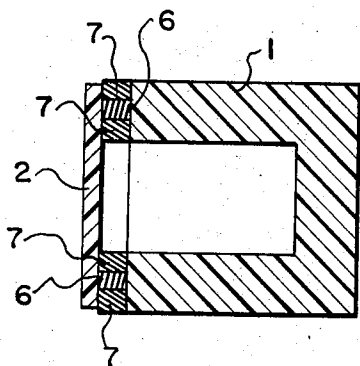


FIG.6a

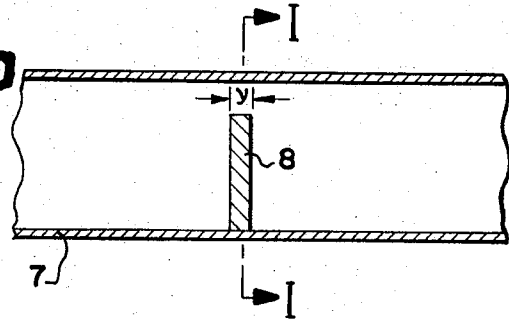


FIG.7

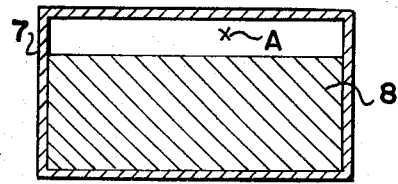
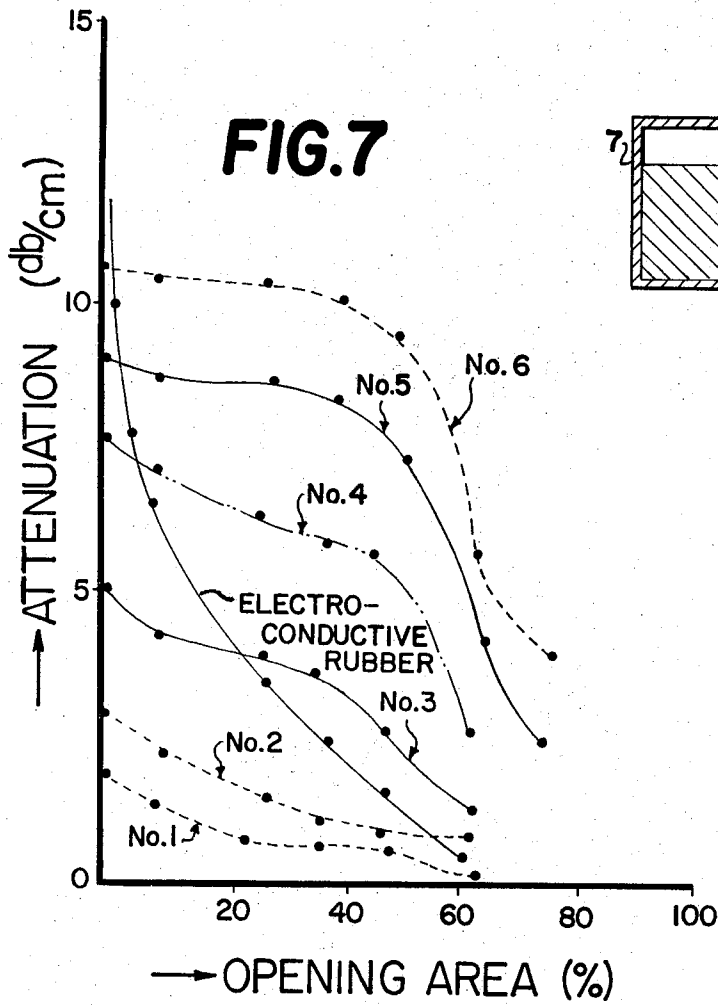


