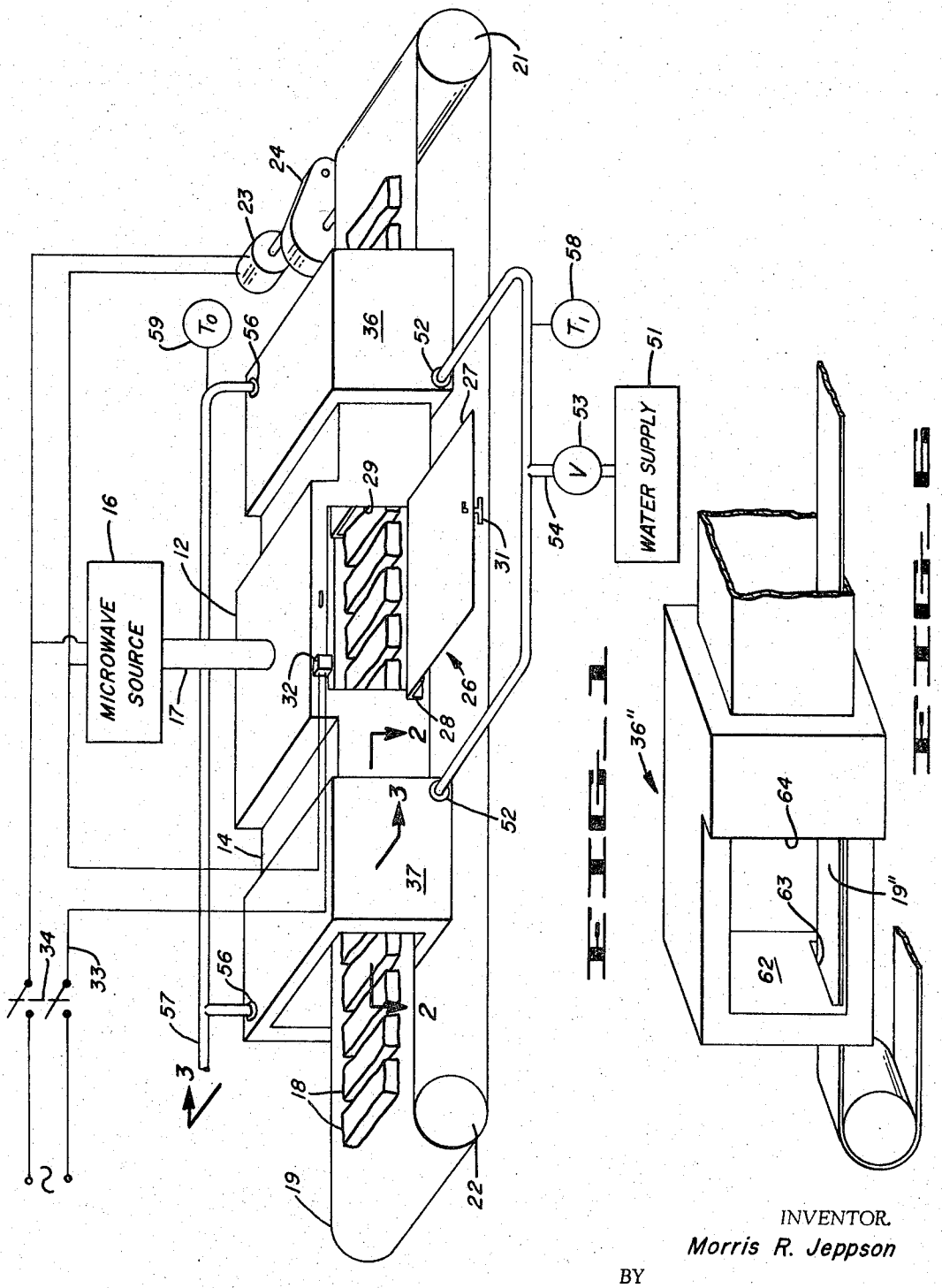
Jan. 23, 1968 M. R. JEPPSON 3,365,562

APPARATUS AND PROCESS FOR MICROWAVE TREATMENT

Filed Sept. 7, 1966 3 Sheets-Sheet 1




INVENTOR.
Morris R. Jeppson

BY
William D. Hager
ATTORNEY

APPARATUS AND PROCESS FOR MICROWAVE TREATMENT

Filed Sept. 7, 1966 3 Sheets-Sheet 2

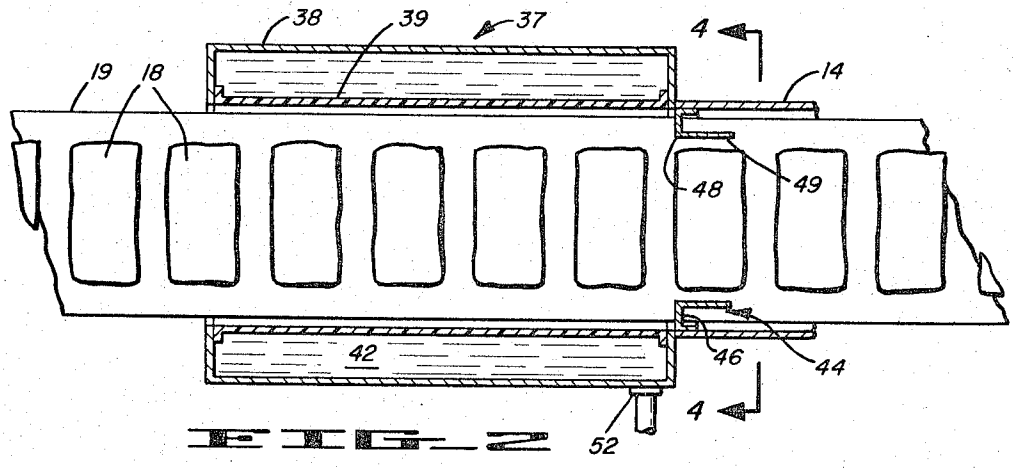



FIG. 2

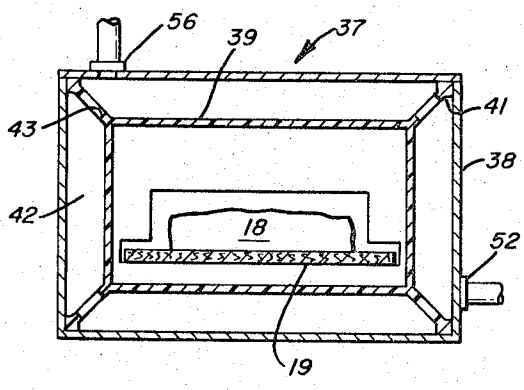



FIG. 3

