United States Patent [19]

Smith, Jr.

[11] **3,793,741**

[45] **Feb. 26, 1974**

[54] **DRYING APPARATUS WITH MOISTURE PROFILE CONTROL**

[75] Inventor: **Horace L. Smith, Jr.**, Richmond, Va.

[73] Assignee: **Smitheen Industries, Inc.**, Richmond, Va.

[22] Filed: **Jan. 7, 1972**

[21] Appl. No.: **216,046**

Related U.S. Application Data

[60] Continuation of Ser. No. 97,943, Dec. 14, 1970, abandoned, which is a division of Ser. No. 46,704, June 16, 1970, abandoned.

[52] **U.S. Cl.** **34/48**, 34/54, 34/68, 34/155

[51] **Int. Cl.** **F26b 19/00**

[58] **Field of Search** 34/23, 48, 54, 68, 152, 155, 34/162

[56] **References Cited**

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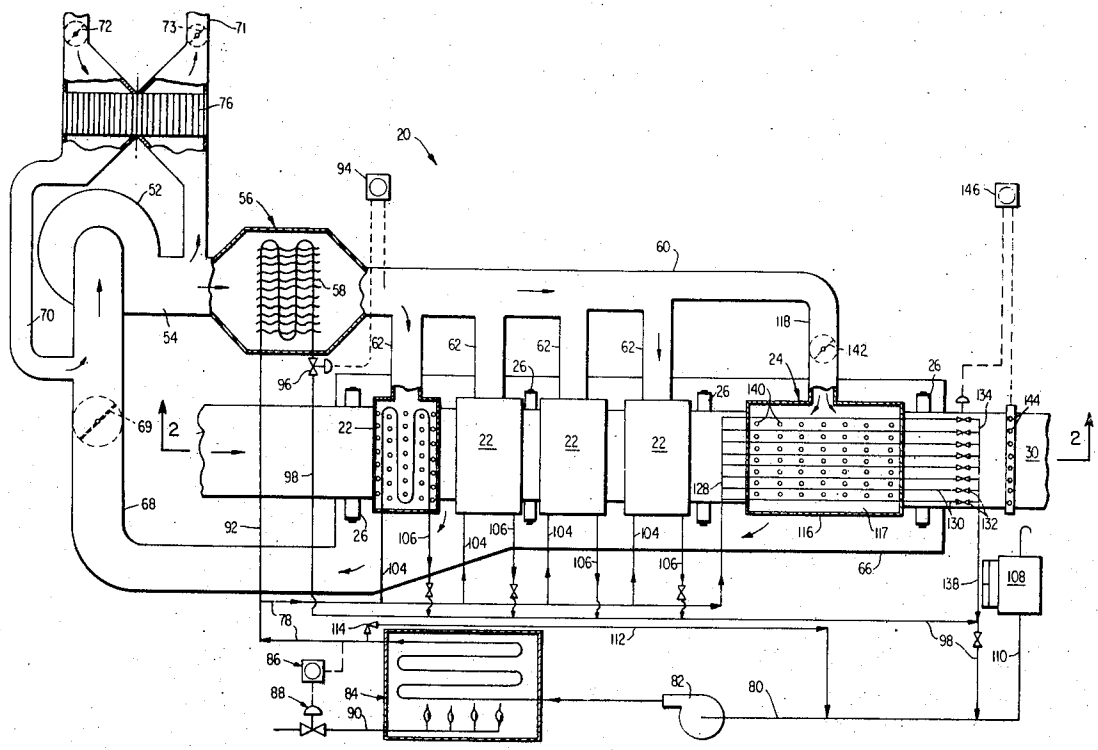
3,403,454	10/1968	Smith	34/68
3,403,456	10/1968	Smith	34/160

Primary Examiner—Carroll B. Dority, Jr.
Assistant Examiner—Larry I. Schwartz
Attorney, Agent, or Firm—Strauch, Nolan, Neale, Nies Kurz

[57] **ABSTRACT**

Apparatus for drying material in web, sheet, and similar forms by a combination of radiant and convective heating in which provision is made for controlling the moisture or other volatiles profile across the width of the material being dried.