FIG.6b

FIG.8

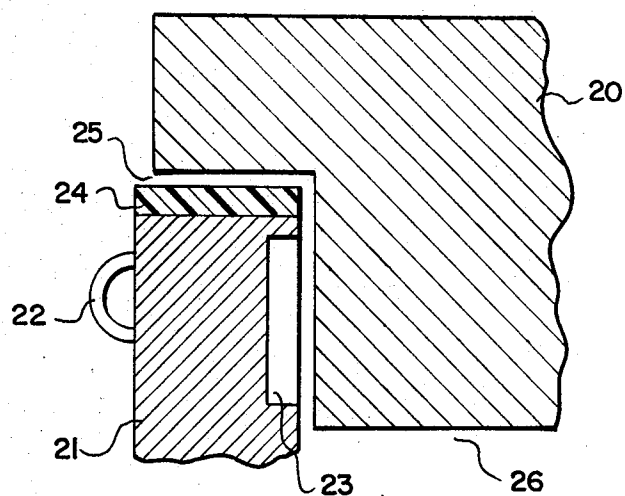
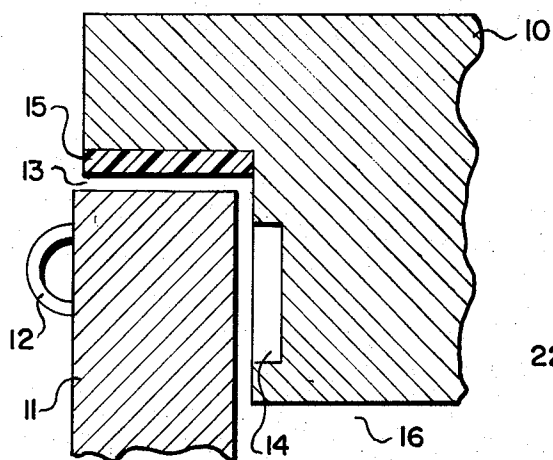
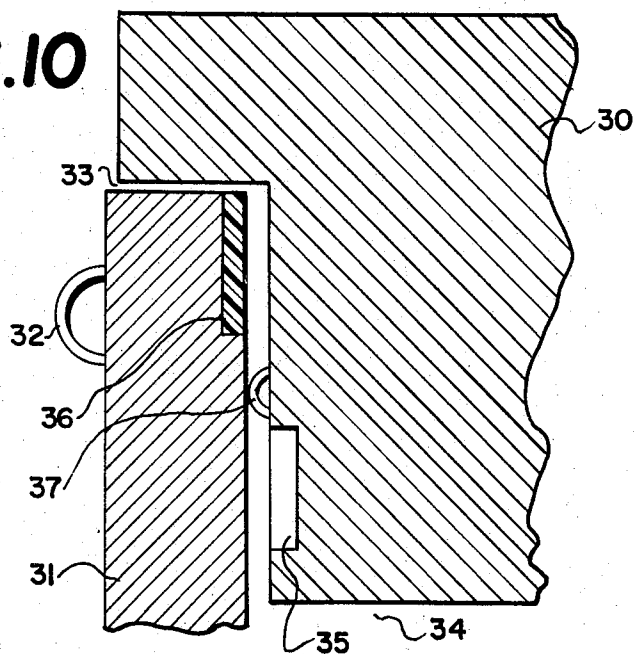


FIG.9

FIG.10



SEAL MEANS FOR PREVENTING THE LEAKAGE OF MICROWAVE ENERGY FROM MICROWAVE HEATING OVEN

This is a continuation of application Ser. No. 259,755, filed June 5, 1972, and now abandoned, which is a continuation-in-part of application Ser. No. 48,137 filed June 22, 1970, now U.S. Pat. No. 3,742,176.

BACKGROUND OF THE INVENTION

A microwave heating oven is utilized for heating an article with microwaves generated by a microwave generating device to raise the temperature of the article within a comparatively short time. The frequency of the microwaves used in the present invention is in a high frequency range, such as 2.45 GHz, as is generally known to those skilled in the art.

In the use of this type of oven there is microwave leakage from a gap, if present, between the body of the microwave heating oven and the door thereof, and the leaking microwaves generate noise in radio receivers or TV sets, and additionally cause radio-frequency burns on the human body.

Measures for preventing the above-mentioned leakage of microwaves have been provided, such as a plate form metal spring placed between the body of the oven and door so that the gap is eliminated thereby. However, such measures are not completely successful since it is very difficult to totally remove the gap between the body of the oven and the door, and even if this gap is totally eliminated, microwave leakage may still be found. The gap may reappear due to the formation of a film of metal oxide on the surface of the metal involved or if foreign matter, such as dust, is present between the oven body and the door. The above-mentioned microwave is an ultrashort microwave of 2.45 GHz, and therefore leakage will easily take place when there is such a gap even when other insulating material is present.

