

Feb. 10, 1970

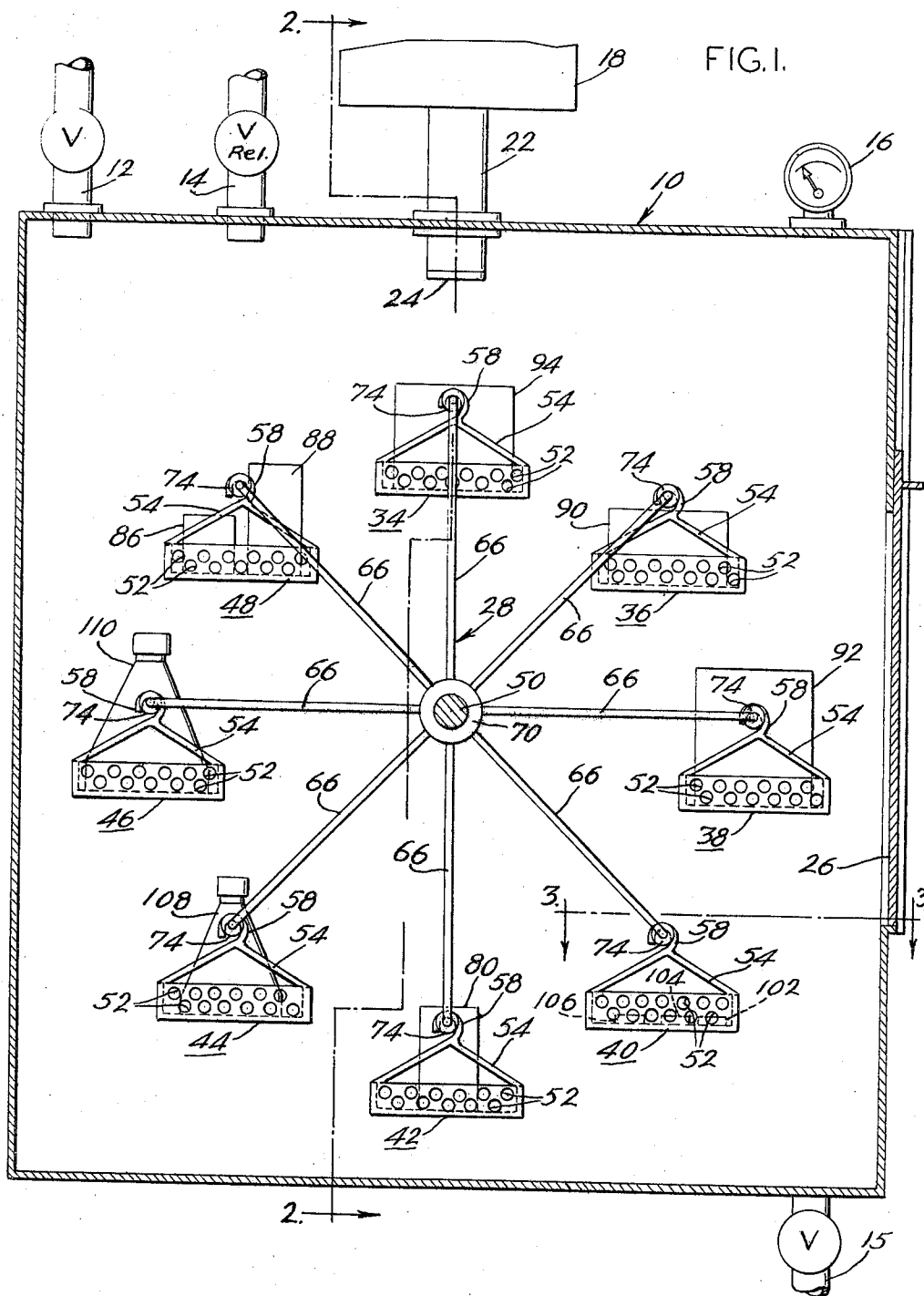
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3,494,722

METHOD AND APPARATUS FOR STERILIZING

Filed June 28, 1967

3 Sheets-Sheet 1



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METHOD AND APPARATUS FOR STERILIZING

