

Sept. 20, 1971

R. M. G. BOUCHER  
METHOD AND APPARATUS FOR DRYING AND STERILIZING  
FABRICS AND THE LIKE

3,605,272

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3 Sheets-Sheet 1

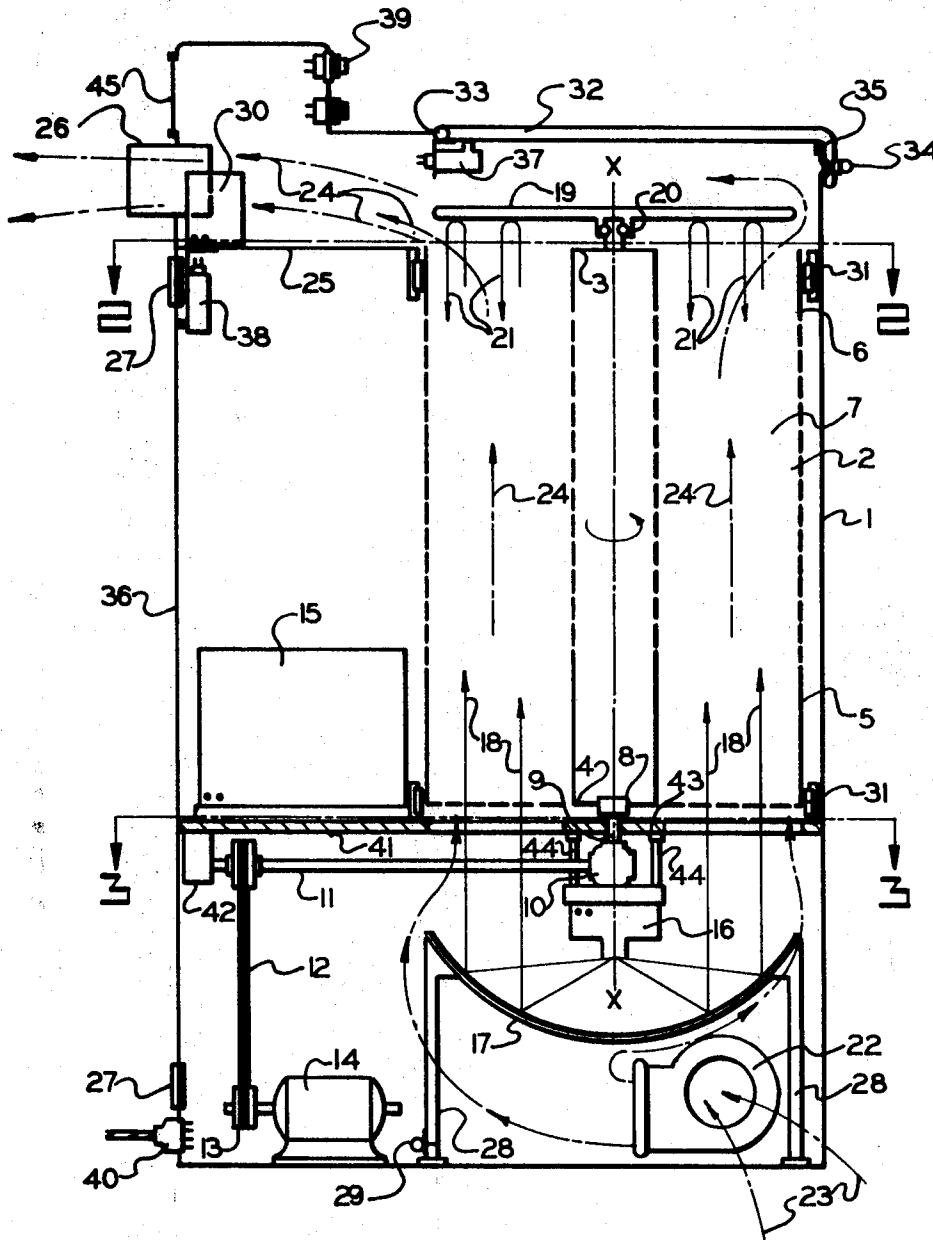


Fig. 1

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3 Sheets-Sheet 2

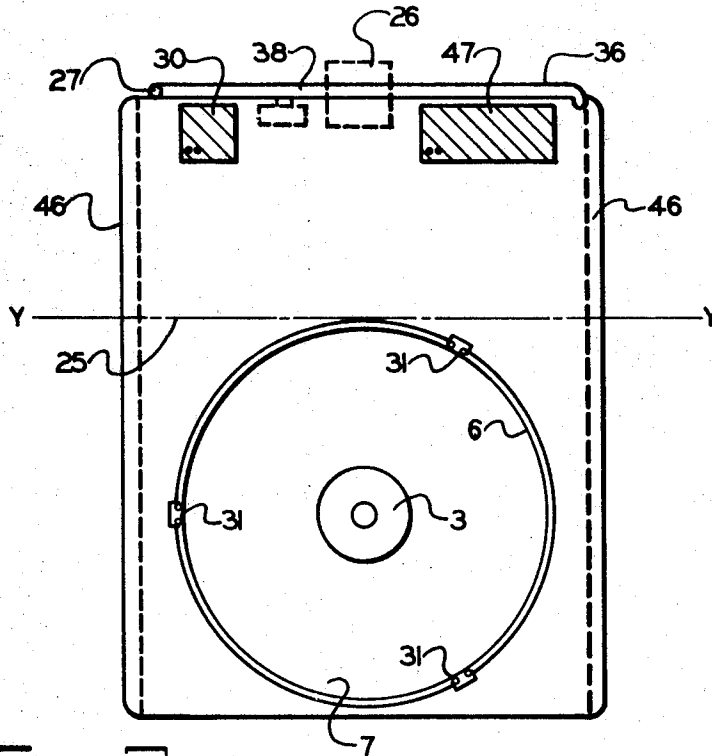


Fig. 2

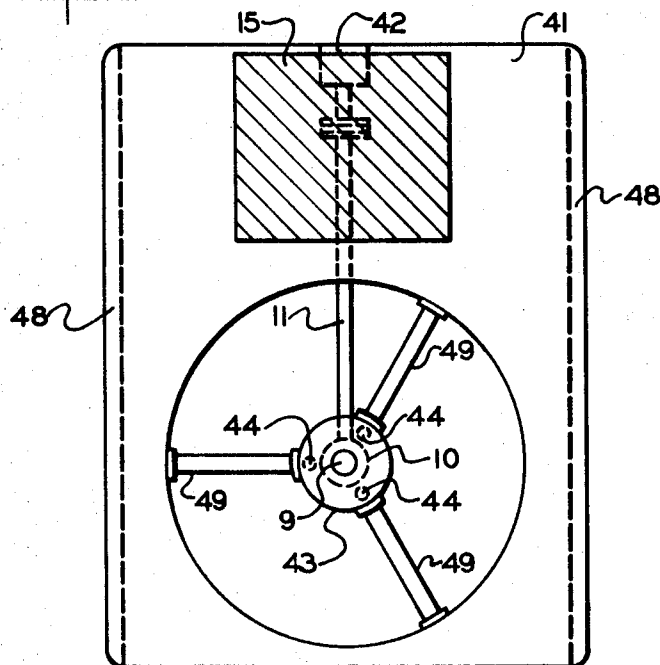


Fig. 3

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3 Sheets-Sheet 3

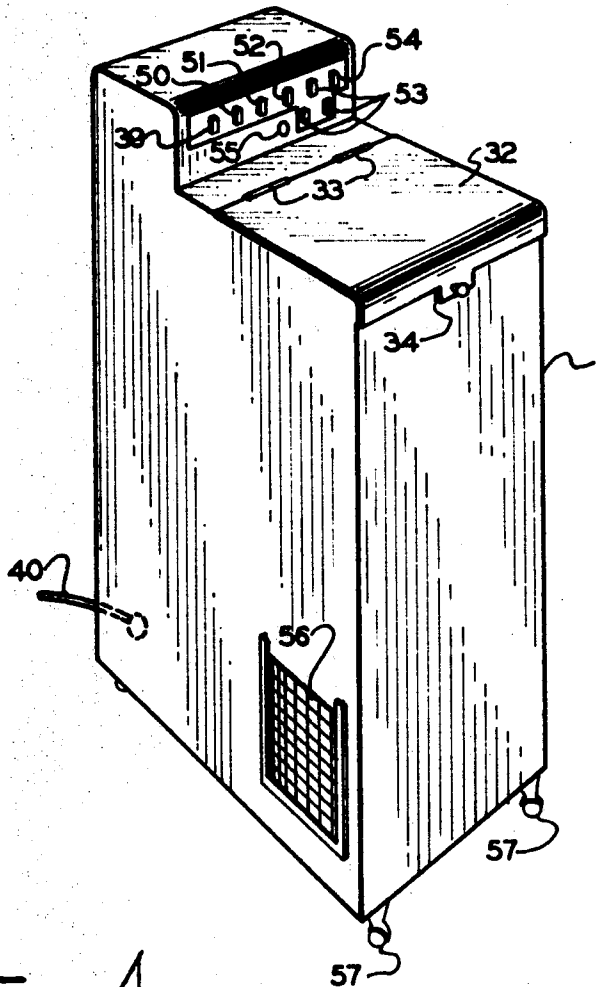


Fig. 4

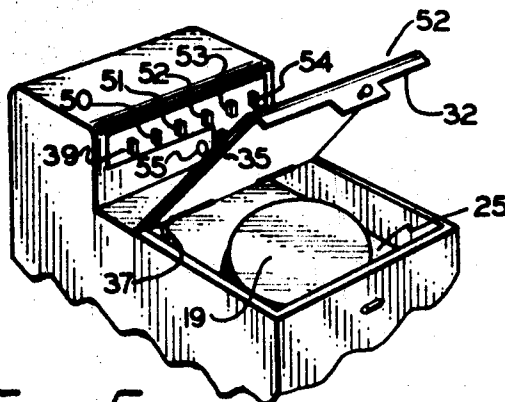


Fig. 5

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## 3,605,272 METHOD AND APPARATUS FOR DRYING AND STERILIZING FABRICS AND THE LIKE

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16 Claims

### ABSTRACT OF THE DISCLOSURE

A method for rapid drying and sterilizing of clothes, fabrics, garments, textiles and the like in which electromagnetic waves (100 to 300,000 MHz.) are combined with a fast moving air stream while the irradiated material rotates slowly in the processing area in a direction transverse to the air stream and