In order to prevent the microwave leakage, the prior art such as in U.S. Pat. No. 2,956,143 issued on Oct. 11, 1960 provides a plate form metal spring placed between the oven body and the door and electroconductive rubber used as packing to tightly close the door onto the main body. In this patent the structure and properties of the electroconductive rubber have not been disclosed, but generally speaking, an electroconductive rubber is prepared by blending natural rubber or synthetic rubber with graphite-type carbon. Since the electroconductive rubber has electroconductivity, the electroconductive rubber reflects the microwaves in the same manner as metal, and the microwave leakage can therefore be prevented. However, rubber will age when it is used for a long time due to the repetition of heating, cooling and compression thereof, and this will cause it to lose its elasticity or be deformed. Consequently, there will be a gap between the above-mentioned electroconductive rubber and the oven body or the door as a result of the continued use of the oven, and this will cause continued microwave leakage.

The present invention has been developed to remove the above-mentioned drawback, and novel sealing means prevents the microwave leakage by absorbing the microwaves even when there is a gap between the oven body and the door. The absorption of the microwaves is achieved by using, in place of the electrocon-

ductive rubber for reflecting the microwave, ferromagnetic material having the property to absorb the leakage. The ferromagnetic material is a mixture composed primarily of ferrite powder.

SUMMARY OF THE INVENTION

The present invention relates to means for preventing microwave leakage through a gap between the oven body and the oven door during the operation of a microwave heating oven, and more particularly to prevention means for such microwave leakage wherein a microwave absorber consisting primarily of ferromagnetic material comprising a mixture composed of the powder of ferrite is placed in the path of microwave leakage.

Microwave output from heating ovens is different in accordance with the application thereof; that is, the microwave output is different depending on whether the oven is used for industrial use or home use. The inventors of the present invention carried out experiments on a microwave heating oven for home use, and the explanation concerning experiments thereon is given in the following paragraphs in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a perspective view in simplified form of a microwave heating oven for home use;

FIG. 2 is a cross-sectional view of the microwave heating oven of FIG. 1 with the door closed and including a metal spring therebetween;

FIG. 3 is a view similar to FIG. 2 showing the addition of the microwave absorbing material of the present invention;

FIG. 4 is a view similar to FIG. 3 showing a further embodiment of the present invention;

FIG. 5 is a view similar to FIG. 3 showing still another embodiment of the present invention;

FIG. 6a is a longitudinal sectional view showing the arrangement of the microwave absorber in a waveguide;

FIG. 6b is a cross-sectional view along the lines 1—1 of FIG. 6a;

FIG. 7 is a graph diagram showing the relation of the gap area shown in FIG. 6b and the microwave attenuation;

FIG. 8 is a cross-sectional view similar to FIG. 3 with cut-away portions showing another embodiment of the present invention having two seals;

FIG. 9 is a view similar to FIG. 8 showing a still further embodiment of the present invention; and

FIG. 10 is a view similar to FIG. 8 showing still another embodiment of the present invention having three seals.

DESCRIPTION OF THE INVENTION

In the accompanying drawings FIG. 1 is a perspective view of a conventional microwave heating oven for home use, and FIG. 2 is a drawing showing a longitudinal sectional view of the embodiment of FIG. 1.

The heating oven consists of a body 1 and a door 2. In order to prevent microwave leakage through a gap 3 formed between the oven body and the door during operation of the oven, a plate form metal spring 4 can be located between the oven body and the door as shown in FIG. 2.

Spring 4 can be mounted on the oven body or on the door, and the oven body and the door are thereby

tightly closed to prevent microwave leakage. However, some microwave leakage can still take place during operation of the oven provided with such a spring as shown in FIG. 2, and a measurement of 4 to 5 mW per 1 cm² has been found at position 5 as shown in FIGS. 1 and 2 in the neighborhood of door 2.

FIGS. 3, 4 and 5 illustrate embodiments of the present invention wherein a microwave absorber 6 is placed in the path through which there is microwave leakage during the operation of the oven. Such leakage path is in the gap formed between oven body 1 of the microwave heating oven and the door 2. It is possible to considerably reduce the amount of the microwave leakage by the absorbing sealing means of the present invention.

For the above-mentioned microwave absorber, a mixture was prepared by mixing ferrite powder and rubber at the weight ratio (wt. parts) 5:1, that is, the mixture was prepared by mixing 4 parts of the ferrite powder in 1 part of a rubber carrier in a dispersed state, and this mixture was used in the present invention. Hereinafter, such mixture is described as rubber-ferrite.

The above-mentioned ferrite is an inorganic compound having spinel structure represented by the general formula given below:



(wherein M is a divalent metal such as Ni, Cu, Zn, Mn, Mg, etc.).