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FIG. 2

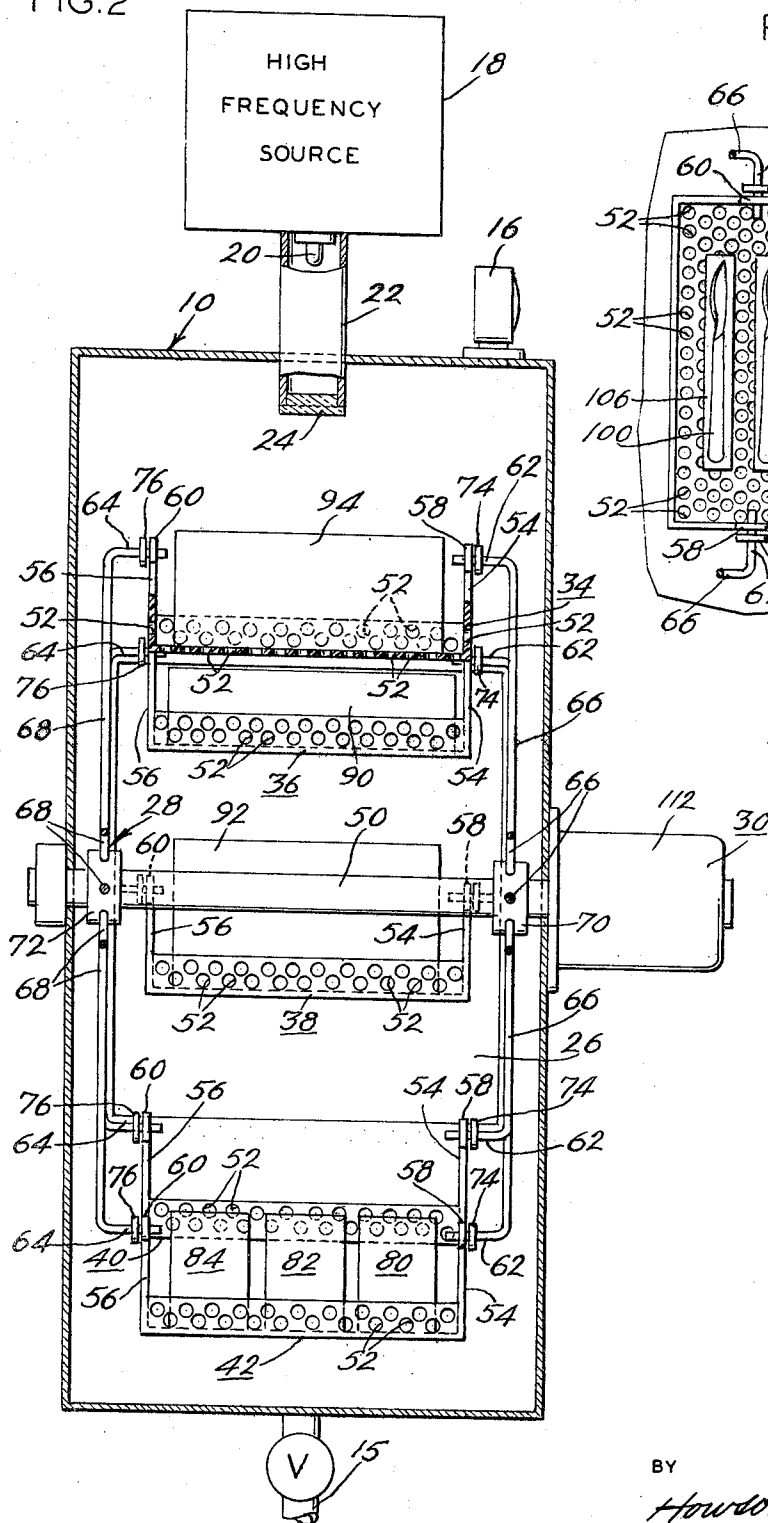
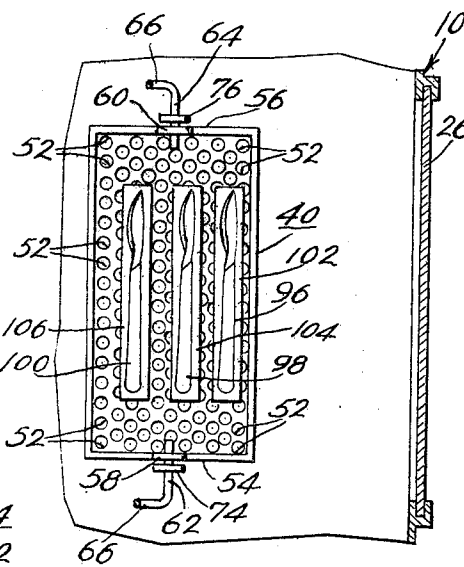