the propagated electromagnetic waves. The apparatus of the invention is the size of a conventional home dryer, is noiseless and can dry a 7-pound fabric workload in two to five minutes while destroying all household germs or microbiological contaminants. It is equipped for automatic operation for different kinds of fabrics and health hazards have been eliminated through the use of automatic safety devices.

This invention relates to a method and apparatus for drying and sterilizing clothes, fabrics, textiles and the like by combining microwave energy with a fast moving gas stream. For a long time attempts have been made to use microwave energy for drying of clothes, linen, etc. in the home.

It was suggested for instance (U.S. Pat. No. 3,410,116) that a drum filled with wet fabrics and made of a material transparent to microwaves could be rotated along its horizontal axis while being irradiated by an external stationary microwave source. That patent describes apparatus in which a relatively cool airflow, in a direction perpendicular to the axis of rotation, was used to carry away the moisture desorbed from the irradiated material. In other methods it was suggested that wet fabrics or textiles could be placed inside a microwave oven of the cavity type through which cold air would be injected sideways during part or all of the irradiation cycle.

The disadvantages of these techniques are obvious to anyone familiar with the state of the art in microwave processing technology. For instance, most of the materials which are usable for microwave energy transmission (glass-ceramic composition such as Pyroceram) are either too expensive to be used as a material for a clothes dryer drum or not suitable from the viewpoint of mechanical strength (e.g. a fast rotating polypropylene drum). In the case of standard ovens into which fabrics are placed in a static position it was quickly discovered that relatively large amounts of air had to be used in order to remove the water vapor uniformly. Therefore, air channeling was always a problem and it was difficult, if not impossible, to meet the requirements for both uniform air penetration throughout the wet fabrics and the oven size which is a function of the microwave radiator output.