17 Claims, 10 Drawing Figures



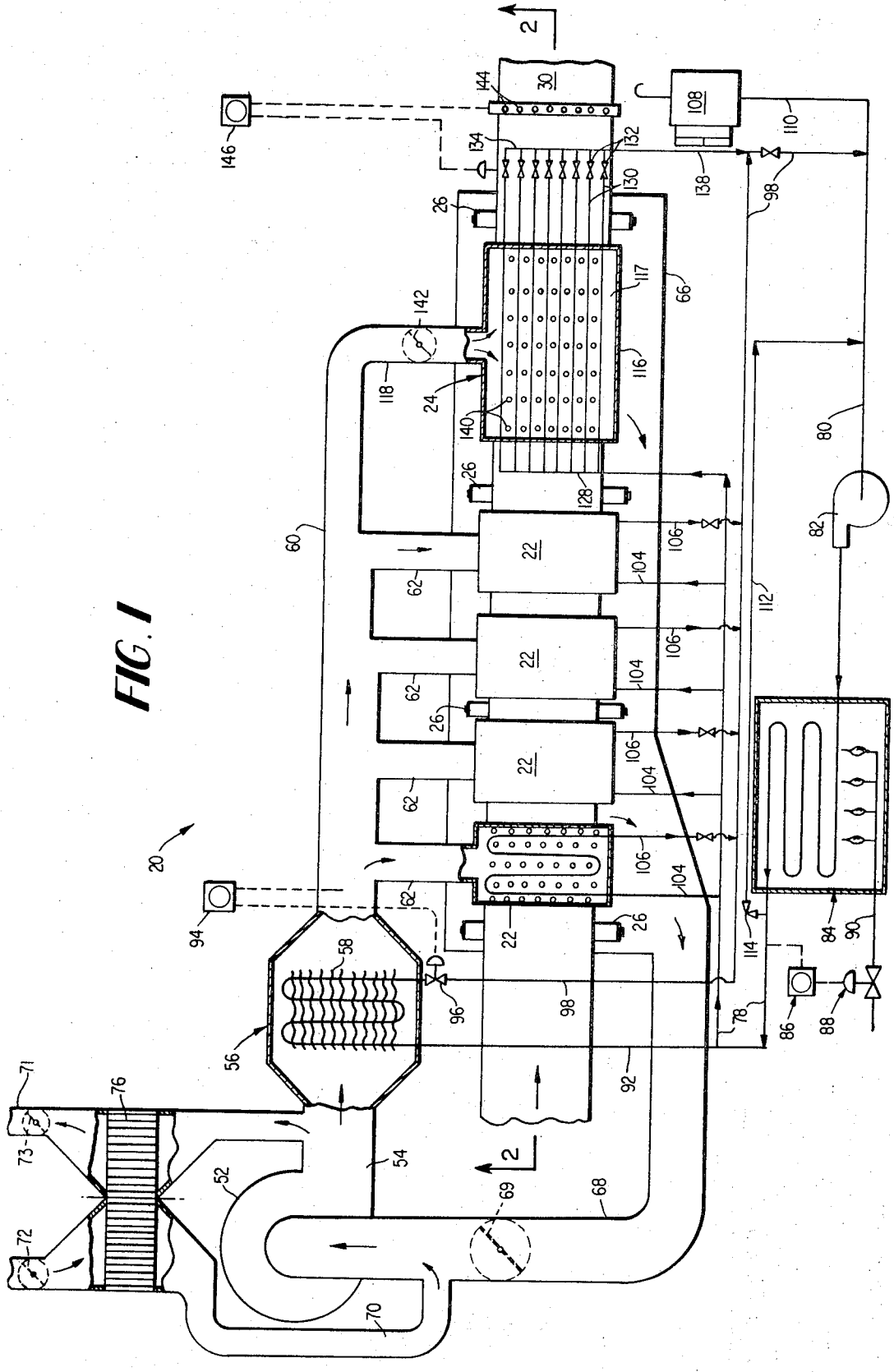


FIG. 1

FIG. 2

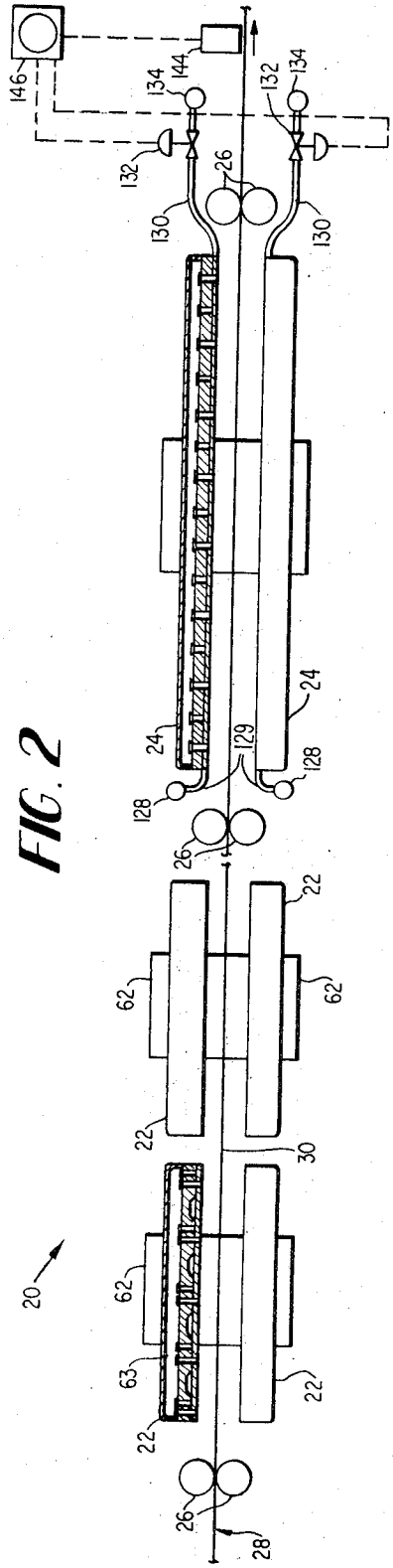

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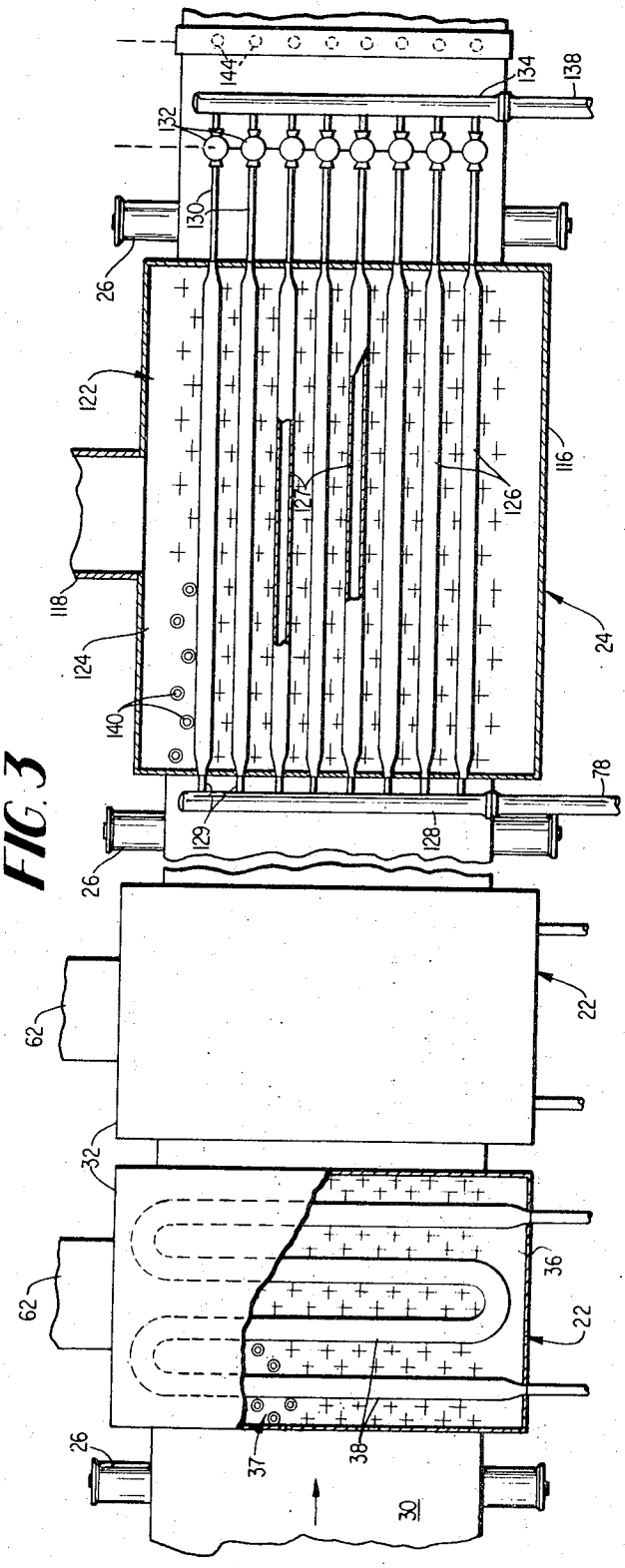
FIG. 3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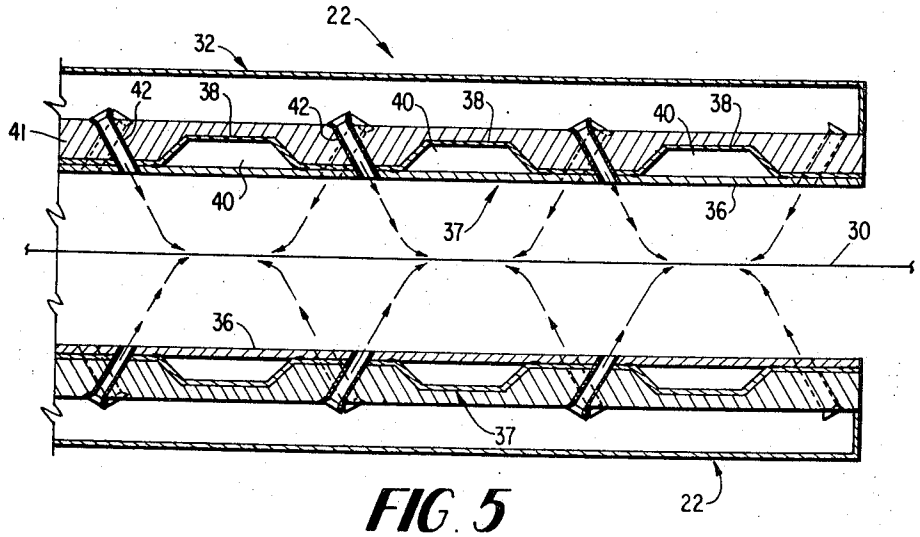
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FIG. 5

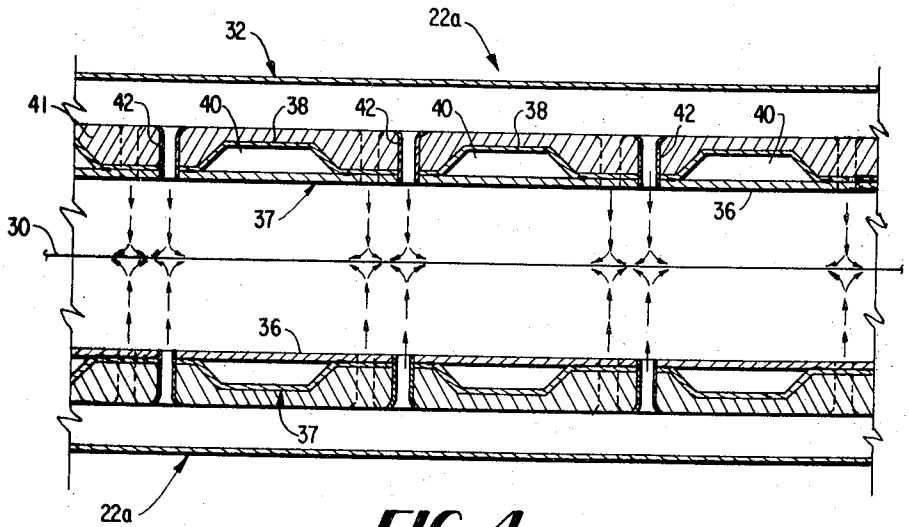
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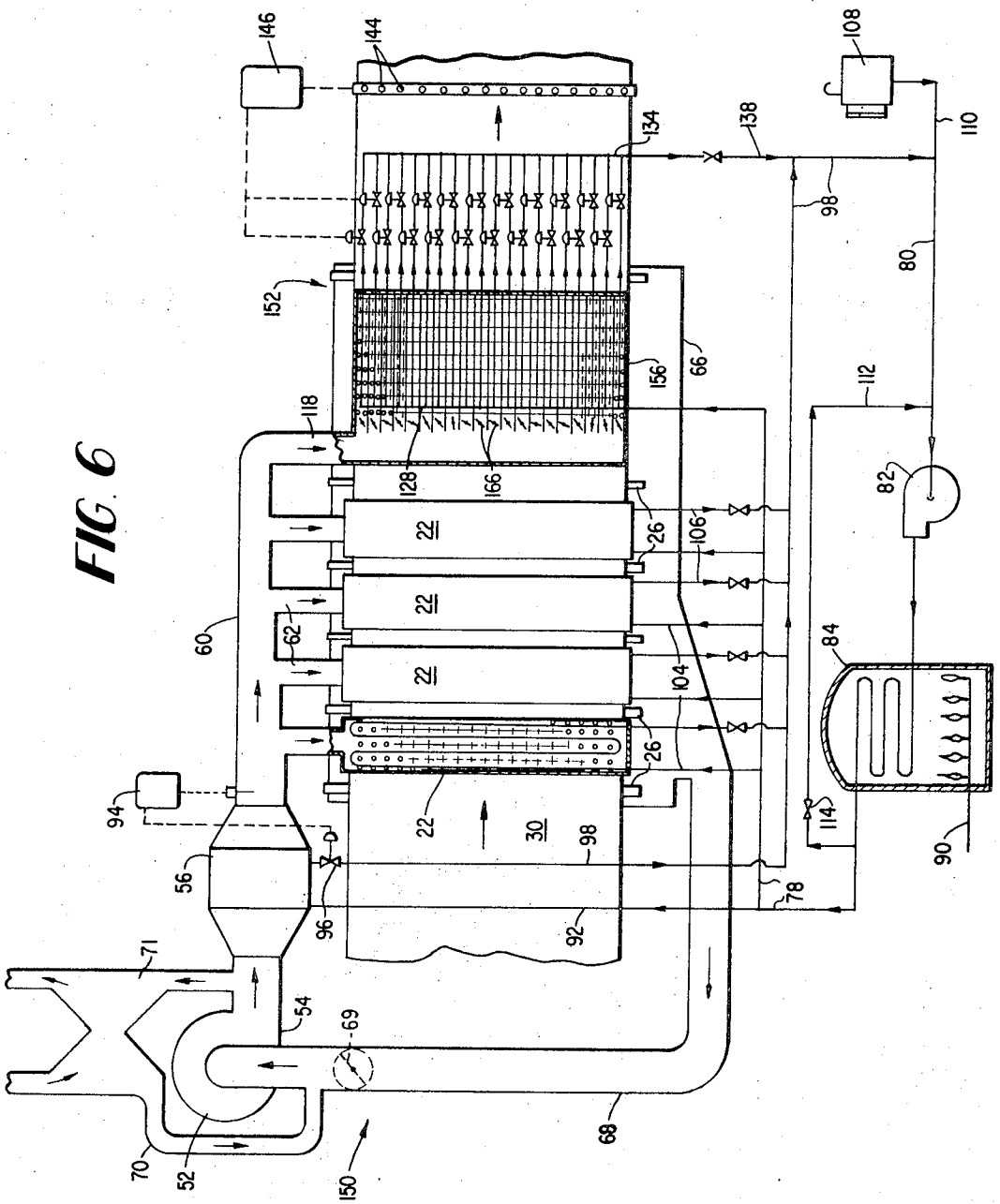
FIG. 4