FIG. 3



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3 Sheets-Sheet 3

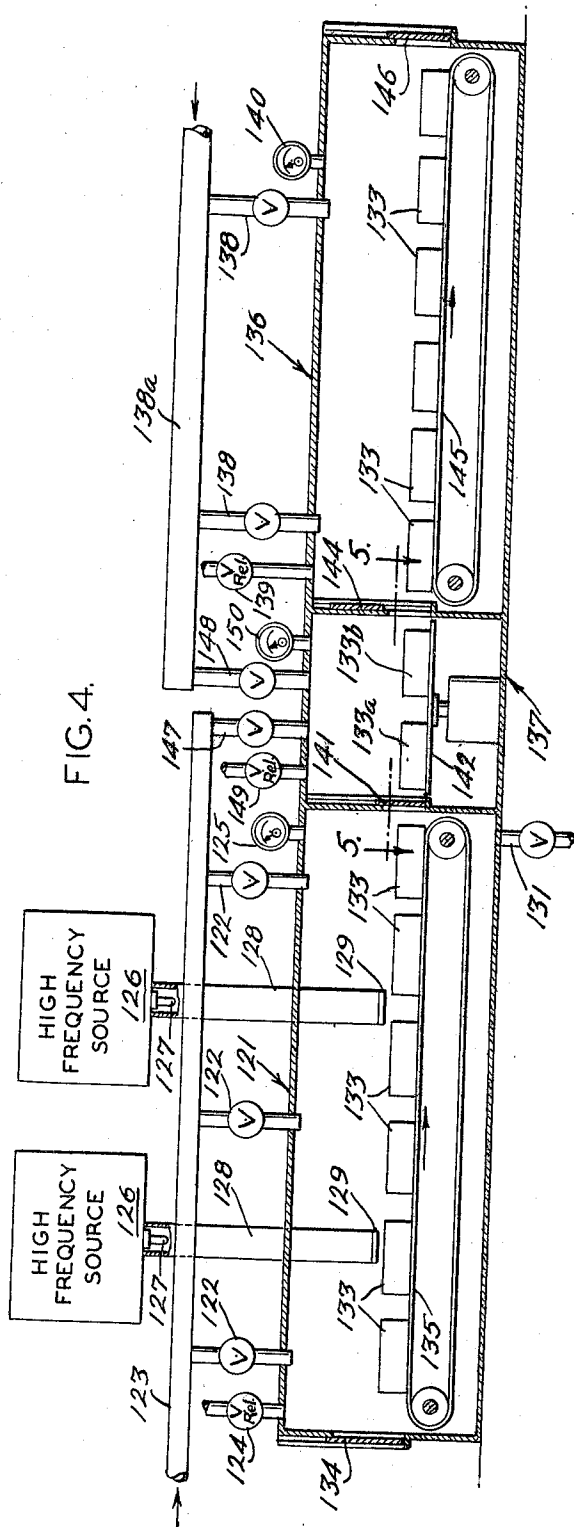


FIG. 4.

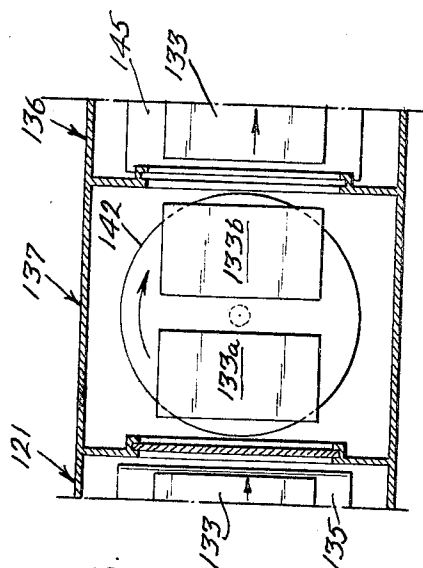


FIG. 5.

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METHOD AND APPARATUS FOR STERILIZING
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Continuation-in-part of application Ser. No. 345,625,
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No. 649,640

Int. Cl. A61l

U.S. Cl. 21—54

18 Claims

ABSTRACT OF THE DISCLOSURE

Method and apparatus for sterilizing articles, which are in a container at least one wall of which is permeable to microwave energy, having a pressure chamber, means for admitting the articles into the chamber, and means for generating microwave energy and for directing the energy into the chamber to provide a high-intensity microwave field region in the chamber. Steam under pressure is supplied into the chamber. Support means for the articles is provided in the chamber and drive means is employed for moving the support means through the high-intensity microwave field region to subject the articles to the microwave energy until the articles are sterile.

This application is a continuation-in-part of copending application Ser. No. 345,625, filed Feb. 18, 1964 and now abandoned, entitled "Method and Apparatus for Preserving Material."

The present invention relates to apparatus for sterilizing articles, such as medical subject matter, space vehicle components, and the like, and, more particularly, to an improved sterilizing apparatus for such subject matter employing the use of microwave energy and steam for more effective and rapid sterilization.

There is a wide variety of subject matter used in medical applications which must be sterilized before initial use and sterilized prior to each reuse. Such medical subject matter includes surgical instruments, dressings, gowns and other medical supplies, for example. Also, culture media in which bacteria is grown are sterilized in medical experimentation and treatment procedures. It is desirable to be able to effectively and expeditiously sterilize medical subject matter before use in operations on patients and in other medical applications. It is also desirable to be able to sterilize large quantities of medical subject matter and be able to retain them in a sterile condition until used in some medical application.

