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MICROWAVE APPARATUS

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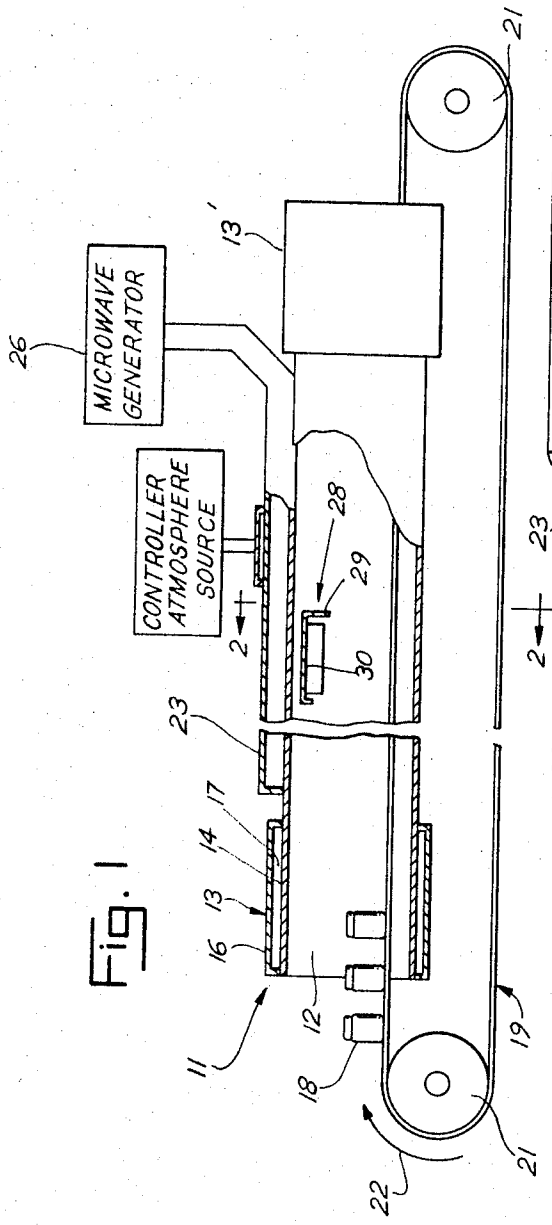



Fig. 1

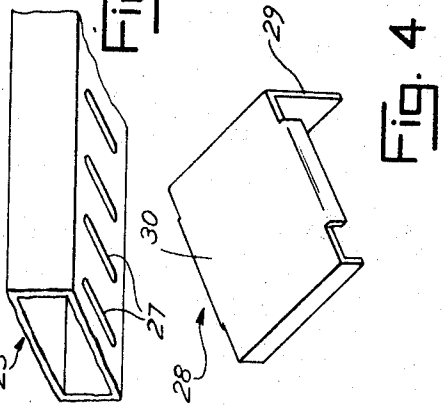



Fig. 3

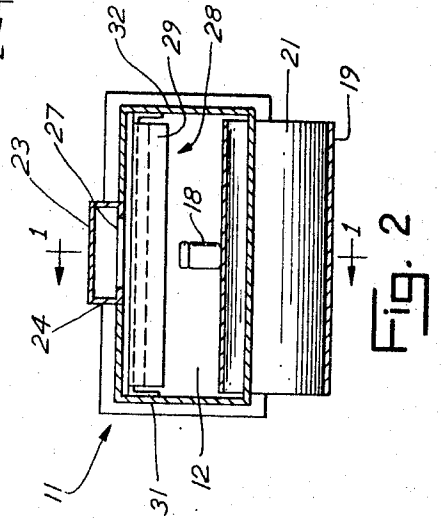



Fig. 2




Fig. 4

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# MICROWAVE APPARATUS

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## ABSTRACT OF THE DISCLOSURE

A microwave processing chamber coupled to a microwave energy source with a plurality of electrical openings along one wall and a baffle in said chamber before at least one of said openings and substantially parallel to said wall but spaced from said opening to stabilize the mode patterns in said chamber.

This invention relates to apparatus for heating materials with microwave energy and more particularly to a microwave distribution system for processing chambers.

Microwave energy has recently been applied to the processing of substances for a variety of purposes. As such energy penetrates dielectric materials and readily heats any water contained therein, microwave irradiation provides a very rapid and efficient means for cooking foods, freeze drying foods, and for drying or heat treating many other products such as paper, wood, and a variety of industrial chemicals.

Processes of the type discussed above generally require a microwave heating chamber in which the product is disposed for irradiation. The microwave heating chambers are encased in metal enclosures to prevent the microwave energy from radiating and to concentrate the energy in the product which has been placed in the cavity for irradiation. In microwave heating chambers, or ovens, common in the art, the dimensions of the enclosure or oven cavity have been generally multiples of the wavelength of the microwave energy utilized and, as a result, there is always present the possibility of having one or more resonant modes excited or existing in them. The modes within the enclosures or oven cavities are established by the operating frequency of the waveguide, the dimensions and geometry of the enclosures or oven cavities and the nature of the material to be heated.

