Dec. 6, 1966 H. L. SMITH, JR 3,289,315

DRYING ROLLS UTILIZING BELTS TRANSPARENT TO INFRARED RADIATION

Filed Oct. 29, 1965 5 Sheets-Sheet 1

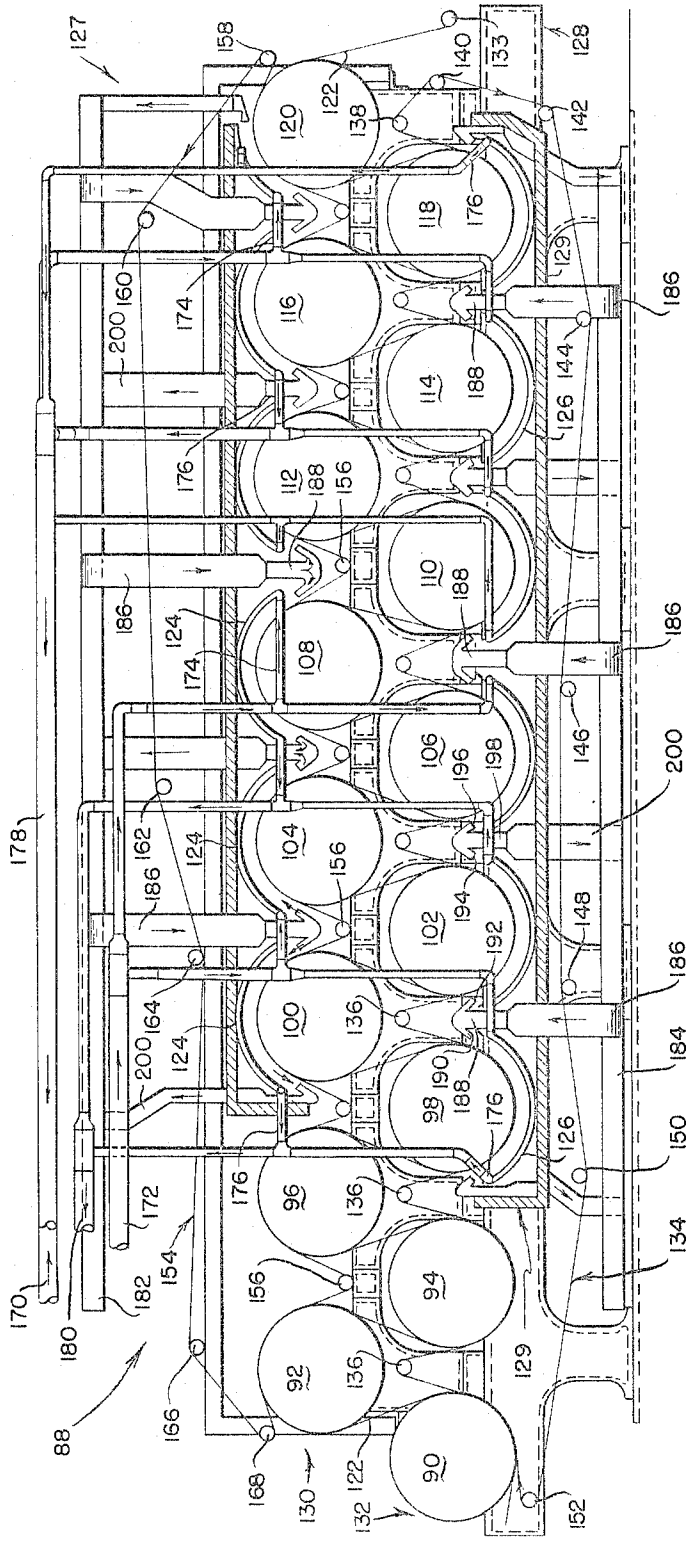


FIG. 1

INVENTOR
HORACE L. SMITH JR.