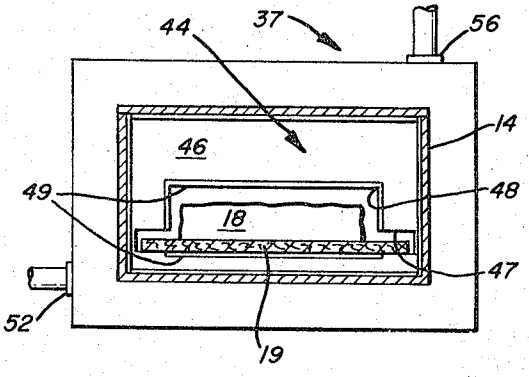



FIG. 4

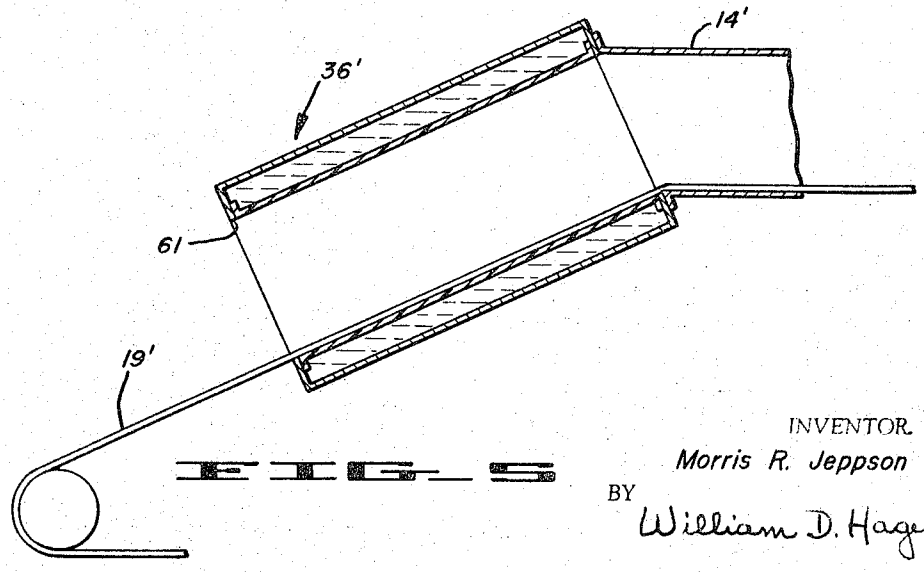



FIG. 5

INVENTOR.
Morris R. Jeppson
BY
William D. Hager
ATTORNEY

Jan. 23, 1968 M. R. JEPPSON 3,365,562

APPARATUS AND PROCESS FOR MICROWAVE TREATMENT

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FIG. 9

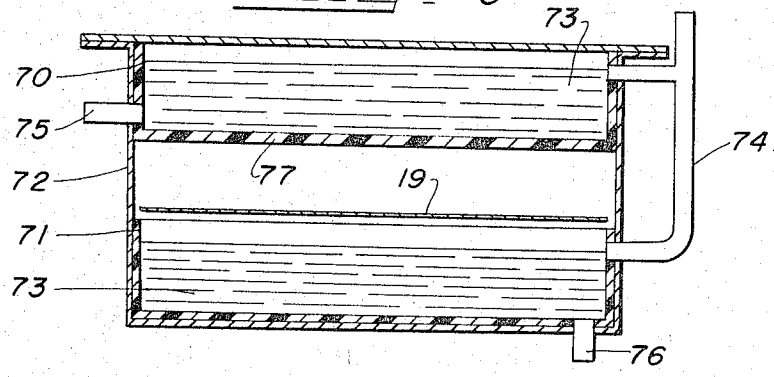



FIG. 7

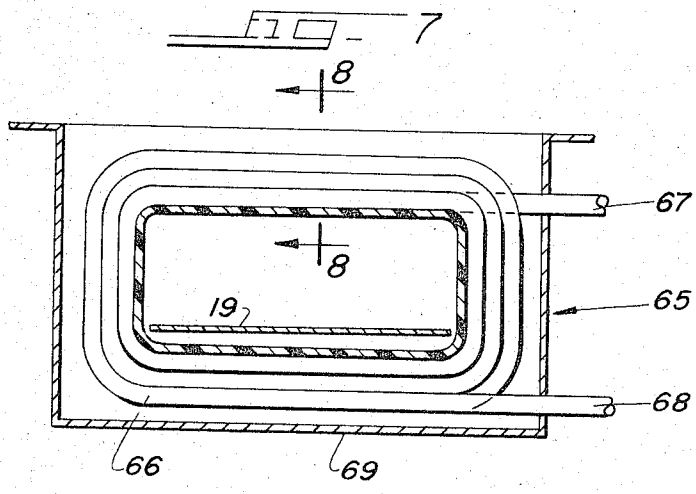
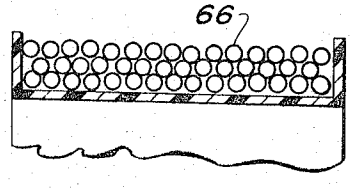