A considerable problem exists in coupling the microwave energy into the enclosures or oven cavities. Coupling systems which consist of a point of excitation may have heating patterns which are dominated more by the location, size or nature of the material being heated than by the cavity resonance. A microwave oven may be required to heat a variety of materials or, if tailored to a specific material, considerable variation in the properties of the material may be encountered during processing. The coupling coefficients of the feed system and the losses in the cavity and the feed systems therefor must be such that the RF generator can operate without damage into heavy or light loads.

Recently, a microwave distribution system has been discovered which is highly efficient. It comprises a high power source coupled to the heating or processing chamber through a very long waveguide or transmission line means which extends along the product irradiation region. The waveguide may itself form a portion of the chamber wall where this construction is convenient. To provide for a distributed injection of energy into the chamber, the wall of the waveguide which faces the product irradiation region of the chamber is open at a plurality of points along the length thereof. The waveguide wall may, for example, be provided with a large number of spaced apart slots which are directed transversely to the axis of the guide.



The openings interrupt the systematically varying current sheet which exists in the wall of an excited waveguide. Owing to the interruption of the current, a time varying electrical field and accompanying perpendicular magnetic field exists across each opening causing a portion of the microwave energy to be radiated therethrough toward the product region of the chamber.

The injected energy will usually, to some extent, be directed obliquely with respect to the axis of the chamber, and such energy has a tendency to propagate rapidly towards the ends of the chamber with a reduced number of passages through the product. To counteract this, a series of sheet reflectors formed of electrically conducting material are mounted transversely in the chamber at intervals along its length. The reflectors extend downwardly from the top wall of the chambers to a level just above the tops of the product containers.

The openings in the wall of the waveguide need be openings in the electrical sense only, that is, the electrical conductor of the waveguide wall is absent at the opening area. If necessary, where energy is to be injected into a vacuum or pressurized chamber, for example, the openings may be physically closed by windows of dielectric material such as glass, ceramic or plastic.

In other applications, no closure is provided and the waveguide is utilized as a highly efficient means for injecting or withdrawing gases at the chamber. This function need not interfere with the electrical operations. Where the waveguide is utilized for gas injection, the flow acts to prevent water vapor from approaching the injection region and inhibits sparking.

The above described energy distribution structure may be used with virtually any type of microwave chamber and serves to maximize the rate at which energy can be injected without field breakdown. By an appropriate variation in the size and spacing of the openings along the waveguide, the relative amounts of energy injected into different portions of the chamber may be controlled. By substituting different waveguides in a given chamber, the distribution of power therein may be modified as is sometimes desirable where the chamber operates on a continuous process basis and is used for treating different products.

As a further advantage, two or more such energy distribution waveguides may be employed on a single chamber without any significant interference between the two microwave sources.

It is an object of the present invention to provide an improved microwave distribution system for processing chambers.

Another object is to control the microwave energy distribution and phase of the various modes within processing chambers.

Still another object is to couple microwave energy into a processing chamber in a fashion such that the microwave source can operate without damage into a heavy, light or no load condition.

A still further object is to utilize a diffuse coupling system such that the localized variations in loading within the microwave processing chamber do not produce operating conditions outside the acceptable limits for the microwave source.

Still another object is to provide a more efficient means for injecting microwave energy into a processing chamber.

A still further object is to provide means for increasing the amount of microwave power which can be fed into a processing chamber.

Still another object is to provide means for obtaining a desired distribution of energy within a microwave processing chamber.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

In accord with such objectives, the energy distribution system of this invention, while generally like the system described above, has a reflector or baffle preferably at or near the central portion of the chamber. It replaces the series of vertically disposed reflectors in the chamber. This baffle has a transverse vertical section spaced from the radiator about ¼ wavelength and extending downward about ¼ wavelength, and a horizontal section spaced about ¼ wavelength from the reflector and about 1¼ wavelengths long. With such an arrangement, a greater stabilizing effect on the mode patterns in the chamber so that the coupling of the microwave energy is relatively insensitive to heavy, light or no load conditions is provided.