Strauch, Nolan, Neale, Nies & Bronaugh
ATTORNEYS

Dec. 6, 1966 H. L. SMITH, JR 3,289,315

DRYING ROLLS UTILIZING BELTS TRANSPARENT TO INFRARED RADIATION

Filed Oct. 29, 1965 5 Sheets-Sheet 2

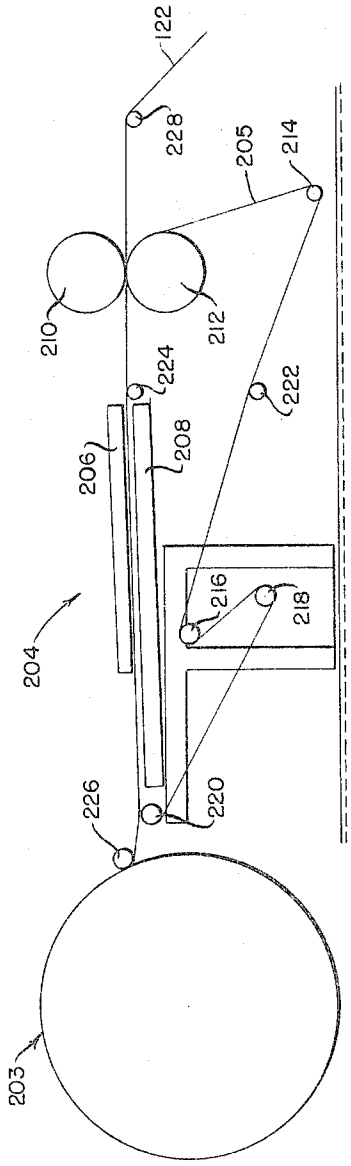


Fig. 2

INVENTOR
HORACE L SMITH JR.

BY Strauch, Nolan, Neale, Nies & Bronaugh
ATTORNEYS

Dec. 6, 1966 H. L. SMITH, JR 3,289,315

DRYING ROLLS UTILIZING BELTS TRANSPARENT TO INFRARED RADIATION

Filed Oct. 29, 1965 5 Sheets-Sheet 3

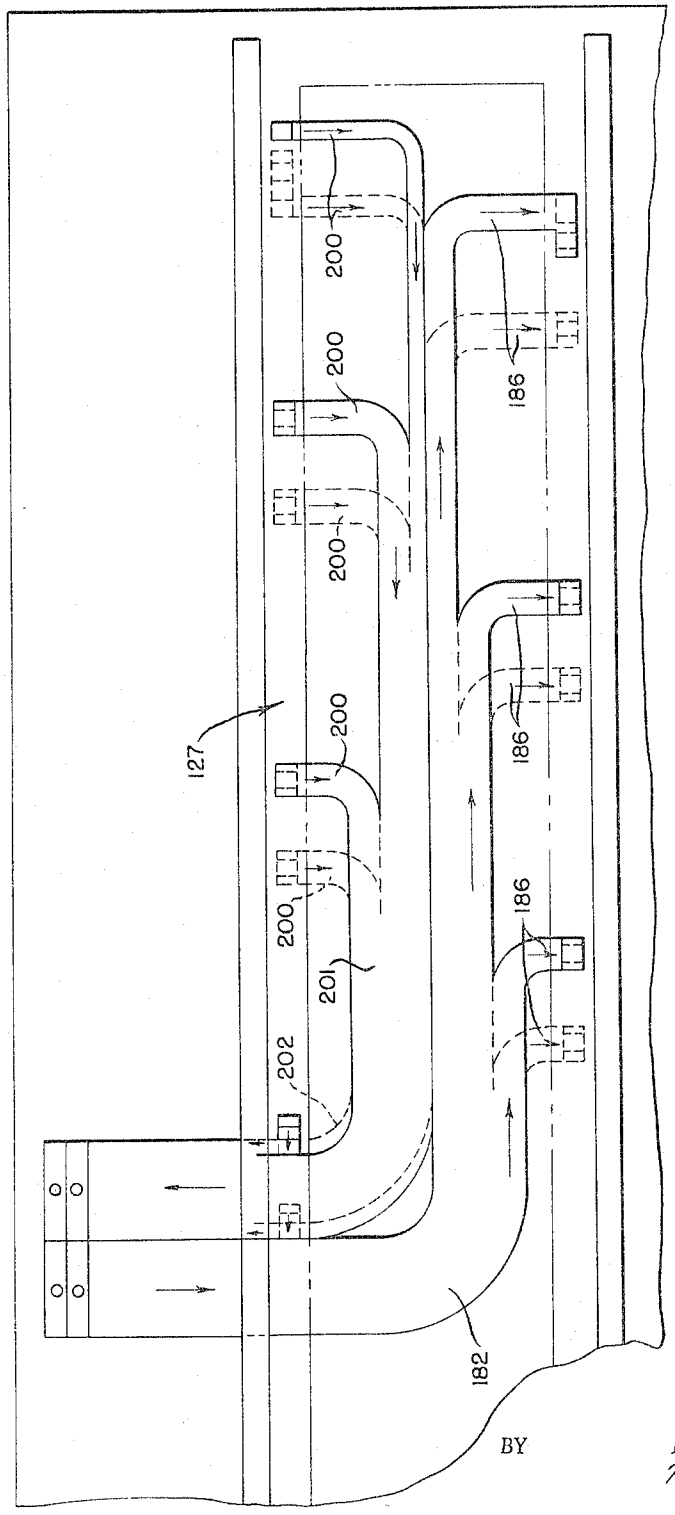


FIG. 3

INVENTOR

HORACE L. SMITH JR.

