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[54] **COMPOSITE MICROWAVE APPLICATOR AND
 PRODUCT CONVEYOR**
9 Claims, 8 Drawing Figs.

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219/10.69
 [51] Int. Cl. **H05b 9/06,**
H05b 5/00
 [50] Field of Search **219/10.65,**
10.55

[56] **References Cited**
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ABSTRACT: Microwave applicators are disclosed for applying microwave energy to a product moved through the applicator. The product being treated may be particulated, liquid, or it may be in sheet form. The microwave frequency range of interest is one such that the treatment zone within the applicator is at least a plurality of wavelengths long. The applicators of the present invention are characterized by including a composite microwave circuit portion and the product conveying structure such that the conveying structure forms a portion of the microwave circuit and such that the product being treated is physically supported upon or supported immediately adjacent the composite microwave circuit and product conveyor portion. Several composite microwave circuit and conveyor structures are disclosed. These structures include vibratory conveyors, slides, air cushion conveyors, and screw conveyors.

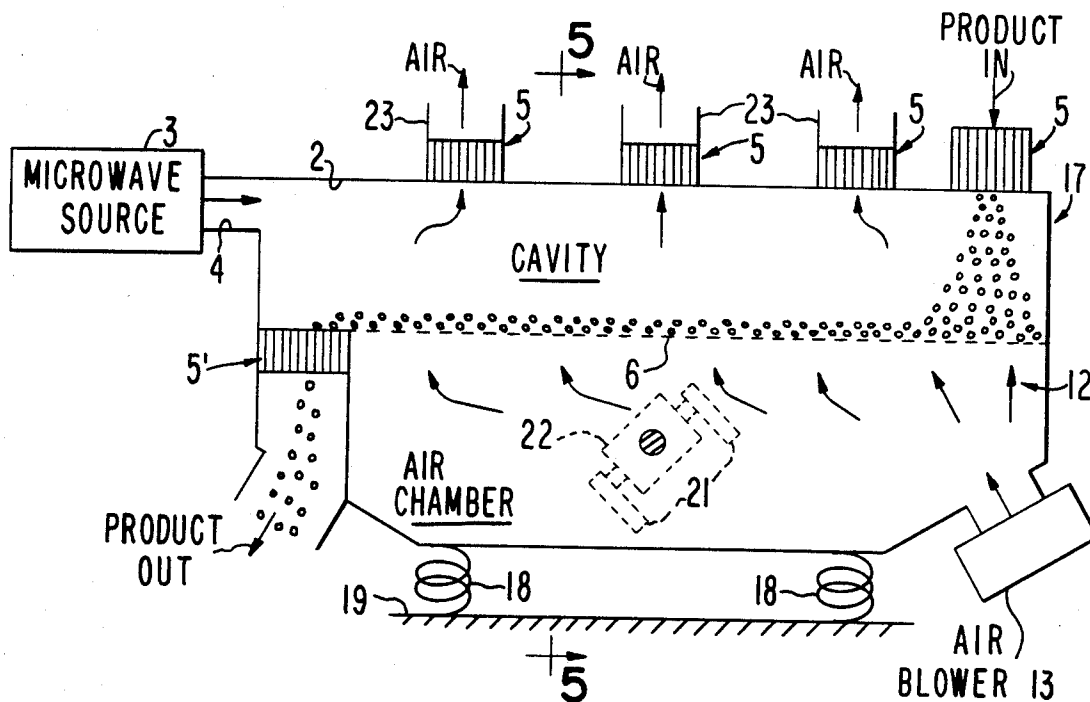


FIG.4

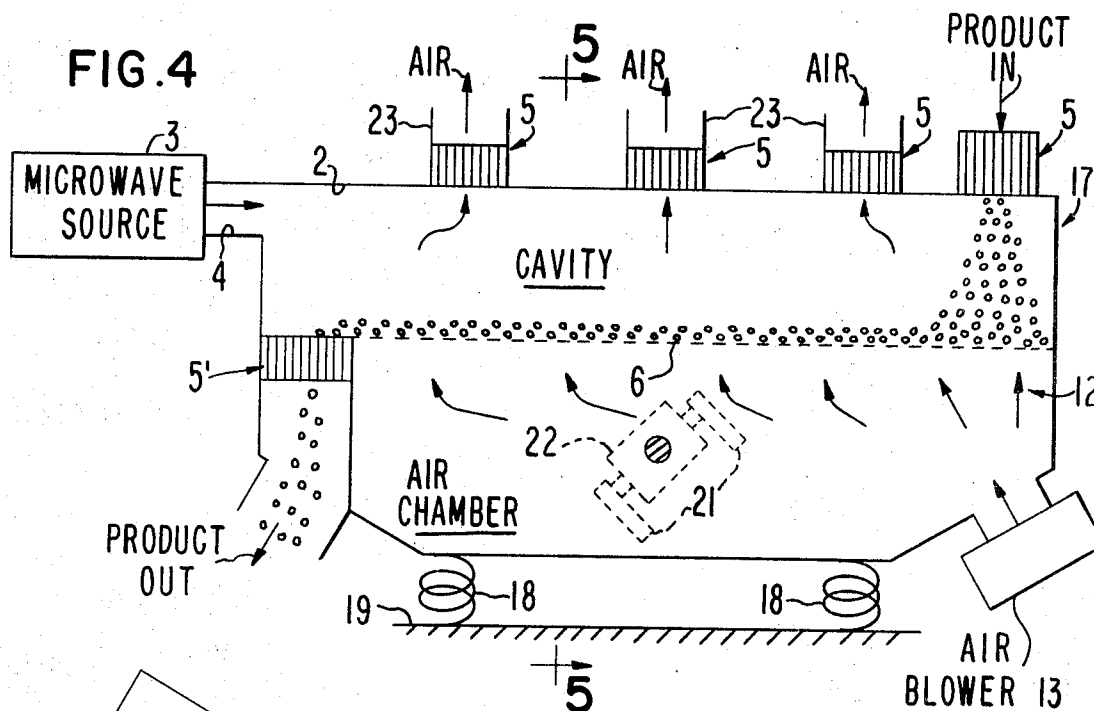


FIG.1

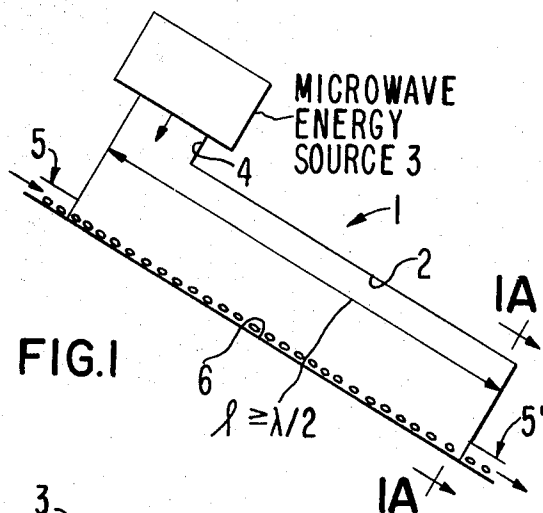


FIG. 1A

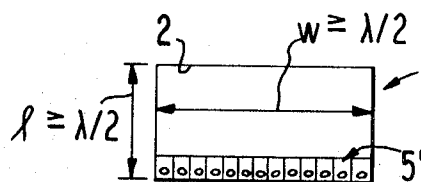


FIG.3

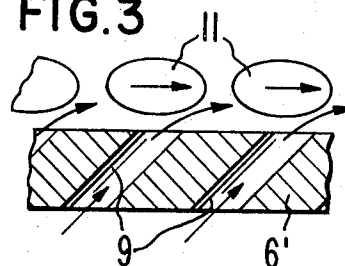
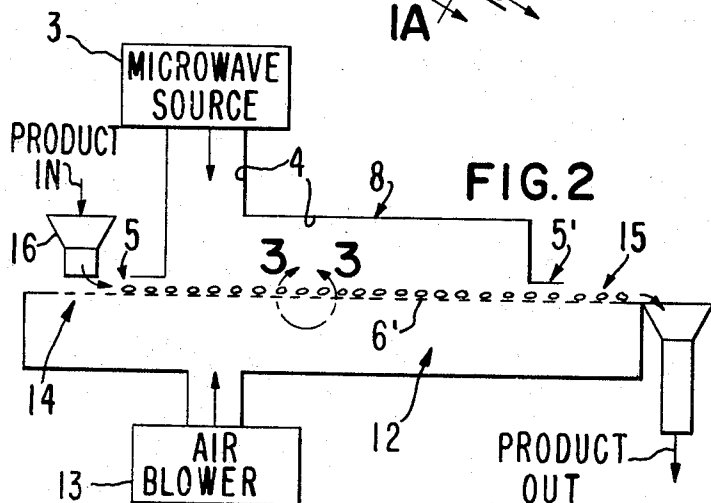


FIG. 2



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FIG. 5

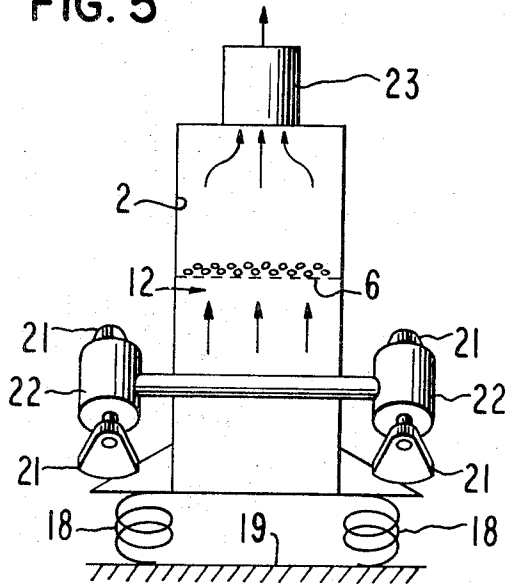


FIG. 6

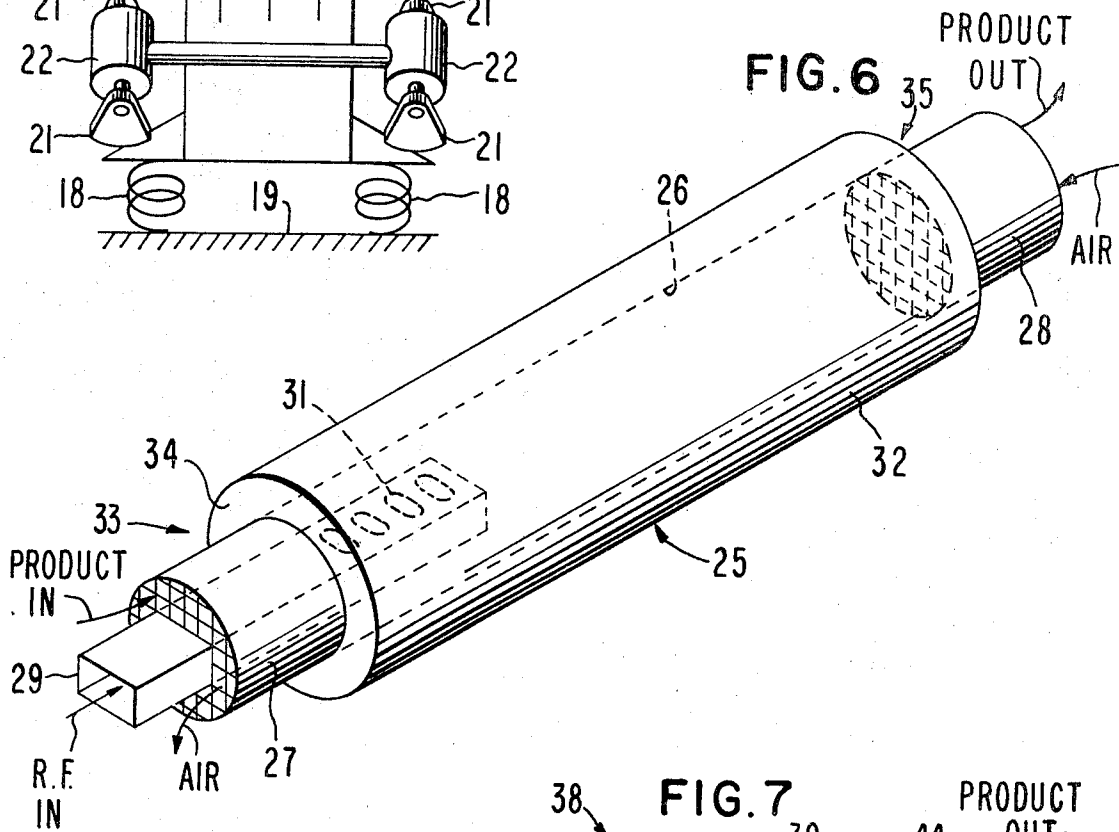
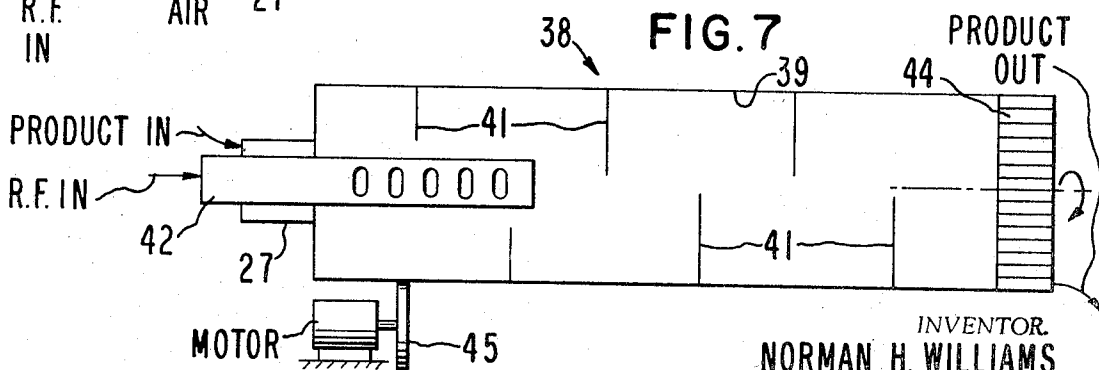