The exact operation of the baffle is not completely understood, nor is it completely understood why it works. It is believed, however, that incoming energy is stored in the space between the enclosure top which contains the radiating apertures and the reflecting baffle. The displacement and conduction currents induced in the baffle produce fields which together with the fields produced by the diffused radiating system result in the excitation of a mixture of modes in such a way that all the energy becomes available to the interior of the chamber. During light or no load operation, the modes remain stabilized and the excess microwave energy is coupled into lossy media in the microwave absorbing chambers. The absorbing chambers may be the microwave traps around the apertures through which the processed material is passed, or a chamber which is purely an auxiliary absorber to reduce the Q of the process enclosure during light or no load operation.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others and the apparatus embodying features of construction, combination of elements and arrangement of parts which are adapted to effect such steps, all as exemplified in the following detailed disclosure, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawing in which:

FIG. 1 is a broken out elevation view of a continuous process microwave chamber having a baffle exemplary of the present invention incorporated therein;

FIG. 2 is a cross section view of the chamber of FIGURE 1 taken along lines 2—2 thereof, illustrating the manner in which the baffle is affixed to the side walls of the chamber;

FIG. 3 is a perspective view of a section of the waveguide structure which supplies power to the chamber of FIGURES 1 and 2; and

FIG. 4 is a perspective view of the baffle incorporated into the chamber of FIGURES 1 and 2.

Similar reference characters refer to similar parts throughout the several views of the drawing.

Referring now to the drawing and more particularly to FIGS. 1 and 2 thereof, there is shown a microwave heating chamber **11** of the general type known in the prior art, for treating substances on a continuous basis.

The primary heating region of chamber **11** is formed by a long horizontal tunnel **12** formed of electrically conducting walls. In the preferred embodiment, the tunnel has a rectangular cross sectional configuration with a greater width than heighth dimension. It is extended at each end by terminating or absorbing sections **13** and **13'** which function to suppress the escape of microwave energy from the ends of the chamber **11**. Each terminating section **13** and **13'** has an inner wall **14** which is of rectangular cross section and which forms an extension of the through passage of tunnel **12**. Spaced outwardly from a dielectric wall **14** is a conducting outer wall **16** and between them is contained a volume of water **17** or other lossy liquid. As the microwave energy is injected at right angles to the axis of tunnel **12**, it tends to propagate toward the ends of the tunnel **12**, by repeated reflections between opposite walls thereof. Upon reaching the terminating sections **13** and **13'**, such energy must repeatedly pass through the water **17** or other lossy liquid and is therefore attenuated rather than being emitted from the tunnel **12**.



The product to be treated, which may be containers of food **18**, for example, is carried through the tunnel **12** by a continuous belt conveyor **19** formed of a dielectric material. The conveyor **19** may be mounted on rotating drums **21** disposed one at each end of the tunnel **12**, with drive being applied to one of the drums in the direction indicated by arrows **22**.

A long waveguide **23** for injecting microwave energy into the chamber **11** is of rectangular cross section and extends along the upper surface of tunnel **12**. The waveguide **23** may form an integral part of the wall of tunnel **12** by being fitted in a matching slot **24** formed in the wall thereof. Waveguide **23** receives power from a suitable conventional source **26** coupled to one end thereof, the opposite end of the waveguide being closed.

A series of openings, such as transverse slots **27**, are spaced along the wall of waveguide **23** that faces the interior of tunnel **12** to provide for the distributed injection of energy from the source **26** into the tunnel. Factors affecting the selection of a suitable configuration and spacing for the slots **27** will be hereinafter discussed in greater detail, the general effect of the slots being to divide the microwave energy from source **26** into increments which are directed downwardly into tunnel **12** at spaced points along the length thereof. The energy is repeatedly reflected between the opposing walls of tunnel **12** and thus the contents of the containers **18** is continually penetrated by the microwaves. In passing through the contents of the containers, a portion of the energy is absorbed with consequent heating thereof.

A baffle **28** formed of electrically conducting material is mounted at or near the central portion of the tunnel **12**, for coupling the microwave energy into the tunnel in a fashion such that the source **26** can operate without damage into a heavy, light or no load condition within the tunnel. The baffle **28** has a transverse vertical section **29** spaced from the top wall **14** of tunnel **12** (forming the radiator) about ¼ wavelength and extending down about ¼ wavelength. The baffle **28** also has a horizontal section **30** which is approximately 1¼ wavelengths long and which is spaced approximately ¼ wavelength from the top wall **14**. The baffle **28** extends across the width of the tunnel **12** and has its side edges electrically affixed to the side walls **31** and **32** thereof.

As indicated above, it is believed that the incoming microwave energy is stored in the space between the top wall **14** of the tunnel **12** and the horizontal section **30** of the baffle **28**. The displacement and conduction currents induced in the baffle **28** produce fields which together with the fields produced by the diffused radiating system formed by the slots **27** result in the excitation of a mixture of modes in such a way that all the energy becomes available to the interior of the tunnel **12**. During light or no load operation, the modes remain stabilized and the excess microwave energy is coupled into the water **17** or other lossy liquid contained within the terminating or absorbing sections **13** and **13'**. The terminating or absorbing sections **13** and **13'** may be purely auxiliary absorbers to reduce the Q of the tunnel **12** during light or no load operation rather than microwave traps integrally formed about the openings through which the product to be treated is passed.