BY Strauch, Nolan, Neale, Nies & Bronaugh ATTORNEYS

Dec. 6, 1966 H. L. SMITH, JR 3,289,315

DRYING ROLLS UTILIZING BELTS TRANSPARENT TO INFRARED RADIATION

Filed Oct. 29, 1965 5 Sheets-Sheet 4

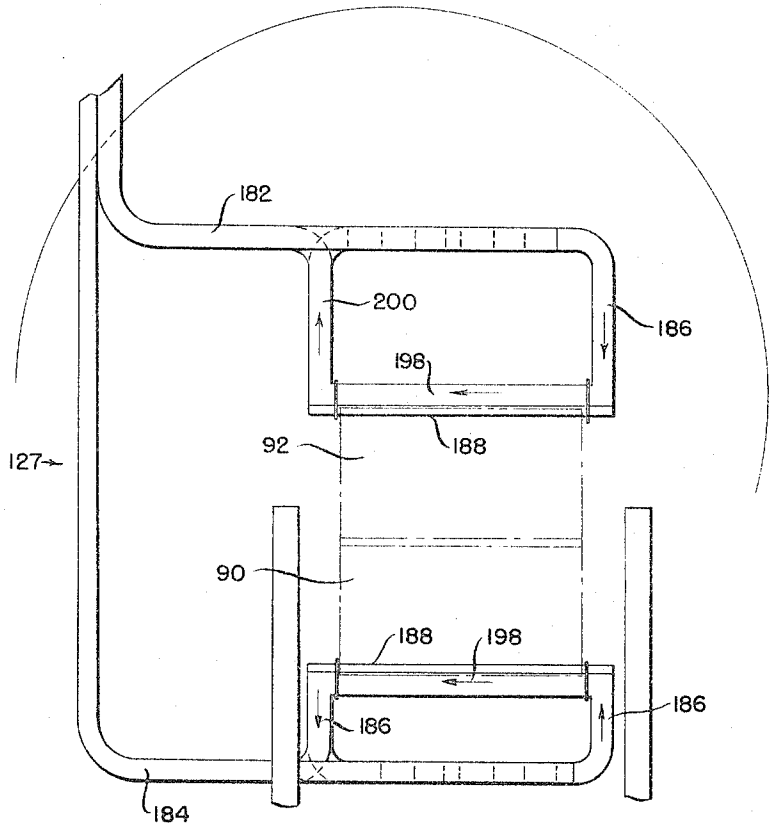


Fig. 4

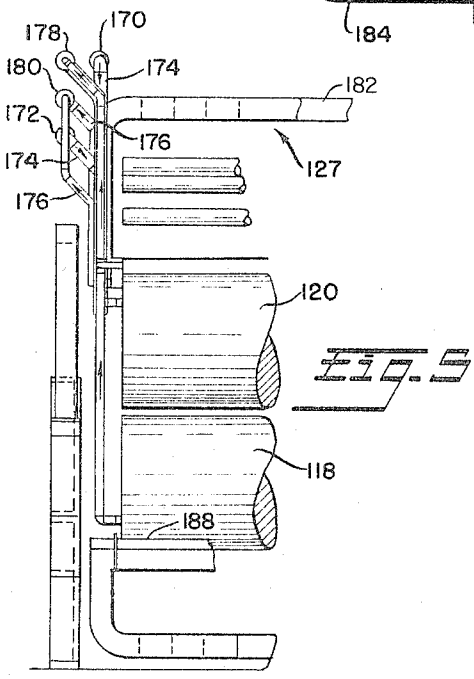


Fig. 5

INVENTOR

HORACE L. SMITH JR.

