

United States Patent

[11] 3,564,187

[72] Inventor **Franklin J. Smith**
Diablo, Calif.
 [21] Appl. No. **791,445**
 [22] Filed **Jan. 15, 1969**
 [45] Patented **Feb. 16, 1971**
 [73] Assignee **Cryodry Corporation**
San Ramon, Calif.
a corporation of California

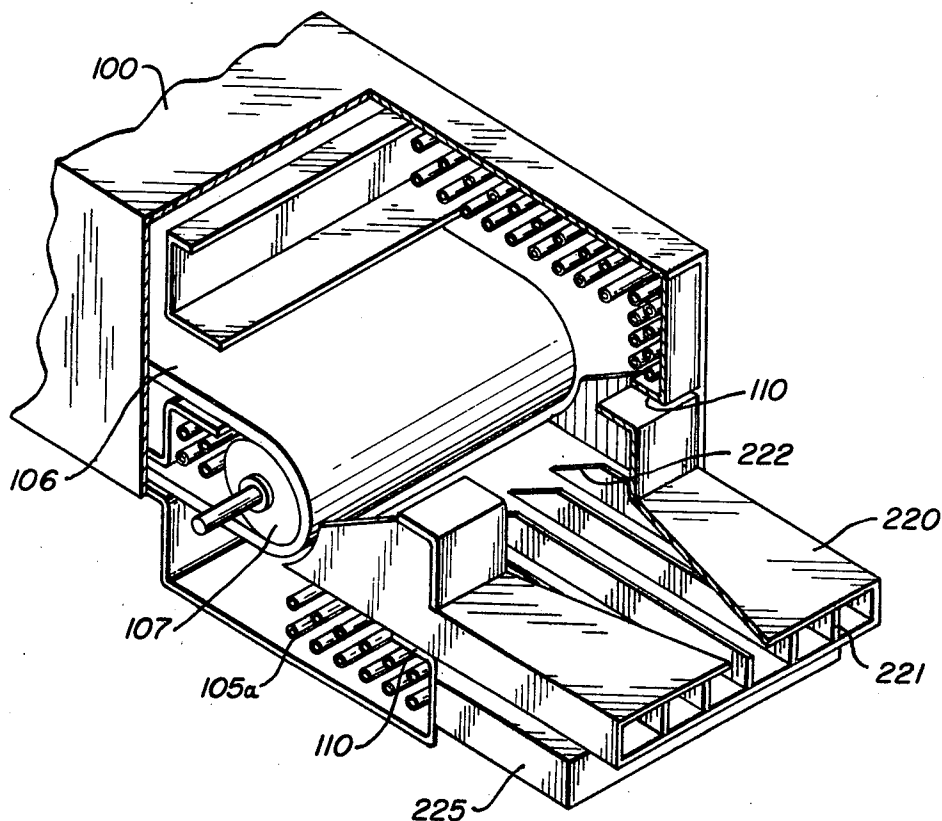
[56] **References Cited**
UNITED STATES PATENTS
 2,866,551 12/1958 Schlebusch..... 219/10.69X
 2,868,939 1/1959 Pound 219/10.55
 3,422,242 1/1969 Miyata 219/10.55
 3,457,385 7/1969 Cumming..... 219/10.55