Such ferrite as mentioned above can be in any composition, but the Ni-Zn type ferrite wherein M is Ni or Zn is most effective. The particle size of the above-mentioned ferrite powder was from 1 to 5 μ .

On the other hand, in this invention natural rubber or synthetic rubber can be used as the rubber to be mixed with ferrite powder, and other high molecular compounds such as plastics can be also used in place of the rubber.

The prepared rubber-ferrite having 1 cm of thickness could give the attenuation of from 7 to 10 db against 2.45 GHZ microwaves.

The above-prepared rubber-ferrite absorber 6 was

The inventors of the present invention have found that there is a relation between the properties of the ferrite or the mixture of the ferrite powder and the effect thereof as a microwave absorber, and the following is an explanation about this relation.

When the relative permeability of the ferrite or the mixture of the ferrite powder and the relative permittivity thereof are respectively set to be μ and ϵ , the following relation can be obtained:

$$\begin{aligned}\dot{\mu} &= \mu' - j\mu'' \\ \dot{\epsilon} &= \epsilon' - j\epsilon''\end{aligned}$$

(wherein μ' and ϵ' are respectively the real parts of relative permeability and relative permittivity; μ'' and ϵ'' are respectively the imaginary parts thereof; and j is an imaginary part unit).

The preferable microwave absorber to be used in the method of the present invention is a ferromagnetic material having the value of $|\dot{\mu}| \times |\dot{\epsilon}| / \mu' \times \epsilon'$ of more than 1.25 and the product of μ' and ϵ' of more than 9.0 (i.e., $\mu' \times \epsilon' > 9.0$).

The following are the reasons for restricting the microwave absorber of the present invention to the ferromagnetic material having the above-mentioned properties.

The ferrite powder to be used in the method of the present invention, can be prepared by forming (pressing) the mixture composed of 20 mol of NiO, 20 mol of ZnO and 60 mol of Fe₂O₃, calcining the mixture at 1,200° C for 1 hour to prepare Ni-Zn type calcined ferrite, and crushing said calcined ferrite in a ball mill for 5 hours. The powder of ferrite has particle size of from 1 to 5 μ and as the organic high molecular compound to be mixed with the above prepared ferrite powder, fluorine-contained rubber [whose trade name is Kel F elastomer] is used, and the above prepared ferrite powder is mixed by the ratio of 0.5, 1.0, 2.0, 4.0, 5.0 and 8.0 parts by weight to 1 part by weight of the fluorine-contained rubber, and the obtained mixture is sufficiently mixed by using a kneader, and thus six kinds of samples from No. 1 to No. 6 were obtained.

The values of μ' , μ'' , ϵ' , and the attenuation (db/cm) against 2.45 GHz microwave of the samples of No. 1 - No. 6 were measured, and the following results were obtained.

Table

Sample No.	μ'	μ''	$ \dot{\mu} $	ϵ'	ϵ''	$ \dot{\epsilon} $	$\mu' \times \epsilon'$	$\frac{ \dot{\mu} \times \dot{\epsilon} }{\mu' \times \epsilon'}$	Attenuation (db/cm)
1	1.20	0.24	1.22	3.50	0.18	3.50	4.2	1.02	2.00
2	1.40	0.38	1.53	4.30	0.20	4.30	6	1.10	3.0
3	1.60	1.22	2.01	5.60	0.24	5.60	9	1.25	5.1
4	1.80	1.92	2.63	6.70	0.32	6.70	12	1.47	7.8
5	1.90	2.23	2.93	7.40	0.32	7.40	14	1.55	8.0
6	2.10	2.58	3.33	8.60	0.40	8.60	18	1.59	10.6

placed at the path through which there is microwave leakage, as shown in FIG. 3. In regard to the size of the rubber-ferrite, x is 2 cm, and the amount of the microwave leakage is from 0.02 to 0.04 mW/cm² when the rubber-ferrite of such a size as mentioned above is placed in the neighborhood of the door, and when compared with the case in which the rubber-ferrite is not used, the microwave leakage was found to have been reduced from 1/100 to 1/200.

1 part by weight of synthetic rubber (Neoprene) and 0.5 part by weight of graphite type carbon (whose particle size is 0.01 μ) were mixed to prepare the electroconductive rubber whose specific resistance is 10 Ω -cm.