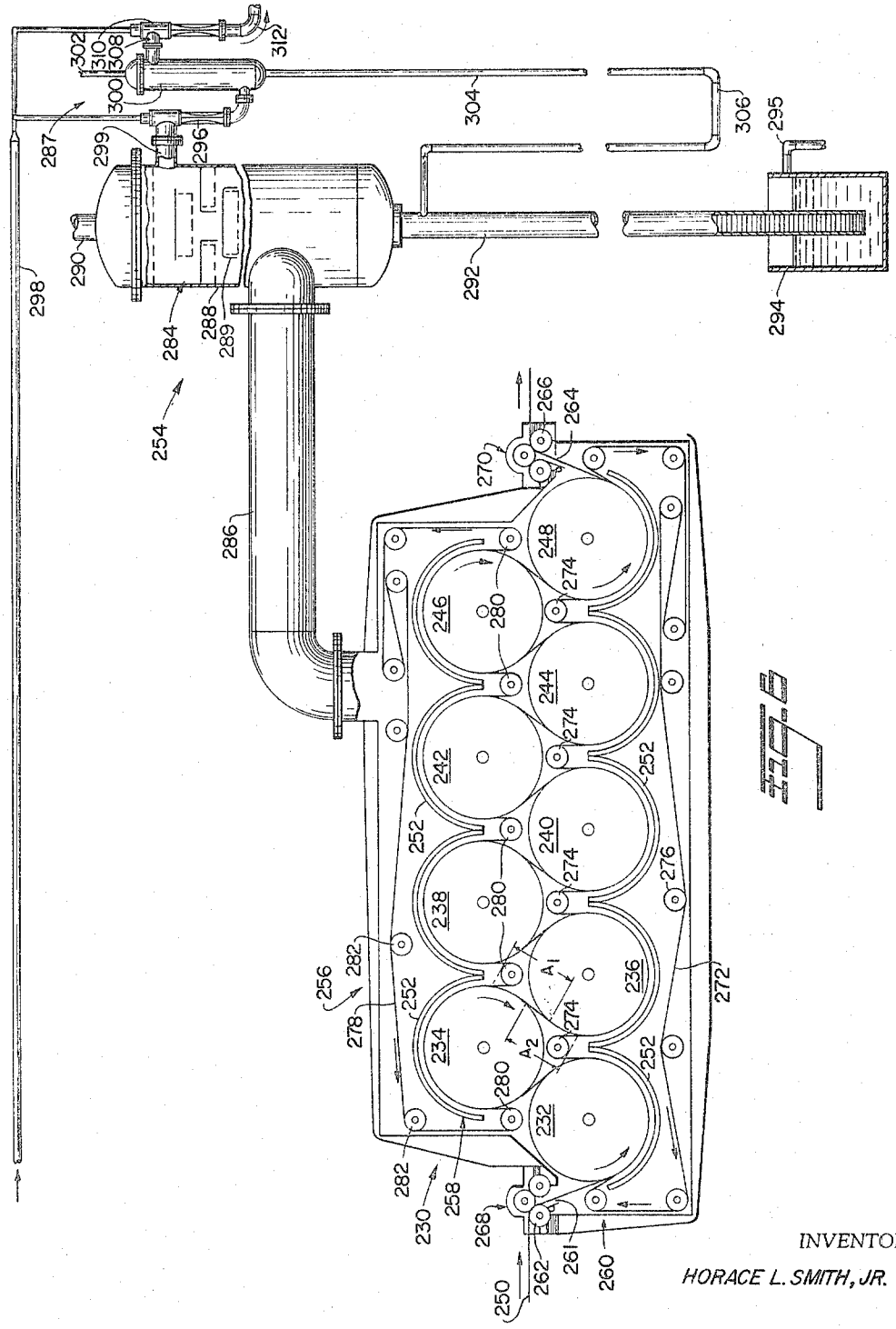
BY Strauch, Nolan, Neale, Nies & Bronaugh

ATTORNEYS

Dec. 6, 1966 H. L. SMITH, JR 3,289,315

DRYING ROLLS UTILIZING BELTS TRANSPARENT TO INFRARED RADIATION

Filed Oct. 29, 1965 5 Sheets-Sheet 5



INVENTOR
HORACE L. SMITH, JR.

BY Strauch, Nolan, Neale, Nies & Bronaugh
ATTORNEYS

United States Patent Office 3,289,315 Patented Dec. 6, 1966

3,289,315

DRYING ROLLS UTILIZING BELTS TRANSPARENT TO INFRARED RADIATION

Horace L. Smith, Jr., Richmond, Va., assignor to Hupp Corporation, Cleveland, Ohio, a corporation of Virginia

Filed Oct. 29, 1965, Ser. No. 505,640
8 Claims. (Cl. 34—92)

This application is a continuation-in-part of application No. 338,382, filed January 17, 1964, by Horace L. Smith, Jr. for Heat Treating Method and Apparatus (now abandoned).

The invention disclosed herein relates to the heat treatment of webs and continuous sheets of material and, more particularly, to the drying of continuous webs of materials such as paper, plastic films, and the like. For convenience, the principles of this invention will be developed by relating them to paper drying. It is to be understood, however, that the principles of this invention may equally well be applied to the drying or heat treating of other, diverse types of web or continuous sheet materials including but not limited to those mentioned above. The term "sheet" will be hereinafter used to include continuous sheets, webs, and similar forms of materials.

Continuous paper sheets are largely conventionally dried by passing them over serially arranged steam heated drying rolls, successive ones of which are vertically displaced so that the drums are arranged in two or more vertically spaced decks. In the normal arrangement in such equipment the paper passes under one roll and over the next one so that heat is transferred by conduction from adjacent drying rolls to opposite sides of the paper to insure equal drying and thereby prevent curling.

Such conventional drying systems have several disadvantages, particularly when operated at high speeds. As the paper passes over successive rolls, substantial portions of both faces of the sheet are in direct contact with the drying rolls. Moisture at and near the surface of the portions of the faces contacting the drying rolls is vaporized but cannot escape directly to the atmosphere because of the physical obstruction of the heating roll. As a result, the vapor pressure at the roll contacting face of the sheet increases, causing the water molecules to migrate toward the opposite exposed face of the sheet. Some of the water vapor will escape from the sheet through the exposed face; but, because the exposed face is relatively cool, many of the water molecules migrating toward the exposed face will condense and remain in the sheet, retarding the drying process.

Escape of water vapor from the sheet being dried is further retarded in such conventional equipment by felt or similar belts looped around the drying rolls and covering the sheet to minimize wrinkles in the sheet and to increase the heat transfer rate between the drying rolls and the sheet by pressing the sheet against the drying rolls. Little, if any, moisture penetrates and escapes from these belts.

As disclosed in my copending application No. 254,674, filed January 29, 1963, for Heat Treating Method and Apparatus, the disadvantages of conventional multiple roll apparatus may be eliminated in many heat treating processes by using felts to press the web being dried into contact only with selected rolls. However, in heat treating some types of products with multiple roll apparatus, it may be necessary or preferable to employ felts on all of the decks of rolls. This is particularly true where the sheet is moving at high speed and would be pulled away from the rolls by its inertia unless mechanically pressed against them.

As discussed above, it is impractical to use conventional

felts on all decks of multiple roll heat treating apparatus in such applications as conventional felts almost completely prevent the escape of evolved volatiles from adjacent the surface of the material being treated. Under such conditions, a sheet dries slowly if at all; and efficiencies are so low that the use of such multiple roll apparatus is not feasible. In these circumstances manufacturers have been forced to operate at low speeds at which inertia is not a problem or to employ other, more expensive types of equipment.

Also, the utilization of conventional felts on all decks of multiple roll heat treating apparatus prevents the combined use of conductive and radiant or convective, conductive, and radiant heating which, I have discovered, permits the use of drying rates much higher than are attainable in conventional multiple roll apparatus and also results in the product being more uniformly dried without the formation of wrinkles or puckers as discussed in my copending application No. 254,674. This is because conventional felts are, for all practical purposes, opaque to the 3.5 to 5.0 micron wave length radiant energy emitted by the most efficacious form of radiant heaters.

I have now discovered that the advantages of employing felts on more than one or all decks of multiple roll apparatus—such as increasing the types of products that can be heat treated and the attainment of materially higher operating speeds—can be realized without the attendant disadvantages of multiple conventional felts by making the felts from an open mesh synthetic material which is, preferably, at least partially transparent to infrared radiation having wave lengths of 3.5 to 5 microns (i.e., infrared radiation emitted from radiators at temperatures ranging from 600° F. to a little over 1000° F.). Several advantages flow from the utilization of such felts. Radiant heating can be employed in multiple roll apparatus so equipped as a substantial proportion of the energy emitted from the radiant heaters will pass through the openings in the felt (which may constitute as much as 50% or more of the area of the felt) and impinge on the sheet being heat treated. A substantial additional fraction of the emitted energy will pass through the felt material itself (the exact percentage will depend upon the particular material and the wave length of the emitted energy) to the material being treated. Consequently, only a small fraction of the emitted energy will not reach the material being treated. Of the radiant energy which does not pass through the felt, the bulk will be reflected and a small amount will be absorbed by the felt. The latter amount is so small that overheating of the felt by absorption of radiant energy is not a significant problem. Most of the reflected energy is absorbed by the radiant heater so that it is not wasted, but is re-emitted and directed back to the sheet being treated.