The vertical section **29** of the baffle **28** is preferably extended exactly vertical, or perpendicular to the top wall **14**, and is preferably exactly ¼ wavelength long. However, experimentation has shown that satisfactory operation may be obtained if it is slightly angularly disposed and slightly less or greater than ¼ wavelength long.

Example I

In an actual application, in an oven which was 39 inches wide and 24 inches high, the baffle **28** was electrically affixed to the side walls of the oven at a position with the horizontal section **30** thereof spaced 2¾ inches below the top. The baffle was 16 inches in width and had a 4 inch vertical section **29**. The microwave source had a frequency of approximately 900 megacycles, however, other frequencies such as 2400 megacycles can be used also, by appropriately altering the size of the oven and properly positioning the baffle **28** in the manner described above.

The baffle **28** in the above described application was mounted in a fashion such that its position could be easily changed. Such a mounting was desirable to permit the position of the baffle along the length of an enclosure to be varied to compensate for the characteristics of different microwave sources or processing materials.

To determine the dimensions and locations of the baffle **28**, the impedance properties of the oven or tunnel were determined for various combinations of sizes and locations of the baffle. Numerous combinations were tested and measurements were made to indicate trends and establish an acceptable impedance match for the microwave source.

It was found that the impedance changed slowly as a function of the spacing of the horizontal section **30** of the baffle from the top wall **14**, the width of the baffle and the length of the vertical section **29**. The spacing of the horizontal section **30** from the top wall **14** was varied from 2 to 4 inches, the width of the baffle from 6 to 16 inches and the length of the vertical section from 1 to 6 inches, with rather broad optimums centered about the actual values set forth above for the positioning of the baffle. The variation of the longitudinal position of the baffle in a region approximately midposition in the oven proved to be the parameter providing the most effective control over the energy distribution in the oven.

With the exception of the above described baffle **28**, the microwave heating chamber **11** can be constructed and operate in the same fashion as the chamber described in the introductory remarks. Accordingly, the presently disclosed chamber **11** has all of the same desirable features and, furthermore, has an energy distribution system which has a far greater stabilizing effect on the mode patterns in the chamber so that the coupling of the microwave energy is relatively insensitive to heavy, light or no load conditions.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be in carrying out the above method and in the construction set forth without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention, which, as a matter of language, might be said to fall therebetween.

What is claimed is:

**1.** In apparatus for treating products with microwave energy comprising, in combination: a processing chamber formed of electrically conducting material, a source of microwave energy, means for coupling and directing said source to said processing chamber through a wall



with a plurality of electrical openings leading into said chamber, and reflector means in said chamber for distributing the microwave energy therein, the improvement comprising a baffle having a first disposed section which is substantially parallel to said wall and is approximately 1¼ wavelengths long and is positioned in said chamber before at least one of said electrical openings but spaced from said opening at least approximately ¼ wavelength from said wall to stabilize the mode patterns in said chamber so that the coupling of said microwave energy to said chamber is relatively insensitive to heavy, light and no load conditions.

**2.** The apparatus of claim **1** wherein said coupling means comprise a waveguide extending along at least a portion of said chamber, said electrical openings being spaced apart along an extensive portion of said wall.

**3.** The apparatus of claim **1** wherein said baffle has a second disposed section vertical to said first section and extending in a direction away from said opening approximately ¼ wavelength.

**4.** The apparatus of claim **3** wherein said first disposed section is spaced approximately ¼ wavelength from said electrically conducting wall and is approximately 1¼ wavelengths long and wherein said second disposed section extends approximately ¼ wavelength.

**5.** The apparatus of claim **1** wherein said baffle is electrically affixed to the walls of said chamber.

**6.** The apparatus of claim **1** wherein said baffle is adjustably affixed to the walls of said chamber whereby the position of said baffle can be easily and quickly adjusted to compensate for the characteristics of different microwave sources and for different products.

**7.** The apparatus of claim **1** wherein said baffle is affixed to the side walls of said chamber along its side edges.

**8.** The apparatus of claim **1** wherein said baffle is formed of an electrical conducting material.

**9.** The apparatus of claim **1** wherein said baffle is positioned longitudinally at a point which is approximately centrally between the ends of said chamber.

**10.** The apparatus of claim **1** wherein said processing chamber has a cross sectional rectangular configuration with said baffle positioned centrally therein.

**11.** The apparatus of claim **1** wherein a plurality of baffles are positioned within said chamber.

**12.** The apparatus of claim **1** wherein said processing chamber has input and output openings and means for conveying products through said chamber from said input to said output openings.

**13.** The apparatus of claim **12** further including terminating sections at said input and output openings of said chamber for reducing the Q of said chamber during light or no load conditions.


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