FIG. 6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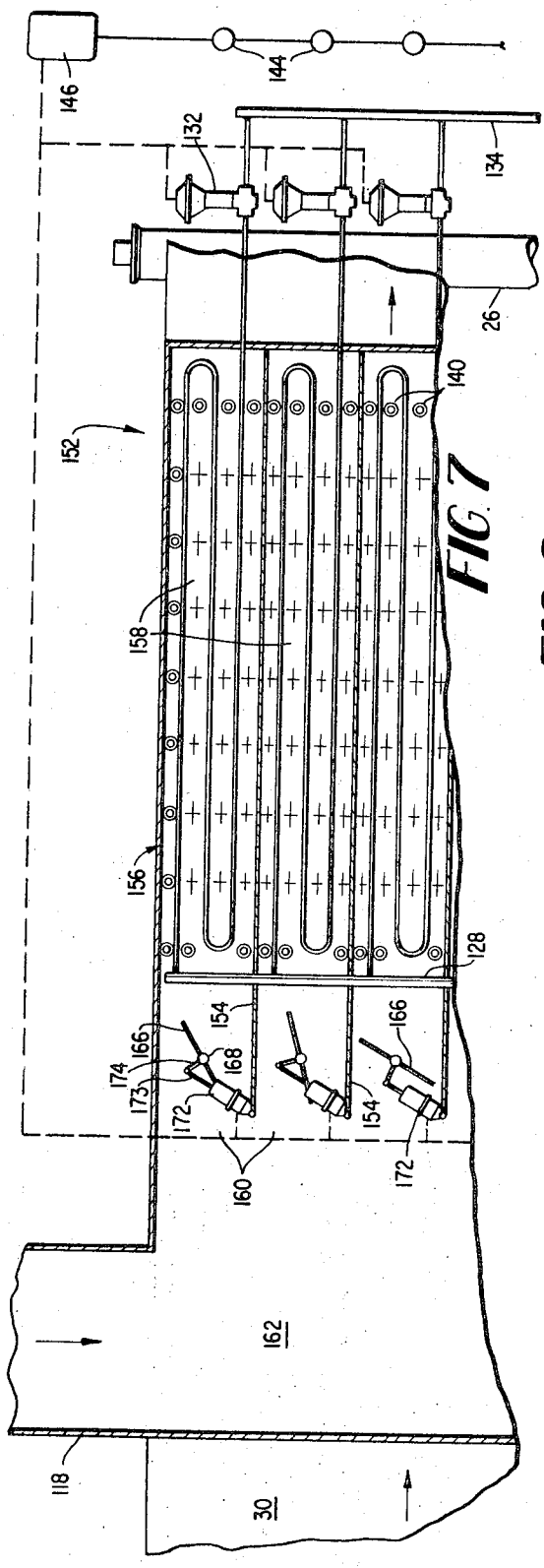
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FIG. 7

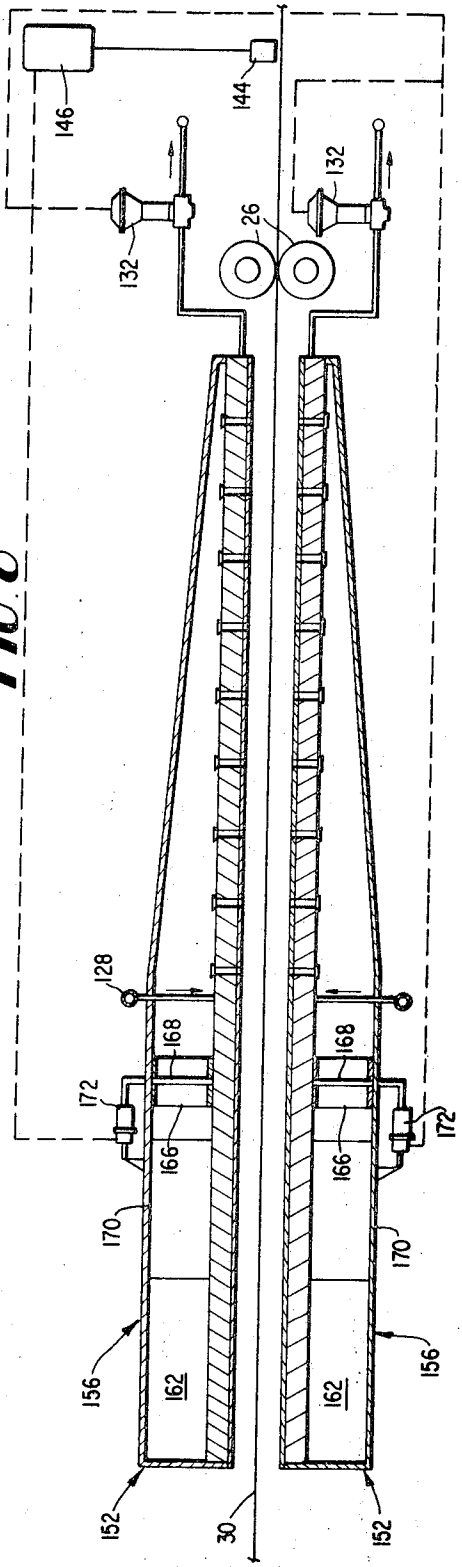
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FIG. 8

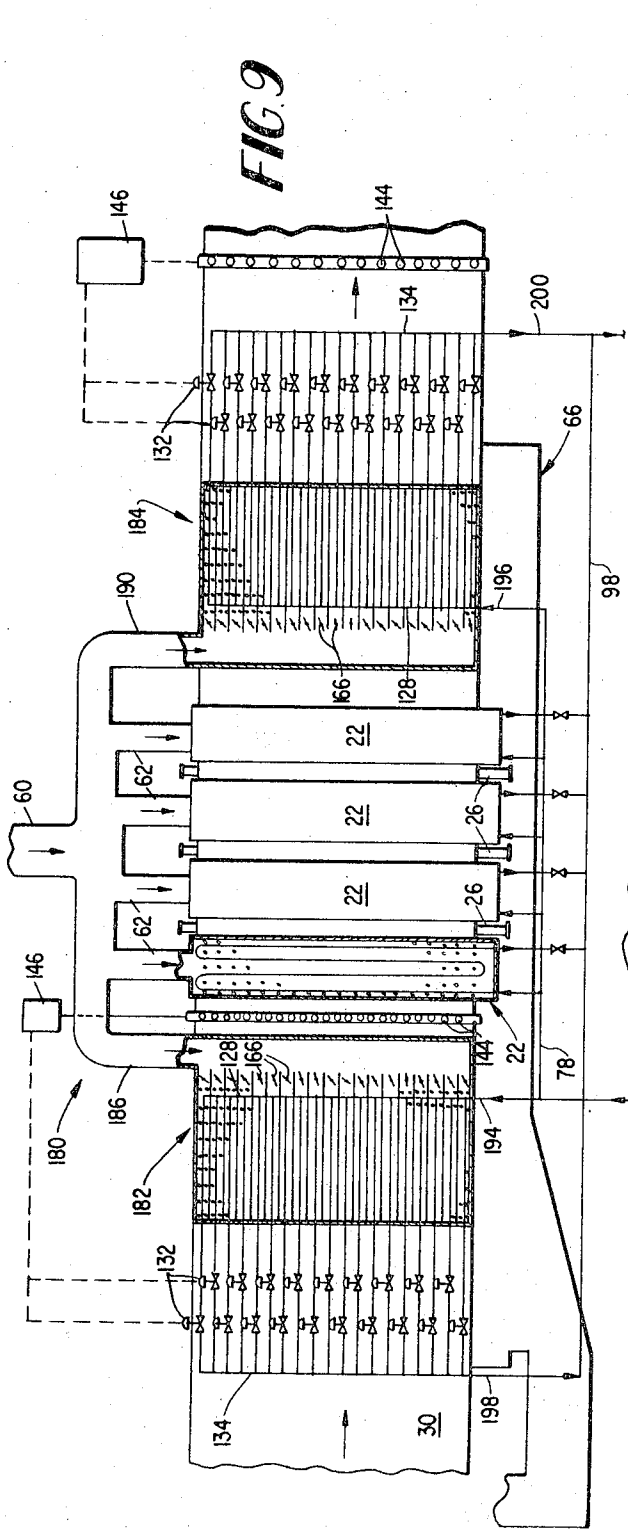
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FIG. 9