The two principal means employed in the prior art for sterilization of medical subject matter involve either the use of chemicals or the use of heat, or a combination of these. Chemicals for sterilization of medical subject matter are used with medical hardware and require drying of the sterilized subject matter under sterile conditions, and, also, if the subject matter is not used immediately, it must be wrapped in sterile cloth. Sterilization of medical subject matter in this manner subjects the subject matter to many conditions in which it can become contaminated. The use of heat to sterilize medical subject matter is most usually accomplished in an autoclave, which includes a chamber that can be filled with steam under pressure having a temperature above 212° F. When subjecting some medical subject matter, such as rubber gloves, to sterilization in an autoclave, the high temperature causes distortion or decomposition of the material, which must remain in the heated environment for a relatively long period of time required for sterilization. When sterilizing other medical subject matter, such as instruments or gowns, in an autoclave, the instruments or gowns are

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wrapped in a multi-thickness cloth which has its ends folded and taped prior to being placed in the autoclave. In order to provide sterilization of such subject matter in an autoclave, a relatively long period of time of subjecting the subject matter to the steam environment is required, and upon removal of the subject matter from the autoclave, some cooling outside of the autoclave generally takes place with the atmosphere, thereby having some convection contact of the subject matter with the atmosphere which may contaminate the subject matter. Furthermore, the use of steam in a conventional autoclave does not provide as effective a percentage of kill of bacteria or other contaminating microorganisms as desirable.

What has been said above also applies generally to other articles which it is desired to sterilize, like components of space vehicles and the like. While the apparatus will be described herein largely in terms of sterilizing medical subject matter, it will be understood that the description is equally applicable to the sterilization of other articles, including components of space vehicles, and the like.

In accordance with the present invention for sterilizing articles, the article or articles is preferably hermetically sealed in a container, which has at least one wall permeable to microwave energy. The subject matter is supported in a pressure chamber and steam is supplied under superatmospheric pressure into the chamber in contact with the container. Microwave energy is generated having a predetermined wavelength and the microwave energy is directed into the chamber to provide a high-intensity microwave field region in the chamber. The subject matter in the chamber is moved through the high-intensity microwave field region to subject the subject matter through its microwave-permeable wall to the microwave energy until the subject matter is sterile.

In the preferred embodiment of the present invention, means is provided for admitting the subject matter into the pressure chamber and support means is employed for supporting the subject matter in the pressure chamber. Drive means is provided for moving the support means through the high-intensity microwave field region to subject the subject matter through the microwave-permeable wall to the microwave energy until the subject matter is sterile. Preferably, the support means comprises a plurality of support surfaces on which medical subject matter is adapted to be positioned, and the drive means is adapted to move the support surfaces through the high-intensity microwave field region successively until the subject matter is sterile.

In accordance with the present invention, sterilization of medical subject matter, which is hermetically sealed in a container, by use of microwave energy and steam enables more effective and expeditious sterilizing of the subject matter. The time required to sterilize the subject matter to the same or a greater degree of sterilization than provided by prior art autoclaves is greatly reduced in the present sterilizing apparatus. With the present apparatus a greater percentage of kill of bacteria and contaminating microorganisms is enabled and certain vegetative spores, which cannot effectively be killed in a conventional autoclave, in a reasonable length of time, can be effectively and quickly killed in the present sterilizing apparatus. Furthermore, with the subject matter sterilized in a hermetically sealed container, the subject matter will remain sterile for longer periods of time than with prior art procedures.

For a better understanding of these and other features and advantages of the present invention, reference is made to the following description and accompanying drawings, in which:

FIG. 1 is a side elevational schematic view, partially in section, of one form, of apparatus that may be used

according to the present invention for sterilizing articles;
FIG. 2 is a sectional view taken along line 2—2 of
FIG. 1;

FIG. 3 is a fragmentary sectional view taken along line
3—3 of FIG. 1;

FIG. 4 is a side elevational schematic view, partly in
section, of another form of apparatus of the present in-
vention; and

FIG. 5 is an enlarged plan view of apparatus shown
in FIG. 4 as seen from line 5—5.

It has been found that the conjoint use of microwave
energy and steam under pressure produces outstanding
and unusual results in the sterilization of subject matter,
especially metallic and non-metallic hardware used in
the medical field and in space vehicles. The present in-
vention permits the sterilization of a wide variety of
medical subject matter, such as surgical instruments, dress-
ings, and other supplies, without inducing distortion or
decomposition of the subject matter. The invention per-
mits the extremely rapid sterilization of medical supplies
in the package form. The sealed container or package of
sterilized subject matter may be stored for long periods of
time at ambient temperatures without in any way con-
taminating the subject matter, thereby keeping the sub-
ject matter sterile and available for use.