It is an object of this invention to provide a method which eliminates the disadvantages of the old approaches by a proper combination of the microwave field, with both the air stream and the motion of the irradiated fabrics.

It is also an object of the present invention to provide a clothes dryer-sterilizer which produces satisfactory, economical results through a new design of the irradiation chamber in which most of the electromagnetic waves are reflected and rereflected so as to concentrate them in the processing area by means of the proper positioning of reflectors both downstream from the radiator and downstream from the microwave main beam.

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It is also an object of the present invention to provide both a method and an apparatus which produce fast and thorough drying when both the main microwave energy beam from the radiator and the airstream flow are oriented in the same direction, namely, parallel to the axis of revolution of the fabric container.

It is a further object of this invention to provide a clothes dryer-sterilizer which is less noisy than the prior art machines since the rotational speed of the basket or perforated drum which contains the irradiated material has been reduced down to a level of one to ten revolutions per minute.

It is a further object of this invention to provide an economical microwave system for the drying-sterilizing of clothes which can be operated either with continuous or pulsed wave emissions. Satisfactory results can be obtained in some cases with an average output from the radiator as low as ten watts.

It is a further object of this invention to provide an apparatus which will not only dry clothes or fabrics in a far shorter time than half the usual drying time of conventional dryers but will also provide complete sterilization in a matter of minutes through the total destruction of microorganisms, bacteria, viruses or even "hard to die" spores such as *Bacillus subtilis* var. *niger*.

It is a further object of this invention to provide a fully automated, clothes dryer-sterilizer which is "push-button" operated and allows safe drying of a wide variety of fabrics (wool, silk, synthetic fibers, etc.) while having the same overall dimensions and flexibility of today's fixed or movable home clothes dryers.

Other objects, advantages, features and uses will be apparent during the course of the following discussion. To aid in the understanding of the present invention, we shall briefly discuss the parts played by microwave energy, internal heat, and air turbulence during the drying-sterilizing process.

As is well known, microwave energy is coherent electromagnetic energy. By this we mean that it is ordered. In other words, we can readily identify its characteristics and can control it with precision. Thermal energy, on the other hand, has random, disordered, characteristics which are not so easily controlled. Although the term microwave, in general, covers a rather wide range of frequencies (from 100 MHz. up to several hundred thousands MHz.), the present invention mainly contemplates the use of frequencies between 100 and 23,000 MHz.

The mechanism through which microwave heating occurs at these frequencies is based upon the dipole moment, or "polarization" of the molecules of the irradiated substance. When the polar molecules (absorbed water in the case of the present invention) are subjected to a strong alternating field, their rapid reorientations within the field create some kind of internal friction resulting in heat. In a more precise sense, one could say that heat is produced through the conversion of the potential energy of polarization into random energy. It is important to note that with microwave heating, no contact with the substance itself is required. In other words, the transfer of energy takes place directly without the necessity of an intermediate medium such as a hot surface or a high temperature air stream. Energy transfer occurs wherever the field penetrates. By a proper choice of the materials used in the construction of our dryer-sterilizer it is then possible to produce heat exclusively inside the wet fabrics while keeping the walls and all the mechanical components of the processing chamber (rotating basket, supports, etc.) cool.

The advantages of this approach over conventional, hot air, dryers based on heat conduction phenomena are numerous. Microwave heating eliminates the inherent in-

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efficiency of generating thermal energy at an outside source. It also eliminates the inefficiency of transferring heat from an external source to the fabric load and reduces eventual reradiation losses. Since microwave energy can be switched on to full power levels and off again by simply flipping a switch, the time lags associated with thermal processes are not present either. It should also be noted that in water removal, less power is absorbed by the fabrics as drying progresses, so that overheating, which often damages delicate fabrics, cannot occur.