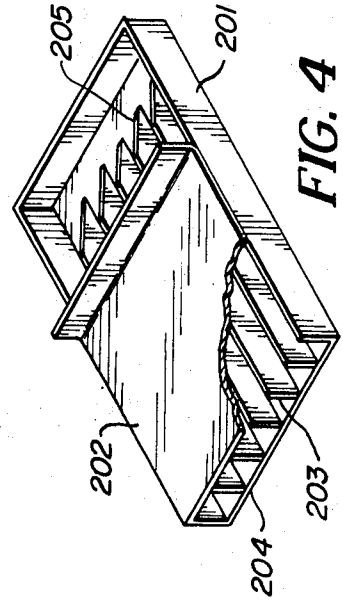
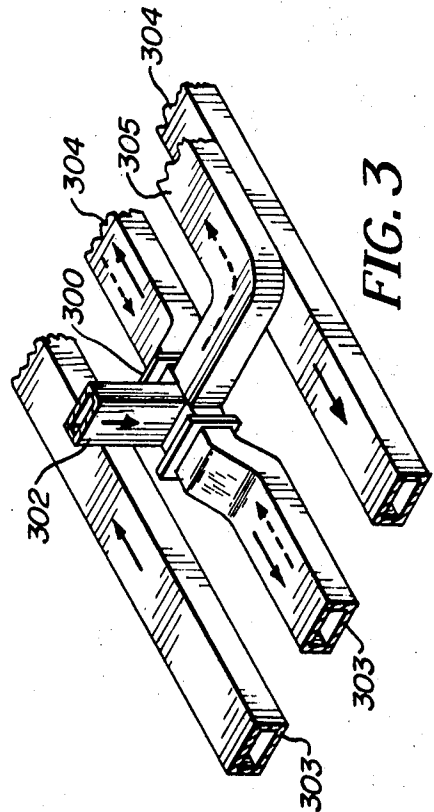
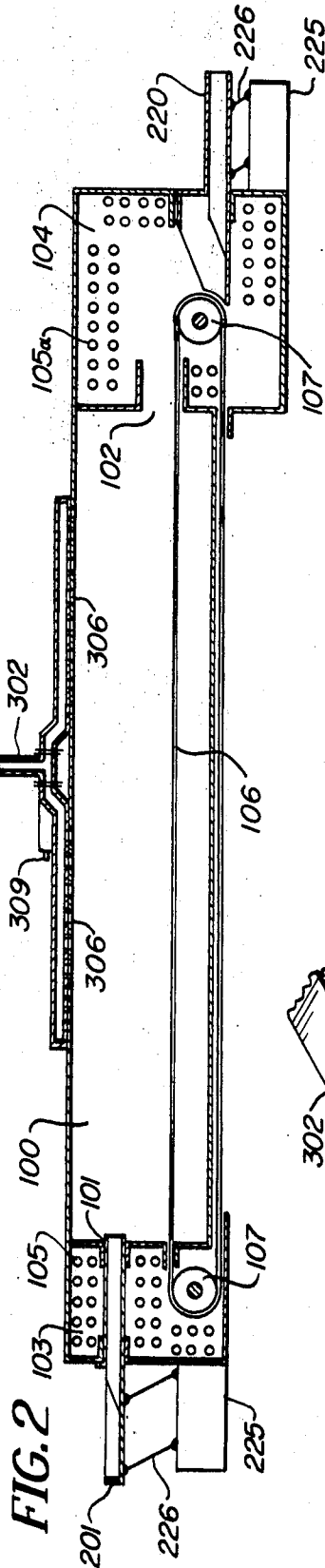
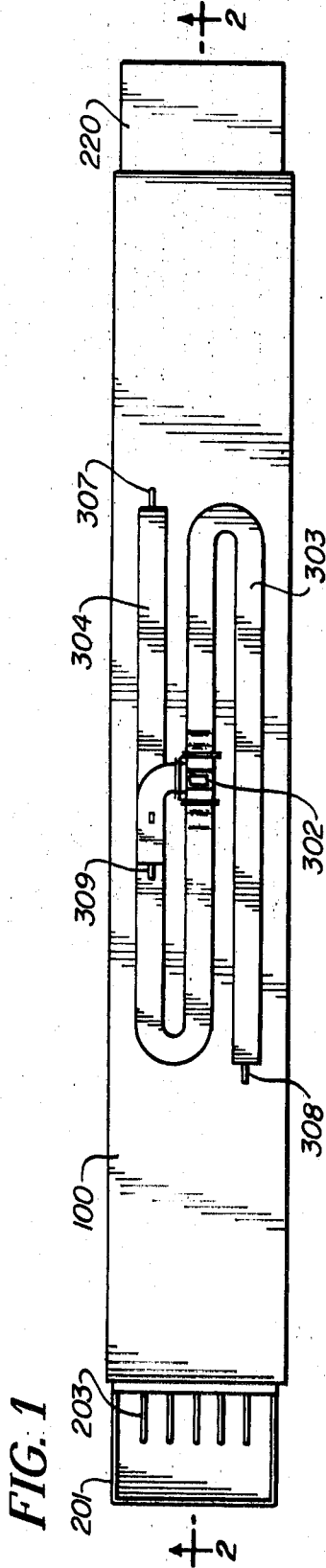
Primary Examiner—J. V Truhe
Assistant Examiner—L.H Bender
Attorneys—Carl C. Batz and Frank T. Barber