The use of either microwave energy or of steam alone
cannot provide the advantageous results obtained through
the conjoint use of microwave energy and steam. The
microwave energy, except with surgical instrument hard-
ware, penetrates the mass of subject matter with conse-
quent agitation of molecules within the subject matter.
This high frequency molecular agitation and bombard-
ment results in frictional heat uniformly distributed
throughout the subject matter. The microwave energy also
heats, by the same mechanism, the walls of the zone in
which the subject matter is held. Without the presence of
steam, the walls would be heated to an unduly high tem-
perature resulting in local overheating disturbing the sub-
ject matter or container. Apparently, the atmosphere of
steam, which is in direct contact with the outside of the
walls of the zone in which the subject matter is contained
and through which the microwave energy must pass be-
fore penetrating the medical subject matter, serves to pre-
vent overheating of the walls and provides more even dis-
tribution of the temperature. The steam also provides
some convection heating of the subject matter through the
container.

Microwave energy, by itself, is not generally effective
to sterilize hardware (metallic and non-metallic, e.g. ce-
ramic) such as metal surgical instruments, ceramic com-
ponents, and the like. The container, in which the subject
matter is sealed, has a moisture vapor transmission rate
so that steam may be transmitted to the interior of the
package. The microwave energy in bombarding the steam
in the package superheats the steam to effectively heat the
subject matter so that the conjoint microwave energy and
steam are effective quickly to sterilize the subject matter
within the container. Furthermore, if contaminating mi-
croorganisms are present on the subject matter in a dried
state, microwave energy will not generally kill the con-
taminating microorganisms. The steam atmosphere pro-
vides moisture which penetrates the container to permit
the microorganisms to take on moisture so that the mi-
crowave energy will be effective to completely sterilize
the subject matter. In any event, the microwave energy
and steam coact synergistically to produce a result not
heretofore obtainable with either alone.

A few drops of liquid capable of vaporizing through
bombardment of microwave energy like water, alcohol,
and the like, are preferably placed within the container,
particularly when the material from which the container
is made has a very low moisture vapor transmission rate,
a few drops of liquid being added to the container when
the subject matter is placed therein. The microwave energy
in bombarding the liquid in the package superheats the
liquid to effectively heat the subject matter in combina-

tion with the steam to sterilize the subject matter within
the container.

As is well known, microwave energy is the electro-
magnetic wave energy of a wavelength falling in the micro-
wave region of the electromagnetic spectrum. The Fed-
eral Communications Commission has presently set aside,
for microwave processing bands of microwave energy
within the range of between about 400 and about 20,000
megacycles per second with a wavelength ranging from
about 13 inches for the low frequencies to about 0.7 inch
for the highest frequencies; specifically: frequencies of
about 890–940 with a wavelength of about 13 inches;
frequencies of about 2450–2500 with a wavelength of
about 4–5 inches; and frequencies of about 17,850–18,000
with a wavelength of about 0.7 inch. The presently pre-
ferred microwave energy for use according to the present
invention is in the middle band having the frequency in
the neighborhood of 2450–2500 megacycles per second.
Microwave energy is generated from a suitable high fre-
quency source, such as a magnetron. The generation and
use of microwave energy by itself is well known since
such has been used for many years in the cooking of food.

The steam pressure employed, as previously stated,
will be above atmospheric pressure, and the particular
pressure employed may depend upon the amount of micro-
wave energy used which in turn may depend upon the
size of the sterilizing chamber and the number of micro-
wave energy generators, e.g. magnetrons, employed. With
a single magnetron, a steam pressure as low as one p.s.i.
gauge has been used; with larger units containing more
magnetrons, pressures as high as about one hundred
p.s.i. gauge or even higher may be desirable.

Referring now to the drawings, in FIGS. 1 and 2 there
is illustrated, schematically, an apparatus which may be
employed in accordance with the present invention to
sterilize medical subject matter sealed in a package. A
pressure chamber generally designated 10 is provided
which is constructed to withstand the steam pressures
that will be employed. Steam under pressure may be ad-
mitted to pressure chamber 10 through valved conduit 12,
shown in FIG. 1, while purging gases and excessive
pressures may be relieved and vented from pressure
chamber 10 through valved conduit 14. A valve conduit 15
may be provided to serve as a drain. The valves employed
may be conventionally constructed to control the steam
pressure within pressure chamber 10 at a predetermined
level. A conventional steam pressure gauge 16 notes the
pressure within chamber 10.

A conventional source of high frequency generally
designated 18, such as a magnetron, is provided which is
energized from a suitable source (not shown). Micro-
wave energy is fed from antenna 20 to wave guide 22
and into pressure chamber 10. The end of wave guide
22 is provided with a microwave-permeable plate 24,
for example of borosilicate glass or quartz, which per-
mits steam from entering wave guide 22.