Although the advantages set forth above were known to those skilled in the art, no home type clothes dryer has been successfully developed in the past. This is mainly due to the fact that very little attention has been paid to the requirements for removal of water vapor from the surface of fabrics. As is well known (Dalton's law), the state of turbulence in the gas phase above the wet material is an important factor which governs the rate of evaporation. In previous designs, a relatively low velocity air flow carried out the moisture very inefficiently as the bulk of the wet fabrics rotated at relatively high speed ( $\approx 500$  r.p.m.).

In this invention this deficiency is corrected by forcing a relatively high speed, air stream, having a velocity of the order of between 100 and 500 feet per minute, through the bulk of the fabrics which are rotated very slowly. To achieve maximum contact between the incoming air and the irradiated fabrics, both reflected radiated waves and the air flow follow the same path in the same upwards direction. This allows a uniform penetration of the air throughout the bulk of the fabrics which rotate at a speed low enough to prevent channeling effects. The combination of a high power microwave beam with a fast air flow moving in the same direction while the fabrics rotate at the speed of the order of ten revolutions per minute is one of the key elements of the invention.

The second major improvement resides in the concentrating of the electromagnetic waves by means of two reflectors placed at each end of the processing area. With such an arrangement, advantage is taken of standing wave effects, reinforcement of the field intensity, and decrease of the risks of radiation leaks. Moreover, a more efficient use of the energy radiated from the radiator is made.

As is well known, the amount of power that can be delivered to a cubic centimeter (or any unit of volume) of wet irradiated fabrics is proportional to the product  $\epsilon \tan \delta E^2$  where  $\epsilon$  is the permittivity (the amount of electric field that is produced by the molecules for a given applied field),  $\tan \delta$  is the loss tangent of the material (proportional to the conductivity),  $f$  is the frequency and  $E$  is the electrical field strength. Since the product  $\epsilon \tan \delta$  will vary for each fabric, different irradiation times (present through a timing device) will be used in order to dry all fabrics with a fixed output power at a fixed frequency.

The invention contemplates the use of a continuous wave emission or a pulsed wave emission. In the latter case, the average power requirements will be decreased while the lethal effects on microorganisms will be enhanced due to sharp variations in the electric field gradient (A. P. Wehner, *Int. Journ. Biometer*, vol. 7, No. 3, 277-282, 1964). Energy savings with pulsed emissions can be quite significant since one microsecond pulses at a repetition rate of 1000 per second deliver a peak power of 250 kw. which corresponds to an average power of only 250 watts.

A third important feature of the invention lies in the fact that through field concentration effects and rapid changes of field strength one can, besides the thermal phenomena, produce important modifications in the metabolism of microorganisms and spores. The combined result of localised dehydration plus electrical field effects is a rapid destruction of the household germs, bacteria or viruses which are often present at the end of a laundry,

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drying operation with conventional hot air dryers. The lethal effects of electromagnetic waves, distinct from thermal destruction, have already been reported for yeast at relatively low temperature (K. Robe, *Food Process Market*, 84-86, March 1966).

In the accompanying drawings, forming a part of this application, and in which like numerals are employed to designate like parts throughout the same:

FIG. 1 is a simplified, elevational view of a preferred form of apparatus of the invention, with a side wall removed, with the insulation and electrical connections excluded for simplicity;

FIG. 2 is a sectional view of the apparatus of FIG. 1, taken along the lines 2-2 of FIG. 1, viewed in the direction of the arrows, rotated 90°;

FIG. 3 is a sectional view of the apparatus of FIG. 1 taken along the lines 3-3 viewed in the direction of the arrows, rotated 90°;

FIG. 4 is a perspective view of the apparatus of FIG. 1 seen from the front (right side of FIG. 1) with the lid closed; and

FIG. 5 is a perspective view of the top of the apparatus of FIG. 4 with the lid open.

As can be seen from FIG. 1, the apparatus consists of a metal housing 1 quite similar to those used today in automatic clothes dryers. Located within the housing is a basket or drum 2 which is mounted so that it rotates around its vertical axis of revolution  $x-x$ . This basket is made of two concentric, vertical cylinders whose axial, inner section is covered at the top 3 and the bottom 4 by two welded metal plates. The inner, outer and bottom walls of the basket are made of perforated metal or chicken wire mesh (large openings of at least  $\frac{1}{2}$  inch). The lower 5 and the upper 6 sections of the vertical cylinders are made of metal which is impervious to fluid flow.

Fabrics to be processed are placed inside the cylindrical spaced indicated by the number 7. Basket 2 is fastened at the bottom to a circular solid piece of metal 8 which is locked on a vertical shaft 9 which is connected to a gearbox transmission device 10. The motion of the basket 2 is the result of rotational energy transmitted through a system of shafts, belts and pulleys 9, 11, 12, 13 which are driven by motor 14. The motor 14 is fastened at the bottom floor of the dryer and controls the rotational speed of the basket which contains the fabrics. The microwave energy system comprises a power supply, signal generator, control module 15 which is connected by a coaxial cable (not shown) to the radiator 16 which contains a Klystron or Amplitron tube. This system emits electromagnetic energy to the contents of the basket. The mouth of the radiator is placed at the focus of a reflector 17 of parabolic shape which reflects the waves and transmits an upward microwave beam of plane, coherent waves 18 having a plurality of parallel rays. A circular, flat, wave reflector 19 is fastened to the top of the revolving basket. This wave reflector can be easily removed at the end of a drying operation since it is fastened on its axis through a simple pressure arrangement 20 (swage lock). Continuous waves or pulsed waves trains 21 are reflected back downwards after they impinge against the bottom, lower side of the circular, flat reflector 19. A blower 22 coupled to a motor (not shown) sucks in the outside air as shown by the arrows 23 after it passes through a filter (not shown). The air is blown in an upwards direction inside the dryer and follows the path indicated by arrows 24. A circular space of the order of one or two inches height is provided between the wave reflector 19 and the separation plate 25 to allow free escape of the moist air from the processing air. A circular pipe 26 fastened on the left wall above the level of the hinges 27 conveys the wet air to a suitable home exhaust system (for instance, a flexible pipe connected with the outside). The bottom reflector (parabolic shape) 17 is supported by three legs 28 (each leg space at an angle of 120° from the next). One of the legs 28 can be collapsed through a hinge system 29 for easy removal of the reflector 17.

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The upper separation plate 25 supports a timer 30 which is of a type which is well-known in the art. To enable smoother rotation of the basket 2, roller bearing units 31 of suitable lengths are in contact with the upper section 6 and the lower section 5 of the basket.

A lid 32, which is mounted to hinges 33, is opened to load fabrics inside the dryer. It closes through a pressure switch arrangement 34 in the front of the unit. A strip of rubber, plastic or other suitable material 35 issued to seal the dryer, when in operation, to make it radiation, leak proof. An access door 36, which is connected to two hinges 27, is located on the rear side of the unit to permit quick opening for servicing.

The electrical system which will enable complete automatic control of the drying-sterilizing operations is well within today's state of the art. For this reason electrical or electronic devices or components have been eliminated from FIG. 1 for the sake of simplicity. However, the pressure sensitive switches 37 and 38, which will shut off the main circuit (and thus cut off microwave emission) when the user opens either the top lid 32 or the rear access door 36, are shown. Also shown are the front panel switches (push button type) which activate the main electrical components of the apparatus: general switch, motor (basket), blower motor, microwave generator, timer, relay boxes etc. The main line plug-in unit 40 is seen at the bottom of the rear side panel.

Lower separation plate 41 supports the microwave power supply, signal generator, control module 15. Support 42 is welded or otherwise suitably affixed to the lower side of the plate 41 to hold the rotating shaft 11, which transmits motion to the gearbox 10, in line. A circular metal plate 43 is attached to the main separation plate 41 by means of three legs 49 which are best seen in FIG. 3. Gearbox 10 and radiator 16 are fastened to the center plate 43 by means of three short metal rods 44. The upper back panel, removable, plate 45 gives access to the electronic circuitry and wiring of the front panel.

FIG. 2 shows the shape of the upper separation plate 25 which is supported laterally by two right angle metal bars 46 welded to the side walls of the dryer. The dashed line y—y is a projection of the axis around which the upper lid 32 rotates. The outside wall 6 of the basket and the empty space 7 into which material to be irradiated is placed, may be seen in FIG. 2. The upper separation plate 25 supports a relay box 47 and an automatic, electrically driven, timer 30. Also shown, in dotted lines, is the projection of the cylindrical pipe 26 which is used to evacuate moist air above the separation plate. Fastened to the bottom of plate 25 is pressure sensitive switch 38 which is also shown in dotted lines. Pressure switch 38 cuts off the main line current as soon as someone opens the rear door for servicing. The roller bearings 31 which help the basket to rotate smoothly are located at three positions (120° apart). They can be placed at different locations, if desired, or completely around the rotating path.

FIG. 3 is a cross sectional view at the level of the lower separation plate. Here again, it can be seen that the plate is supported laterally and underneath by two right angle bars 48. Three heavy metal legs 49 fasten the center plate 43 to the lower separation plate 41. Plate 41 is thicker than the upper plate 25 because it supports the heavier components of the dryer. The numeral 15 designates the space occupied by the power supply, signal generator and control module which feeds the microwave radiator through a standard, coaxial, insulated cable which is not shown in the drawings. Also shown in dotted lines is the position occupied at a lower level by the shaft 11, the pulley, and the shaft support 42 which is fastened to the lower side of the plate 41.

FIG. 4 is a perspective view of the dryer-sterilizer seen from the front. The front panel is provided with the different push-buttons which successively activate the main line switch 39, the blower 50, the basket motor 51, the microwave signal generator 52, the timer 53, which can

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be set for various kinds of fabrics, and the general safety switch 54 for immediate shut-off in case of malfunctioning or emergency. A pilot-light 55, when lit, indicates that the dryer is in operation. The electrical and/or electronic circuitry, which enables one to perform the sequence of automatic operations hereabove mentioned, is well known to anyone skilled in the art and for the sake of simplicity they are not described in detail. Also shown in FIG. 4 is a disposable and replaceable air filter 56 which can easily be fastened or removed from the external lower left side of the apparatus. The electrical connection 40 with the main AC line (120 or 220 volts, 60 cycles) is shown in the lower rear side of the dryer. Also shown are optional roller casters 57 which, if needed, would help to easily move the unit to different locations in the home.

FIG. 5 is the upper part of the unit represented in FIG. 4 but the lid 32 has been opened to show the respective positions of the wave reflector plate 19, the safety switch 37 and the radiation insulating joint 35.

Without departing from the framework of the present invention it must be well understood that, according to the results derived, the present invention can be applied to variable volumes of gas at different temperatures or at multiple pressures, and that, still without departing from the scope of the invention, the structural details of the described apparatus, the dimensions and the shapes of their members (such as the basket shape which could for instance be cylindrical with a plain solid rod on its axis) and their arrangement (the relative position of the basket motor and blower for instance) may be modified, and that certain members may be replaced by other equivalent means (parabolic reflector by a conical or ellipsoidal reflector).

In order to illustrate the possibilities of the invention more concretely, by a precise example, but without limiting the scope of the invention, following is an example of a drying-sterilizing operation. With a dryer-sterilizer of the type hereabove described 7 pounds of wet linen have been processed at an irradiation time between two and five minutes. The linen had a water content of the order of between 4 and 6 pounds. The microwave power output from the signal generator-radiator system averaged between 0.5 and 1.5 kw. (continuous wave). The nominal emission frequency was 2450 MHz.±25 MHz. The rotational speed of the basket containing the wet linen was 10 revolutions per minute. The blower capacity under loading conditions was of the order between 50 and 100 standard cubic feet per minute. Hundreds of samples were taken after each drying operation for examination of the bacteriological flora. All tests and bacteriological assays showed complete absence of live household germs or viruses within the limit of the operating conditions.