Referring to FIG. 6a and FIG. 6b, a plate form rubber-ferrite 8 having 6 mm of thickness (y) or a plate form electroconductive rubber 8 having 6 mm of thickness (y) were prepared from the above-prepared rubber-ferrite (Sample No. 1 - No. 6) or the above-

prepared electroconductive rubber, and the above-prepared plate form rubber-ferrite 8 or the plate form electroconductive rubber 8 were inserted into a waveguide 7 of Model WRJ-2 (5.46 cm × 10.9 cm). The sizes of said plate form rubber-ferrite and said plate form electroconductive rubber were selected in such a manner that the ratio of the opening area (gap A) of the waveguide to the cross-sectional area of the waveguide, could be 0 percent, 10 percent, 20 percent, 30 percent, 40 percent, 50 percent, 60 percent and 70 percent, and by using 2.45 GHz microwaves, the amount of attenuation of the microwaves in the case of the above-mentioned opening areas were measured, and the values as shown by the curves of FIG. 7 were obtained.

As is apparent from the above-mentioned curve in FIG. 7, in the case of electroconductive rubber, the amount of attenuation is abruptly reduced as the opening area is increased, and when there is even a slight gap, the effect for preventing microwave leakage deteriorates.

As is shown by the curves in FIG. 7, Sample No. 6 among the above-prepared rubber-ferrites is the most effective, and the effect of Sample No. 1 is the poorest.

From the above given table and the curves, for the ferromagnetic material for preventing microwave leakage, those having $\mu' \times \epsilon'$ of more than 9 and the value of $|\dot{\mu}| \times |\dot{\epsilon}| = \mu' \times \epsilon'$ of more than 1.25 are preferable.

In regard to the manner in which the rubber-ferrite is applied, there are a number of forms in addition to the manner shown in FIG. 3, for example, as shown in FIGS. 4 and 5.

Measurements were carried out on the forms shown in FIG. 4 and FIG. 5, and substantially the same results were obtained as in the embodiment shown in FIG. 3.

The rubber-ferrite 6 shown in FIG. 4 includes a copper net 9 (whose mesh is 1 mm), and the material 7 shown in FIG. 5 is an electroconductive rubber. From these embodiments the inventors of the present invention found out that the effect of microwave absorption can be increased by using additional means in addition to the rubber-ferrite alone.

It has been found out that most of the leaking microwaves can be absorbed by the rubber-ferrite placed in the path through which the microwave passes, regardless of forms of structure of the rubber-ferrite, if said rubber-ferrite has a predetermined size. An advantage of the rubber-ferrite is its elasticity and flexibility, and therefore it is convenient when used for the purpose of the present invention.

In order to place the rubber-ferrite, as the above-mentioned microwave absorber, in the path through which the microwaves of the heating oven passes, it may be fixed on the main body of the oven or on the door, and for fixing the above-mentioned wave absorber, adhesion by means of adhesive, or fixation by means of fixing tools, or the like is used.

FIGS. 8, 9 and 10 illustrate further embodiments of the present invention in which the sealing effect or microwave leakage prevention provided by the rubber-ferrite is combined with one or more additional seals. In FIG. 8 a body 10 of the microwave heating oven is associated with a door 11 having a handle 12. Door 11 closes on oven body 10 as shown resulting in a gap 13 as explained hereinbefore. During operation there will be microwave leakage along the path created by gap 13. Accordingly, in the embodiment shown in FIG. 8 a

first seal is provided by a volumetric resonant cavity 14. The use of a resonant cavity is well known in the prior art for preventing microwave leakage by providing a terminating conducting surface having a predetermined location with respect to the gap. This feature is described in the prior art by U.S. Pat. No. 3,525,841 issued on Aug. 25, 1970.

The embodiment in FIG. 8 includes rubber-ferrite material provided as a second seal 15. As shown in FIG. 8, rubber-ferrite 15 is located within oven body 10 along the surface adjacent gap 13 and extending in a longitudinal direction above and transverse to the longitudinal direction of the closed door. Resonant cavity 14 is located within oven body 10 adjacent to gap 13 and extends in a longitudinal direction generally parallel to the longitudinal direction of door 11 in the closed position. Oven body 10 includes an intermediate or operating area 16 within which the microwave energy is generated. Leakage that would normally pass through the path created by gap 13 is attenuated or prevented by first seal 14 and second seal 15 in the manner described hereinbefore. It is seen from the embodiment of FIG. 8 that the additional resonant cavity seal 14 assists the attenuation provided by rubber-ferrite seal 15.