Medical subject matter to be sterilized is admitted
to and removed from pressure chamber 10 through door
26, shown in FIGS. 1 and 3. The medical subject matter,
which is preferably hermetically sealed in a container, is
supported in the pressure chamber 10 by support means
generally designated 28 having a plurality of support sur-
faces on which the medical subject matter may be posi-
tioned. The support surfaces are moved through the high-
intensity microwave field region successively by drive
means generally designated 30 in order to subject the
subject matter supported on the support surfaces to the
microwave energy until the subject matter is sterile.

More specifically, the medical subject matter is sup-
ported in the pressure chamber by support trays 34,
36, 38, 40, 42, 44, 46 and 48, as shown in FIGS. 1 and 2,
which are in turn supported from a central shaft 50
journaled in bearings in opposite sidewalls of the cham-
ber. Tray 34, and the other trays which are like it, is
preferably made of a molded rigid plastic material,

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such as polypropylene, polystyrene, polyethylene or polymethyl methacrylate. The support trays are provided with a plurality of spaced openings, generally designated 52, in their bottoms and sidewalls to permit the steam to freely contact a container of medical subject matter supported on the trays. The trays are provided with integral support pieces 54 and 56 at each end of the trays, the support pieces extending upwardly from the ends of the trays to form hooks 58 and 60, respectively, centrally positioned over the ends of the trays. The hooks 58 and 60 of each tray are adapted to be hung over aligned rods 62 and 64, respectively, which are horizontal projections from radially extending parallel bars 66 and 68, respectively, fixed in hubs 70 and 72, respectively, rotatable with shaft 50. The rods 62 and 64 are provided with positioning spacers 74 and 76, respectively, between which the hooks of each tray are adapted to be positioned on the rods, as shown in FIG. 2. The trays are supported symmetrically around shaft 50 by aligned pairs of rods formed as projections of pairs of parallel bars; and, as shown in FIGS. 1 and 2, the pairs of bars are fixed to respective hubs 70 and 72 to extend radially outwardly therefrom, and are spaced circumferentially and equiangularly from each other around the respective hubs 70 and 72. By supporting the trays in this manner, as shaft 50 is rotated, rotating the trays, the bottoms of the trays will remain oriented in a horizontal position. Shaft 52 is rotated by a motor 112 through suitable gearing (not shown) to provide rotation of the shaft at slow speeds.

Also, the motor 112 could be operated to drive shaft 50 through suitable indexing means (not shown) so that the trays are rotated to their uppermost position in their path of travel adjacent the wave guide and each tray stopped in that position for a predetermined period of time, at least until the subject matter on the tray is sterile.

The trays may be loaded with medical subject matter while supported in the chamber or may be removed from the chamber, loaded with subject matter to be sterilized and repositioned in the chamber on any of the sets of rods for supporting the trays. Various types of medical subject matter are shown schematically in FIGS. 1-3 hermetically sealed in containers and supported in the pressure chamber. The containers may be made of glass, certain treated papers, thin synthetic resin or plastic material, such as polypropylene, polyethylene, polyvinylidene chloride, polyethylene terephthalate, polystyrene, polymethyl methacrylate, or the like, which is permeable to the microwave energy so that the subject matter may be impinged upon by the microwave energy. The types of medical subject matter schematically shown by way of illustration includes packages of dressings 80, 82 and 84 on tray 42; surgical linens 86 and 88 on tray 48, and 90 on tray 36; and surgical gowns 92 on tray 38, and 94 on tray 34; each package being hermetically sealed in a plastic container. There is shown in FIG. 3 three scalpels 96, 98 and 100, each hermetically sealed in plastic containers 102, 104, and 106, respectively, on tray 40. Also, capped flasks 108 on tray 44, and 110 on tray 46, may contain culture media, for example, to be sterilized in chamber 10.

The distance that the trays are held from the end of the wave guide at their uppermost position in their path of travel adjacent the wave guide will depend upon the length of the tray so that the entire support surface of the tray will be in the high-intensity microwave field region. Preferably, the distance between the end of the wave guide and support surface is made equal to an odd multiple of a quarter of a wavelength of the microwave energy, when the support surface of each tray is in its uppermost position of travel.

The precise time of treatment with microwave energy and steam will depend upon the size of the mass of subject matter being treated, the temperature of the steam, the temperature of the incoming subject matter and other variable factors which control the flow of heat and

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the heating of a particular subject matter from one temperature to another. It is not possible to state a range of temperatures and times which will be applicable for all medical subject matter. In any event, the time and temperature employed during the sterilization will be that resulting at least in sterilization of the particular subject matter. In other words, the minimum conditions of temperature and the time according to the present invention is dictated by the reduction of the microorganism (bacteria and spore) count to zero. While this can be determined by routine conventional microorganism count tests it is probably more satisfactory in view of the many variables involved, to subject samples of the particular treated subject matter to accelerated incubation tests to arrive at the precise conditions preferred for any particular subject matter. As should be apparent from the foregoing description, the medical subject matter is placed on particular trays in the pressure chamber or placed on particular trays and then the trays hung in the pressure chamber. The apparatus is then started by introducing steam into the pressure chamber, activating the high frequency microwave source and starting rotation of the trays by energizing motor 112 to rotate shaft 50. In this manner, each of the trays is successively moved through the high-intensity microwave field region adjacent the end of wave guide 22 at the top of the path of travel of each tray. The trays are rotated in a cyclic manner through the high-intensity microwave field region in the steam atmosphere until the medical subject matter supported on each tray is sterile.