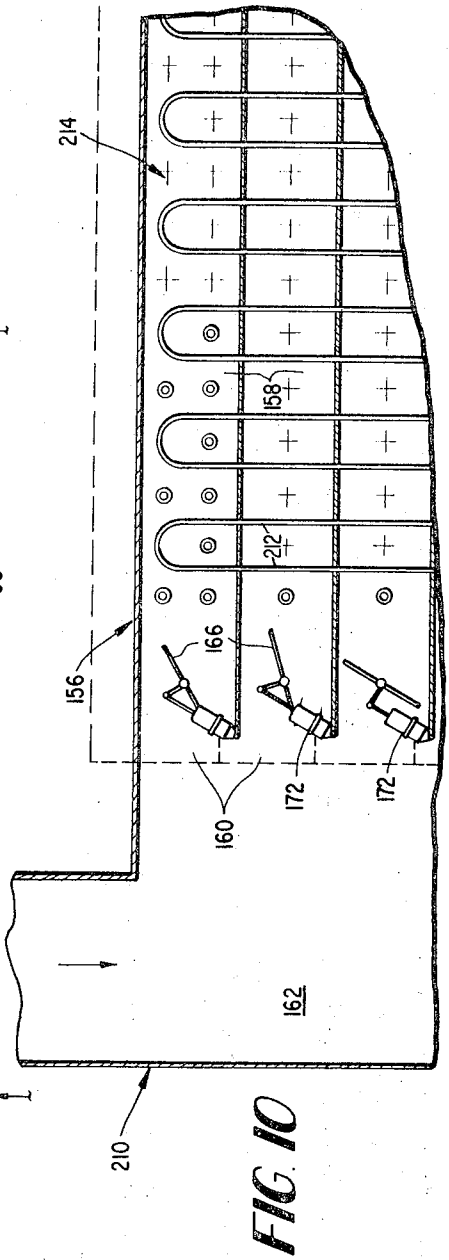
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FIG. 10

DRYING APPARATUS WITH MOISTURE PROFILE CONTROL

This application is a continuation of Application No. 97,943 filed Dec. 14, 1970 now abandoned, which is a division of Application No. 46,704 filed June 16, 1970 which is now abandoned.

This invention relates to drying and, more particularly, to the drying of materials in sheet, web, and similar configurations.

Paper, fiberboard, and other cellulosic products as well as other materials in web, sheet, and similar forms have, except in the immediate past, been dried almost exclusively on drum type dryers. In this method the material to be dried is successively moved over a large number of steam-heated, rotating rolls or cylinders arranged in one or more decks. The rolls transfer heat to the material being dried by conduction, causing evaporation of moisture or other volatiles from the web.

Such dryers have a number of disadvantages. One of these is that the surface temperature profiles of the rolls or cylinders are not uniform throughout their length but typically vary up to some 30° to 40° Fahrenheit. Also, the concentration of evolved volatiles adjacent the surfaces of the rolls will vary considerably throughout their length. As a result, there is uneven drying across the width of the material; and material dried on this conventional equipment therefore typically has a highly irregular moisture or volatiles profile. This is, of course, undesirable because of the resultant lack of uniformity in the dried product.

Another problem with an irregular volatiles profile is that this makes the material subject to breakage when it is in web form. When the web breaks, the system must be shut down and the broke removed from the dryer section. This downtime is enormously expensive in the case of modern, high-speed equipment in which the web may commonly be 30 feet wide.

In my previous U.S. Pat. Nos. 3,403,454 issued Oct. 1, 1968, for HEAT TREATING APPARATUS FOR WEB AND SHEET MATERIAL and 3,403,456 issued Oct. 1, 1968 for IMPINGEMENT TYPE DRYING APPARATUS, I disclose a novel drying technique in which uniform evolution of volatiles across the width of the material being dried is obtained by a combination of radiant heating and impinging air. Consequently, this novel drying technique eliminates one of the major causes of irregular volatiles profiles.

However, other major sources of an irregular profile in the dried product are not compensated for by the technique just discussed. These are attributable to factors such as an uneven concentration of pulp in papermaking and similar machines, unevenness of press rolls, and the like. (See in this regard, U.S. Pat. No. 3,089,252 issued May 14, 1963, to Daane for WEB MOISTURE PROFILE CONTROL FOR PAPER MACHINE.) The drying technique described in my issued patents does not satisfactorily eliminate such irregularities since it is designed to produce a fixed heat distribution pattern, and the profile irregularities attributable to the factors just discussed can vary considerably over a period of time as the product is formed.

I have now discovered that irregularities originating before the material to be dried enters the dryer or drying section can be corrected by adding to the dryer one or more radiant heating-fluid impingement units in which the distribution of radiant energy and/or impinging air in each of several narrow regions spanning the material being dried can be individually regulated. Consequently, the rate of evaporation in each of these regions can be matched to the concentration of volatiles in the material, resulting in a dried sheet, web, etc., with a substantially uniform volatiles profile.

The novel volatiles profile correcting units of the present invention may be located at either the wet or the dry end of the dryer section although the former location will in most cases be preferred. Also, in some applications, profile correction can be advantageously employed at both the wet and dry ends of the dryer section.

My novel volatiles profile correcting units can also be employed to advantage in conjunction with dryers other than those discussed above. Accordingly, in another aspect, the present invention provides novel, improved volatiles profile correcting units which can be employed to advantage with various types of dryers, either as "add-on" units or as integral dryer units.

Moisture profile control units have heretofore been proposed, those disclosed in the following U.S. Pat. being typical: No. 2,269,236 issued Jan. 6, 1942, to WELLMAR for METHOD AND DEVICE FOR CONTROLLING THE HEAT SUPPLY IN CELLULOSIC DRYERS: No. 2,837,830 issued June 10, 1958, to FRY for METHOD AND APPARATUS FOR DRYING FLEXIBLE SHEET MATERIAL; No. 3,052,991 issued Sept. 11, 1962, to GOLDNER for APPARATUS FOR UNIFORM ACCELERATED DRYING OF WEB MATERIAL; No. 3,161,482 issued Dec. 15, 1964, to GSCHWIND for FLUID DISTRIBUTING APPARATUS FOR MATERIAL TREATING; No. 3,167,408 issued Jan. 26, 1965 to JUSTUS for DRYER HOOD CONSTRUCTION FOR WEB MATERIAL; No. 3,214,845 issued Nov. 2, 1965, to HUFFMAN for MOISTURE MEASURING AND SELECTIVE DRYER CONTROL SYSTEM; No. 3,284,920 issued Nov. 15, 1966, to HAYRINEN for APPARATUS FOR DRYING WEB MATERIAL; No. 3,292,274 issued Dec. 20, 1966, to SETH for ARRANGEMENT IN A DRYER or A SIMILAR TREATMENT PLANT; and No. 3,293,770 issued Dec. 27, 1966 to RAUSKALB for WEB DRYING PERMITTING WIDTHWISE MOISTURE CONTROL.

However, these previously proposed moisture profile controls differ considerably from the profile correcting units I have invented, both in structure and in mode of operation. Furthermore, they do not possess the versatility or efficacy of the novel units described herein.

From the foregoing it will be apparent that the primary object of the present invention is the provision of novel, improved apparatus for drying material in sheet, web, and similar configurations.

Another important and related object of the invention resides in the provision of novel, improved drying apparatus in which provision is made for controlling the concentration of volatiles in the material being dried across its entire width.