FIG. 9 illustrates a further embodiment of the present invention utilizing a first and a second seal for preventing microwave leakage. Body 20 of the microwave heating oven includes a closeable door 21 having a handle 22. The first seal is provided by a volumetric resonant cavity 23, and the second seal is provided by a rubber-ferrite material 24, both seals being located within the door 21. As previously explained, a gap 25 is formed when the door is closed, and microwave energy generated from interior 26 of the oven body tends to leak out to the path provided by gap 25. This leakage is prevented by first seal 23 as explained hereinabove in connection with FIG. 8 and further prevented by rubber-ferrite seal 24 as explained hereinbefore. Both seals are formed to extend longitudinally and are positioned within door 21 adjacent to gap 25. Rubber-ferrite seal 24 extends longitudinally in a direction transverse to the door along the top thereof, and resonant cavity 23 extends in a direction parallel to the longitudinal dimension of the closed door.

FIG. 10 illustrates a further embodiment of the present invention utilizing three seals for preventing microwave leakage, the third seal constituting a plate form spring similar to the type shown in FIGS. 2-4. In FIG. 10 body 30 of the microwave heating oven includes a closeable door 31 having a handle 32. In the closed position a gap 33 is formed, and microwave energy generated from interior portion 34 of the oven body can pass out through the path provided by gap 33 unless prevented. Such prevention is provided by a first seal formed in the oven by volumetric resonant cavity 35. A second seal is provided by rubber-ferrite material 36 located in door 31, and the third seal is provided by a plate form metal spring 37 located between door 31 and the oven body in the closed position. In the operation of the oven shown in FIG. 10 the spring 37 will help maintain door 31 close to the body of oven 30 to minimize gap 33 and prevent microwave leakage thereby. Any remaining microwave leakage is further prevented by the first seal 35 and the second seal 36 as explained hereinabove. Resonant cavity 35 is positioned within the oven body 30 in a manner similar to the positioning in FIG. 8 and extends longitudinally ad-

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jacent gap 33 and parallel to the longitudinal dimension of door 31. Rubber-ferrite seal 36 is positioned within door 31 adjacent gap 33 and extends longitudinally downward from the top of the door as shown in FIG. 10 in a direction parallel to the longitudinal dimension of the door. Spring 37 is located between the first and second seals in the closed position.

FIGS. 8, 9 and 10 illustrate various locations of a plurality of seals utilized for microwave leakage prevention. However, it is to be understood that FIGS. 8, 9 and 10 are merely illustrative disclosures and that other modifications and locations of the seals are possible as long as at least one of the seals is a rubber-ferrite seal and the seals are located adjacent the gap so that they will be in the path of microwave leakage.

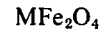
It will be further understood that various other changes and modifications may be made by those skilled in the art with reference to the use of rubber-ferrite means for absorbing microwave leakage as described above without departing from the scope of the invention as defined by the following claims.

What we claim is:

1. A microwave oven comprising a body formed by walls and having an opening in one of said walls; a door provided for closing said opening; said body and said door in a closed position defining a path through which microwave energy may leak from the inside to the outside of said oven; and leakage prevention means comprising a volumetric resonant cavity in one surface of said path, and a layer of ferromagnetic material located directly along one surface defining said path and spaced from said cavity, the layer of ferromagnetic material incompletely blocking the opening of said path and having a surface exposed to said path, said surface of said ferromagnetic material and opposed surface of

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said path forming a gap therebetween, said ferromagnetic material consisting of a mixture of the powder of ferrite and an organic high molecular weight compound, said ferrite having the formula:



wherein M is a divalent metal such as Ni, Cu, Zn, Mn or Mg, and said high molecular weight compound being selected from the group consisting of natural rubber and synthetic rubber, the thickness of the gap being in the order of from approximately 5 percent to 50 percent of the thickness of the layer of ferromagnetic material.

2. A microwave oven according to claim 1 in which said leakage prevention means further comprises a metal spring extending completely across said path, thereby forming a seal blocking said path.

3. A microwave oven according to claim 1 wherein said volumetric resonant cavity is located in said oven body, and said layer of ferromagnetic material is located on said oven body.

4. A microwave oven according to claim 1 in which said volumetric resonant cavity is located in said door, and said layer of ferromagnetic material is located on said oven body.

5. A microwave oven according to claim 1 in which said volumetric resonant cavity is located in said oven body and said layer of ferromagnetic material is located on said door.

6. A microwave oven according to claim 1, in which said volumetric resonant cavity is located in said door, and said layer of ferromagnetic material is located on said door.

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