The teachings of the invention may be practiced within the following parameters:

- 55 Microwave emergency frequency: 100 to 300,000 MHz.
- Type of wave: continuous or pulsed at a repetition rate between one per nanosecond and one per minute
- Airflow: 10 to 150 standard cubic feet per minute
- Basket rotation: 1 to 500 revolutions per minute
- 60 Direction of the microwave energy beam is parallel to the direction of airflow and transverse to the direction of basket rotation.

While the invention has been described by means of specific examples and in a specific embodiment, it is not limited thereto, for obvious modifications will occur to those skilled in the art without departing from the spirit or scope of the invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. The method of drying and sterilizing materials such as textiles which comprises:
  - placing the material in a metal container rotatable about a vertical axis;
  - applying an electromagnetic field at a frequency in the

range of about 100 to 300,000 MHz. to the material; moving a gas stream rapidly through the material; the directions of the beam of the electromagnetic field and of the gas stream being parallel to each other and to the axis of rotation; and rotating the material at a velocity of the order of between 1 and 500 revolutions per minute.

2. The invention of claim 1 wherein the velocity of the gas stream is of the order of between 100 and 500 feet per minute.

3. The invention of claim 2 wherein the electromagnetic field is a continuous wave emission.

4. The invention of claim 2 wherein the electromagnetic field is a pulsed wave emission having a repetition rate of the order of between one per nanosecond and one per minute.

5. The invention of claim 1 wherein the electromagnetic field is a continuous wave emission.

6. The invention of claim 1 wherein the electromagnetic field is a pulsed wave emission having a repetition rate of the order of between one per nanosecond and one per minute.

7. The invention of claim 1 wherein at least a portion of the energy of the electromagnetic field is reflected through the material at least once.

8. The invention of claim 7 wherein at least a portion of the reflected portion of the energy of the electromagnetic field is rereflected through the material at least once.

9. The invention of claim 1 wherein the velocity of the gas stream is of the order of between 100 and 500 feet per minute and at least a portion of the energy of the electromagnetic field is reflected through the material at least once.

10. The invention of claim 9 wherein at least a portion of the reflected portion of the energy of the electromagnetic field is rereflected through the material at least once.

11. Apparatus for drying and sterilizing materials comprising:

a metal basket for receiving the material to be dried which is rotatable about a vertical axis thereof; means for emitting a beam of electromagnetic energy through the material parallel to the vertical axis of the metal basket;

means for moving a gas stream through the material in a direction parallel to the direction of the beam of electromagnetic energy;

means for rotating the metal basket such that the material contained therein is subjected to the effect of the beam of electromagnetic energy and the flow of gas stream.

12. The invention of claim 11 wherein: the means for emitting a beam of electromagnetic energy through the material comprises: a source of continuous waves and a reflector;

the reflector being spaced from one end of the basket and mounted so that the electromagnetic energy is directed through the material in parallel rays.

13. The invention of claim 12 including a second reflector spaced from the other end of as basket so that at least a portion of the electromagnetic energy is redirected through the material.

14. The invention of claim 11 wherein: the means for emitting a beam of electromagnetic energy through the material comprises:

a source of pulse waves and a reflector; the reflector being spaced from one end of the basket and mounted so that the electromagnetic energy is directed through the material in parallel rays.

15. The invention of claim 14 including a second reflector spaced from the other end of the basket so that at least a portion of the electromagnetic energy is redirected through the material.

16. Apparatus for drying and sterilizing materials such as textiles comprises:

a housing; a cylindrical, metal drum to receive the materials mounted within the housing so as to be rotatable about a vertical axis with respect thereto;

means for emitting a beam of electromagnetic energy through the material parallel to the vertical axis;

means spaced from one end of the drum for reflecting the beam of electromagnetic energy to produce a plurality of parallel rays;

means spaced from the other end of the drum for rereflecting the beam of electromagnetic energy;

means for moving a gas stream through the material in a direction parallel to the direction of propagation of the beam of electromagnetic energy;

means for rotating the drum in a direction transverse to the directions of propagation of the beam of electromagnetic energy and of the movement of the gas stream;

at least a portion of the wall of the drum being perforated to permit the free flow of the gas therethrough.

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U.S. Cl. X.R.

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