FIGURE 4 illustrates, schematically, another form of apparatus for treating a plurality of packages or containers of articles in a continuous or semi-continuous (intermittent) manner. Numeral 121 represents the pressure chamber in which the microwave energy-steam treatment takes place, steam being admitted through valved conduits 122 from steam line 123. Numeral 124 is a relief valve through which purging gases and excessive steam pressure may be removed. Numeral 125 represents a steam pressure gauge. Numeral 126 represents the conventional high frequency source, such as a magnetron, equipped with antenna 127, wave guide 128 and protecting plate 129. Valved conduit 131 serves as a drain. In admitting containers 133 to chamber 121 through door 134, movement (intermittent or continuous depending on the feeding means) of endless belt 135 may be employed until the belt is filled with the containers. Door 134 may then be closed, steam admitted to the chamber until the requisite pressure has been achieved and then the high-frequency sources 126 are turned on. When treatment is complete, the high-frequency sources 126 are turned off and the containers are transferred to pressure chamber 136 through pressure lock 137. In chamber 136 the packaged subject matter 133 is permitted to cool somewhat, while still under pressure, before removing them, through door 146, to the atmosphere. Hence, chamber 136 is equipped with valved conduit means 138 attached to line 138a for admitting a gas, preferably an inert gas, such as nitrogen, argon, and the like, to the desired pressure. Pressure relief valve 139 and pressure gauge 140 are provided. The pressure in chamber 136 should be of a level to prevent rupturing of the containers until they have cooled to the point where their internal pressure will not cause rupturing upon removal of the containers to the atmosphere. A water spray (not shown) or even submersion in water (not shown) may be employed in chamber 136 to aid in cooling the containers.

As stated, packages or containers 133 which are hot and have an internal pressure corresponding to that in chamber 121, are admitted to chamber 136 through pressure lock compartment 137. This is done by first opening door 141 to transfer each last succeeding container 133 on endless belt 135 to turntable 142 as container 133a. When this has been done door 141 is closed, turntable 142 is rotated 180° so that the container is now adjacent

door 144 as container 133b. Door 144 is now opened and the container is transferred to endless belt 145 in chamber 136. Endless belt 145 is moved until it is filled with the containers which had been treated in chamber 121. In the meantime, chamber 121 can be filled with new containers to be treated. After the containers in chamber 136 have cooled under pressure to the point where they can be safely removed to the atmosphere without rupture they may be removed through door 146 through movement of endless belt 145.

To maintain substantially constant pressure conditions between chamber 121, lock compartment 137 and chamber 136, steam may be admitted to lock compartment 137 through valved conduit 147 which is also attached to line 123, and inert gas, is also admitted to lock compartment 137 through valved conduit 148 which is attached to line 138a. Pressure lock compartment 137 may be provided with the usual pressure relief valve 149 and pressure gauge 150.

FIGURE 5 shows a plan, schematic, view, somewhat enlarged, taken along line 5—5 in FIGURE 4 and shows transfer of container 133a to position 133b on turntable 142 before being admitted into chamber 136. It should be realized, however, that other means may be employed to transfer the treated containers from the treatment chamber to the cooling chamber. Similarly, other means may be employed to move the containers through the chamber, since the essential features, as far as the present invention is concerned, can be utilized for the intended purpose in a wide variety of mechanisms and apparatus.

It should be appreciated by those skilled in the art that the apparatus in accordance with the present invention provides many advantages over prior art methods and apparatuses for sterilizing articles. The employing of both steam and microwave energy enables a much faster means of killing of microorganisms, at least seventy-five percent faster than conventional autoclaves. Moreover, overall effective kill of microorganisms with the present invention is greater than with conventional autoclaves. Since the medical subject matter is subjected to high temperatures in the present apparatus for a lesser period of time, subject matter which could not be sterilized in conventional autoclaves because they would be distorted or decomposed during the prolong subjection to heat, can be sterilized in the present invention. Furthermore, it has been found that certain U.S. Government vegetative spores cannot be effectively killed within a reasonable time in conventional autoclaves but can be quickly and effectively killed in the apparatus of the present invention.

While the present invention has been described with particular reference to specific embodiments thereof in the interest of complete definiteness, it should be understood that it may be embodied in a large variety of forms diverse from the one specifically shown and described without departing from the scope and spirit of the invention as defined by the appended claims.

I claim:

1. Apparatus for sterilizing a medical article, said article being in a hermetically sealed container at least one wall of which is permeable to microwave energy, comprising: a pressure chamber, means for generating microwave energy, means for directing said microwave energy into said chamber to provide a high-intensity microwave field region therein, means for supplying steam under superatmospheric steam pressure into said chamber, means for admitting said article into said chamber, support means for supporting said article in said chamber, and drive means for moving said support means through said high-intensity microwave field region to subject said article through said microwave-permeable wall to said microwave energy until said article is sterile.

2. The apparatus of claim 1 in which said support means comprises a plurality of support surfaces supported in the chamber for supporting a plurality of articles, said drive means being adapted to move said sup-

port surfaces through said high-intensity field region successively until said articles are sterile.

3. The apparatus of claim 1 in which said means for generating microwave energy generates said energy having a wavelength within the range of about 0.7 to about 13 inches.

4. The apparatus of claim 1 in which the support means comprises a plurality of support surfaces for supporting a plurality of articles, said support surfaces being supported from and spaced around a common axis, said support surfaces being supported to remain horizontal around said axis, said drive means being adapted to cause rotation of said support surfaces about said axis to move said support surfaces through said high-intensity field region successively until said articles are sterile.

5. The apparatus of claim 1 in which said steam supplied into said chamber is at a pressure of from about 1 to about 100 p.s.i. gauge.

6. The apparatus of claim 1 in which said hermetically sealed container comprises a container of synthetic resin material at least one wall of which is permeable to microwave energy.

7. The apparatus of claim 1 in which said drive means moves said support means through said high-intensity microwave field region at a predetermined distance from said means for directing said microwave energy, said predetermined distance being equal to an odd multiple of a quarter of a wavelength of said microwave energy.

8. The apparatus of claim 1 in which said support means comprises at least one support surface supported in said chamber on which said article is adapted to be positioned, said drive means being adapted to move said support surface through said high-intensity microwave field region in a cyclic manner until said article is sterile.

9. The apparatus of claim 8 in which said support surface is provided with a plurality of openings to permit said steam to circulate therethrough.

10. The apparatus of claim 1 wherein there is additional and separate means for removing said article from said chamber, and wherein said support means comprises a moving surface adapted to travel from said means for admitting said article to said means for removing said article.

11. Apparatus for sterilizing an article, said article being in a container at least one wall of which is permeable to microwave energy, comprising: a first pressure chamber, means for admitting said container to and removing said container from said first chamber, means for generating microwave energy and for directing said energy into said first chamber, means for supplying steam under superatmospheric steam pressure into said first chamber, means for holding said container in said first chamber in a position such that said article in said container will be subjected through said microwave-permeable wall to said microwave energy until said article is sterile, a second pressure chamber, means for admitting said container to and removing said container from said second chamber, means for supplying a cooling gas under pressure into said second chamber, and means for holding said container in said second chamber at least until the temperature thereof has dropped to where said container will not rupture upon exposure to atmospheric conditions.

12. The apparatus of claim 11 further comprising pressure lock means for maintaining a predetermined pressure level, and means for moving said container from said first chamber into said pressure lock means and for moving said container from said pressure lock means into said second chamber.

13. A method of sterilizing an article in a pressure chamber, comprising the steps of: sealing said article in a container at least one wall of which is permeable to microwave energy; supporting said container in said pressure chamber; supplying steam under superatmospheric steam pressure into said pressure chamber; gener-

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ating microwave energy having a predetermined range of wavelength; directing said microwave energy into said chamber to provide a high-intensity microwave field region in said chamber; and moving said container through said high-intensity microwave field region to subject said article through said microwave-permeable wall to said microwave energy until said article is sterile, there being a vaporized liquid in said container at a time when said article is being subjected to said microwave energy.

14. The method of claim 13 wherein said vaporized liquid is provided by placing a few drops of vaporizable liquid within the container with said article before sealing the container.

15. A method of sterilizing an article in a pressure chamber, comprising the steps of: supporting a sealed container, the contents of which are to be sterilized, at least one wall of which container is permeable to microwave energy, in said pressure chamber; supplying steam under superatmospheric steam pressure into said pressure chamber; generating microwave energy having a predetermined range of wavelength; directing said microwave energy into said chamber to provide a high-intensity microwave region in said chamber, and subjecting said contents through said microwave-permeable wall to said microwave energy until sterile, there being a vaporized liquid in said container at a time when the contents are being subjected to said microwave energy.

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16. The method of claim 15 wherein said vaporized liquid is water vapor.

17. The method of claim 16 wherein said microwave energy has a wave length of from about 0.7 to about 13 inches.

18. The method of claim 17 wherein said microwave energy has a wave length of about 4-5 inches.

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