United States Patent [19]

Staats

[11] **3,854,219**

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[54] **ELECTRONIC DRYER**

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[73] Assignee: **General Electric Company,** Louisville, Ky.

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[52] **U.S. Cl.** **34/1,** 34/48, 219/10.55

[51] **Int. Cl.** **F26b 3/34**

[58] **Field of Search** 34/1, 17, 48, 55, 68, 133; 219/10.55

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Primary Examiner—Charles J. Myhre
Assistant Examiner—Paul Devinsky
Attorney, Agent, or Firm—Frederick P. Weidner; Francis H. Boos

[57] **ABSTRACT**

A dryer includes a cabinet having a drying chamber mounted therein. A blower connected by a duct to the drying chamber draws air through the chamber from openings provided in both the chamber and the cabinet. The output of a source of microwave energy is introduced into the duct which functions as a waveguide to direct the microwave energy to the drying chamber. As the microwave energy heats and causes to vaporize the water in the articles to be dried, the evaporated moisture is drawn out of the chamber by the air flowing therethrough and is exhausted to atmosphere. In one embodiment, the dryer is formed as a clothes dryier wherein the drying chamber takes the form of a rotating tumbling drum mounted within the cabinet and the air entering the drum is preheated.

9 Claims, 5 Drawing Figures

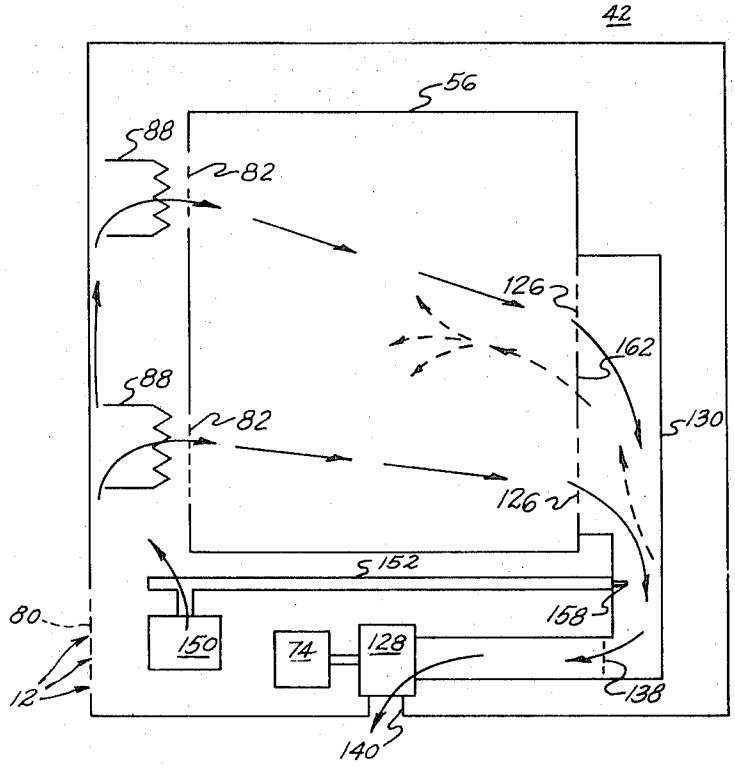


FIG. 1

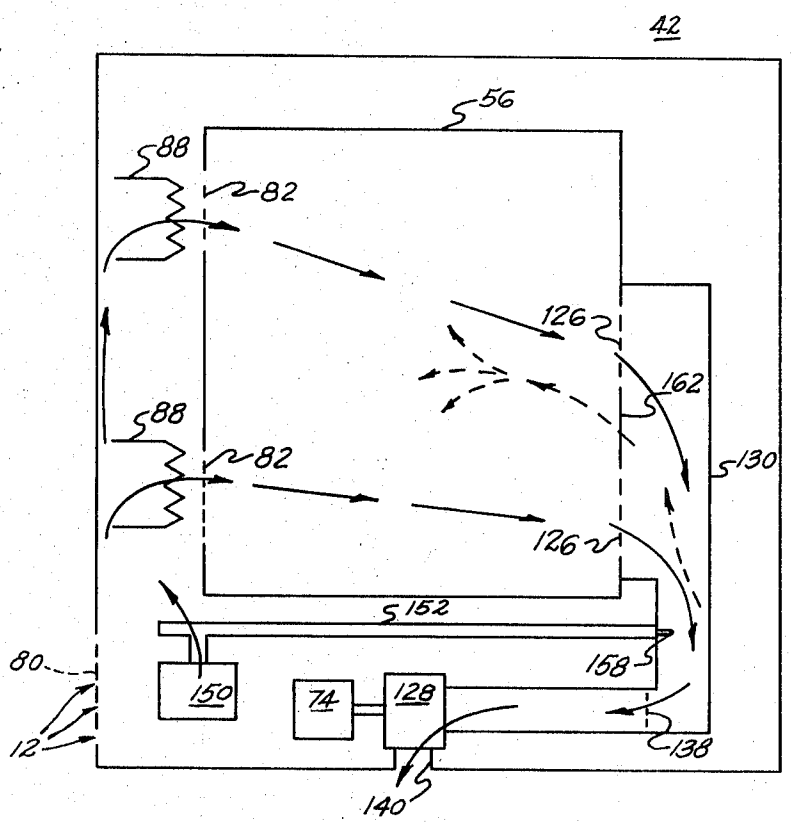


FIG. 2

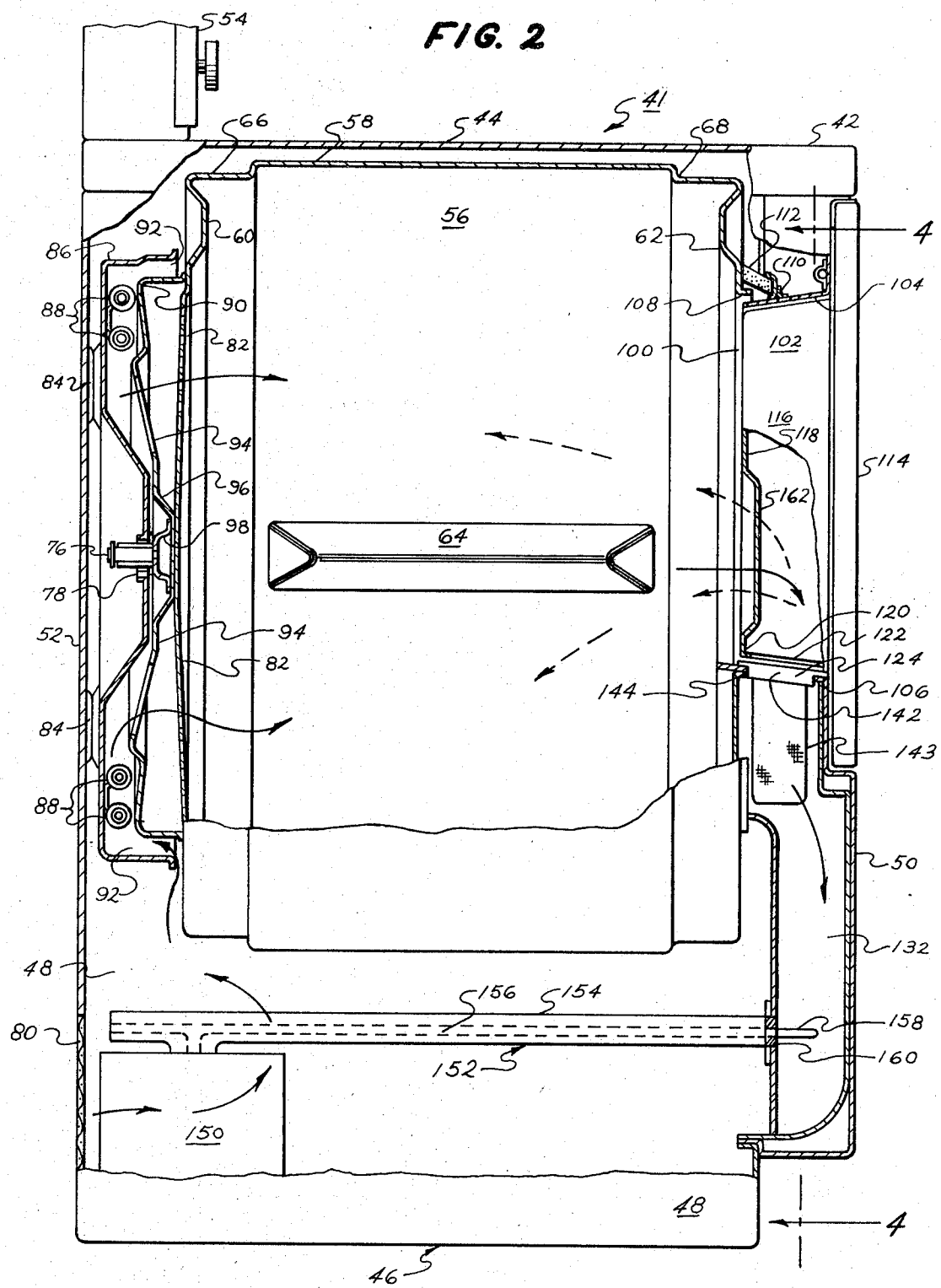

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FIG. 3