Additional objects, other important features, and further advantages of the present invention will become apparent from the appended claims and as the ensuing detailed description and discussion proceeds in conjunction with the accompanying drawing, in which:

FIG. 1 is a generally diagrammatic plan view of drying apparatus incorporating the principles of the present invention;

FIG. 2 is a section through the apparatus of FIG. 1, taken substantially along line 2—2 of the latter Figure;

FIG. 3 is a fragment of FIG. 1 to an enlarged scale;

FIG. 4 is a fragmentary longitudinal section through a radiant heating-fluid impingement unit employed in the drying system of FIG. 1;

FIG. 5 is a fragmentary transverse section through a volatiles profile correcting unit employed in the drying system of FIG. 1;

FIG. 6 is a view similar to FIG. 1 of a second form of drying apparatus embodying the principles of the present invention;

FIG. 7 is a fragment of FIG. 6 to an enlarged scale;

FIG. 8 is a longitudinal section through a volatiles profile correcting unit employed in the drying system of FIG. 6;

FIG. 9 is a view similar to FIG. 1 of a third form of drying apparatus embodying the principles of the present invention; and

FIG. 10 is a plan view of yet another volatiles profile correcting unit embodying the principles of the present invention.

Referring now to the drawing, FIGS. 1–3 depict a single pass dryer **20** having fluid impingement and radiant heating units **22** for drying the product to be treated and a novel unit **24** for correcting the volatiles profile across the width of the product, which is constructed in accord with the principles of the present invention. Dryer **20** also includes a series of parallel, spaced apart, rotatably mounted rolls **26** establishing a path **28** for the product or material being dried which is in the form of a web **30.** (Dryer **20** will typically also include endless, open mesh belts or felts for confining and preventing warpage of web **30** together with idler and drive rolls for supporting and effecting movement of the felts. For convenience and clarity, these components have not been shown.) Except as discussed below the dryer components are of conventional construction and will not be described further herein.

As shown in FIG. **2,** units **22** are located between adjacent rolls **26** and on both sides of path **28** to dry web **30** by simultaneously applying radiant heat to both sides of the web to evolve volatiles from it. Units **22** also direct air or other treating fluid at high velocity into contact with the upper and lower surfaces of the web to assist in evolving the volatiles and to scour evolved volatiles from adjacent its surfaces. The high velocity fluid thus prevents a retardation of the drying process by eliminating the formation of a stagnant layer adjacent the web and, in addition, causes evaporative cooling adjacent the surfaces of the material being treated and thereby prevents it from being overheated. It is preferred that the treating fluid also be heated since a hot, high velocity fluid such as air is a highly effective drying agent.

Referring now to FIGS. **1–5,** each of the radiant heating-fluid impingement units **22** incorporated in dryer **20** includes a casing **32** having an open side which faces downwardly in the case of the units above path **28** and upwardly in the case of those below the path. The open side of each casing **32** is closed by the radiant energy emitting plate **36** of a radiant heater **37** incorporated in each unit **22.** Plates **36** are fabricated of a material which is a good thermal conductor and has a relatively high coefficient of emission. One satisfactory material of this sort is sheet steel.

Sealed to the rear or inner side of each radiant energy emitting plate **36** as by welding are members **38** providing interconnected fluid flow channels **40** disposed in parallel, spaced relationship and extending at right angles to the path **28** of web **30** through the drying apparatus. (As an alternate, properly configured tubing may be fixed to the inner sides of plates **36** to provide the flow channels as disclosed in my U.S. Pat. No. 3,403,454, for example.) A heat transfer liquid is circulated through channels **40** as will be described hereinafter in more detail. This fluid heates plates **36,** causing them to radiate energy in the infrared portion of the electromagnetic spectrum. (To increase the emissivity of plates **36,** the surfaces of the plates facing the path **28** of web **30** may be coated with a material having a high coeffectient of emission. A number coatings suitable for this purpose are described in my U.S. Pat. No. 3,262,494 issued July 26, 1966, for HEAT EXCHANGERS.) As best shown in FIGS. **4** and **5,** channels **40** are covered with insulation **41** to prevent the dissipation of sensible heat.

Disposed between each of the channels **40** are fluid flow nozzles **42,** which communicate at their inlet ends with the interior of casing **32.** The outlets of nozzles **42** extend through radiant plates **36** and are flush with the surfaces of the latter facing web **30.**

Referring now to FIGS. **3–5,** there will typically be two rows of nozzles **42** between the channels **40** of the radiant heater in each of the radiant heating-fluid impingement units **22.** However, the number of nozzles in each row and the number of rows are not critical and will vary for different applications of the invention.

Nozzles **42** may be oriented normally to the path **28** of web **30** as shown in FIG. **4.** However, it is preferred that they be inclined at an angle to the web as shown in FIG. **5** in which the radiant heating-fluid impingement unit is identified by reference character **22*a***. This gives the air or other gas flowing through the nozzles a velocity and pressure distribution pattern which results in minimization of flutter of the web as it moves at high speed through the radiant heating-fluid impingement unit. Also, the inclined nozzle arrangement virtually eliminates areas in which the flow velocities are too low to produce the desired scouring effect. (To further promote the scouring effect of the air or other fluid flowing through nozzles **42,** the nozzles in one of the two rows between adjacent radiant heater flow channels may be inclined in the direction of movement of web **30** and those in the other row inclined in the opposite direction.) This is important since it produces uniformity of treatment.

Referring next to FIG. **1,** the treating fluid is supplied to units **22** by a blower **52** connected through a duct **54** to a fluid heater **56.** As it flows through the fluid heater, the treating fluid is heated by a heat exchanger **58.** From heater **56,** the fluid flows through main supply duct **60** and branch supply ducts **62** to plenum chambers **63** in the casings of units **22.**

From plenum chambers **63** the fluid flows through nozzles **42** and impinges on web **30** to assist in evolving volatiles and to scour them away from the surface of the web as described above. The spent fluid, together with its burden of evolved volatiles, flows from adjacent web **30** into an exhaust plenum **66.** (Because a volatiles profile correcting unit is employed in dryer **20,**

the relatively sophisticated arrangement of exhaust plenums and ducts employed in the dryers described in my U.S. Pat. Nos. 3,403,454, and 3,403,456 to promote uniform drying across the width of the material is not necessary. Accordingly, the provision of a profile correcting unit makes it possible to simplify the exhaust system and thereby reduces the cost of the dryer or drying section.) extending along one side of dryer **20** and then through return duct **68** to blower **52**. A valve or damper **69** in duct **68** may be adjusted to control the rate of flow of fluid through the closed circulation system just described.

In many applications of the present invention the percentage of moisture or other volatiles in the treating fluid must be closely controlled to produce the desired characteristics in the treated product. To permit such control return duct **68** is provided with a make-up duct **70**; and a vent duct **71** branches from the duct **54** between blower **52** and fluid heater **56**. Valves **72** and **73** control the flow through make-up and vent ducts **70** and **71**, respectively. By adjusting valves **72** and **73**, recirculated fluid can be discharged from the system and replaced with fluid having a lower content of volatiles to maintain the concentration of volatiles in the fluid delivered to units **22** at the desired level. Valves **72** and **73** may be adjusted manually or, if desired, may be automatically adjusted by controllers of any suitable type or by a system of the type described in my U.S. Pat. No. 3,208 158 issued Sept. 28, 1965, for DRYRES.

An economizer **76** of conventional construction may be connected between the vent and make-up ducts to extract sensible heat from the vented fluid and add it to the make-up fluid. This recovers otherwise wasted heat, increasing the efficiency of the drying system.

Referring still to FIG. **1**, the heat exchanger **58** in fluid heating unit **56** as well as the radiant heaters **37** in radiant heating-fluid impingement units **22** are of the type through which a heated fluid heat transfer medium is circulated to elevate them to the desired temperature. The preferred heat transfer mediums are high boiling point organic liquids and eutectic mixtures of inorganic salts, which can be circulated at extremely high temperatures in liquid form. Suitable media of this type are discussed in detail in my U.S. Pat. No. 3,262,494.

The system illustrated in FIG. **1** for heating and circulating the liquid heat transfer medium includes a storage tank (not shown) from which the liquid can be pumped to the main circulation system. This includes main supply and return conduits **78** and **80** and is a closed loop through which the liquid is circulated by a pump **82**.

From main return conduit **80** the heat transfer liquid flows into a liquid heating unit **84** where it is heated to the desired temperature. This unit may be of any desired construction and preferably includes a temperature responsive controller **86** which so regulates the flow of fuel to the burner or burners in the heating unit through valve **88** and conduit **90** as to maintain the temperature of the heated liquid flowing into main supply conduit **78** substantially constant.

From main supply conduit **78**, part of the heated liquid flows through branch supply conduit **92** to the heat exchanger **58** in fluid heater **56**. The volume of flow through conduit **92** is controlled by temperature responsive controller **94**, which is connected to a valve **96** in conduit **92**, and has a sensor (not shown) in supply duct **60**. Controller **94** regulates valve **96** so as to maintain the temperature of the treating fluid flowing into the supply trunk substantially constant.

From fluid heating unit **56**, the heat transfer liquid flows through return conduit **98** back into the main return conduit **80**.

Another portion of the heat transfer liquid flowing through main supply conduit **78** is diverted through supply conduits **104** to the radiant heaters **37** in radiant heating-fluid impingement units **22** of dryer **20**. From heaters **37** to the heat transfer liquid flows through conduit **106** and return conduits **98** and **80** back to heating unit **84**.