[54] **MICROWAVE OVEN**
7 Claims, 6 Drawing Figs.

[52] U.S. Cl..... **219/10.55,**
219/10.61
 [51] Int. Cl..... **H05b 9/06,**
H05b 5/00
 [50] Field of Search..... **219/10.55,**
10.61

ABSTRACT: A continuous process microwave oven especially adapted for heating bulky low-density materials in which relatively high-speed input and output vibratory conveyors are provided.





INVENTOR
Franklin J. Smith
BY *Carl C. Batz*
ATTY

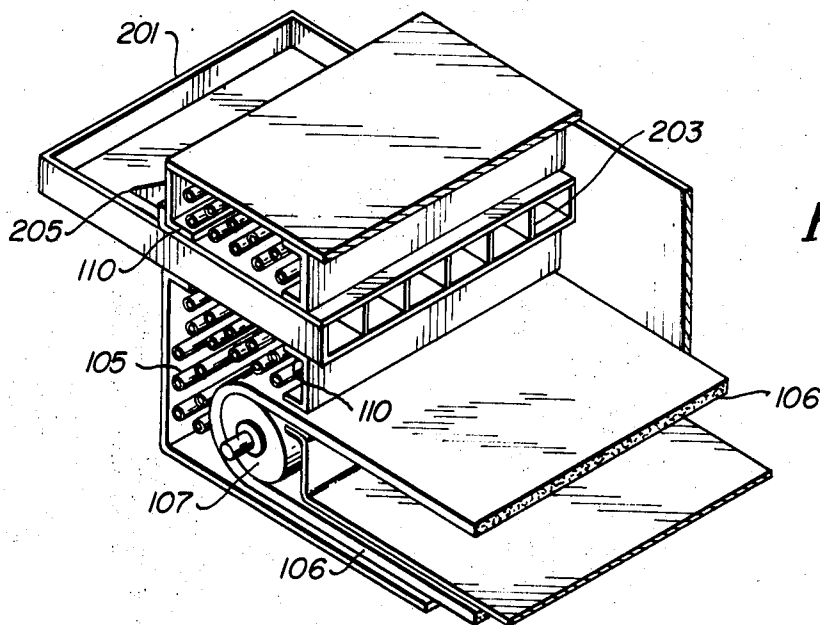


FIG. 5

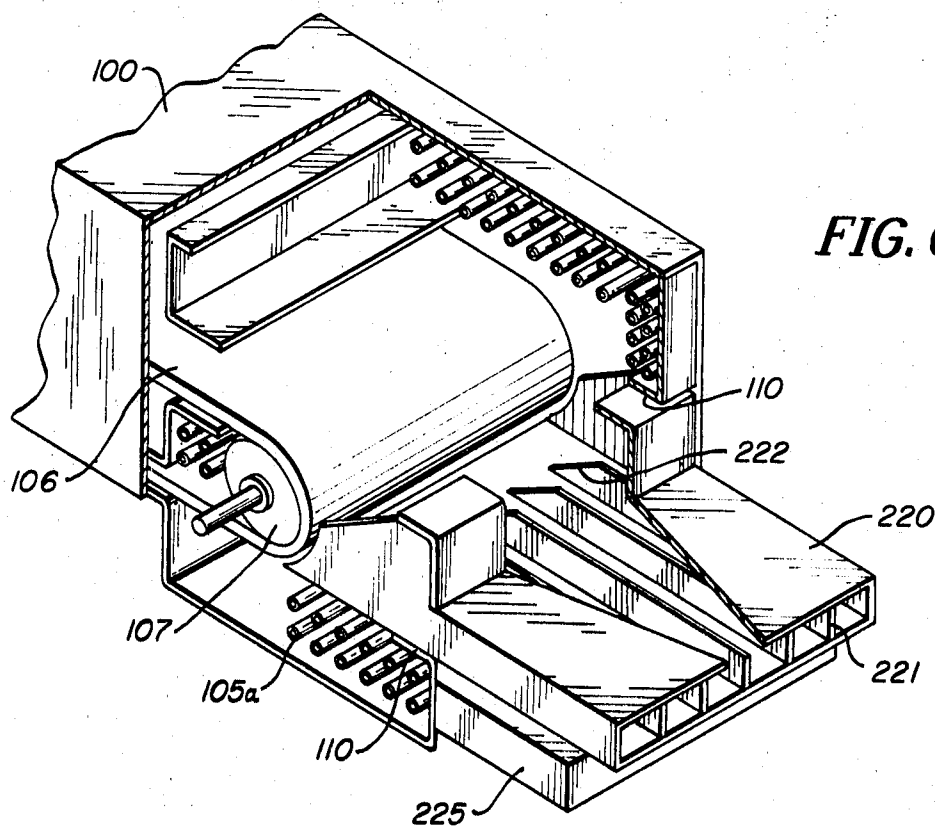


FIG. 6

INVENTOR
Franklin J. Smith
BY *Carl C. Batz*
ATTY.

MICROWAVE OVEN

BACKGROUND OF THE INVENTION

High frequency energy has been shown to be extremely useful in various heating and drying applications. The use of such energy in the microwave region has been suggested for batch-type operations in which the energy is confined within a substantially closed chamber; and more recently, in continuous process applications in which a product can be constantly introduced into and withdrawn from a microwave treating chamber. In these continuous process operations, openings must be provided in the treating chamber in order to get the product to be treated into and out of the chamber. The requirement for these openings in a microwave-treating chamber produces problems and limitations.

One problem encountered in this type of operation is the requirement to prevent the escape of microwave energy through the openings, as this represents not only an inefficient operation but also a hazard to personnel in the surrounding area. Moreover in a continuous process, the actual amount of product representing the load which is present in the chamber at any given time may be subject to considerable variation, that is it may be difficult to maintain the load within the chamber at a constant level. When the load in the chamber is insufficient to absorb substantially all of the microwave energy being introduced, the unused energy may be reflected back to the microwave source and the intensity of this reflected energy may be sufficient to cause serious damage to the equipment.

One solution to these problems which has been suggested is to surround the entrance and exit vestibules with some type of lossy liquid, such as water, which can absorb the unused microwave energy which would otherwise escape through the openings. Also the use of these lossy traps prevents the coupling of excess energy back to the microwave source when the product load is insufficient to absorb all of the available energy. However, the amount of energy which is required to be absorbed in these lossy traps is a measure of the efficiency of the treating chamber, in that the energy absorbed in the traps represents a loss of energy which would otherwise be available for heating or drying the product within the chamber.

Another method which has been suggested to deal with this problem is to dimension the openings so as to be waveguides beyond cutoff, that is, the openings are sufficiently small relative to the wavelength of the energy within the chamber so that the energy will not propagate through the openings. Heretofore this type of configuration has been considered to be unsuitable to the processing of bulky products because the openings are too small to allow the passage of sufficient amounts of such bulky products to make the method usable and commercially feasible.