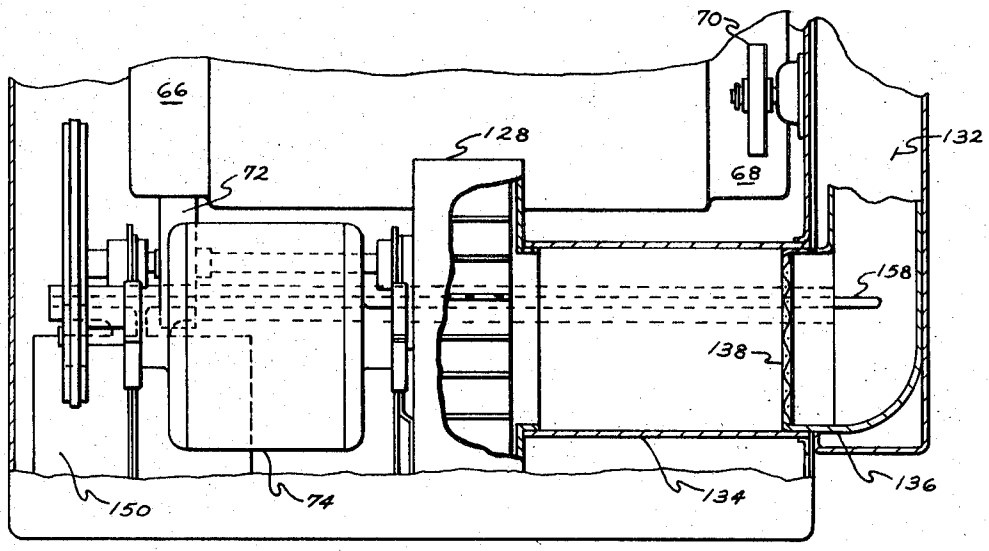

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FIG. 5

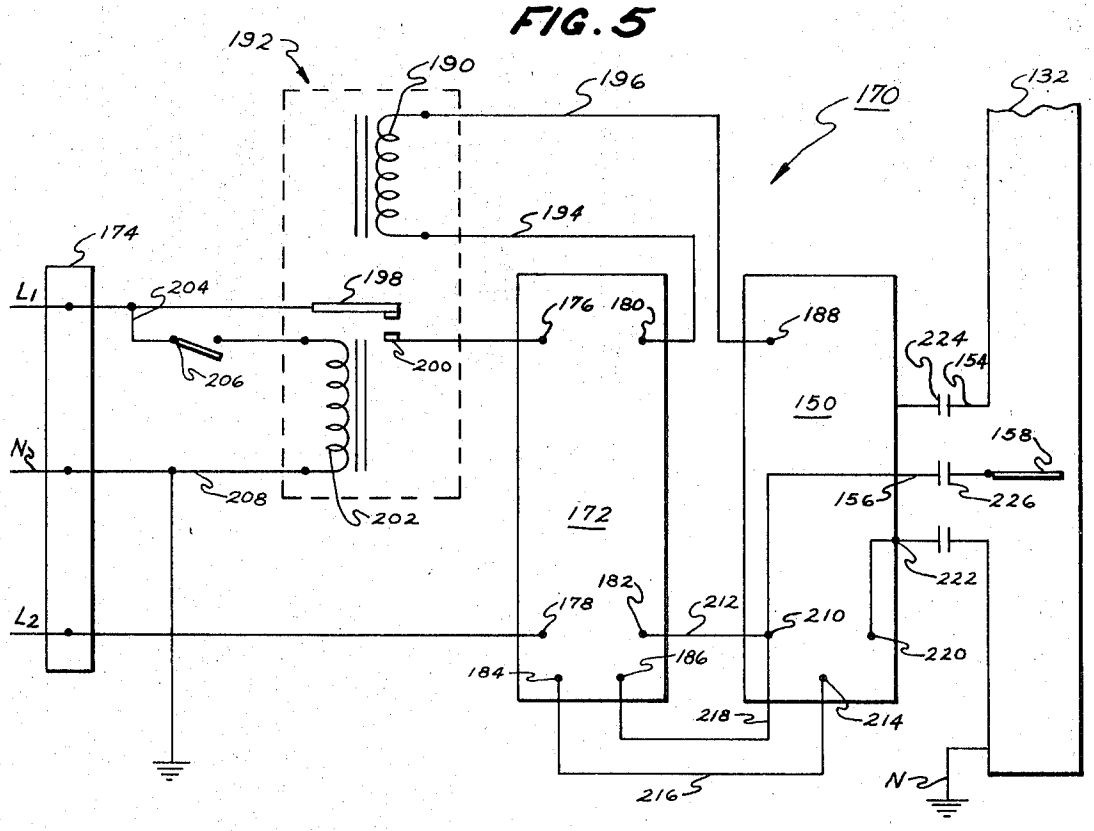
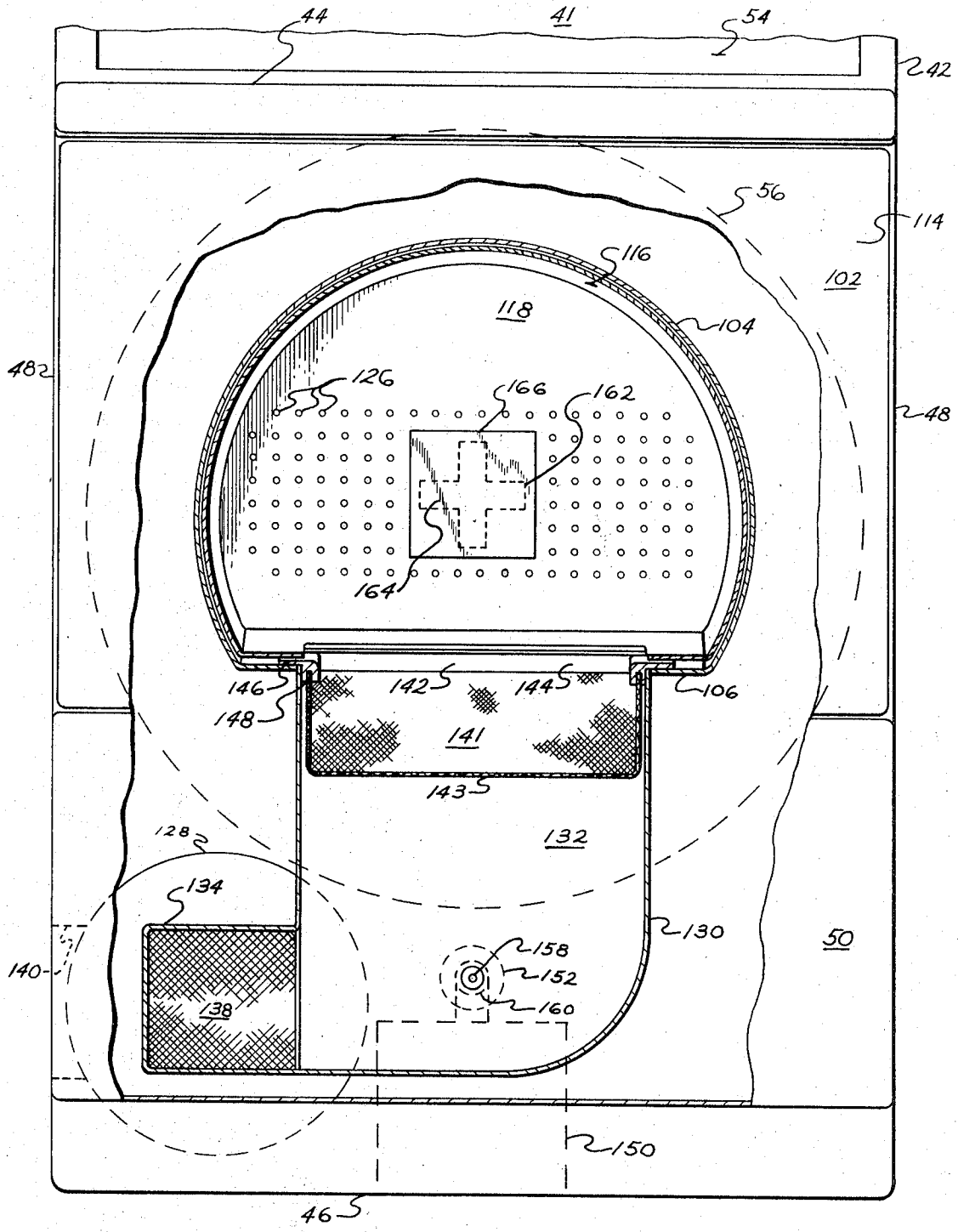

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FIG. 4


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ELECTRONIC DRYER

BACKGROUND OF THE INVENTION

This invention relates generally to drying machines. More specifically, it relates to machines for drying wet material utilizing microwave radiation as a source of energy for causing evaporation, and a preheated air flow for removing the evaporated moisture.

The use of ultrahigh frequency electromagnetic energy, such as microwave energy, for heating is, of course, well known in the art. Devices producing microwave energy have found utility in industrial heating processes for some years and more recently have been utilized for cooking on commercial and home usage bases. The industrial uses of microwave energy have included the utilization of microwave devices for drying such things as painted articles or articles which have been glued or caused to adhere to each other by the use of some kind of adhesive. Typically, in drying applications the microwave energy has been supplied by providing a radiator in the form of a coil which is excited by a microwave source and radiates energy to wet articles caused to pass within the turns of the coil. Such applications have, of necessity, involved some means for feeding the article to the area encompassed by the coil, such means usually including some kind of conveyor or article transport device.

There are, however, numerous situations where it is desired to dry objects, yet, it is uneconomical or impracticable to utilize conveyors for transporting the articles to and from an area encompassed by a microwave coil radiator. Consequently, the drying of articles in a chamber becomes desirable. In order to permit drying to proceed rapidly and efficiently when a chamber is used, it is desirable to provide means for removing from the chamber the moisture evaporated from the articles.

There are, of course, other applications of microwave energy for heating articles in a chamber, as for instance, cooking. The article to be heated is placed within the chamber, an oven, and the energy is coupled to the interior of the chamber. In this kind of application, of course, drying of the food is the last thing that is desired for the removal of water from cooked foods generally adversely affects their taste and texture.

Therefore, it is an object of this invention to provide a novel drying machine wherein microwave energy is utilized within a chamber to evaporate moisture from wet materials therein, and a preheated air stream is utilized to remove the evaporated moisture from the chamber.

It is a further object of this invention to provide a novel drying machine which utilizes heated moving air to remove moisture evaporated from wet objects by the microwave energy and which utilizes a single conduit functioning as part of the microwave energy transmitting means and as part of the air moving means so as to provide a relatively economical and compact arrangement which at the same time is efficient in its operation.