The heat transfer liquid circulation system also includes an expansion tank **108** connected by branch conduit **110** to main return conduit **98** and a bypass conduit **112** connected between supply conduit **78** and return conduit **80**. A pressure relief valve **114** in bypass conduit **112** insures continued flow under abnormal conditions such as conduit blockage and therefore prevents such abnormal conditions from causing damage to the system.

Further details and the advantages of the foregoing heating and circulating system are described in my U.S. Pat. No. 3,236,292 issued Feb. 22, 1966, for DRYERS, for example.

Drying apparatus of the type described above is very efficient and is highly effective in providing uniformity of drying. However, as discussed above, I have now discovered that even greater uniformity in the dried product can be accomplished by incorporating in the drying section an additional unit capable of correcting the volatiles profile across the width of the material being dried.

Referring now to FIGS. **1** and **3**, the novel units **24** incorporated in dryer **20** to correct the volatiles profile of web **30** are disposed both above and below the path **28** of web **30** in series with radiant heating-fluid impingement units **22** as best shown in FIG. **2**. Each of the units **24** includes a casing **116** defining a plenum chamber **117**, which is connected by a branch supply duct **118** to the main impingement fluid supply duct **60**. Spent fluid is returned through exhaust plenum **66** to main fluid return duct **68**. The sides of casings **116** facing web **30** are closed by a radiant heater **122** including a radiant energy emitting plate **124** spanning the open side of the casing and a plurality of channel defining members **126** sealed as by welding to the interior or back side of the radiant energy emitting plate. As best shown in FIG. **3**, members **126** provide a plurality of parallel, spaced apart flow channels **127** extending in the same direction as path **28** of web **30**. At one end, the flow channels are connected in parallel to an inlet header **128** by conduit **129**. At the opposite end, the flow channels are connected by conduits **130**, in which flow control valves **132** are interposed, to an outlet header **134**. The radiant heater is preferably insulated in the same manner as the radiant heaters **37** in radiant heating-fluid impingement units **22**.

Referring now specifically to FIG. **1**, inlet header **128** is connected to the liquid heat transfer medium supply line **78**. The outlet header is connected by conduit **138** to branch return conduit **98**.

As in the case of the radiant heating units **37** incorporated in radiant heating-fluid impingement units **22**, the radiant energy emitting plates **124** may be covered with a high emissivity coating to incarease the absorption of

energy from liquid flowing through channels **127** and to increase the emissivity of the plates.

Also included in the volatiles profile correcting units **24** are nozzles **140,** a row of such nozzles being disposed between each of the flow channel defining members **126.** These nozzles may be of the type described above in conjunction with units **22.**

It will be apparent from the foregoing that unit **24** also contributes to the evolution of volatiles from web **30** by a combination of radiant energy and impinging gaseous fluid, the flow of the latter being controlled by a valve or damper **142** in supply duct **118.** The rate of evolution of volatiles from different lateral regions of web **30** can be made different and proportioned to the concentration of the volatiles in the different regions of the material by independently adjusting the valves **132,** which control the flow of heat transfer liquid through the different flow channels **127.**

As the rate-of-flow of the heat transfer liquid through a channel is decreased, the temperature of that portion of the radiant energy emitting plate **124** contacted by the fluid and the adjacent portions drops, decreasing the amount of energy emitted from such portion of the plate and impinging on the part of web **30** thereopposite. Therefore, by reducing the flow of heat transfer liquid through the channels opposite the drier parts of the web, the rate of evolution of volatiles from such parts of the web may be decreased without lowering the rate of evolution of volatiles from those parts of the web having a higher concentration of volatiles. By thus varying the rate of drying across the width of the material, it can be so dried that it will have a uniform moisture or other volatiles profile across its width.

The regulation of valves **132** may be accomplished manually or automatically, if desired. One suitable automatic control system, shown schematically in FIGS. **1** and **3,** includes a moisture or other volatiles sensor **144** for each of the flow control valves **132.** One example of a suitable sensing arrangement is described in TAPPI 52, Feb. 1969, pages 276–278. Another suitable system is described in PLYWOOD AND PANEL, Mar. 1969, page 11. Volatiles sensors **144** are connected to a conventional programmed controller **146,** which in turn is connected to valves **132** to adjust the valves so as to proportion the flow rate through the associated channel to the volatiles concentration in the region of the web opposite the conduit.

A number of variations may be made in the arrangement of the volatiles profile correcting unit without departing from the scope of the present invention. For example, the profile may be corrected by varying the distribution of the impinging fluid across the width of the material being dried rather than controlling the lateral distribution of the radiant energy as in the embodiment of the invention just described. Or, if desired, the lateral distribution of both the impinging fluid and radiant energy may be proportioned to the volatiles concentration in the material. An arrangement for controlling the lateral distribution of the impinging fluid or radiant energy or both is illustrated in FIGS. **6–8.**[7]

Referring now to the Figures just mentioned, the drying section **150** illustrated in FIG. **6** is identical to the drying section **20** described previously except for the details of the profile correcting arrangement **152** employed in the latter. This unit differs from the unit **24** discussed above primarily by inclusion of an arrangement for independently regulating the flow of the impinging fluid through a number of channels or ducts disposed in side-by-side relationship in the unit. More particularly, in profile correcting unit **152** vertical, longitudinally extending partitions **154** divide the interior of casing **156** into a plurality of side-by-side channels **158** extending in the same direction as web path **28.** The inlet ends **160** of channels **158** communicate with a plenum **162** at the inlet end of casing **156.** Plenum **162** is supplied with impinging fluid through supply duct **118.**

As best shown in FIG. **8,** a flow controlling valve or damper **166** is rotatably supported in the inlet end of each channel **158** by a vertical pivot member **168** which extends upwardly through the top wall **170** of casing **156.** Dampers **166** are adjusted by motors **172** having piston rods **173** pivotally connected to cranks **174.** These cranks are fixed to the shafts **168** on which the dampers are mounted. Motors **172** are actuated to adjust the positions of dampers **166** by a control system which may be substantially identical to that described above in conjunction with the embodiment of FIGS. **1–5.**

Profile correcting unit **152** also differs from the unit **24** described above in that the outer casing wall **170** is inclined from the horizontal so that the flow channels **158** for the impinging fluid are tapered, decreasing in depth from their inlet to their outlet ends. This arrangement provides a uniform longitudinal pressure distribution profile in the flow channels.

As indicated above, the lateral distribution of radiant energy or impinging fluid or both can be regulated in unit **152** to correct the moisture or other volatiles profile of web **30.** The lateral distribution of radiant energy is regulated by adjusting valves **132** to control the flow of heat transfer liquid through channels **127** as described above. The lateral distribution of impinging fluid is regulated by the adjustment of dampers **166.** Either valves **132** or dampers **166** or both may be employed, depending upon the application of the dryer section. Typically, one controller will be used to adjust both valves **132** and dampers **166.** However, if desired, two controllers may be used so that the valves and dampers can be separately or independently regulated.

Another variation which may be made within the scope of the present invention is the location of the profile correcting unit. As discussed above, in many applications of the present invention, variations in the volatiles profile across the width of the material being dried will occur in the wet end of the machine as opposed to the dryer section. In such applications, it may prove advantageous to locate the profile correcting unit at the wet end rather than the dry end of the dryer section. Also, in some applications, it may prove advantageous to locate one profile correcting unit at the wet end of the dryer section and a similar unit at the dry end to provide a final correction in the profile of the material being dried. An arrangement of the latter type is shown in FIG. **9** in which the reference characters employed are the same as those utilized earlier except to the extent that the components of the several embodiments of the invention are different.

Referring now to the FIGS. just mentioned, the dryer section **180** illustrated in FIG. **9** includes a first profile correcting unit **182** located at the wet end of the section ahead of radiant heating-fluid impingement units **22** and a second profile correcting unit **184** located at

the dry end of the section after units **22.** These units may be of the type shown in FIG. **1,** in which only the distribution of radiant energy laterally of the material being dried is controlled or of the type shown in FIG. **6** in which the distribution of radiant energy or of impinging fluid or both may be controlled. Unit **182** is connected to fluid supply duct **60** by branch supply duct **186.** Unit **184** is similarly connected to the main supply duct by branch supply duct **190.** The radiant heating units of the two profile correcting units are connected to heat transfer liquid supply conduit **78** by branch conduits **194** and **196** and to return conduit **98** by branch conduits **198** and **200.** In this arrangement either unit **182** or **184** or both of these units may be employed, as appropriate, to provide a uniform volatiles profile across the width of the material being dried.

FIG. **10** shows yet another form of volatiles profile correcting unit **210** constructed in accord with the principles of the present invention. This unit is similar to that illustrated in FIG. **6** and discussed above, differing only in that the channels **212** for the heat transfer liquid in radiant heating unit **214** extend laterally across the width of the material being dried, and no provision is made for individually regulating the flow of heat transfer liquid through these channels. That is, in unit **210** volatiles profile correction is obtained solely by varying the lateral distribution of the impinging fluid across the width of the material being dried. This unit has the advantage of extreme simplicity. Also, the back-and-forth, serpentine arrangment of the channels in radiant heater **214** provides a uniform average temperature across the web, and, at the same time, a high temperature gradient from the inlet to the outlet of the channel system. Thus, this particular arrangement provides both uniform drying across the web and efficient utilization of the sensible heat in the heat transfer liquid.