Faced with the aforementioned problems, we have sought methods and apparatus which is suited to the microwave heating of bulky, low-density materials providing relatively large input and output openings but wherein these openings are substantially filled by a specially designed conveyor structure. The insertion of the conveyor structure into the microwave-treating chamber openings produces a treating chamber which is capable of passing substantial quantities of bulky low-density materials while at the same time the openings in the chamber are essentially closed to the microwave energy.

It is an object of the present invention therefore to provide an apparatus for treating substances with microwave energy, specifically an apparatus which is useful in the heating of bulky, low-density materials. It is a further object of the invention to provide a microwave-heating apparatus in which bulky low-density materials may be continually processed and in which means is provided to prevent the leakage of microwave energy from the chamber through the product inlet and outlet openings. It is a further object of the invention to provide a microwave-heating apparatus which is adaptable to varying loads and which provides means to prevent the coupling of ex-

cess energy to the microwave source. A still further object of the invention is to provide a microwave-heating apparatus with a novel input and output conveyor system that will allow the passage of substantial quantities of bulky low-density materials but will suppress the passage of microwave energy. Further objects and advantages of the invention will become apparent as the specification proceeds.

The apparatus of the present invention may comprise a microwave-treating chamber having a throughput conveyor operating lengthwise through the chamber, an input conveyor adapted to transport material to be treated from the outside of the chamber to the throughput conveyor, and an output conveyor adapted to receive the treated product from the throughput conveyor to transport the product out of the treating chamber, the input and output conveyors being configured so as to prevent or suppress the leakage of microwave energy from the treating chamber. The microwave energy may be coupled to the chamber through the use of a hybrid junction, in which one arm of the junction is configured so as to receive none of the incoming microwave energy, but which arm will receive the majority of the reflected energy. This arm may then be coupled to a matched load to absorb the reflected energy. Lossy traps may also be provided at the input and output of the treating chamber.

The preferred embodiments of the present invention will be more specifically described by reference to the attached drawings in which:

FIG. 1 is a diagrammatic plan view of the apparatus illustrating the general configuration and location of the input and output conveyors and the microwave energy hardware;

FIG. 2 is a diagrammatic front section view in elevation of the apparatus taken along lines 2-2 in FIG. 1;

FIG. 3 is a partial perspective view of the microwave energy distribution system;

FIG. 4 is a perspective view partially cutaway of a typical input conveyor tray removed from the apparatus;

FIG. 5 is a partially cutaway perspective of the input end of the apparatus showing the positioning of the input conveyor tray within the treating chamber;

FIG. 6 is a partially cutaway perspective view of the output end of the apparatus showing the positioning of the output conveyor tray within the treating chamber.

The apparatus may consist of a generally elongated rectangular processing chamber 100. At one end of processing chamber 100 is inlet port 101 for introducing the product into the processing chamber, and at the other end is outlet port 102, where the treated product may be withdrawn. Surrounding inlet port 101 and outlet port 102 are trapping areas 103 and 104 respectively, which may consist of a series of tubes 105 and 105a surrounding the openings. These tubes are adapted to have a lossy absorbing media such as water continuously circulated through them.

A throughput conveyor 106 is provided in the lower portion of processing chamber 100. Preferably the upper portion of conveyor 106 extends longitudinally through and within processing chamber 100, whereas the lower portion of conveyor 106 runs just below the bottom of treating chamber 100. It is preferred to have the pulley and drive means 107 for throughput conveyor 106 located outside of the influence of the microwave region within processing chamber 100. Preferably drive pulleys 107 are located within trapping areas 103 and 104 at each end of the processing chamber.

At the input end of processing chamber 100 input conveyor 201 is provided. Input conveyor 201 is arranged such that a portion of the conveyor tray is positioned within inlet port 101 of the processing chamber, and the remaining portion of input conveyor 201 is positioned outside of processing chamber 100 and outside of trapping area 103. Preferably input conveyor 201 is configured to closely match the configuration of inlet port 101 such that only a small clearance is present between the top, bottom and sides of input conveyor 201 and the walls of inlet port 101 as shown most clearly in FIG. 5.

Microwave energy will not propagate through a duct which has dimensions smaller than one-half of its wavelength in free space. Input conveyor 201 and output conveyor 220 make use of that microwave characteristic. As shown best in FIG. 4 input conveyor 201 is in the general shape of the rectangular tray having a partial top portion 202 and a plurality of vertical dividers 203 joined at bottom portion 204, the tray and the dividers 203 being made of an electrically conductive material, preferably metal. The vertical dividers 203 partition conveyor 201 into a plurality of sections. The dividers 203 are spaced in a manner such that the dimensions of the resulting sections will be sufficiently small so as to be waveguides below cutoff for the microwave frequency utilized in processing chamber 100. Since each of the sections is a waveguide below cutoff, the interior end of conveyor 201 is electrically opaque. Since the microwave energy used in processing chamber 100 will not propagate through any of the sections of conveyor 201, the insertion of conveyor 201 into inlet port 101 electrically closes inlet port 101 except for the small annular clearance between the conveyor and the opening. In this manner the escape of microwave energy through the inlet port is effectively suppressed. At the same time, a sufficient plurality of sections is utilized in conveyor 201 in order that the total cross-sectional area of the conveyor will be sufficiently large to accommodate the desired product flow. The number of vertical dividers 203 used in a particular application and the dimensions of the sections formed thereby will depend upon the frequency of the microwave energy to be used in the processing chamber and the desired rate of product flow. It is preferred that the exterior edges 205 of the vertical dividers 203 are beveled which allows for easier and smoother separation of product input into the various sections of conveyor 201.

Output conveyor 220 is similarly configured and constructed of similar materials as input conveyor 201, except that the interior edges 22 of vertical dividers 221 are beveled in order to more easily divide the finished product into the sections of output conveyor 220 as the product is received from throughput conveyor 106. Moreover, the vertical dimension of the portion of output conveyor 220 which is located within trapping area 104 is greater than the vertical dimension of that portion of output conveyor 220 which is located outside of the trapping area in order to accommodate a substantial depth of product being discharged from throughput conveyor 106.

As shown most clearly in FIGS. 5 and 6, the inlet port 101 and outlet port 102 are fitted with horizontal lips 110 in order to further suppress the leakage of microwave energy from the processing chamber 100 into trapping areas 103 and 104, and to prevent the escape of any untrapped microwave energy to the surrounding outside area. Inasmuch as there is a small clearance between conveyors 201 and 220 and horizontal lips 110, the electrical effect is to create a parallel transmission line at each of these spaces. Accordingly, the length of horizontal lips 110 measured along the longitudinal axis of the apparatus is preferably equal to one-fourth of the wavelength of the microwave energy being used in process chamber 100. When so dimensioned, horizontal lips 110 will act as quarter-wave chokes for the microwave energy and will tend to suppress transmission and leakage.

In order to move the product along conveyor 201 and conveyor 220, the conveyors are actuated by a vibratory drive mechanism 225, shown schematically in FIG. 2. The vibratory drive mechanism may be of a variety of types generally known in the field of conveyors, and further illustration of this particular component is unnecessary. For example in one known mechanical drive mechanism a motor imparts rotation to a wheel eccentrically mounted to the base of the conveyor tray thereby causing the tray to move in oscillatory motion, which motion is constrained by the supporting links 226. Various types of electromagnetic vibratory drive means are also available for this function.

It is preferred that the inlet port 101 be positioned above throughput conveyor surface 106 in order that an adequate product bed depth can be established on the throughput conveyor. This is particularly applicable in the treatment of low density materials in which a fairly deep bed of material is desired for the most efficient use and absorption of the microwave energy within the processing chamber. Moreover it can be seen that outlet conveyor 220 is positioned below the surface of throughput conveyor 106 in order to be able to receive and accommodate the product outflow.

The microwave energy distribution system is illustrated in FIG. 1 through 3. In FIG. 3 the input flow of microwave energy is indicated by the solid arrows, and the flow of reflected microwave energy is indicated by the dotted arrows. Microwave energy from a source (not shown) is introduced through the vertical arm 302 of hybrid junction 300. The microwave energy will be evenly divided between horizontal arms 303 and 304 due to the propagation characteristics of hybrid junction 300. This characteristic is attributable to the fact that vertical arm 302 branches from the broad wall of the hybrid junction 300, whereas horizontal arm 305 branches from the narrow wall of hybrid junction 300. For this reason the microwave energy entering vertical arm 302 couples equally into horizontal arms 303 and 304 but due to the 180° phase difference no energy couples into horizontal arm 305. The microwave energy is propagated through arms 303 and 304 and transmitted into processing chamber 100 through plurality of slots 306 located commonly in the bottom wall of the waveguide and the top wall of the processing chamber. Whatever microwave energy is not absorbed within the processing chamber or within trapping areas 103 and 104 is reflected back through slots 306 into waveguide arms 303 and 304, returning to hybrid junction 300 in the directions indicated by the dotted arrows in FIG. 3. Ordinarily the energy propagated back through arm 303 will divide equally between vertical arm 302 and horizontal arm 305, and energy reflected back through arm 304 will divide between vertical arm 302 and horizontal arm 305 also. If coherent signals of equal amplitude and phase couple into arms 303 and 304, the resulting signals in vertical arm 302 will be out of phase and cancel, and as a result all of the reflected microwave energy will couple into horizontal arm 305. In operation this condition is created as closely as possible through the provision of sliding short circuits 307 and 308 at the termination of horizontal arms 303 and 304 respectively. Horizontal arm 305 is terminated in a matched load 309. In this manner the microwave circuit can be tuned to some extent. Due to the configuration of conveyor 201 and the use of horizontal lips 110 as quarterwave chokes, the lossy trapping area 103 can be effectively decoupled from processing chamber 100. Should the product load within the chamber become light at any time thereafter the amount of microwave energy which will be unused within the chamber and unabsorbed within the trapping area will be increased. When this occurs horizontal arm 305 and matched load 309 help to insure that the amount of microwave energy reflected back to the source remains within acceptable limitations.

OPERATION

In the operation of the present apparatus, the product to be treated is placed upon input conveyor 201 in that portion of the conveyor which extends out of the trapping area 103. The vibratory drive mechanism 225 is actuated causing conveyor 201 to oscillate in vibratory motion, thereby moving the product from the exterior of trapping area 103 through the trapping area and into processing chamber 100 where the product is discharged onto throughput conveyor 106. When processing bulky low-density materials it is desirable to maintain a sufficient bed depth on throughput conveyor 106 to absorb substantially all of the microwave energy within the processing chamber. The bed depth created can be controlled by controlling the relative product throughput speed of conveyors 201 and 106. It is preferred to operate conveyor 201 at

a product flow speed substantially greater than the product flow speed of conveyor 106 in order that the desired bed depth will build up on conveyor 106. As the product is discharged onto throughput conveyor 106, additional product is continually introduced onto the exterior end of input conveyor 201 in order to maintain a constant flow of product into process chamber 100.

Microwave energy from a microwave source is propagated downwardly through vertical arm 302 of hybrid junction 300 where it divides into the side arms 303 and 304. The energy is propagated through horizontal arms 303 and 304 from which it is transmitted into process chamber 100 via slots 306. The microwave energy entering the processing chamber passes repeatedly through the product load within the chamber, and the bulk of the microwave energy is absorbed and dissipated within the product load, thereby causing the product to be heated. The microwave energy which is not dissipated in the product load will be either absorbed in the lossy trapping areas 103 and 104 or will be reflected from the process chamber 100 back to hybrid junction 300. Due to the characteristics of hybrid junction 300 previously described, the reflected energy will be coupled to horizontal arm 305 to be absorbed in matched load 309.

When the treated product reaches the output end of process chamber 100, it is discharged from throughput conveyor 106 onto output conveyor 220. Preferably output conveyor 220 is operated at a higher rate of product flow than throughput conveyor 106 in order that the treated product may be promptly passed along conveyor 220 and out of the processing chamber. In this matter, a substantial bed depth of product can be accommodated and passed by conveyor 220. The product is moved along conveyor 220 through the vibratory movement of the conveyor imparted to it by vibratory drive mechanism 225.

The unique configuration of the input and output conveyors, and their installation in the inlet and outlet ports of the process chamber, make the present apparatus particularly well suited to the microwave heating of bulky low-density materials such as flakes, chips and the like. Heretofore, it has been difficult to process this type of product in a microwave chamber on a continuous basis. The low-density of the material makes it desirable to have a relatively deep bed of material within the process chamber for the most efficient absorption of microwave energy, while at the same time, a deep bed of material inside the chamber ordinarily requires a large inlet and outlet port in the chamber, which in turn gives rise to unacceptable microwave energy losses through these ports. In the present apparatus the individual sections of the input and output conveyors are dimensioned so as to be waveguides beyond cutoff, thereby reducing effectively the propagation of microwave energy through the inlet and outlet ports while the conveyors are positioned within the ports. At the same time, the use of a plurality of sections in each conveyor gives a combined conveyor cross section large enough to carry the necessary product volume. In this manner, the microwave energy can be effectively confined in the process chamber although large quantities of bulky product are continuously introduced and withdrawn from the chamber, and by operating the input and output conveyors at a higher rate of speed than the throughput conveyor, a substantial bed depth of product can

be maintained within the process chamber to efficiently utilize the microwave energy.

While in the foregoing specification, the construction and operation of specific embodiments have been described in some detail, it will be understood that such description is in the way of illustration and that many variations may be made by those skilled in the art without departing from the spirit and scope of the invention which is intended to be defined in the appended claims.

I claim:

1. In a continuous process microwave oven of the class having a horizontally oriented inlet port therein, the combination comprising a horizontally oriented electrically conductive conveyor tray in said inlet port, said conveyor tray being divided into a plurality of sections, each of said sections being dimensioned so as to suppress the propagation of microwave energy therein, and means for moving said conveyor tray in vibratory motion to move a product along said conveyor tray in a substantially horizontal path.

2. The combination according to claim 1 wherein said sections are defined by a plurality of electrically conductive dividers normal to the base surface of said tray and coextensive with the direction of product flow along said tray.

3. The combination according to claim 2 wherein said conveyor tray has an extending portion outside of said inlet port and adapted to receive product to be conveyed into said microwave oven.

4. The combination according to claim 3 wherein said dividers terminate within said extending portion, the ends of said dividers being beveled to facilitate the passage of product from said extending portion into said sections.

5. In a continuous process microwave oven of the class having a microwave treating chamber and a horizontally oriented inlet port communicating with said chamber whereby product to be treated is passed through said port into said chamber, the improvement comprising a horizontally oriented electrically conductive conveyor tray having a portion in said port and coextensive therewith and an extending portion outside of said port adapted to receive product thereon, said tray being divided into a plurality of sections, each of said sections being dimensioned so as to suppress the propagation of microwave energy therein, and means for moving said tray in vibratory motion to move a product from said extending portion into said chamber along a substantially horizontal path.

6. A continuous process microwave oven comprising a process chamber having horizontally oriented inlet and outlet ports therein, a first conveyor means horizontally oriented in said inlet port and dimensioned so as to suppress emission of microwave energy through said inlet port, a second conveyor means lengthwise of said process chamber adapted to receive material discharged from said first conveyor means, a third conveyor means horizontally oriented in said outlet port adapted to receive material discharged from said second conveyor means and dimensioned so as to suppress emission of microwave energy through said outlet port, and means to move said first and third conveyor means in vibratory motion to move material along a substantially horizontal path.

7. The apparatus according to claim 6 wherein said first and third conveyors operate a rate of product flow which is greater than the rate of product flow of said second conveyor.