A particular application wherein drying apparatus in accordance with the invention may find utility is a clothes drying machine such as is used in the home or commercial operations. Such machines have rotating clothes tumbling drums mounted within a protective cabinet. Included in the space between the tumbling drum and the protective cabinet are the means for mounting the drum for rotation, a motor for rotating the drum and a blower to blow dry, heated air over and through the clothes as they are tumbled within the drum. A door is provided to give access through the cabinet to the drum interior to permit the user to place wet clothes within the drum and to remove the dry clothes therefrom. It is believed that a considerable advantage in performance and the economics of manufacture can be achieved by the utilization of apparatus in accordance with this invention in such a dryer, and particularly where the clothes tumbling drum and the conduit or duct for directing airflow through the drum are advantageously formed in the customary manner from sheet metal.

It is another object of this invention to provide a clothes dryer which utilizes microwave energy as a drying medium and which does not require a substantial reconstruction of a conventional clothes dryer.

It is still another object of this invention to provide a clothes dryer utilizing microwave energy as a drying medium which is safe for use by relatively unskilled operators as simple but effective means is provided to prevent microwave radiation from entering the atmosphere or any place where a user could inadvertently place his hands or any other part of his body.

It is a still further object of this invention to provide a means for automatically interrupting the transmission of microwave energy to a drying chamber when all of the wet material therein has been dried to a predetermined degree of dryness.

It is still another object of this invention to provide a dryer utilizing microwave energy wherein automatic control of the source of microwave energy is effected without the necessity of any sensing or timing devices so as to interrupt the transmission of microwave energy to the drying chamber when all of the wet material has been dried to a predetermined degree of dryness.

SUMMARY OF THE INVENTION

In accordance with the present invention there is provided an electronic dryer comprising a casing within which is mounted a drying chamber for accommodating items to be dried. Also included is air circulating means and a conduit associated with the drying chamber for circulating a stream of air therethrough and generating means is provided which is adapted to produce ultrahigh frequency electromagnetic energy at a predetermined frequency. Means are provided for coupling the generating means with the conduit for transmitting energy from the generating means to the conduit, the conduit serving both as an air duct and as a waveguide for the electro-magnetic energy. The moisture evaporated from wet articles placed in the drying chamber is carried from the drying chamber by the air stream and is exhausted through the conduit to the exterior of the cabinet.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of apparatus embodying the invention;

FIG. 2 is a side elevational view partially broken away and partially in section illustrating a preferred embodiment of the invention in a clothes drying machine;

FIG. 3 is a partial side elevational view of the clothes drying machine shown in FIG. 2, partially broken away

and partially in section, illustrating the blower apparatus and drive machinery;

FIG. 4 is a front elevational view in partial section taken generally along the lines 4—4 in FIG. 2 illustrating the flow path for air and microwave energy; and

FIG. 5 is a schematic diagram of a control circuit embodying an aspect of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIG. 1, there is shown an electronic dryer in accordance with the present invention. The apparatus includes an outer casing or cabinet 42 preferably of sheet metal construction. The cabinet 42 is provided with air inlet means 12 and air egress means such as exhaust 140 whereby air may enter the cabinet enclosure from the atmosphere, flow through the interior thereof and be thereafter exhausted to the atmosphere. Air inlet 12 is covered by a screen 80 which prevents the undesirable entrance of large particles of foreign matter into the enclosure. Air is drawn into and exhausted from the cabinet 42 by air circulation means such as a blower 128 mounted therein and driven by a motor 74. Mounted within the cabinet 42 is a microwave impermeable drying chamber 56 into which is placed the item or items to be dried. Drying chamber 56 is provided with an air ingress 82 and air outlet means, such as a plurality of perforations 126, in a spaced-apart relationship, whereby air flowing through chamber 56 will readily remove moisture evaporated from the articles being dried therein. As can be readily seen, air ingress 82 and outlet means 126 are depicted in FIG. 1 as perforations in opposing sides of the drying chamber 56. A conduit 130 connects the air outlet means or perforations 126 through the input of the blower 128. By virtue of the arrangement illustrated, when the blower 128 is operating, air is drawn into cabinet 42 through air inlet 12 and flows along the path indicated by the air shown in solid lines, into the drying chamber 56 through the air ingress 82 and out through the perforations 126 to the conduit 130, to blower 128 which vents to atmosphere.

In accordance with one embodiment of this invention, a heat source 88 may be positioned within the cabinet 42 so as to be in the path of the air flow into the drying chamber 56 through air ingress 82. The heat source is shown as being of the electrical resistance type; however, in another embodiment of this invention, heat source 80 may be a gas burner, the flame of which heats the air flowing into drying chamber 56.

Mounted within the cabinet 42 adjacent the air inlet 12 is generating means 150 for producing ultrahigh frequency electromagnetic energy such as microwave energy. Generating means 150 may be any of several well known types, but is preferably a cross-field discharge device, or a magnetron of the type disclosed in U.S. Pat. No. 3,458,755-Staats, issued July 29, 1969 and assigned to the same assignee as the present invention. Coupled to the output terminals of the generating means 150 is a coaxial transmission line 152, transmission line 152 terminating in a section of conduit 130. The termination of line 152 is provided by antenna means such as antenna 158 coupled to the inner conductor of the coaxial line 152.

Antenna 158 is adapted to radiate microwave energy into conduit 130 which serves as a waveguide for propagating the microwave energy toward drying chamber 56. Disposed in the center of the air outlet means 126 is a microwave window 162 which is closed by a sheet or cover of microwave transparent material. More particularly, the microwave energy radiated by antenna 158 into conduit 130 is propagated upwardly therealong, as shown by the dashed arrows, entering the drying chamber 56 through microwave window 162. Window 162 has a perimeter which is greater than one wavelength of the frequency of operation of the magnetron 150 such that it may function for its intended purpose as is well known to those skilled in the art.

To prevent transmission of the microwave energy through the conduit 130 toward the blower 128, a microwave reflector such as wire mesh screen 138 is provided. Wire mesh screen 138 serves to reflect the microwave energy and confine it to the conduit 130 while at the same time permitting passage of air drawn through conduit 130 by blower 128. Likewise, the perforations forming air ingress 82 will not permit the passage of microwave energy therethrough, such that the microwave energy is confined within the microwave impermeable drying chamber 56.

In operation, the items to be dried are inserted into the drying chamber 56 by suitable means (not shown in this FIGURE but shown and described later in connection with a clothes dryer embodying the invention) and the motor 74 is energized to cause the blower 128 to operate. The operation of the blower 128 drawing air through the air outlet perforations 126 and conduit 130 creates an area of reduced pressure in drying chamber 56 and thereby generates a stream of air through the drying apparatus. This stream of air is drawn into the cabinet and through the air inlet 12. As shown by the solid line arrows, the air flow sweeps over the generating means or magnetron 150 to cool the magnetron and heat the air to a small extent, being then drawn upwardly through the air ingress 82 into the drying chamber 56. Prior to entering the drying chamber, the air is further heated by heat source 88 to a predetermined temperature range, the upper limit of which is less than that temperature which would cause damage to the items being dried, such as by physical deterioration or scorching or burning. The elevated temperature of the air flowing through the drying chamber 56 is of course desirable, as the moisture carrying capacity of the air is increased with elevated temperature. Upon entering the drying chamber 56, the air is swept over the articles to be dried, picking up moisture therefrom, then flowing out of the drying chamber 56 through air outlet 126 to be exhausted to atmosphere by a conduit 130 and blower 128.

At or about the same time that the blower motor 74 is energized, magnetron 150 is energized to begin producing microwave energy at the output terminals thereof at a predetermined ultrahigh frequency, preferably in this embodiment at 915 MHz. This microwave energy is transmitted along the transmission line 152 and is radiated by the antenna 158 into conduit 130. Conduit 130 is dimensioned to act as a waveguide at the frequency of operation of the generating means 150 and propagates the microwave energy toward microwave window 162. As previously pointed out, mesh screen 138 serves to reflect the microwave energy impinging thereupon to confine it such that it may not reach blower 128, while at the same time permitting air to be drawn through conduit 130 toward blower 18. Microwave energy is transmitted from conduit 28

through microwave window 162 into the interior of drying chamber 56.

In the drying chamber, the microwave energy is selectively absorbed by the wettest portions of the items to be dried, serving to heat and vaporize the moisture or water content of the items in a manner well known in the art. As the water content of the wet items is vaporized by the microwave energy, it is freed from the items and is carried from the drying chamber 56 by the air stream passing therethrough as described above. In this manner, the wet articles are quickly and efficiently dried to any desired degree of dryness. It is a quality of microwave drying that the wettest articles absorb the most microwave energy whereby the drying of such articles is speeded considerably while at the same time articles which are not quite so wet are prevented from being scorched. Thus, there is achieved a rapid and uniform drying of a load of items of varying degree of wetness.

It will also be noted that the heating and vaporizing of the moisture in the articles to be dried is facilitated by the fact that the stream of air can be heated before it passes through the drying chamber 56 to effect conventional convection drying of the wet articles. As previously set forth, this heating of the air stream is accomplished by its passage over heat source 88. Some additional preliminary heating of the air stream is effected by the passage of the air stream over generating means 150 as the air stream enters the cabinet 42 through the air inlet 12. Thus while the air stream serves to cool the generating means 150, the heat drawn therefrom is utilized to provide additional warming of the air stream to enhance its drying affect on the wet articles in the drying chamber 56. Similarly, the air flow may serve to cool the power supply (not shown in FIG. 1) for the generating means, by positioning the power supply in the air flow path in the same manner as the generator or generating means 150.

As previously stated, a particular embodiment of this invention, wherein its objects and advantages are readily employed, is a domestic clothes dryer. FIG. 2 illustrates such a clothes dryer generally designated by reference numeral 41. A dryer, in accordance with this invention, may utilize a mechanical structure which is similar to that disclosed in U.S. Pat. No. 3,009,259 - Simpson, assigned to the same assignee as the present invention, the disclosure of which is incorporated herein by reference.

The dryer includes an outer casing or cabinet 42 comprising a top wall 44, a bottom wall 46, a pair of opposite side walls 48, a front wall 50 and a rear wall 52, all preferably of sheet metal construction. Mounted at the rear end of top wall 44 is a panel 54 on which are mounted the controls of the dryer. A drum 56 having a generally cylindrical side wall 58, a generally circular rear end wall 60 and an annular front wall 62, is preferably of sheet metal construction and is mounted within the cabinet 42 for rotation about a substantially horizontal axis. The cylindrical side wall 58 of drum 56 is provided on the inner surface thereof with a plurality of tumbling ribs 64 for engaging the fabric or clothing as the drum rotates to cause tumbling of the clothing in a well known manner. The drum 56 thus defines a microwave impermeable drying chamber for accommodating wet clothing to be dried.

In order to support and rotate the drum 56, recessed cylindrical wall 66 and 68 are disposed at the rear and front ends respectively of the cylindrical side wall 58. The front recessed portion 68 of the drum side wall 58 is rotatably supported within the cabinet 42 by means of a pair of idler roller wheels 70, one of which is shown in FIG. 3.

As also seen in FIG. 3, the rear recessed wall portion 66 of the cylindrical side wall 58 is supported by a drive roller wheel 72 driven by an electric motor 74 which also drives the blower as will be subsequently described. The idler roller wheels 70 and the drive roller wheel 72 constitute elements of a known home dryer as shown in the patent to Simpson, mentioned above. Referring again to FIG. 2, the axis of rotation of the drum 56 is maintained in vertical alignment of the drive roller wheel 72 by the inner action of a stub shaft 76 secured at the center of circular rear end wall 60 and an elongated slot 78 formed in a member to be hereinafter described which is supported from the rear wall 52 of the cabinet 42. The slot 78 has a relatively large vertical dimension and a relatively small horizontal dimension only slightly greater than the diameter of the shaft 76, whereby the slot 78 prevents sidewise motion of the shaft 76 therein but accommodates a small degree of vertical motion of the shaft 76 and the drum 56 resulting from the driving motion imparted thereto by the driving roller wheel 72. The details of construction of the shaft 76 and its cooperation with the slot 78 are disclosed in the aforementioned U.S. Pat. No. 3,009,259.

Having described the dryer drum 56 and the means for supporting it for rotation in the cabinet 42, the means for providing an air flow through the cabinet and drum will now be described. Air enters the cabinet 42 through an air inlet formed by air inlet screen 80 disposed at the bottom of rear wall 52, and thereafter enters the drying drum 56 through air ingress means formed as an annular array of perforations 82 in the rear end wall 60 of drum 56.

Rigidly secured to the rear wall 52 of cabinet 42 by suitable means, such as welding at points 84, is an outer baffle member 86 having secured on the inner surface thereof a plurality of heating elements 88 comprising a heat source. The heating elements 88 may be of the electrical resistance type and may be generally annular in shape so as to be substantially coextensive with the annular array of perforations 82 in the rear wall 60 of the drum 56. An inner baffle member 90 is rigidly secured about the periphery thereof to the rear wall 60 of the drum 56 and is disposed within the outer baffle member 86. The inner baffle member 90 is slightly smaller than the outer baffle member 86 and is disposed a slight distance inwardly therefrom and cooperates therewith to form an annular air inlet passage 92 therebetween. The inner baffle member 90 is further provided with an annular series of openings 94 opening into the rear wall 60 of drum 56. Thus, a path for air flow is provided through the air inlet passage 92 between the baffle members over the heating elements 88 through the openings 94 and perforations 82 into the drum 56. It will be noted that the inner baffle member 90 has a depressed central portion 96 to which is secured a bracket 98 supporting shaft 76 set forth above.

Access means for placing articles to be dried in the drum 56 and for removal therefrom are provided by a substantially circular access aperture or opening 100 formed in front wall 62 of drum 56 and by a hollow mi-

crowave impermeable door **102** preferably of sheet metal construction provided in front wall **50** of cabinet **42** in alignment with the access opening **100.** The upper portion of the front wall **50** of the cabinet **42** is provided with a doorway defined therein by a door frame or electrically conductive door seat **104** which comprises a part-cylindrical wall sloping inwardly from the drum **56** and having a substantially flat horizontal bottom portion **106,** which effectively truncates the upper portion of the part-cylindrical door seat **104** and slopes inwardly toward the drum. The door seat **104** is disposed substantially in axial alignment to the access opening **100** of drum **56** with its cylindrical portion being substantially concentric with access opening **100** and the inner edge of the door seat **104** being received within a cylindrical flange **108** integrally formed with front wall **62** and spaced radially inward a slight distance therefrom to provide clearance to permit free rotation of the drum **56.**

Mounted on the outer surface of the door seat **104** around the periphery thereof is a flange **110** having secured thereto a ring seal **112** preferably formed of felt-like material and extending rearwardly therefrom and engaging the front wall **62** of the drum **56** in a sealing relationship so as to prevent leakage of air from the drum **56** between the flange **110** and the door seat **104.** The door **102** is hingedly mounted on the front wall **50** of the cabinet **42** and includes an outer imperforate section **114** generally rectangular in shape, and a hollow inwardly extending portion **116** which is shaped complementary to the door seat **104** and is closed at its inner end by the inner wall **118.** The door **102** is movable between an open position extending outwardly from the front wall **50** substantially normal thereto and a closed position wherein the hollow inwardly extending portion **116** is received within the door seat **104** and closes the access opening **100.** The inwardly extending portion **116** of the door **102** has a flat bottom portion **120** provided with a generally rectangular opening **122** therein spaced complementary to an opening **124** in the flat horizontal bottom portion **106** of door seat **104** and disposed in registry therewith when the door is in its closed position. The inner wall **118** of the door **102** is provided with a plurality of microwave impermeable perforations or openings **126** therethrough communicating with the hollow interior of the door **102** whereby air may flow from the drum **56** through openings **126** and the hollow interior of door **102** to openings **122** and **124.**

Referring now to FIGS. **2, 3** and **4,** the means by which air flows from the drum **56** through perforations **126** and inner wall **118** of the door **102** to be exhausted from the cabinet **42** will be described. The intake of a centrifugal blower **128** driven by electric motor **74** is connected to a conduit such as duct **130** which includes a front section **132** and a rear section **134.** The front section **132** is substantially rectangular in crosssection and extends upwardly along the front wall **50** of the cabinet **42** from the lower end thereof and then terminates in an open upper end connected to the flat bottom section **106** of the door seat **104** in registry with the opening **124** therein. The rearward extending portion **136** of the front section **132** is connected to the rear section **134** as best shown in FIG. **3.** Spanning the joint between the front and rear sections of the duct **130** is a wire mesh screen **138** which serves as a reflector of microwave energy as will be hereinafter described. The exhaust of centrifugal blower **128** is directed to an outlet or exhaust opening **140.**

Carried by the flat bottom portion **106** of door seat **104** in the opening **124** therein is a lint trap generally designated by the numerals **141** and which is provided with a mounting collar **142** and a filter screen **143.** The mounting collar **142** is substantially rectangular in shape and is provided with a screen supporting flange **144** shaped complementary to the opening **124** and extending downwardly into the open upper end of the front duct section **132.** Integral with the upper end of the screen supporting flange **144** and extending outwardly therefrom is a mounting flange **146** which overlies the bottom **120** of the door seat **104** about the periphery of the opening **124** therein for supporting the lint trap **141** thereon.

The screen **143** is preferably formed of a fine wire mesh and defines a bag or basket having an open upper end embedded in a screen supporting flange **148** on the mounting collar **142** and having a closed lower end extending downwardly into the upper end of the front duct section **132.** The screen is shaped complementary to the front duct section and is spaced a slight distance inwardly therefrom so as to provide a clearance between the screen and the inner surface of the front duct section around the entire periphery thereof. In particular, the upper end of the screen is embedded in the mounting collar **142** a slight distance inwardly of the inner surface of the duct section **132** so as to be spaced therefrom by the thickness of the screen supporting flange **148,** the perimeter of which is dimensioned so as to be greater than the wavelength of the frequency of operation of the microwave generator provided. The mounting collar **142** is preferably formed of plastic or other microwave transparent material as will be explained more fully hereinafter. Disposed in the bottom of the cabinet **42** adjacent the air inlet screen **80** is a magnetron **150** for producing microwave energy of a predetermined high frequency, and may be of the type disclosed in U.S. Pat. No. 3,458,755, as mentioned above.

Coupled to the output terminals of the magnetron **150** is a coaxial transmission line **152** which includes a hollow outer conductor **154** and insulated therefrom by suitable means, an inner conductor **156.** The transmission line **152** terminates at the front section **132** of the duct **130,** the outer conductor **154** being connected to the duct section **132** and the inner conductor **156** terminating in antenna means such as an antenna **158.** The antenna **158** extends into the duct section and both the inner conductor **156** and the antenna **158** are insulated from the duct section and the outer structure by an insulating spacer **160.** The antenna **158** is adapted to radiate microwave energy into the front section **132,** this front section serving as a waveguide for propagating microwave energy toward the drum **56** as will be described in detail below.

There is provided in the inner wall **118** of the door **102** a microwave window generally designated by the numeral **162** and including a generally cross-shaped opening **164** covered by a plastic sheet or cover **166** which is formed of suitable microwave transparent material. The perimeter of the opening **164** is greater than one wavelength of the frequency of operation of the magnetron **150** whereby the opening serves as a microwave aperture or window as is well known to those skilled in the art.