Units of the type illustrated in FIG. **10** may be located at either the wet end or the dry end of a dryer or dryer section. Alternatively, such units may be employed at both ends of the dryer or dryer section as shown in FIG. **9** or may be employed at one such end with one of the types of profile correcting units described earlier being employed at the other end.

Still other modifications may be made in the structure discussed above without exceeding the scope of the present invention. For example, the temperature of the impinging fluid or heat transfer liquid supplied to the profile correcting unit may be varied rather than the volume rate-of-flow. Such variations are of course intended to be covered by the appended claims to the extent they are not expressly excluded therefrom.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by Letters Patent is:

1. A unit for correcting the volatiles profile across the width of material being dried comprising a plurality of radiant heater means disposed in side-by-side relationship and adapted to laterally span and emit radiant energy onto the material being dried; control means for independently regulating the amount of radiant energy emitted from each of said radiant heater means; a plurality of gaseous fluid supply means disposed in side-by-side relationship and adapated to also laterally span the material being dried; means operable concomitantly with the operation of the radiant heater means for so directing a gaseous fluid from the plurality of supply means onto that portion of the material being dried by the impingement of radiant energy thereon as to scour away from the material volatiles evolved therefrom; and control means for individually regulating the amount of fluid directed from each said supply means onto the material being dried.

2. A unit for correcting the volatiles profile across the width of material being dried comprising casing means; radiant heating means disposed in said casing means, said radiant heating means comprising a plurality of fluid conduit means disposed in side-by-side relationship and an independently regulatable valve means for controlling the flow of fluid through each of said conduit means; means providing in said casing means a plurality of duct means disposed in side-by-side relationship and extending in the same direction as the fluid conduit means; an independently adjustable valve means for regulating the flow of gaseous fluid through each of said duct means; and means for directing fluid from each of said duct means toward the material being dried.

3. The profile correcting unit of claim **2,** wherein there is a one-to-one correspondence between the number of the fluid conduit means and the duct means for the gaseous fluid and including control means which comprises a signal generating concentration-of-volatiles sensor for each conduit means and the associated duct means and a controller responsive to the signals generated by said sensors, said controller being operatively connected to the valve means associated with the conduit means and to the valve means associated with the duct means and said controller being adjustable to control the valve means associated with the conduit means or the valve means associated with the duct means or both the valve means associated with the conduit means and the valve means associated with the duct means.

4. The apparatus of claim **19,** wherein the means for directing the fluid from said duct means toward the material being dried comprises nozzles having inlets in each said duct means and extending through the duct means to the exterior thereof, said nozzles being inclined from the vertical toward the sides of the duct means, part of the nozzles associated with each duct means being inclined toward one side of the duct means and the remainder of such nozzles being inclined toward the opposite side of the duct means.

5. Apparatus for drying materials in web, sheet, and similar forms comprising a material support means for establishing a path for the material to be dried; at least one radiant heating-fluid impingement unit disposed adjacent said path, each said unit comprising radiant heating means for directing radiant energy against said material to evolve volatiles therefrom and means for so directing a gaseous fluid against that portion of said material against which the radiant energy is directed as to scour evolved volatiles away from said material; and means disposed adjacent said path in series with said radiant heating-fluid impingement unit or units for cor-

recting the volatiles profile across the width of the material being dried by individually regulating the rate of evolution of volatiles from successive lateral portions of said material, said profile correcting means comprising radiant heating means which includes a plurality of conduit means disposed in side-by-side relationship and extending in the direction of said path; means for effecting a flow of a heat transfer fluid through each said conduit means; and means for individually regulating the flow of heat transfer fluid through each said conduit means and thereby controlling the intensity of the radiant energy directed onto the portion of the material opposite the conduit means; said profile correcting means further including a plurality of duct means disposed in side-by-side relationship adjacent and extending in the same direction as said path; means operable concomitantly with the direction of radiant energy onto the material for effecting a flow of gaseous fluid through said duct means toward the material being dried; and means for individually regulating the flow of fluid through each of said duct means and thereby controlling the rate of impingement of the fluid on the portion of the material opposite the duct means.

6. Apparatus for drying material in web, sheet, and similar forms, comprising material support means for establishing a path for the material to be dried; radiant heating means adjacent said path for directing radiant energy against said material to evolve volatiles therefrom, said radiant heating means comprising a plurality of conduit means disposed in side-by-side relationship and extending in the direction of said path and means for effecting a flow of a heat transfer fluid through each said conduit means; means for so directing a flow of a gaseous fluid against that portion of said material onto which the radiant energy is directed as to scour evolved volatiles away from the surface of the material against which the radiant energy is directed, said means comprising a plurality of duct means disposed in side-by-side relationship adjacent and extending in the same direction as said path, means operable concomitantly with the direction of radiant energy onto the material for effecting a flow of gaseous fluid through each said duct means, and means for directing said fluid from each said duct means toward the material being dried; and means for controlling the volatiles profile across the width of the material being dried by individually regulating the rate of evolution of volatiles from successive lateral portions of the material being dried, comprising means for individually regulating the flow of heat transfer fluid through each said conduit means and thereby controlling the intensity of the radiant energy directed onto the lateral portion of the material opposite the conduit means and means for individually regulating the flow of fluid through each of said duct means and thereby controlling the rate of impingement of the fluid on the lateral portion of the material opposite the duct means.

7. Apparatus for drying materials in web, sheet, and similar forms comprising a material support means for establishing a path for the material to be dried; at least one radiant heating-fluid impingement unit disposed adjacent said path, each such unit comprising radiant heating means for directing radiant energy against said material to evolve volatiles therefrom and means for so directing a gaseous fluid against said material as to assist in evolving volatiles therefrom and as to scour evolved volatiles away from the material; and means disposed adjacent said path in series with said radiant heating-fluid impingement unit or units for correcting the volatiles profile across the width of the material being dried by individually regulating the rate of evolution of volatiles from successive lateral portions of the material being dried, said profile correcting means comprising radiant heating means which includes inlet and outlet header means at first and second locations along and extending transversely across the path for the material to be dried; a plurality of conduit means extending in side-by-side relationship in the same direction as said path disposed between and communicating with said inlet and outlet header means; means for effecting a flow of a heat transfer fluid through each said conduit means; and valve means for individually regulating the flow of heat transfer fluid through each said conduit means and thereby controlling the intensity of the radiant energy directed onto the portion of the material opposite the conduit means, said profile controlling means further including a casing through which the conduit means of the radiant heating means extend disposed adjacent and spanning the path for the material to be dried; means providing inlet and exhaust plenums in the opposite ends of the casing; a plurality of partitions disposed in side-by-side relationship in said casing and extending parallel to the path of material movement to divide said casing into a plurality of duct means extending in the same diretion as the path and communicating with said inlet and exhaust plenums; means for effecting a flow of gaseous fluid through each said duct means; means for directing said fluid from each said duct means toward the material being dried; and means for individually regulating the flow of fluid through each of said duct means and thereby controlling the rate of impingement of the fluid on the portion of the material opposite the duct means, said last-mentioned means comprising a damper in each of said duct means and means for individually regulating the positions of said dampers.

8. Apparatus for drying material in web, sheet, and similar forms, comprising material support means for establishing a path for the material to be dried; radiant heating means adjacent said path for directing radiant energy against said material to evolve volatiles therefrom, said radiant heating means comprising inlet and outlet header means at first and second locations along and extending transversely across the path for the material to be dried, a plurality of conduit means extending in side-by-side relationship in the same direction as said path disposed between and communicating with said inlet and outlet headers, and means for effecting a flow of heat transfer liquid through each said conduit means; means for so directing a flow of a gaseous fluid against said material as to assist in evolving volatiles therefrom and as to scour evolved volatiles away from the surface of the material against which the radiant energy is directed, said last-mentioned means comprising a casing through which the conduit means of the radiant heating means extend adjacent and spanning the path for the material to be dried, means providing inlet and exhaust plenums in the opposite ends of the casing, a plurality of partitions disposed in side-by-side relationship in said casing and extending parallel to the path of material movement to divide said casing into a plurality of duct means extending in the same direction as the path and communicating with said inlet and exhaust plenums, and means for effecting a flow of gase-

ous fluid from said inlet plenum through said duct means into said exhaust plenum; and means for controlling the volatiles profile across the width of the material being dried by individually regulating the rate of evolution of volatiles from successive lateral portions of the material comprising valve means for individually regulating the flow of heat transfer fluid through each said conduit means and thereby controlling the intensity of the radiant energy directed onto the lateral portion of the material opposite the conduit means and means for individually regulating the flow of fluid through each of said duct means and thereby controlling the rate of impingement of the fluid on the lateral portion of the material opposite the duct means; said last-mentioned means comprising a damper in each of said duct means and means for individually regulating the positions of said dampers.