FIG. 7



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COMPOSITE MICROWAVE APPLICATOR AND PRODUCT CONVEYOR

DESCRIPTION OF THE PRIOR ART

Heretofore, microwave applicator structures have included microwave circuits such as cavity resonators, waveguides and the like which had inside dimensions corresponding to a plurality of wavelengths at the frequency of the microwave energy supplied to such applicator structure. In the prior art, it was thought that since microwave heating of material in the applicator occurs due to the effects of electromagnetic fields in the space enclosed by the applicator, the material should be positioned in regions spaced from the sidewalls within the applicator structure. Accordingly, for example, a low-loss dielectric belt conveyor was typically used or the material was fed through the applicator in a self-supporting strip with the material passing through a treatment zone such that the material to be treated was at least approximately a quarter of a wavelength away from the conductive surface of the applicator. In this manner, the applicator could be designed so that the material was dielectric or in a strong magnetic field if the material was conductive or both if the material was semiconductive.

A typical prior art applicator is disclosed in U.S. Pat. No. 2,500,752, issued Mar. 14, 1950. One of the problems with this prior art type of applicator is that the dielectric belt, even though it is made of a low-loss dielectric material, is heated by the microwave energy tending to reduce its useful life. In addition, since the belt passes through the applicator in a region of strong electric field, approximately an odd number of quarter wavelengths up from the conductive surface of the applicator, strong electric field coupling to the slot in the side of the applicator through which the belt passes occurs. Therefore relatively complicated and expensive microwave traps are required to prevent the escape of microwave energy from the applicator through the slots through which the belt travels. Generally speaking the maximum power that can be applied to the applicator is determined by the voltage breakdown in the trap structure. Moreover, the traps absorb a substantial amount of microwave energy and contribute to low microwave efficiency.

Therefore it is desirable to provide a microwave applicator structure wherein the end traps can be eliminated and wherein the dielectric conveyor belt can be eliminated.