FIG. 8




INVENTOR
MORRIS R. JEPPSON
BY Carl C. Batz
Atty

United States Patent Office

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3,365,562

# APPARATUS AND PROCESS FOR MICROWAVE TREATMENT

Morris R. Jeppson, Danville, Calif., assignor to Cryodry Corporation, San Ramon, Calif., a corporation of California

Continuation-in-part of applications Ser. No. 497,433, Oct. 18, 1965, and Ser. No. 505,114, Oct. 18, 1965, which were continuations-in-part of application Ser. No. 245,010, Dec. 17, 1962. This application Sept. 7, 1966, Ser. No. 589,149

22 Claims. (Cl. 219—10.55)

## ABSTRACT OF THE DISCLOSURE

Substances such as food products are heated by microwave energy injected into a treating zone which is opened to accommodate transport of the substances, and energy attempting to escape is attenuated efficiently because of its exposure to lossy dielectric liquid in an attenuation zone communicating with the treating zone and also accommodating transport of the substances.

This application is a continuation-in-part application disclosing and claiming only subject matter disclosed in my copending application Ser. No. 497,433, filed Oct. 18, 1965, and in my copending application Ser. No. 505,114, filed Oct. 18, 1965, now both abandoned, both of which copending applications were continuing applications in part disclosing and claiming subject matter disclosed in my application Ser. No. 245,010, filed Dec. 17, 1962, which was copending therewith and is now abandoned.

The present invention relates to apparatus and a process for heating food products and the like by microwave energy and more particularly to a microwave chamber having access ports which may remain open during operation whereby products may be continuously passed through the chamber, and to a microwave process in which microwave energy tending to leak from the treatment chamber is attenuated before escaping. By the term "microwave energy" I mean radiant electrical energy which has a frequency between about 200 and 10,000 megacycles.

The processing of foods by exposure to microwave energy is widely practiced in industrial plants and, using smaller scale equipment, in restaurants and in homes. In each case, the principal components of the heating unit are a chamber enclosure formed of electrically conducting material and an oscallator or other source of microwave energy which is coupled to the chamber. Owing to the low loss factor of the chamber walls, very little energy is dissipated therein. The energy is reflected by the chamber walls which remain cool. Virtually all foods however are lossy dielectric materials from the electrical standpoint. Foods which are placed in the chamber therefore absorb the microwave energy and are rapidly and efficiently heated.

Basic advantages of microwave heating over more conventional forms are the basic relatively short heating time and a greater uniformity of heating within the product. Under proper conditions, the technique is more efficient than other cooking methods in that only the product itself is heated to any significant extent and virtually all the heat produced is generated directly within the product.

It has been difficult however to utilize microwave heating on a continuous process basis owing to the need to eliminate any leakage of microwave energy from the chamber. Leaking microwave energy can cause biological



effects which are injurious to nearby personnel and may cause interference in radio and television communications. Such leakage is also wasted power which increases operating costs.

Microwave leakage does not pose serious problems where products are treated on a batch basis inasmuch as the chamber may be completely closed during operation without difficulty. For high volume operations, however, it is much more efficient to utilize a continuous process in which products are continually fed into the chamber, transported therethrough by a suitable conveyor, and continually removed. The basic problem encountered under these conditions is that the continuous process chamber should have permanently open access ports. Such ports, in the case of chambers operating at microwave frequencies, are a source of considerable leakage in the absence of corrective provisions.

For systems operating below about 100 megacycles (corresponding to a wave length of ten feet) it is possible to use a conveyor which enters and leaves the chamber through permanently open tunnels which have cross-sectional dimentions that are small in comparison with the operating wave length. This does not result in leakage inasmuch as wave energy will not propagate through an opening which is small relative to its wave length. From the standpoint of efficient heating, however, it is desirable that higher frequencies, typically in the range of from 400 mc. to 8000 mc., for example, be employed. At these microwave frequencies, serious leakage will occur from openings of sufficient size to admit the product unless special isolating arrangements are employed.

The present invention provides a microwave processing chamber having open access tunnels equipped with a compact, inexpensive and efficient means for preventing any significant leakage of microwave energy, the chamber therefore being adapted to high volume continuous processing of food products and the like.

The invention comprises a process for treating materials with microwave energy comprising maintaining a microwave treating zone by injecting microwave energy into a chamber while reflecting energy inwardly of the chamber at the chamber walls while maintaining an opening in said chamber for introduction of material to be treated, containing microwave energy which leaks from said chamber through said opening within a confined channel, passing material to be treated through said treating zone, and circulating lossy dielectric liquid in said channel and into exposure to microwave energy in said channel whereby said microwave energy in said channel is attenuated by said liquid.

The invention may include a heating chamber having electrically conducting walls and having a microwave generator coupled thereto through a waveguide or the like. An entrance tunnel and an exit tunnel are formed at opposite ends of the chamber and a suitable continuous conveyor extends through the chamber and the access tunnels. The microwave input is aligned to avoid the injection of microwave energy directly toward the tunnels. Owing to multiple reflection of the energy from the conducting walls, and to scattering, however, some of the energy will reach the region of the tunnels. The tunnels are accordingly formed in a unique manner to absorb all but an insignificant amount of such energy.

In particular, the tunnels are comprised of an outer wall of electrically conducting material and an inner wall formed of dielectric material which is spaced from the outer wall a distance of several inches, preferably a distance at least equal to one quarter wave length of the microwave energy supplied to the chamber. The space between the outer and inner walls of the tunnel is made fluid tight and is filled with a lossy dielectric liquid, water being highly suitable for this purpose.

Using the described microwave injection arrangement, most of the energy in the chamber undergoes multiple reflections back and forth between opposite walls of the chamber and very little is directed straight out through the tunnel openings. Microwave energy which reached the tunnel openings behaves in a similar manner, the energy being repeatedly reflected between opposite conducting outer walls of the tunnel as it propagates relatively slowly along the axis thereof. Such energy must repeatedly pass through the water volume and it is therefore absorbed and attenuated as it moves through the tunnel. While some energy will reach the ends of the tunnels, the leakage may be reduced to any desired value by extending the length of the tunnel a sufficient distance.

Variations in the general arrangement of the tunnel may be made to reduce the residual leakage of microwave energy without extending the tunnel an impractical distance. If the tunnels are inclined with respect to an axis extending through the entrance and exit openings of the heating chamber, for example, then the portion of the energy which travels directly out through the openings will also be intercepted by a water volume. Alternately, the tunnels may be provided with end walls containing a water volume similar to that of the tunnel sidewalls, access to the conveyor being provided through an opening in one sidewall of the tunnel.

With another modification, the continuously operating chamber may be employed to cook food products for differing amounts of time as may be required where such a chamber is used in a restaurant for example. Specifically, the central part of the chamber may be provided with a conventional hinged door in addition to the access tunnels through which the conveyor moves. By means of the door, articles which are to be heated to a lesser extent than those which are fed into the entrance tunnel are placed within the chamber at an appropriate position on the conveyor. To avoid energy leakage, opening of the door operates an interlock which de-activates the microwave source.

In addition to stopping the emission of microwave energy from an open microwave heating chamber, the invention has other highly useful results, one being that of maintaining an adequately constant load on the microwave generator under all conditions. The product which is present in the chamber under normal operating conditions constitutes the load to which the microwave generator is matched. During start-up and shut-down, however, or through operator error, there are times when there is little or no product on the conveyor. Under these conditions, the mis-match on the microwave generator could be severe enough to cause tube damage in the absence of preventive means or steps. The access tunnel structure as hereinbefore described provides such a means inasmuch as the microwave energy, in the absence of any product in the chamber, reflects back and forth between the chamber walls until its enters the end tunnels. The step of providing a lossy dielectric liquid in the access tunnel as hereinbefore described provides such a step inasmuch as the microwave energy, in the absence of any product in the chamber, reflects back and forth between the chamber walls until it enters the end tunnels. The water volume of the tunnels then absorbs the energy and functions as a microwave load.

It is generally necessary to continually circulate water through the tunnel walls, to avoid boiling, and by monitoring the temperature differential between the input and output water, a useful check on the operation of the heating chamber may be maintained. A variation in the temperature differential indicates either a change in conveyor loading, a change in the output power of the microwave source, or a change in the characteristics of the product undergoing processing.

Accordingly, it is an object of this invention to provide a practical, efficient and safe apparatus and process for heating food products and the like by exposure to microwave energy on a continuous process basis.



It is an object of this invention to provide a microwave heating chamber which may have permanently open access ports into which products may be continuously fed and from which products may be continually removed.

It is an object of this invention to provide a process in which the microwave heating chamber may have permanently open access ports into which products may be continuously fed and from which products may be continually removed.

It is another object of the invention to provide a means and a process for substantially reducing the leakage of microwave energy through openings in processing chambers.

It is another object of this invention to provide a microwave processing chamber which may utilize a conveyor for the transport of products therethrough.

It is still another object of the invention to facilitate the use of extremely high frequency microwave energy for the heating of foods on a continuous process basis.

It is a further object of the invention to provide a microwave heating chamber and a microwave heating process in which a satisfactory load is coupled to the microwave source irrespective of the amount of the product in the chamber.

It is still a further object of this invention to provide a continuous process microwave heating chamber having an efficient means for monitoring changes in the processing conditions, and to provide a continuous process microwave heating process which enables the monitoring of changes in the processing conditions.

It is still another object of the invention to provide a microwave chamber and a microwave process in which products to be heated may be continuously passed through a microwave chamber and in which products which are processed at the same time may be selectively heated for varying amounts of time.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification taken in conjunction with the accompanying drawing, in which:

FIGURE 1 is a perspective view of a microwave heating chamber for processing products on a continuous basis and in which electrical components and the water supply means are shown schematically.

FIGURE 2 is a partial plan section view taken along line 2—2 of FIGURE 1 and showing internal details of one of the access tunnels of the heating chamber of FIGURE 1,

FIGURE 3 is a cross section view taken along line 3—3 of FIGURE 1 showing further details of the access tunnel,

FIGURE 4 is a cross section view taken along line 4—4 of FIGURE 2,

FIGURE 5 is a diagrammatic view of a modified form of access tunnel for the heating chamber of FIGURE 1 in which the leakage of wave energy is further reduced, and

FIGURE 6 is a diagrammatic view of a second modified form of access tunnel for further reducing the emission of microwave energy from the chamber of FIGURE 1.

FIGURE 7 is a cross section view of another alternative form of access tunnel for reducing the emission of microwave energy from the chamber of FIGURE 1.

FIGURE 8 is a cross section view taken along line 8—8 of FIGURE 7 showing further details of the access tunnel.

FIGURE 9 is a cross section view of a further alternative form of access tunnel.

Referring now to the drawing and more particularly to FIGURE 1 thereof, the heating chamber of the installation is formed by a long housing 11 which is open

at the ends and which may be of rectangular cross section. At least the interior walls of the housing **11** are formed of a highly conductive material such as aluminum or copper. The central portion **12** of housing **11** is of slightly greater height than the ends **13** anr **14** thereof to define the microwave injection region.

A microwave generator **16**, which may be an oscillator, for example, is coupled to the central portion **12** of housing **11** through means such as a waveguide **17**, the waveguide being arranged to inject the microwave energy in a direction normal to the long axis of the housing **11**, in this instance directly downwardly from the central region of the top of the housing.

The product to be heated, which may be cuts of meat **18**, for example, is carried through the housing **11** by a conveyor belt **19**. The upper portion of the continuous belt **19** extends through housing **11**, at a level which is a small distance above the floor thereof, and extends for a distance from each end thereof. The belt **19** is mounted on drums **21** and **22** at opposite ends **13** and **14** of the housing **11** with the lower section of the belt passing beneath the housing. The belt **19** is formed of a flexible electrically non-conductive and preferably non-absorbent material, any of various well known plastics or treated fabrics being suitable for this purpose.

To drive the belt **19**, drum **21** at the entrance end of the housing **11** is turned by an adjustable speed electrical drive motor **23** which is coupled to the drum through a speed reduction mechanism **24**.

In those cases where it may be desired to heat different units of the product **18** for differing periods of time, such as is required in the cooking of steaks in a restaurant for example, the operator's side of the housing **11** may be provided with a door assembly **26**. By means of the door, products **18** may be removed from the heating chamber prior to making a complete passage through the housing **11** or alternately may be placed in the chamber at an advanced position on the belt **19**.

Door assembly **26** may be comprised of a conductive plate **27** having a lower edge attached to housing **11** by a hinge **28** along the bottom of a rectangular opening **29** in the sidewall of the opening. A suitable handle and latch **31** is mounted on the upper margin of the door to secure the door in the closed position. To avoid energy leakage upon the opening of door **28**, a normally open interlock switch **32** is mounted on the housing **11** in position to be closed by a portion of door plate **27** only when the door itself is in the closed position. One of the leads **33** which supplied electrical power to the apparatus, through a control switch **34**, is connected to both the microwave source **16** and belt drive motor **23** through the interlock switch **32**. Opening of the door assembly **26** thus stops both the injection of microwave energy into housing **11** and the motion of the conveyor belt **19**.

Considering now the means by which the leakage of energy from the ends of housing **11** is reduced to a negligible value, thick-walled tunned assemblies **36** and **37** are disposed at ends **13** and **14** respectively of the housing. The conveyor belt **19** passes through each of the tunnels **36** and **37**, which may be of rectangular cross-section and which in effect form a continuation of the housing **11**.

Referring now to FIGURES 2, 3 and 4 in conjunction there is shown the internal construction of one of the tunnels **37**, and the other tunnel **36** being of essentially similar design. The tunnel **37** includes an outer wall **38** formed of electrically conducting material and shaped into a rectangular fluid tight enclosure of greater height and width than the adjacent end **14** of housing **11**. The end of the wall **38** which is adjacent housing end **14** is turned inwardly to form a juncture therewith and the opposite end of the wall is angled inwardly in a similar manner.

Spaced inwardly from wall **38** is a rectangular inner wall **39** having a height and width corresponding to that of the end **14** of housing **11**. Inner wall **39** extends



through the length of the tunnel **37** and is secured to the inwardly turned ends of the outer wall **38** in a fluid tight manner. To add strength and rigidity to the inner wall **39**, projections **41** formed along each corner thereof extend to the corresponding corners of the outer wall **38**. To allow for the circulation of water **42** between the walls **38** and **39**, openings **43** are provided along the length of each projection **41**. The inner wall **39**, including projections **41**, is formed of a dielectric material such as plastic, glass, ceramic, or the like which is transparent to microwave energy.

Referring now to FIGURE 4 in conjunction with FIGURE 2, the containment of microwave energy within the housing **11** may be enhanced by utilizing an electrically conductive baffle **44** to limit the passageway at end **14** of the housing to the minimum area needed for passing the particular products **18** which are to be processed. The baffle **44** in this embodiment includes a rectangular plate **46** conforming to the cross-sectional configuration of the housing end **14** and secured transversely therein. A narrow horizontal slot **47** is provided in plate **46** through which the conveyor belt **19** passes and a larger opening **48** is contiguous with the slot to provide for the passage of product **18** through the baffle. The effectiveness of the baffle is increased by providing a lip **49** around the margins of the opening **48**, and beneath the belt **19**, which projects backwardly into the housing **11** for a distance of several inches.

Referring now again to FIGURE 1, water is circulated between the inner and outer walls of the tunnels **36** and **37** from a source **51** which is connected to a fitting **52** at the base of each tunnel through a control valve **53** and branched supply conduit **54**. Outlet fittings **56**, which are transpierced through the outer wall **38** of each tunnel at the top thereof, connect with an outlet conduit **57** leading to a drain or to a cooling and recirculating system.

To provide a means for indicating the temperature differential between the incoming and outflowing water, for monitoring the processing conditions as hereinbefore described, a first thermometer **58** is coupled to the supply conduit **54** and a second thermometer **59** is situated at output conduit **57**.

In operation, the belt drive motor **23** and microwave source **16** are energized by closing switch **34**. Units of the product **18** are then periodically placed on the belt **19**, the product thereby being carried through the heating chamber at a uniform rate. Changes in the degree of heating of the product **18** may be made by adjusting the output power of the microwave source **16** or by varying the speed of the conveyor belt **19**. If a particular unit of the product **18** is to be heated to a lesser extent than the remainder of the product undergoing processing at the same time, it may be removed through door **26** prior to making a complete passage through the housing **11** or, alternately, it may be placed at an advanced position on the belt **19** by means of the door.

The microwave energy injected into housing **11** through waveguide **17** is repeatedly reflected between the conducting walls of the housing and in this manner propagates toward the tunnels **36** and **37**. Thus the energy passes repeatedly through the product **18** and a portion of the energy is absorbed thereby with each passage. The absorbed energy appears as heat within the product **18**.

The energy which reaches the tunnels **36** and **37** without being absorbed by the product **18** propagates along the tunnels in a similar fashion, i.e., by reflection between opposite portions of the conducting outer walls **38** thereof. In so doing, the energy must pass repeatedly through the lossy water volume **42**, as well as the product **18** in the tunnel, and is therefore almost completely attenuated prior to reaching the open ends of the tunnels.

A typical embodiment which may be used in the practice of the invention as shown in FIGURE 1 has a housing **11** with a height, at central portion **12** of 11 inches and a width of 20 inches. The central portion **12** of the

housing has a length of 8 feet. Tunnels **36** and **37** are 2 feet long and the thickness of the water volume **42** in the walls thereof is 4 inches. Microwave source **16** may be operated at a frequency ranging from 400 to 8000 megacycles with a power output from one to several hundred kilowatts. In a unit having the dimensions given above, and designed for industrial food processing, a typical power input is 60 kw.

Modifications may be made in the tunnel structure to reduce the escape of microwave energy to a still greater extent. As shown in FIGURE 5 for example, the tunnel **36'** may be inclined with respect to the adjacent end **14'** of the heating chamber so that the small proportion of the microwave energy which travels directly out the housing chamber opening will also be intercepted by a water volume. For this purpose, the tunnel **36'** should be inclined sufficiently that the upper edge **61** of the outer end of the tunnel is below the level of the floor of the housing end **14'**. The angle at which the conveyor belt **19'** must travel to enter and leave the heating chamber may be reduced, while satisfying the foregoing condition, by lengthening the tunnel **36'** an appropriate amount. Minimizing this angle also has the beneficial effect of increasing the distance which horizontally directed microwaves must travel through water.

Referring now to FIGURE 6, an alternate arrangement for interposing a water volume in the path of microwave energy which travels directly along the tunnel **36''** consists of providing an endwall **62** thereon, the endwall containing a water volume similar to that heretobefore described. A thin slot **63** in endwall **62** provides for the passage of the conveyor belt **19''** and a large opening **64** is provided in a sidewall of the tunnel **36''**, near the end thereof, for the introduction or removal of product.

Referring to FIGURE 7, a further alternate arrangement for interposing a water volume in the path of microwave energy tending to escape at the entrance or exit of the heating chamber is shown. Tunnel assembly **65** may be used at the end **13** in place of tunnel assembly **36**, and a similar assembly may be used at the end **14** in place of assembly **37**. The tunnel assembly **65** comprises a continuous helical tube **66** which encloses the end of conveyor **19**. The tube **66** is made of dielectric material. Inlet **67** and outlet **68** respectively feed and drain the helical tube **66** with lossy dielectric liquid. The helical tube is enclosed within an open-ended tunnel enclosure **69** formed of electrically conductive material which acts to reflect the excessive microwave energy that may enter the tunnel back and forth across the helical tube containing the lossy dielectric liquid until it is absorbed.

Referring to FIGURE 9, a further alternative arrangement for interposing a water volume in the path of microwave energy tending to escape at the entrance or exit of the heating chamber is shown. The arrangement involves the use of pans **70** and **71** positioned above and below conveyor **19** within an open-ended tunnel enclosure **72**. The enclosure **72** is formed of electrically conducting material to effect repeated reflection of the microwave energy that might reach the tunnel enclosure until it is eventually absorbed in the lossy dielectric liquid **73** contained in the pans. A flow from the upper to the lower pan is preferably established via an upper pan drain and standpipe **74** to equalize such absorption. A cascading flow over the top of the upper pan with a flow along the walls can also be used. Inlet conduit **75** and outlet conduit **76** provide for a feeding and drainage and/or a recirculation of the liquid.

The pans **70** and **71** may be open-topped especially where the product treated will not be substantially affected by the higher humidity that will be encountered in such an arrangement. The upper pan **70** has a base **77** formed of dielectric material to permit passage of the microwave energy within the tunnel into the lossy dielectric liquid contained in the pan.

Each of the embodiments above described for use in the practice of the invention contemplates a microwave treating chamber having an opening through which material to be treated may be passed into the chamber. Preferably the chamber has two openings, one through which the material to be treated is passed into the chamber and a second opening through which treated material is passed from the chamber.

The injection of microwave energy into the treating chamber causes the microwave energy to disperse within the chamber and at least a small part of the energy tends to move toward and leak through the entrance opening or the exit opening.

For protecting against this hazard of leakage, this invention utilizes a tunnel structure which communicates with such an opening into the chamber and serves to attenuate the spray energy which otherwise would spill through the opening and onto the material in the machine to cause a hazardous condition.

The use of the tunnel structures permit movement of the material to be treated along a passageway through a tunnel and into the opening in the treating chamber while attenuating in the tunnel the microwaves which leak from the chamber. Likewise in the case of a second opening for exit of the treated material from the chamber a tunnel structure permits movement of the treated material from such opening through a passageway in the tunnel while attenuating the microwaves which leak out the exit opening.

The term "conveyor" as used herein is intended to include other means for transportation than mechanical belts or the like; and in fact may include pipes, conduits, etc. whereby fluid or particulate materials such as chemicals, powders, grains, or other materials including foodstuffs or drugs may be transported therethrough.

Although the invention has been herein discussed primarily with reference to the processing of food products, the invention may also be utilized for the continuous processing of other lossy dielectric materials which require heating. The invention may, for example, be employed for such purposes as hardening thermosetting plastic products or for curing plywood.

While the invention has been disclosed with respect to a particular embodiment and certain specific modifications thereof, it will be apparent that many variations are possible within the spirit and scope of the invention and thus it is not intended to limit the invention except as defined in the following claims.

What is claimed is:

**1.** In an apparatus for heating substances by means of microwave energy, the combination comprising a heating chamber housing, a tunnel opening into at least one wall of said housing, said housing including said tunnel having walls formed of electrically conducting material, means for injecting microwave energy into said housing, means forming a fluid-tight enclosure within said tunnel in proximity to the wall thereof, said enclosure means forming an inner wall for at least a substantial portion of said tunnel and being formed of dielectric material, and a volume of lossy liquid disposed within said enclosure.

**2.** In apparatus for heating substances by means of electromagnetic wave energy as described in claim **1**, the further combination of an inlet and an outlet conduit connecting with said enclosure, and means coupled to said inlet conduit for circulating said liquid through said enclosure.

**3.** In an installation for processing substances by exposure to microwave energy, the combination comprising a heating chamber housing having electrically conductive walls, a tunnel extending into said housing and forming an access opening thereto, said tunnel having an electrically conductive outer wall, a dielectric inner wall disposed within at least a portion of said tunnel and spaced from said outer wall thereof to form a fluid-tight passageway therebetween, and means for circulating a lossy dielectric liquid between said inner and outer walls of said tunnel.

**4.** An installation for processing substances by expo-

sure to microwave energy as described in claim 3 and wherein said dielectric liquid is water.

5. In an apparatus for heating substances with microwave energy, the combination comprising a heating chamber housing having electrically conducting walls, a tunnel structure extending through a wall of said housing and forming an access opening therefor, said tunnel having an electrically conducting outer wall and a dielectric inner wall spaced from said outer wall and forming a fluid-tight passageway therebetween, means for establishing a flow of dielectric liquid through said passageway, and means for injecting said wave energy into said housing in a direction substantially normal to the centerline of said tunnel.

6. An apparatus for heating products by exposure to microwave energy comprising, in combination, a heating chamber housing having electrically conducting walls, a pair of tunnels transpierced through the walls of said housing at spaced apart regions thereof, said tunnels having electrically conducting walls, a fluid-tight enclosure disposed within each of said tunnels for retaining a volume of dielectric liquid adjacent an extensive area of the conducting walls of each thereof, said enclosures being formed of non-conductive material, a source of said microwave energy coupled to said heating chamber, and a conveyor means extending through each of said tunnels and said heating chamber for carrying said products therethrough.

7. A continuous process apparatus for heating substances by means of microwave energy comprising, in combination, a tubular housing having open opposite ends and being formed of electrical conductor, means for injecting electromagnetic energy into a central region of said housing, a pair of access tunnels disposed one at each end of said housing and forming continuations thereof, each of said tunnels having an electrically conductive outer wall and a non-conductive inner wall spaced from the outer wall to form a fluid-tight enclosure therebetween, a volume of dielectric liquid disposed in said enclosure, and a continuous conveyor belt having a section extending through said housing and said tunnels for carrying said substances to be heated therethrough.

8. A tunnel structure for providing access to a chamber in which microwave energy is present comprising, in combination, a tubular outer wall formed of electrical conductor, and having openings at opposite ends, dielectric means forming a fluid-tight passageway within said tunnel adjacent an extensive area of the inner surface of said conducting outer wall, said dielectric passageway being confined to the vicinity of said wall whereby substances may be passed through said tunnel, and means for circulating a lossy dielectric liquid through said passageway, whereby energy which propagates into said tunnel is absorbed by said dielectric liquid rather than being emitted from said tunnel.

9. An apparatus for heating products by exposure to microwave energy comprising, in combination, a heating chamber housing having electrically conducting walls, a pair of tunnels transpierced through the walls of said housing at spaced apart regions thereof, said tunnels having electrically conducting walls, a fluid-tight enclosure disposed within each of said tunnels for retaining a volume of dielectric liquid adjacent the conducting walls of each thereof, said enclosures being formed of non-conductive material, a source of said microwave energy coupled to said heating chamber, a conveyor means extending through each of said tunnels and said heating chamber for carrying said products therethrough, a water supply conduit connected to said enclosure of each of said tunnels, said supply conduit being coupled to a source of water under pressure, a drain conduit connected to said enclosure of each of said tunnels, and a first thermometer coupled to said drain supply conduit and a second thermometer coupled to said drain conduit whereby the temperature differential between water entering and leaving at least one of said tunnels is indicated, thereby providing a means for monitoring processing conditions within said heating chamber.

10. A continuous process apparatus for heating substances by means of microwave energy comprising, in combination a tubular housing having open opposite ends and being formed of electrical conductor, means for injecting electromagnetic energy into a central region of said housing, a pair of access tunnels disposed one at each end of said housing and forming continuations thereof, each of said tunnels having an electrically conductive outer wall and a non-conductive inner wall spaced from the outer wall to form a fluid-tight enclosure therebetween and further having a conductive endwall and a non-conductive endwall spaced therefrom and forming a fluid-tight enclosure which is transpierced by a slot, each of said tunnels further having an access opening in a sidewall thereof, a volume of dielectric liquid disposed in said enclosures between said conductive and non-conductive walls, and a continuous conveyor belt having a section extending through said housing and said tunnels and through said slots in the endwalls thereof for carrying substances to be heated through said apparatus.

11. A continuous process apparatus for heating substances by means of microwave energy comprising, in combination, a tubular housing having open opposite ends and being formed of electrical conductor, means for injecting microwave energy into a central region of said housing, a pair of access tunnels disposed one at each end of said housing and forming continuations thereof, each of said tunnels having an electrically conductive outer wall and a non-conductive inner wall spaced from the outer wall to form a fluid-tight enclosure therebetween, a volume of dielectric liquid disposed in said enclosure, a continuous conveyor belt having a section extending through said housing and said tunnels for carrying said substances to be heated therethrough, and a pair of electrically conducting baffles, one of said baffles being disposed at the juncture between said housing and each of said tunnels in transverse relationship to the passageway therethrough, each of said baffles having an opening of substantially the minimum size needed to pass said conveyor belt and said substances to be heated, each of said baffles having a lip around said opening which projects into said housing.

12. A continuous process apparatus for heating substances by means of microwave energy comprising, in combination, a tubular housing having open opposite ends and being formed of electrical conductor, means for injecting microwave energy into a central region of said housing, a pair of access tunnels disposed one at each end of said housing and forming continuations thereof, said tunnels being inclined with respect to the centerline of said housing, each of said tunnels having an electrically conductive outer wall and a non-conductive inner wall spaced from the outer wall to form a fluid-tight enclosure therebetween, a volume of dielectric liquid disposed in said enclosure, and a continuous conveyor belt having a section extending through said housing and said tunnels for carrying said substances to be heated therethrough.