9. Apparatus for drying material in web, sheet, and similar forms, comprising material support means for establishing a path for the material to be dried; radiant heating means adjacent said path for directing radiant energy against said material to evolve volatiles therefrom, said radiant heating means comprsing inlet and outlet header means at first and second locations along and extending transversely across said path, a plurality of conduit means extending in side-by-side relationship in the same direction as said path between and communicating with said inlet and outlet header means, and means for effecting a flow of heat transfer fluid through each said conduit means; means operable concomitantly with the operation of the heat transfer means for so directing a flow of a gaseous fluid against that portion of said material onto which the radiant energy is directed as to assist in evolving volatiles therefrom and as to scour evolved volatiles away from the surface of the material against which the radiant energy is directed; and means for correcting the volatiles profile across the width of the material being dried comprising valve means for individually regulating the flow of heat transfer fluid through each said conduit means and thereby controlling the intensity of the radiant energy directed onto the portion of the material opposite the conduit means and, therefore, the rate of evolution of volatiles from successive lateral regions of the material being dried.

10. Apparatus for drying materials in web, sheet, and similar forms comprising a material support means for establishing a path for the material to be dried; at least one radiant heating-fluid impingement unit disposed adjacent said path, each such unit comprising radiant heating means for directing radiant energy against said material to evolve volatiles therefrom and means for so directing a gaseous fluid against said material as to assist in evolving volatiles therefrom and as to scour evolved volatiles away from said material; and means disposed adjacent said path in series with said radiant heating-fluid impingement unit or units for correcting the volatiles profile across the width of the material being dried, said last-mentioned means comprising radiant heating means which includes inlet and outlet header means at first and second locations along and extending transversely across said path, a plurality of conduit means extending in spaced apart, side-by-side relationship in the direction of the path between and communicating with said inlet and outlet header means, and means for effecting a flow of a heat transfer fluid from said inlet header means through said conduit means to said outlet header means; means operable concomitantly with the operation of said radiant heating means for effecting a flow of a gaseous fluid from a location on the opposite side of the radiant heating means from the path of the material being dried through said radiant heating means and against the material being dried to scour from adjacent said material volatiles evolved therefrom; and valve means for individually regulating the flow of heat transfer fluid through each said conduit means and thereby controlling the intensity of the radiant energy emitted from said heating means and directed against the portion of the material opposite the conduit means and, therefore, the rate of evolution of volatiles from successive lateral regions of the material being dried.

11. The apparatus of claim **10,** wherein the profile correcting means comprises two independently regulatable units, one of said profile correcting units being disposed at the wet end of the drying apparatus ahead of the radiant heating-fluid impingement unit or units and the other of said profile correcting units being disposed at the dry end of the machine following the radiant heating-fluid impingement unit or units.

12. The drying apparatus of claim **9,** wherein the means for effecting the flow of gaseous fluid against the material being dried includes a casing disposed adjacent and spanning the path for the material to be dried, said casing having an inlet plenum in one end thereof and an exhaust plenum in the other end thereof; a plurality of partitions in side-by-side relationship in said casing, said partitions extending parallel to said path and dividing said casing into a plurality of duct means extending in the same direction as said path and communicating with said inlet and exhaust means; and means for effecting a flow of gaseous fluid from the inlet plenum through the duct means to the exhaust plenum; and means for directing said fluid from each of said duct means toward the material being dried.

13. The drying apparatus of claim **12,** together with means for individually regulating the flow of fluid through each of said duct means and thereby controlling the rate of impingement of the fluid on the portion of the material opposite the duct means and, therefore, the rate of evolution of volatiles from successive lateral regions of the material, said last-mentioned means comprising a damper in each of said duct means and means for individually regulating the positions of the dampers.

14. Apparatus for drying materials in web, sheet, and similar forms comprising a material support means for establishing a path for the material to be dried; at least one radiant heating-fluid impingement unit disposed adjacent said path, each such unit comprising radiant heating means for directing radiant energy against said material to evolve volatiles therefrom and means for so directing a gaseous fluid against said material as to assist in evolving volatiles therefrom and as to scour evolved volatiles away from said material; and means disposed adjacent said path in series with said radiant heating-fluid impingement unit or units for correcting the volatiles profile across the width of the material being dried, said profile correcting means comprising a casing disposed adjacent and spanning the path for the material to be dried, said casing having an inlet plenum in one end thereof and an exhaust plenum in the other end thereof; a plurality of partitions in side-by-side relationship in said casing, said partitions extend-

ing parallel to said path and dividing said casing into a plurality of duct means extending in the same direction as said path and communicating with said inlet and exhaust plenums; means for effecting a flow of gaseous fluid from the inlet plenum through the duct means to the exhaust plenum; means for directing said fluid from each of said duct means toward the material being dried; and means for individually regulating the flow of fluid through each of said duct means and thereby controlling the rate of impingement of the fluid on the portion of the material opposite the duct means and, therefore, the rate of evolution of volatiles from successive lateral regions of the material, said last-mentioned means comprising a damper in each of said duct means and means for individually regulating the positions of said dampers.

15. Apparatus for drying material in web, sheet, and similar forms, comprising material support means for establishing a path for the material to be dried; radiant heating means adjacent said path for directing radiant energy against said material to evolve volatiles therefrom; means for so directing a flow of a gaseous fluid against said materail as to assist in evolving volatiles therefrom and as to scour evolved volatiles away from the surface of the material against which the radiant energy is directed, said last-mentioned means comprising a casing disposed adjacent to and spanning the path for the material to be dried, said casing having an inlet plenum in one end thereof and an exhaust plenum in the other end thereof, a plurality of partitions in side-by-side relationship in said casing, said partitions extending parallel to said path and dividing said casing into a plurality of duct means extending in the same direction as said path and communicating with said inlet and exhaust plenums, means for effecting a flow of gaseous fluid from the inlet plenum through the duct means to the outlet plenum, and means for directing said fluid from each of said duct means toward the material being dried; and means for controlling the volatiles profile across the width of the material being dried comprising means for individually regulating the flow of fluid through each of said duct means and thereby controlling the rate of impingement of the fluid on the portion of the material opposite the duct means and, therefore, the rate of evolution of volatiles from successive lateral regions of the material being dried, said last-mentioned means comprising a damper in each of said duct means and means for individually regulating the positions of said dampers.

16. Apparatus for drying materials in web, sheet, and similar forms comprising a material support means for establishing a path for the material to be dried; at least one radiant heating-fluid impingement unit disposed adjacent said path, each such unit comprising radiant heating means for directing radiant energy against said material to evolve volatiles therefrom and means for so directing a gaseous fluid against said material as to assist in evolving volatiles therefrom and as to scour evolved volatiles away from said material; and means disposed adjacent said path in series with said radiant heating-fluid impingement unit or units for correcting the volatiles profile across the width of the material being dried, said last-mentioned means comprising radiant heating means which includse inlet and outlet header means at first and second locations along and extending transversely across said path, a plurality of conduit means extending in spaced apart, side-by-side relationship in the direction of the path between and communicating with said inlet and outlet header means, and means for effecting a flow of a heat transfer fluid from said inlet header means through said conduit means to said outlet header means; means operable concomitantly with the operation of said radiant heating means for effecting a flow of gaseous fluid from a location on the opposite side of the radiant heating means from the path of the material being dried through said radiant heating means and against the material being dried to scour from adjacent said material volatiles evolved therefrom; valve means for individually regulating the flow of heat transfer fluid through each said conduit means and thereby controlling the intensity of the radiant energy emitted from said heating means and directed against the portion of the material opposite the conduit means and, therefore, the rate of evolution of volatiles from successive lateral regions of the material being dried; a moisture sensing means disposed in the direction of material movement from each said conduit means; and control means connecting each said moisture sensing means with the valve means which controls the flow of heat transfer fluid through the conduit means upstream from said moisture sensing means.

17. A unit for correcting the volatiles profile across the width of material being dried comprising a radiant heater means adapted to laterally span and emit radiant energy onto the material being dried, said radiant heater means comprising inlet and outlet header meands capable of being so oriented as to extend transversely across said material, a plurality of conduit means extending in side-by-side relationship between and communicating with said inlet and outlet header means, and means for effecting a flow of heat transfer fluid through each said conduit means; means operable concomitantly with the operation of the radiant heating means for so directing a flow of a gaseous fluid against that portion of said material onto which the radiant energy is directed as to assist in evolving volatiles therefrom and as to scour evolved volatiles away from the surface of the material against which the radiant energy is directed; and means for correcting the volatiles profile across the width of the material being dried comprising valve means for individually regulating the flow of heat transfer fluid through each said conduit means and thereby controlling the intensity of the radiant energy directed onto the portion of the material opposite the conduit means and, therefore, the rate of evolution of volatiles from successive lateral regions of the material being dried.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,793,741 Dated February 26, 1974

Inventor(s) Horace L. Smith, Jr.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Front page, item 73, change "Smitheen" to --Smitherm--.

Column 5, line 29, change "DRYRES" to --DRYERS--.

Column 7, line 60, after "Figs. 6-8[7]" add --(To the extent that the dryer 150 illustrated in Figs 6-8 and dryer 20 are the same, their components are identified by identical reference characters.)--.

Claim 4, line 1, change "19" to -- 12 --.

Claim 9, line 6, change "comprsing" to --comprising--.

Claim 15, line 7, change "materail" to --material--.

Claim 16, line 15, change "includse" to --includes--.

Claim 17, line 6, change "meands" to --means--.

Signed and sealed this 17th day of September 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents