APPARATUS FOR DRYING MATERIALS EMPLOYING SPACED MICROWAVE HEATING AND TRANSVERSE-FLOW MOISTURE FLUSHING STATIONS


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ABSTRACT

A plurality of slotted straight waveguide sections of a folded waveguide structure are positioned at spaced stations along the path which the material to be dried is transported. A plurality of nozzles are positioned following each slotted waveguide section on both sides of the waveguide slots to direct high velocity streams of air to impinge normally on opposite surfaces of the material. A source of negative pressure is coupled to the locations of the nozzles to direct the impingement of air along an exhaust path laterally of the path traveled by the material, a portion of which is parallel to the surface of the material at its surface.

5 Claims, 5 Drawing Figures
APPARATUS FOR DRYING MATERIALS EMPLOYING SPACED MICROWAVE HEATING AND TRANSVERSE-FLOW MOISTURE FLUSHING STATIONS

This is a continuation of application Ser. No. 701,691 filed Jan. 30, 1968, and now abandoned.

BACKGROUND OF THE INVENTION

In manufacturing wood, paper, textile and other materials which require the removal of moisture, often it is desirable to produce finished materials having a uniform moisture profile at a selected moisture content level. To obtain a uniform moisture profile with conventional conduction, convection and radiant drying equipment, it has been the practice to first overspray the material so that the moisture content of the wettest spots is less than that desired for the finished material. To achieve moisture leveling, i.e., the equalization of the moisture content of the wet and dry spots in the material, the overried material is then rewet by storing it in a regulated temperature and humidity environment.

However, the technique of overdrying and rewetting is characterized by many disadvantages. For example, in overdrying wood the outer surfaces are dried more than the inside of the wood body. This results in the outer surfaces shrinking relative to the inside body of the wood. As a consequence of the relative shrinkage, the wood cracks and splits, such cracking and splitting generally referred to as "checking." Overdrying also has a harmful effect on the ultimate quality of materials in other ways, viz., reduces the strength of materials, and often leads to warping of wood and paper materials. Furthermore, while in the overdried state, the materials tend to tear, break or otherwise easily fracture with handling. In addition to these disadvantages, drying by conduction, convection and radiant techniques do not provide a moisture profile having the degree of uniformity desired.

To overcome the disadvantages of conventional conduction, convection and radiant drying equipment and provide materials with a more uniform moisture profile, it has been proposed to dry materials with microwave energy. Microwave drying has the advantage of providing an enhanced moisture profile without overdrying and rewetting. Unfortunately, in removing the moisture from the material with microwaves, the moisture tends to collect in the microwave applicator and on the surface of the material. The collection of moisture in the microwave applicator is objectionable and should be avoided because it leads to the eventual malfunctioning of the microwave drying system. Furthermore, the objectionable moisture that collects on the surface of the material being dried forms a barrier which hampers and often prevents the further removal of moisture from the material since the moisture within body of the material cannot be removed through the moisture boundary formed on the surfaces of the material. In addition, the moisture which collects on the surface of the material can soak back into the material, thereby further reducing the effectiveness of removing moisture by microwave techniques. Also, the presence of moisture on the surface of the material being dried tends to absorb some of the microwave energy, thereby reducing the efficiency of the microwave drying system.

Although various techniques have been tried to prevent this deleterious collection of objectionable moisture, none have been successful enough to make microwave techniques economically practical for industrial applications of drying materials to low moisture content levels.

Therefore, considerable advantage is to be gained by providing a microwave drying apparatus which obviates deleterious overdrying and rewetting to obtain materials having a uniform moisture profile at low moisture content levels. Additional advantages will be realized where a microwave drying apparatus is provided which is economically practical for large scale industrial drying applications.

SUMMARY OF THE INVENTION

The present invention is an apparatus for drying moisture-laden materials by alternately subjecting the materials to microwave energy and a high velocity gas flow. More particularly, it was found that moisture-laden materials could be economically dried directly to low moisture content levels, i.e., 5%, with microwave energy by performing the microwave drying in steps at spaced microwave drying stations and, at least in between microwave drying stations, subjecting the material to a high velocity gas flow, e.g., air streams, directed along paths which transversely intersect the material surface. At each air stream station, the high velocity air stream ruptures and removes the layer of objectionable moisture formed on the surface of the material during its subjection to microwave energy at the preceding microwave drying station. By so removing the objectionable moisture that would otherwise collect in the microwave applicator and on the surface of the material, microwave techniques can be employed to remove moisture from the material economically regardless of the level of the moisture content of the material.

Subjecting the moisture-laden material alternately and separately to microwave energy and a high velocity gas stream is particularly advantageous because the structure of the microwave applicator is greatly simplified as compared to that which would be required to subject the material simultaneously to microwave energy and a high velocity gas stream. Furthermore, drying the material in steps, i.e., at spaced microwave drying stations, and removing the moisture from the surface of the material at locations following each of the drying stations facilitates preventing objectionable moisture from collecting in the microwave applicator system and preventing objectionable moisture from collecting on the surface of the material. The present invention is characterized by these advantages because by removing the objectionable moisture extracted from the material at one drying station before the material passes through the succeeding drying station, only a small percentage of the moisture in the material is freed to be present in the microwave applicator and on the surface of the material at any time. In practice, it has been found particularly advantageous to dry materials with a folded waveguide microwave applicator having a plurality of spaced slotted waveguide sections joined together to form a serpentine microwave path. One or more of the slotted waveguide sections may be arranged to define a drying station at which moisture is extracted from the material by the force of the applied microwave energy. To remove the extracted moisture which tends to collect on the surface of the material as it passes through each slotted waveguide section, high
velocity air streams are directed to impinge the material along a path which transversely intersects the surface of the material, preferably, in each of the spaces between the straight waveguide sections. Means are provided to direct the impinged air along a path, a portion of which is parallel to the surface of the material at its surface. By directing the impinged air parallel to the surface of the material, the moisture is swept from the surface and is entrained in the air flow, thereby facilitating the carrying away of the moisture from that expected in the absence of moisture in the microwave applicator and on the surface of the material.

Accordingly, it is an object of the present invention to provide an apparatus for drying materials to a more uniform moisture profile. More particularly, it is an object of the present invention to provide an apparatus for accomplishing such drying which obviates deleterious overdrying of the materials.

Another object of the present invention is to provide an apparatus for drying materials with microwave energy whereby dried materials are obtained with a more uniform moisture profile at low moisture content levels without deleterious overdrying.

A further object of the present invention is to provide a microwave drying apparatus which is economically practical for industrial applications.

Still another object of the present invention is to provide an apparatus for drying materials to a more uniform moisture profile at low moisture content levels which does not impair the quality of the materials.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The foregoing and other objects and advantages of the present invention will become more apparent from the following detailed description and appended claims considered together with the accompanying drawings in which:

FIG. 1 is a schematic representation of the apparatus of the present invention.

FIG. 2 is a cross sectional side elevational view of an embodiment of the drying apparatus of the present invention.

FIG. 2A is an exploded cross sectional view of the part of FIG. 2 delineated by line 2A—2A.

FIG. 3 is a cross sectional end view of the drying apparatus taken along lines 3—3 of FIG. 2.

FIG. 4 is a cross sectional top view of a segment of the drying apparatus taken along lines 4—4 of FIG. 2.

**DESCRIPTION OF PREFERRED EMBODIMENT**

Considering the present invention with reference to FIG. 1, material to be dried, such as wood veneer 11, is transported by, for example, a roller conveyor means 12 at a selected velocity through a plurality of microwave drying stations 13 at locations spaced longitudinally along the travel of the material 11. The number of drying stations 13 employed and the velocity at which the material 11 is transported by the conveyor means 12 are governed principally by the microwave energy available for drying at the drying stations 13, the degree of microwave coupling to the material 11 being dried, the width and thickness of the zone being dried, and the amount of moisture to be removed from the material 11. At each of the drying stations 13, the material 11 being dried is subjected to microwave energy at a selected frequency and energy level which may be applied thereto by various microwave applicators. For example, in the drying apparatus of the present invention, a folded waveguide microwave applicator such as illustrated in FIGS. 2—4 having a slotted waveguide section at each microwave drying station 13 is employed to apply drying microwave energy to the material 11. Examples of some of the other microwave applicators that might be employed to apply drying microwave energy to the material 11 are capacitive heating applicators, individually excited waveguides, microwave cavities, and directional microwave radiators.

For reasons of efficiency and uniformity of drying, it is particularly advantageous to pass the material 11 through a microwave energy filled volume, such as provided by a slotted waveguide type microwave applicator 15, whereby opposite sides of the material 11 is subjected simultaneously to microwave energy. However, in certain instances, for example, when fixing a veneer to one side of a wood substrate, it may be desirable to subject only one side 14 of the material 11 to microwave energy. Furthermore, in other instances, for example, when a coating is cured on opposite sides of the material, it may be desirable to subject first one side 14 and then the other side 16 of the material 13 to microwave energy. In the former case, directional microwave radiator-type microwave applicators could be employed at the microwave drying stations 13 to apply the microwave energy to the material 11 by directing it at side 14 thereof. In the latter case, directional microwave radiators could be arranged to direct microwave energy to be applied first to one side 14 of the material 11 at one or more microwave drying stations 13 and then to the opposite side 16 at other drying stations 13.

When drying moisture-laden materials with microwave energy, moisture collects on the surface of the materials. As explained hereinafter, the presence of this moisture is detrimental to the microwave drying operations. To prevent the collection of the objectionable detrimental moisture, high velocity, e.g., about 5,000 to 20,000 linear feet per minute (1 ft./min.), gas streams are formed and directed to impinge normally on the surfaces of the material 11 on which the moisture tends to collect. The high velocity gas streams are directed to impinge the material 11 at moisture removal stations 17 located at least in between adjacent microwave drying stations 13. If desired, high velocity gas streams also may be directed against the material 11 at moisture removal stations preceding the first drying station and following the last drying station. The gas streams are formed from gas having a relative humidity not greater than about 90%. In the illustrated embodiment, a centrifugal delivery pump 18 provides a gas, such as air, at a particular pressure head and is coupled via air plenum 19 to jet nozzles 21, which are located at the moisture removal stations 17 and are spaced apart from the microwave drying stations 13. The velocity of each of the air streams leaving the jet nozzles 21 is determined by the pressure head, the pressure of the region into which the air stream is directed, the shape of the nozzle, and the size of the mouth of the nozzle. When drying wide materials, a plurality of jet
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nozzles 21 may be provided at each of the moisture removal stations 17 arranged laterally of the travel of material 11.

The impinging high velocity air streams free the objectionable moisture adhering to the surface of the material 11. However, if this freed moisture is not quickly removed from the vicinity of the material 11, it may re-settle onto the surface. To prevent any significant amount of the freed moisture from resettling onto the surface, the air which formed the impinging high velocity streams is removed by an exhaust means 22 from the vicinity of the moisture removal stations 17 along a path, a portion of which is parallel to the surface of the material at its surface in the moisture removal stations. The freed moisture is entrained in the flow of air and is exhausted with the air being removed from the vicinity of the moisture removal stations. By directing the air to be removed along a path which is parallel to the surface of the material at its surface in the moisture removal stations 17, a sweeping action is formed by the air over the surface of the material 11 on which moisture tends to adhere. This sweeping action facilitates the freeing of the adhering moisture from the material 11 and entraining the freed moisture in the air flow, thereby preventing objectionable resettling of the freed moisture onto the material.

The removal of the moisture from the surface of material 11 is beneficially accomplished by providing negative pressure regions 23 at the moisture removal stations 17 and directing the impinged air laterally of the travel of the material 11 from one side to the other thereof. This may be effected by coupling a centrifugal suction pump 24 by a suitable exhaust plenum 26 and exhaust ducts 27 to the various moisture removal stations 17 to forcibly collect and exhaust air and entrained moisture. The desired laterally parallel air flow is formed by providing compartments 28 at each of the moisture removal stations 17 which preferentially direct the air which formed the impinging high velocity streams and the entrained freed moisture to the exhaust ducts 27 coupled to the compartments 28 at ends 29 at one side of the travel of the material 11. Suitable openings 30 are provided in the compartments 28 to allow the material 11 to pass therethrough.

To facilitate entraining the freed moisture in the impinged air and removing the moisture from the moisture removal stations 17, the air which forms the high velocity air streams is first heated by suitable steam coils or a gas heater 31. Heated air is preferred because it can carry greater quantities of moisture. However, the temperature of the air should be kept below that which will cause an undesirable chemical or physical change in the material being dried, such as surface hardening. Also, the lower the temperature of the air, the fewer are the problems associated with insulating the air flow system from the surroundings. An air temperature of less than 225°F can be used to remove the moisture in accordance with the present invention. In the case where water is the predominant moisture being removed, air heated to a temperature of about 220°F is suitable. Higher air temperatures can be used where such temperatures are not detrimental to the material being dried.

The above-described invention can be conducted by various types of microwave applicator apparatus. However, FIGS. 2-4 illustrate a particularly unique apparatus in accordance with the present invention. More specifically, this embodiment of the present invention includes a conveyer means, such as driven rollers 32, for transporting material to be dried along a defined path so that the various functions necessary to accomplish the desired drying may be conducted at stations therealong. Each of the driven rollers 32 is journal mounted and supported at opposite ends by columnar members 33. The rollers 32 are driven by a suitable motor 34 coupled thereto by a link chain transmission system including driving sprocket 35, idler sprockets 36 and 37, driven sprockets 38, and link chains 39 and 40. The driven rollers 32 are particularly suited for transporting heavier materials such as wood sheets. However, other types of conveyer means such as, for example, belts and pull through conveyer means, can be employed to transport lighter wood, paper and textile materials.

To dry the materials transported by the conveyer, a folded waveguide structure 41 is employed. The folded waveguide structure 41 includes a plurality, such as eight, of straight slotted rectangular waveguide sections 42 positioned at locations spaced longitudinally along the path defined by the driven rollers 32. The waveguide sections 42 are intercoupled by mitered return bends 43 joined thereto by waveguide flanges 44 to define a serpentine path for microwave energy to flow through 45 and 47 for passing material through the waveguide sections 42 are provided in the opposite waveguide wide walls 45 and 50 orientated perpendicular to the path defined by the driven rollers 32. The folded waveguide structure 41 is supported by resting the opposite ends of its straight sections 42 on the horizontally orientated U-shaped channel members 48 and 49 that extend longitudinally of the path defined by the driven rollers 32. Suitable fastening means, for example, welds, bolts, clamps, etc., may be provided to fix the folded waveguide structure 41 to the U-shaped channel members 48 and 49.

The U-shaped channel members 48 and 49 also serve to support the columnar members 33 holding the driven rollers 32. The columnar members 33 are fastened to the U-shaped channel members 48 to support the driven rollers 32 in the space 51 between straight waveguide sections 42 with the uppermost extent of the driven rollers in a plane just above the plane defined by the lower edges 52 and 53 (See FIG. 2A) of the slots 46 and 47 in adjacent wide walls 45 and 50 of the straight waveguide sections 42. The U-shaped channel members 48 and 49 also serve to journal support the idler sprockets 36 and 37 associated with each of the driven rollers 32 subjacent the folded waveguide structure 41. This permits a single motor 34 to be coupled to drive all of the driven rollers 32. Power is coupled from the single motor 34 to all of the driven rollers 32 by the horizontally orientated link chain 39 driving each pair of idler sprockets 36 and 37 associated with each of the driven rollers 32. In turn, the idler sprockets 36 and 37 transmit power to the associated vertically-orientated link chains 40 to drive the driven sprockets 38 fixed to the driven rollers 32 located overhead.

During the drying operation, moisture-laden material such as wood is transported through each of the waveguide sections 42 by the operation of the driven rollers 32. The folded waveguide structure 41 is excited to propagate microwave energy by a microwave energy source 54 coupled at one end 56 thereof by the waveguide flange 57. To absorb the microwave energy
which is not dissipated, for example, in drying materials or when operating under no load conditions, and thereby prevent the generation of potentially damaging reflections, a microwave energy dissipating structure such as a water load 58 may be joined by a waveguide flange 59 to terminate the opposite end 61 of the folded waveguide structure 41. Preferably, the folded waveguide structure 41, microwave energy source 54 and water load 58 are constructed so that under loaded conditions, i.e., when material is being dried, the folded waveguide structure 41 operates as a traveling wave device.

The folded waveguide structure 41 is excited by source 54 to propagate dominant mode TE waves with its electric field component extending between the opposite waveguide wide walls 45 and 50. The slots 46 and 47 are located centrally in the wide walls 45 and 50 to be at the maximum electric field point of the propagating TE waves.

As moisture-laden material is subjected to microwave energy in each of the excited straight waveguide sections 42, moisture carried by the material is brought to the surfaces of the material, some of which adheres thereto. As explained hereinbefore, this adhering moisture is objectionable and should be removed. To remove the adhering moisture, high velocity streams of warm air are directed to impinge normal to opposite surfaces of the material lying in the plane of the waveguide slots 46 and 47. To form the high velocity streams of air, a plurality of, for example, nine vertically-oriented jet nozzles 62 are positioned at least in each space 68 between adjacent straight waveguide sections 42. The jet nozzles 62 between adjacent waveguide sections 42 are spaced far enough apart from adjacent waveguide sections so that moisture adhering to the surface of the material can be sufficiently removed by the high-velocity air streams, so that any moisture which may collect in the microwave waveguide sections 42 will not be sufficient to detectably reduce the rate of heating of the material. The jet nozzles 62 are disposed laterally of the path along which material is transported by the driven rollers 32 and are supported with the mouths 69 of the nozzles beneath the plane defined by the lower edges 52 and 53 of the waveguide slots 46 and 47. The jet nozzles 67 serve to free the objectionable moisture adhering to the lower surface of the material as it is transported by the driven rollers 32. For optimum effectiveness of removing the adhering moisture, the jet nozzles 67 of successive moisture removal stations having subjacent jet nozzles 67 in the same manner as are the jet nozzles 62 positioned above the path along which the material being dried is transported.

The high velocity air streams impart a rather large force to the material against which they are directed. These forces are large enough to damage or destroy materials, such as paper, which are unable to withstand large stresses. Hence, when drying such materials as paper and the like, the jet nozzles should be arranged on both sides of the material at each moisture removal station so that the destructive forces exerted thereon by the high velocity air streams on one side of the material is balanced by forces exerted on the material by the high velocity air streams on the opposite side. In the drier illustrated in FIGS. 2-4, the driven rollers 32 would be replaced by jet nozzles and the material such as paper would be conveyed through the alternately positioned microwave drying and moisture removal stations by a driven take-up roller located at one end of the drier.

The warm air forming the high velocity air streams is supplied at a selected head pressure by a centrifugal delivery pump 71 having internally located gas heating coils. An air plenum chamber 72 and air ducts 73 and 74 are provided to deliver the warm air from the pump 71 to the jet nozzles 62 and 67. The air plenum chamber 72 is a vertical casing positioned adjacent the metered return bends 43 to extend longitudinally along the travel of the material at one side of the folded waveguide structure 41. The top wall 76 of the air plenum chamber 72 is provided with an inlet port 77 for coupling the chamber 72 in gas flow communication with the delivery pump 71. The delivery pump 71 is supported at opposite sides thereof by brackets 78 and 79 secured to the top wall 76.

Warm air is distributed to the jet nozzles 67 lying beneath the path traveled by the material by the air duct 74. The air duct 74 is a horizontal casing positioned below the folded waveguide applicator 41 to extend laterally and longitudinally along the travel of the material. One end 81 of the air duct 74 opens into and is secured to the air plenum chamber 72 at the lower end of the plenum chamber wall 82 proximate the folded waveguide structure 41. The opposite end 83 of the air duct 74 is closed by a wall 84. The top wall 86 of the air duct 74 also supports the U-shaped channel members 48 and 49 that support the driven rollers 32 and folded waveguide structure 41. Suitable fastening means may be employed to secure the U-shaped channel members 48 and 49 in place.

The air duct 73 distributed the warm air to the jet nozzles 62 overlaying the path traveled by the material. The air duct 73 is a horizontal casing positioned above the folded waveguide structure 41 to extend laterally and longitudinally along the travel of the material. One end 87 of the air duct 74 opens into and is secured to the air plenum chamber 72 at the upper end of the
plenum chamber wall 82. The opposite end 88 of the air duct 74 is closed by a wall 89. The columnar members 33 which jointly support the driven rollers 32 extend upward to render additional support to the air duct 73 at its bottom wall 91.

All of the jet nozzles 62 overlying the path traveled by the material open into and are supported to depend from the air duct 73. Similarly, all of the jet nozzles 67 beneath the path traveled by the material open into and are supported to extend vertically upward from the air duct 74.

For most effective removal of the objectionable moisture freed from the material being dried, means are provided to direct the normally impinged air parallel the surface of the material at its surface. In the apparatus of the present invention, this is accomplished by exhausting the impinged air and entrained freed moisture at one side of the folded waveguide structure 41 to cause the impinged air to flow laterally of the travel of the material being dried. For most effective lateral air flow, the impinged air and entrained moisture is exhausted at the side 92 of the folded waveguide structure 41 opposite that at which the air plenum chamber 72 is located. Although the air plenum chamber 72 and air ducts 73 and 74 prevent the impinged air from exhausting directly through the top and bottom and the side opposite the exhaust side 92 of the folded waveguide structure 41, the impinged air could exhaust at the feed end 93 or discharge end 94 of the folded waveguide structure 41. To prevent the impinged air from exhausting at these locations, end walls 96 and 97 are placed across the feed end 93 and discharge end 94 respectively. At a location aligned with the waveguide slot 46 at the feed end 93 of the folded waveguide structure 41, the end wall 96 is provided with an opening 98 so that the material to be dried can be fed into the drier. The space between the opening 98 and the proximate waveguide section 42 is bridged with wall members 99 around the periphery of the opening 98. Similarly, the end wall 97 is provided with an opening 101 for withdrawing material from the drier which is aligned with the waveguide slot 47 at the discharge end 94 of the folded waveguide structure 41. The space between the opening 101 and the proximate waveguide structure 42 is bridged with wall members 102 around the periphery of the opening 101.

Although the impinged air may be exhausted directly to the surrounding atmosphere from the side 92 of the folded waveguide structure 41, the parallel air flow across the surface of the material being dried is considerably enhanced by establishing a negative pressure condition at the locations of the jet nozzles. To establish the negative pressure condition, and exhaust plenum 103 in the form of a vertical casing is positioned to extend longitudinally along the travel of the material at the side 92 of the folded waveguide structures 41 opposite the air plenum chamber 72. The exhaust plenum opens into the space between the air ducts 73 and 74 in which the folded waveguide structure is positioned. A centrifugal suction pump 104 supported by brackets 106 and 107 at the top wall 108 of the exhaust plenum 103 is coupled in air flow communication with the exhaust plenum 103 by the exhaust port 109. The centrifugal suction pump 104 establishes a negative pressure in the exhaust duct 103 and at the location of the jet nozzles 62 and 67 resulting in a tangential air flow along the upper and lower surfaces of the material being dried as it passes between the jet nozzles. The centrifugal suction pump 104 also serves to exhaust the waveguide sections 42 through their slots 46 and 47 thereby curbing the build-up of moisture in the waveguide sections 42.

To reduce the moisture content of ½ inch thick 1/2 x 5 feet boards of wood from 70 to about 5 percent, the rollers 32 are driven to transport four of the wood boards at the rate of 15 feet per minute. The microwave source 54 is operated at 915 Mc to deliver 10 Kw of power to eight slotted waveguide sections 42 measuring 9.75 x 2.44 inches with 1 inch wide, 4 ½ feet long slots 46 and 47. The centrifugal delivery and suction pumps 71 and 104 are operated to establish high velocity air streams which issue from the jet nozzles 62 and 67 at a velocity of about 8000 ft/min. To reduce the moisture level from 70 to about 5 percent, about 40 passes through the folded waveguide structure 41 including eight straight slotted rectangular waveguide sections 42 is required. However, a single pass through about 320 sections of the folded waveguide structure 41 will accomplish the same result.

While the present invention has been described in detail with respect to a particular embodiment, numerous modifications and variations are possible without departing from the scope of the present invention. Therefore, the present invention is not intended to be limited except as by the terms of the following claims.

What is claimed is:

1. Apparatus for treating material with microwave energy, said apparatus comprising means for moving said material along a predetermined path; a plurality of microwave devices located in spaced-apart relation with respect to each other along said path, each microwave device being adapted to subject said material to microwave energy as said material is moved along said path; a plurality of gas discharge devices disposed along said path at locations intermediate the locations of at least some of said microwave devices, each gas discharge device being spaced apart from the microwave device closest thereto, and each gas discharge device being adapted to direct a flow of gas to impinge upon said material as said material is moved along said path, the velocity of said gas being sufficient to break up and remove any moisture layer that may form on the surface of said material; and means for extracting the gas discharged by said gas discharge devices after said gas has impinged upon said material, said extraction means being adapted so that the gas directed onto said material at each of said intermediate locations is caused to flow across the surface of said material transversely to the path of said material before said gas is extracted, each gas discharge device being spaced far enough from each adjacent microwave device that moisture on the surface of said material can be sufficiently removed by the transverse gas stream so that the moisture which collects in each microwave device will not be sufficient to detectably reduce the rate of heating of said material.

2. Apparatus according to claim 1 wherein said microwave devices and said gas discharge devices are contained within a first walled structure which forms an exhaust conduit, and said first walled structure is contained within a second walled structure, the space between the walls of said first structure and said second structure forming a gas inlet plenum, said gas discharge devices being adapted to provide for entry of gas from
said plenum into said first walled structure for impingement upon the material to be treated; and said extraction means comprises means for creating a region at a location at an end of said exhaust conduit at a side of the path of the material to be treated, in which region the pressure is less than the pressure of the gas as said gas exits from said gas discharge devices, whereby said gas is drawn from said gas discharge devices into said region of lower pressure along a path adjacent the surface of said material to be treated and in a direction generally transverse to the path of travel of said material.

3. Apparatus according to claim 1 wherein said means for moving said material along said predetermined path comprises at least one roller adapted to come into contact with a first side of said material, said roller being located in one of said intermediate locations substantially in alignment with one of said gas discharge devices, the axis of said alignment being normal to the path of said material, said one discharge device providing for gas impingement upon a second side of said material whereby the pressure of the gas from said one gas discharge device forces said material into contact with said roller.

4. Apparatus according to claim 1 wherein said gas discharge devices comprise jet nozzles.

5. Apparatus according to claim 4 wherein said nozzles are disposed in sets, each set of nozzles being disposed transversely to the path of said material.