Thus the door **102** and the duct section **132** cooperate to form a waveguide for transmitting microwave energy from the transmission line **152** into the drying chamber of the drum **56.** More particularly, the microwave energy is radiated by the antenna **158** into the front section **132** which then functions as a waveguide to propagate the microwave energy upwardly therealong to the open upper end thereof. At this point, the wire mesh screen **143** of lint trap **141** is opaque to the microwave energy but the mounting collar **142** is formed of a material which is transparent to that energy and as the perimeter of the screen supporting flange **144** is greater than the wavelength of the frequency of operation of the generating means, the flange **148** thereof serves as a microwave aperture for the microwave energy. The microwave energy then passes through the opening **124** in the door seat **104** which also has a perimeter greater than one wavelength of the frequency of operation of the generator, and thence into the hollow interior of the door **102.** From the door **102** the microwave energy passes through the microwave window **162** into the drying chamber of the drum **56.** It will be noted that the window **162** is necessary to permit the transmission of microwave energy through the inner wall **118** of the door since the perforations **126** therein are too small to permit the transmission of such energy therethrough. Similarly, the perforations **82** in the rear wall **60** of the drum **56** will not permit the passage of microwave energy therethrough whereby the energy is confined within the drum **56.**

In order to further insure that no microwave energy escapes from drum **56,** the door seat **104** and the inner portion **116** of the door **102** overlap a distance corresponding to approximately ¼ of the wavelength of the frequency of operation of magnetron **150** whereby the inner portion of the door **102** cooperates with the door seat **104** to form a quarter-wave choke joint to block the passage of microwave energy therebetween.

In operation, wet clothes to be dried are placed in the drum **56** through the access opening **100,** when the door **102** is in its open position. After the door **102** is closed, the drive motor **74** is energized to begin rotation of the drum **56** and the tumbling of the clothes therein. At the same time the blower **128** is rotated to create an area of reduced pressure in the drying chamber and thereby create a stream of air through the dryer **41.** This air stream is drawn into the cabinet **42** through the air inlet opening in screen **80,** sweeps over the magnetron generator **150** and is drawn upwardly through the opening **92** between baffle members **86** and **90,** over the heating elements **88** and through the perforations **82** of the drum **56** into the drying chamber thereof. The air stream is then swept over the clothing in the drum **56** and outwardly through the perforations **126** in the door **102** into the hollow portion thereof, through the aligned openings **122** and **124** in the door **102** and the door seat **104,** respectively, through the lint screen **143,** the front duct section **132,** the wire mesh screen **138** and the rear duct section **134** to the blower **128.** From the blower the air stream is exhausted through the exhaust outlet **140** to the atmosphere.

At this time the magnetron **150** is also energized to produce microwave energy at a predetermined high frequency, preferably in this embodiment at 915 MHz. The microwave energy is transmitted along transmission line **152** and is radiated by the antenna **158** into the duct front section **132.** Duct section **132** propagates the microwave energy toward the lint trap **141.** It will be noted that transmission of microwave energy through the duct **130** toward the blower **128** is prevented by the wiremesh screen **138** which serves to reflect the radiated energy thereby to confine it to the duct portion **132.** The microwave energy is then transmitted through the aperture provided around the filter screen **143,** through the opening **122** into the interior of the door **102** and then through the microwave window **162** into the drying chamber of the drum **56.**

In the drying chamber of the drum **56,** the microwave energy is selectively absorbed by the wettest portions of the clothes, serving to heat and vaporize the moisture of water content of the clothing in a well known manner. As the water in the wet clothing is vaporized by means of microwave energy, it is carried from the drying chamber of the drum **56** by the air stream passing therethrough as described above. In this manner the wet clothes are quickly and efficiently dried to any desired degree of dryness. It is an important factor of microwave drying that the wettest clothing absorbs the most microwave energy whereby the drying of heavy materials such as towels which hold a great deal of moisture is accelerated considerably while at the same time the lighter clothing which is already dried is prevented from being scorched. Thus, there is achieved a rapid and uniform drying of each load even though the load may comprise many different weights and textures of materials.

It will also be noted that the heating and vaporizing of the moisture in the clothing is accelerated by the fact that the air stream is heated before it passes through the drying chamber of the drum **56** so that it effects conventional air convection drying of the wet clothing while being able to hold more moisture. This is accomplished by the passage of the air stream over the heating elements **88** located between the baffle elements **86** and **90.** Additional preliminary heating of the air is effected by the passage of the air stream over the magnetron **150** as the air stream enters the cabinet **42** through the intake screen **80.** Thus, the air stream serves to cool the magnetron and the heat drawn therefrom is utilized to provide additional warming of the air to enhance its drying effect on the wet clothing.

Referring now to FIG. **5** of the drawings, there is illustrated a circuit diagram for the control means for the dryer **41** and the magnetron **150,** the circuit being designated generally by the numeral **170.** Circuit **170** includes the magnetron **150** and a power supply **172** therefor. Circuit **170** is coupled through a three wire Edison network which, in a typical household installation, may provide 236 volts single phase 60 HzAC and includes ungrounded conductors L1 and L2 and a grounded neutral conductor N. The three conductors terminate in an electrically insulating terminal block **174.** The power supply **172** is provided with a pair of input terminals **176** and **178** coupled respectively to the line conductors L1 and L2. A first pair of output terminals **180** and **182** supply a rectified and filtered DC voltage which constitutes the DC voltage which constitutes the DC operating potential for the magnetron **150.** A second pair of output terminals **184** and **186** supply relatively low voltage AC power for energizing the magnetron heater.

The output terminal **180** is connected to an input terminal **188** of the magnetron **150** through one coil **190**

of a latching relay **192** via conductors **194** and **196**. The latching relay **192** includes a movable contact **198**, a fixed contact **200**, a closing coil **202** and the coil **190** which functions as an opening coil. The contacts **198** and **200** are connected in series between the line conductor L1 and the input terminal **176** of the power supply **172**. The line conductor L1 is also connected to one terminal of the closing coil **202** by means of a conductor **204** and a momentary switch **206**. The other terminal of the coil **202** is connected by a conductor **208** to the neutral line N. In addition to the input terminal **188**, the magnetron **150** is provided with an input terminal **210** which is connected via a conductor **212** to the output terminal **182** of the power supply **172**. A third input terminal **214** is provided for the magnetron **150** and it in turn is connected via conductor **216** to the output terminal **184** of power supply **172** while the conductor **218** connects the output terminal **186** of power supply **172** to the magnetron input terminal **210**.

The anode of the magnetron **150** is represented by a terminal **220** and is connected to one end of the outer conductor **154** of the transmission line **152** as at **222**, the inner conductor **156** of the transmission line **152** being connected to the input terminal **210**. The other end of the inner conductor **156** is connected to the antenna **158** while the other end of the outer conductor **154** is connected to the duct front section **132** which in turn is connected to the cabinet **42** as described above and is grounded as at N for safety purposes. However, since the output of the magnetron **150** may not be grounded there is provided a capacitive coupling **224** in the outer conductor **154** and a capacitive coupling **226** in the inner conductor **156** to provide DC isolation between the duct section **132** and the magnetron **150**.

In operation, when it is desired to energize the magnetron **150** after the wet clothing has been loaded into the drying chamber of the drum **56** and the door **102** has been closed, the momentary switch **206** is closed thereby energizing the closing coil **202** of relay **192**. Upon energization of the coil **202** the movable contact **198** is moved into engagement with the fixed contact **200** to complete an energizing circuit to the input terminals **176** and **178** of the power supply **172**. The power supply when energized provides the DC and AC operationg potentials for the magnetron **150**.

In accordance with the present invention, it has been found that the anode current drawn by the magnetron **150** from the power supply **172** is a function of the load impedance reflected to the magnetron **150** by the wet clothing in the drum **56**. Thus, when a dryer in accordance with the invention begins to operate, the impedance reflected to the magnetron **150** by the relatively high water content of the very wet clothing in the drum **56** is such that the magnetron anode **220** draws a relatively low current. However, as the clothes in the drum **56** are dried and the moisture content thereof reduced, the impedance reflected to the magnetron **150** is such that the anode current drawn thereby correspondingly increases. Accordingly, the current through the opening coil **190** of the relay **192** also increases. The operating parameters of the relay **192** are chosen so that when the clothing has been dried to a predetermined degree of dryness, the anode current of the magnetron **150** will be sufficient to energize the coil **190** to open the contacts **198** and **200**. In this manner, the power supply **172** is disconnected from the power line L1 and accordingly de-energizes when the clothing has been sufficiently dried, thereby de-energizing the magnetron **150** and interrupting the flow of microwave energy therefrom.

It will, of course, be recognized that suitable control apparatus for the control and cycling of the drive motor **74** and the heating elements **88** will also typically be provided in a dryer in accordance with the invention, such control apparatus being well known in the art. In addition, as is well known in the art, interlock switches may be provided to prevent energization of the magnetron **150** unless the door **102** is in its closed position. Further, microwave filters may be provided in the transmission line **152** to limit propagation therefrom of harmonics of the frequency of operation of the magnetron **150**.

From the foregoing, it will be seen that there has been provided an improved drying machine wherein uniform drying is obtained for materials of varying weight and absorbency. In addition, there has been provided an electronic or microwave clothes dryer which efficiently utilizes the space available and existing structure of a conventional home dryer.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be understood that various modifications may be made therein and it is intended to cover in the appended claims all such modifications which fall within the true spirit and scope of the invention.

What is claimed is:

1. An electronic fabric dryer comprising:

a cabinet having a microwave impermeable drying chamber therein for accommodating fabrics to be dried;

generating means including a magnetron for producing microwave energy at a predetermined ultra-high frequency;

air circulating means associated with said drying chamber for circulating a stream of air therethrough;

a conduit coupling said circulating means with said drying chamber thereby serving as an air duct, said conduit also serving as a waveguide to conduct said microwave energy to said drying chamber;

an air inlet disposed upstream of said magnetron such that said air stream serves to cool said magnetron while said magnetron serves to preheat said air stream;

a heat source disposed in said air stream upstream of said drying chamber for further heating said preheated air stream before it enters said drying chamber thereby serving to accelerate the drying process;

output means coupling said magnetron with said conduit for transmitting energy from said magnetron to said conduit, whereby moisture from said fabrics is heated and vaporized by said microwave energy and by said preheated air stream and is carried from said drying chamber by said air stream; and

control means associated with said generating means and said heat source, the control means being responsive to the moisture content of said fabrics to interrupt the transmission of microwave energy into said drying chamber and to interrupt the supply of heat to said air stream when said fabrics have reached a predetermined degree of dryness.

2. The invention of claim 1 wherein said heat source comprises an electric resistance heating element.

3. An electronic clothes dryer comprising:

a cabinet having a microwave impermeable drying chamber therein for accommodating clothes to be dried;

generating means including a magnetron for producing microwave energy at a predetermined ultrahigh frequency;

a blower associated with said drying chamber for circulating a stream of air therethrough;

a conduit coupling said blower with said drying chamber, the conduit thereby serving as an air duct;

an air inlet associated with said cabinet and disposed upstream of said magnetron such that said airstream serves to cool said magnetron while said magnetron serves to preheat said air stream;

a heat source disposed in said air stream upstream of said drying chamber for further heating said preheated air stream before it enters said drying chamber;

output means including a pair of output terminals associated with said magnetron and a coaxial transmission line coupled therewith, an antenna means, the free end of the coaxial transmission line being coupled with the antenna means, the antenna means being insulated from said conduit and positioned to radiate microwave energy into said conduit, said conduit serving as a waveguide to conduct said radiated microwave energy to said drying chamber in a direction opposite to the flow of air therethrough; and

control means associated with said generating means and said heat source, the control means being responsive to the moisture content of said clothes to interrupt the transmission of microwave energy into said drying chamber and to interrupt the supply of heat to said air stream when said clothes have reached a predetermined degree of dryness.

4. The invention of claim 3 further including a microwave reflector disposed in said conduit between said blower and said antenna means to prevent the transmission of microwave energy to said blower.

5. The invention of claim 3 wherein:

said cabinet has an access aperture spaced apart from said air inlet the access aperture communicating with said drying chamber, and said conduit having one end thereof terminating adjacent the access aperture;

a hollow microwave impermeable door movable between a closed position and an open position is provided to control access to said drying chamber through said access aperture, the door having first and second openings therein providing communication with the hollow interior thereof, the first opening having a microwave window therein for accomodating transmission of microwave energy therethrough into said drying chamber, the first opening also including a plurality of perforations impermeable to microwave energy but allowing the free flow of air therethrough, the door in the closed position thereof placing the second opening in registry with the free end of said conduit to provide a path for the stream of air from the atmosphere to said inlet and said drying chamber and said hollow door and said conduit and said blower and further to provide a path for microwave energy from said magnetron through said conduit and said hollow door and said microwave window into said drying chamber.

6. The invention of claim 5 wherein said microwave window comprises a generally cross-shaped opening in said door, the microwave window having a cover associated therewith overlying the cross-shaped opening, the cover being transparent to microwave energy while preventing the passage of fabric through the opening into the hollow interior of said door.

7. The invention of claim 6 wherein said drying chamber comprises a generally cylindrical metallic drum mounted for rotation about a substantially horizontal axis, the drum having an air ingress and an access aperture at spaced-apart points thereof, said air ingress being impermeable to microwave energy but allowing the free flow of air therethrough.

8. The invention of claim 7 further including an electrically conductive door seat mounted adjacent said access aperture such that the door seat overlaps said door in the closed position thereof a distance corresponding to one-fourth of the wave length of said predetermined ultrahigh frequency thereby providing a choke joint to prevent the escape of microwave energy from said cabinet.

9. The invention of claim 3 wherein said control means comprises a power supply, a relay having a pair of contacts coupled in series with an input of the power supply and a coil winding coupled in series between an output of the power supply and an input of said magnetron, the relay being responsive to the current through the input of said magnetron for opening the contacts and de-energizing the power supply and said magnetron and said heat source when the current through the input of said magnetron reaches a predetermined value as the result of the drying of the wet fabric to a predetermined degree of dryness.

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