A typical prior art applicator for conductive materials is disclosed in U.S. Pat. No. 3,171,009.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved microwave applicator.

One feature of the present invention is the provision, in a microwave applicator, of a composite product conveyor and microwave circuit structure such that the microwave circuit can be utilized as the product conveyor, thereby eliminating the separate conveyor structure with its attendant deficiencies such as belt wear and end trap power limitations.

Another feature of the present invention is the same as the preceding feature wherein the composite conveyor and microwave circuit structure is a support structure for supporting material to be treated within the treatment zone.

Another feature of the present invention is the same as any one or more of the preceding features wherein the composite conductive structure is porous to provide gas passageways therethrough for passing gas therethrough to the material being treated, whereby an air cushion conveyor may be employed or dry-air passed through the product for removal of the moisture from the product.

Another feature of the present invention is the same as any one or more of the preceding features wherein the microwave applicator includes a cavity resonator structure and wherein the composite conductive structure is a wall of the cavity resonator.

Another feature of the present invention is the same as any one or more of the preceding features wherein the conveyor means includes a vibratory conveyor for vibrating the composite structure or includes a screw conveyor for moving the material through the applicator.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic longitudinal sectional line drawing, partly in block diagram form, of a microwave applicator employing a slide conveyor forming a portion of the microwave circuit.

FIG. 1A is a view of the structure of FIG. 1 taken along line 1A-1A in the direction of the arrows,

FIG. 2 is a schematic longitudinal sectional line diagram of a microwave applicator employing a composite microwave circuit and air conveyor,

FIG. 3 is an enlarged sectional view of a portion of the structure of FIG. 2 delineated by line 3-3,

FIG. 4 is a longitudinal sectional schematic line diagram of a microwave applicator employing a composite microwave circuit and vibratory conveyor,

FIG. 5 is a sectional view of the structure of FIG. 4 taken along line 5-5 in the direction of the arrows,

FIG. 6 is a schematic perspective view of a microwave applicator of the present invention, and

FIG. 7 is a schematic longitudinal sectional view of a microwave applicator of the present invention employing a screw-type conveyor.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1 and 1A there is shown a microwave applicator 1 incorporating features of the present invention. More specifically, the microwave applicator 1 includes an elongated multimode cavity resonator structure 2 excited into resonance with microwave energy supplied from a microwave energy source 3 and fed into the resonator 2 via a suitable coupling circuit such as a waveguide 4 or coupling loop, not shown.

The product to be treated with microwave energy is fed into the resonator structure 2 via an input grating 5 which comprises a series of rectangular waveguide sections having internal dimensions below cutoff at the operating frequency to prevent escape of microwave energy from the resonator structure 2 while permitting the product to pass through the individual sections of the grating. A similar grating 5' is provided at the opposite end of the resonator 2 to permit the treated product material to leave the applicator 2.

The applicator 2 is elevated at the input end such that the lower wall 6 of the resonator 2 forms a slide-type conveyor such that the product material to be treated slides down the inclined inner surface of the wall 6 and leaves the applicator via output grating 5'. Thus, the lower wall 6 of the resonator 2 forms a composite structure in that it forms a part of the microwave circuit and also serves as the slide conveyor for conveying the product through the applicator. A treatment zone is thus defined which is immediately adjacent the inside surface of cavity wall 6. The lower side of the treatment zone is defined by wall 6.

It has been found that adequate microwave heating of the dielectric product material is obtained even though the product is passed through the applicator 1 directly supported upon or supported, as by a cushion of air, immediately adjacent a conductive wall of the applicator, such as wall 6. This is found to be the case even though the composite microwave circuit and conveyor portion 6 has one or more dimensions large compared to a half wavelength at the operating frequency. More specifically, the length l , width w , and height h of the cavity over the composite circuit portion may have dimensions l , w , or h which are in excess of one-half wavelength at

the operating frequency. Useful operating frequencies are above 300 MHz. and typical frequencies and power levels are 915 MHz. at 25 kw. or 2,450 MHz. at 30 kw.

The advantage of employing a composite microwave circuit portion and conveyor structure is that the requirement for a separate dielectric conveyor belt is thereby eliminated along with its attendant disadvantages of short operating life and tendency to start fires by becoming overheated due to making repetitive passes through the microwave applicator. Moreover, by eliminating the belt, the end traps are eliminated thus permitting higher power levels to be employed in the applicator.

Referring now to FIG. 2 there is shown an alternative microwave applicator 8 employing features of the present invention. This applicator 8 is essentially the same as that of FIG. 1 except that it employs an air conveyor, i.e., tiny jets of air propel the product material 11 along the surface of the lower wall 6 of the resonator 2 in the manner more clearly shown in FIG. 3. More particularly, the lower wall of the resonator 6' is provided with a multitude of small gas passageways 9 passing through the lower wall and inclined at a substantial angle toward the direction of the desired travel of the product material 11. An air chamber 12 is provided below the lower wall 6' and air is fed into the air chamber 12 from an air source such as a blower 13. The product to be treated is supplied through a hopper which drops the product onto an air conveyor portion which extends outwardly on the resonator 2 at 14. The product is conveyed along the lower wall 6' through the resonator 2 and out the opposite end at 15 through output grating 5' and into a suitable product receptacle such as a hopper 16'. One advantage of the use of the air-type conveyor is that the air may be dry and serve the dual function of conveying the product through the applicator and for carrying away moisture liberated during the heating process. Alternatively, for treating thin webs of material pulled through the applicator, the air ducts 9 may serve to support the web on an air cushion immediately adjacent the perforated wall 6' of the resonator 2. Thus, in this case, the perforated wall 6' serves as an air bearing or support structure for the conveyor as well as a wall of the resonator 2.

Referring now to FIGS. 4 and 5, there is shown an alternative microwave applicator 17 incorporating features of the present invention. Applicator 17 is essentially the same type of applicator previously described in FIGS. 1 through 3 with the exception that the applicator 17 utilizes a vibratory conveyor system for conveying the dielectric product material along the inside wall 6 of the cavity 2. More specifically, the product drops through an egg crate-type input grating 5 and drops through the cavity 2 to the lower wall 6. The product is conveyed along the wall 6 toward the output grating 5' by a natural frequency conveying action of a vibrating conveyor. More particularly, the applicator 17 is supported upon 4 springs 18 from a solid support 19. A motor, not shown, rotationally drives an eccentrically mounted weight 21 about a shaft 22. The rotational speed of the eccentric weight is adjusted for a natural resonant frequency of the spring-supported system such that the lower wall of the cavity 2 is caused to be displaced along a sine curve in accordance with the laws of simple harmonic motion. Movement of the wall consists of a series of very gentle throws and catches such that during each cycle there is both pressure and motion between the wall 6 and the conveying material. As a result, the material being conveyed is conveyed along the wall 6 from the input end to the output end at approximately 30 feet per minute. Also the vibration of the cavity wall 6 provides a mode-stirring effect within the resonator 2. A suitable conveyor is commercially available from the carrier division of Rex Chair Belt Inc. Louisville, Ky., as Model QAC-246OS-8GA(304S/S)-10F-(2-1HP).

The particular applicator 17 was utilized for drying and heating almonds. Cavity wall 6 was provided with a multitude of gas passageways directed substantially normally to the surface of the wall such that the air flowing from the air chamber

12 through the cavity wall 6 and into the cavity 2 served to aerate the almonds and to remove the moisture liberated by the heating thereof. A number of air outlet ducts 23 are provided in the upper wall of the cavity 2 and each included a conductive egg crate-type grating 5 to prevent escape of microwave energy from the cavity 2 thereby permitting the air to exhaust through the ducts 23.

Referring now to FIG. 6, there is shown an alternative microwave applicator 25 incorporating features of the present invention. The applicator 25 includes a hollow cylindrical conductive mesh element 26 defining the perforated conductive walls of a cylindrical cavity resonator. The ends of the resonator are closed off by conductive egg crate gratings 27 and 28 defining a cluster of waveguides below cutoff and allowing the product to pass through input grating 27 into the resonator 26 and to exit from the resonator via output grating 28. Microwave energy is applied to the resonator 26 via a waveguide 29 which is coaxially disposed of the resonator 26 and which passes through the center of the input grating 27. The waveguide 29 includes an array of coupling slots 31 near its inner end for coupling wave energy from the waveguide 29 to the resonator 26. A suitable microwave energy source 1 not shown, is connected to the input end of the waveguide 29.

A tubular jacket 32 surrounds the resonator 26 in concentric relation therewith. The jacket 32 is closed at one end 33 via an annular wall 34. Air is ducted into the annular space between the jacket 32 and the cavity 26 from end 35. The air stream passes through the perforations in the cavity wall 26 and exits from the product input grating 27 for removing moisture from the product being treated.

In a preferred embodiment, the applicator 25 is elevated at the end which receives the product such that the product feeds through the applicator by gravity. In addition, the applicator may be rotated about its longitudinal axis to facilitate tumbling of the product to assure more even treatment thereof by the microwave fields of the resonator 26. As an alternative, the applicator 25 may be vibrated in the manner previously described with regard to the vibratory conveyor of FIGS. 4 and 5 to agitate the material being treated and to convey the product from the input end to the output end of the applicator 25.

Referring now to FIG. 7, there is shown an alternative applicator 38 of the present invention. The applicator 38 is similar to that of FIG. 6 and includes a hollow cylindrical tubular conductor 39 defining one wall of the microwave cavity circuit. A twisted ribbon-shaped metallic conductive fin 41 is spirally located inside of the tubular conductor 39. A cylindrical tubular waveguide 42 interconnects a microwave source, not shown, to the applicator 38. The waveguide 42 is concentrically disposed along the axis of the tubular conductor 39 and is apertured with a plurality of coupling slots at its inner end within the conductive structure 39 for coupling microwave energy from the source to the applicator 38.

An egg crate grating 27 of a tubular cluster of waveguides 27 surrounds the waveguide 42 to permit the product to pass through the egg crate openings while preventing the escape of microwave energy from the applicator 38. The waveguide passes through the center of the egg crate grating 27. The opposite end of the tubular applicator 39 is closed by an egg crate-shaped grating 44 to prevent escape of microwave energy from that end of the microwave circuit while permitting the product being treated to exit through the output grating 44. The ribbon-shaped fin 41 serves as a screw-type conveyor as the applicator 38 is rotated about its longitudinal axis by a motor driven drive wheel 45.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, 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.

I claim:

1. In a microwave applicator, a conductive microwave circuit structure for supporting microwave energy and defining a microwave treatment zone, a microwave energy source for supplying microwave energy to said treatment zone, and a conveyor structure for conveying material to be treated through said treatment zone of said applicator structure for the application of microwave energy to the material to be treated, said conveyor and said microwave circuit structure including a common conductive structure portion defining a boundary of said treatment zone, and said common structure portion having a dimension in excess of a half wavelength at the frequency of microwave energy being applied.

2. The apparatus of claim 1 wherein said common conductive structure portion is a support structure for supporting the material to be treated within the treatment zone.

3. The apparatus of claim 1 wherein said common conductive structure is porous to provide gas passageways therethrough for the flow of gas to the material being treated.

4. The apparatus of claim 1 wherein said conductive microwave structure includes a microwave cavity resonator,

and wherein said common conductive structure is a wall of said cavity resonator.

5. The apparatus of claim 2 including means for vibrating said support structure for causing the material supported thereon to be conveyed therealong by a series of throws and catches produced by vibratory motion of said support structure.

6. The apparatus of claim 1 wherein said common conductive structure is a twisted ribbon-shaped member which is rotatable to form a screw-type conveyor.

7. The apparatus of claim 1 wherein said common conductive structure is a tubular conductor.

8. The apparatus of claim 7 including means for rotating said tubular conductor.

9. The apparatus of claim 3 wherein the gas passageways are inclined at a substantial angle to the surface of the perforated conductive structure, whereby the gas passing through the passageways has a substantial velocity component parallel to the surface of the conductive structure for forming an air conveyor for conveying the material to be treated through the applicator structure.

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