13. In apparatus for heating substances by means of microwave energy, the combination comprising means for housing material during heating thereof, a tunnel communicating with said housing means and through which material to be heated may be passed into said housing means, means for injecting microwave energy into said housing means whereby said energy is propagated in said housing means and to a lesser extent in said tunnel, said tunnel including means for retaining a volume of liquid therein in exposed relation to radiation of microwave energy in said tunnel, and means for circulating lossy dielectric liquid through said retaining means, whereby microwave energy radiated into said tunnel is attenuated by liquid in said retaining means.

14. In apparatus for heating substances by means of microwave energy, the combination comprising means for

housing material during heating thereof, a tunnel communicating with said housing means and through which material to be heated may be passed into said housing means, a second tunnel communicating with said housing means and through which material heated within said housing means may be passed therefrom, means for injecting microwave energy into said housing means whereby said microwave energy is propagated in said housing means and to a lesser extent in said tunnels, each of said tunnels including means for retaining a volume of liquid therein in exposed relation to radiation of microwave energy therein, and means for circulating lossy dielectric liquid through the retaining means of each of said tunnels, whereby microwave energy radiated into said tunnels is attenuated by liquid in the retaining means of said tunnels.

15. In apparatus for heating substances by means of microwave energy, the combination comprising means for housing material during heating thereof, a tunnel communicating with said housing means and through which material to be heated may be passed into said housing means, means for injecting microwave energy into said housing means whereby said energy is propagated in said housing means and to a lesser extent in said tunnel, said tunnel including electrically conductive wall material and means for retaining a volume of liquid within said tunnel between said wall material and positions through which material to be heated may be passed into said housing means, at least part of said retaining means being substantially transparent to microwave energy and exposing liquid in said retaining means to radiation of said microwave energy within said tunnel whereby microwave energy propagated in said tunnel may pass through liquid in said retaining means to be attenuated thereby and be reflected by said wall material to again be attenuated by liquid in said retaining means.

16. In apparatus for heating substances by means of microwave energy, the combination comprising means for housing material during heating thereof, a tunnel communicating with said housing means and through which material to be heated may be passed into said housing means, a second tunnel communicating with said housing means and through which material heated within said housing means may be passed therefrom, means for injecting microwave energy into said housing means whereby said microwave energy is propagated in said housing means and to a lesser extent in said tunnels, each of said tunnels including electrically conductive wall material and means for retaining a volume of liquid therein between said wall material thereof and positions through which material to be heated may be passed, at least part of each of said retaining means being substantially transparent to microwave energy and exposing liquid therein to radiation of microwave energy in the tunnel, and means for circulating lossy dielectric liquid through the retaining means of each of said tunnels, whereby microwave energy propagated into each of said tunnels may pass through liquid in said retaining means thereof to be attenuated thereby and be reflected by said wall material thereof to again be attenuated by liquid in the same retaining means.

17. In apparatus for heating substances by means of microwave energy the combination set forth in claim 16 and including a conveyor extending through said first mentioned tunnel, through said chamber, and through said second tunnel, and wherein each of said means for retaining a volume of liquid is disposed between said conveyor and said conductive wall material of a different one of said tunnels.

18. In apparatus for heating substances by means of microwave energy the combination set forth in claim 17 wherein each of said means for retaining a volume of liquid extends below said conveyor and has lossy dielectric liquid circulated therethrough below said conveyor.

19. In an apparatus for heating substances by exposure to microwave energy, the combination comprising a heating chamber having electrically conductive walls and having an inlet and an exit opening, means for injecting microwave energy into said chamber and a tunnel leading from each said opening, said tunnel having electrically conductive walls with a volume of lossy dielectric liquid within said walls in a continuous helical tube disposed adjacent the walls of said tunnel to absorb the microwave energy which reaches said tunnel from said chamber, means for establishing a flow of said dielectric liquid through said tube, and conveyor means extending through said chamber and through each helical tube in said tunnels whereby said substances may be continuously fed into and removed from said apparatus.

20. A process for treating materials with microwave energy comprising maintaining a microwave treating zone by injecting microwave energy into a chamber while reflecting energy inwardly of the chamber at the chamber walls and while maintaining an opening in said chamber for introduction of material to be treated, containing microwave energy which leaks from said chamber through said opening within a confined channel, passing material to be treated through said treating zone, and circulating lossy dielectric liquid in said channel and into exposure to microwave energy in said channel whereby said microwave energy in said channel is attenuated by said liquid, and wherein the microwave energy within said channel is contained and attenuated by reflecting said energy within a tubular enclosure about said channel through reflection paths including the circulated lossy dielectric liquid.

21. In a process for treating materials with microwave energy wherein said materials to be treated are passed through an opening into a microwave treating zone, the steps of passing said materials prior to their entrance into said treating zone through an attenuation zone which is connected with said treating zone by said opening, and circulating a lossy dielectric liquid into said attenuation zone and into exposure to microwave energy in said attenuation zone whereby microwave energy which has leaked through said opening attenuated in said liquid, and including reflecting microwave energy which passes through said liquid back through said liquid and thereby causing said energy to pass repeatedly through said liquid and be attenuated by each repeated passage through said liquid.

22. In a process for treating materials with microwave energy wherein materials to be treated are passed through an opening into a treating zone and through another opening out of said zone, the steps of passing said materials prior to their entrance into said zone through a first attenuation zone and, after they have passed through said treating zone, through a second attenuation zone, and circulating a lossy dielectric liquid into each of said attenuation zones and into exposure to microwave energy within said attenuation zones whereby microwave energy which has leaked into said attenuation zones from said treating zone is absorbed in said liquid.

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RICHARD M. WOOD, *Primary Examiner.*

L. H. BENDER, *Assistant Examiner.*