The use of my novel, open mesh, synthetic felts also permits the use of convection heating since heated gases can readily circulate through the openings in the felt into contact with the material being treated. In addition, evolved volatiles can readily escape through the same openings, a process further aided by the circulation of the hot heating gases into contact with the sheet material. This is an important advantage as a combination of convective, conductive, and radiant heating permits the attainment of drying rates much higher than have heretofore been possible in multiple roll apparatus.

It has been proposed heretofore that the supporting felts in other types of heat treating apparatus be made from an open mesh material; viz., wire mesh. Exemplary of the patents disclosing this type of felt in U.S. Patent No. 1,359,141 issued November 16, 1920, to J. E. Alexander for Longitudinal Drier for Paper Making Machines. Wire mesh felts, like conventional felts, are unsuitable for use in heat treating apparatus of the type to which the

present invention pertains. They have the advantage over conventional felts that radiant energy can pass through the mesh openings to the material being treated so that wire mesh felts are significantly less opaque to infrared radiation than conventional felts. Also, evolved volatiles can pass through the mesh openings, eliminating the pronounced tendency of conventional felts to prevent such volatiles from escaping. However, in the present invention, the supporting felts are constantly flexed as they pass over the drying rolls and around the end and other direction changing rolls. Wire mesh felts deteriorate so rapidly under constant flexing that they are economically impractical.

The preferred open mesh synthetic felts are a material improvement over wire mesh felts since they are effected to only a negligible extent by flexing. In addition, they are substantially more transparent to infrared radiation than wire mesh felts since the strands of wire in the latter are opaque to energy in the infrared portion of the electromagnetic spectrum; and the radiant energy can, therefore, only pass through the openings in the mesh. The strands of the synthetic open mesh felts employed in the present invention, in contrast, are at least partially transparent to infrared radiation so that radiant energy can pass through the felt's strands to the web as well as through the mesh openings. This is an advantage of significant importance, as the mesh openings will generally not exceed 50% of the area of the felt.

The principles of the present invention may be employed to great advantage in multiple roll heat treating apparatus of the type disclosed in my copending applications Nos. 254,674 and 338,382 in which a combination of radiant, conductive, and convective heating is employed. These principles may also be advantageously employed in multiple roll heat treating apparatus of the Minton type in which the heated rolls are disposed in an evacuated chamber. In fact, Minton dryers having twice the capacity of conventional Minton dryers of the same size can readily be constructed in accord with the principles of the present invention.

From the foregoing, it will be apparent that one object of the present invention resides in the provision of improved methods of and apparatus for drying or otherwise heat treating continuous, moving sheets of material.

Another specific object of the present invention resides in the provision of improved plural roll heat treating apparatus having a subsantially higher capacity than heretofore available apparatus of this type.

Another object of the present invention resides in the provision of novel apparatus for heat treating continuous, moving sheets of material in which heat is transferred to the sheet by radiation and in which a stream of air is directed across the surface of the moving sheet to further heat the sheet and to remove from adjacent the sheet moisture evolved from it.

A further specific object of the present invention resides in the provision of novel improved heat treating apparatus of the Minton type.

It is yet another specific object of the present invention to provide improved multi-roll apparatus for heat treating continuous, moving sheets of material in which the conventional moisture trapping felt belts heretofore employed are eliminated.

Another specific object of the present invention resides in the provision of novel, improved, plural deck, multiple roll, heat treating apparatus provided with felts on more than one deck and arranged to heat the material being treated by a combination of radiation and conduction or radiation, conduction, and convection.

A further specific object of this invention resides in the provision of multiple roll heat treating apparatus equipped with novel felts through which heated fluids can circulate into contact with the material being treated and through which evolved volatiles may escape from adjacent the material.

A further specific object of the present invention is the provision of multiple roll heat treating apparatus equipped with felts capable of passing a substantial portion of incident radiant energy having a wave length of about 3.5–5.0 microns.

It is yet another object of the present invention to provide novel methods of heat treating sheet material by a combination of radiation, conduction, and convection.

Another specific object of the present invention resides in the provision of novel methods of heat treating sheet materials in vacua by a combination of radiant and conductive heat transfer.

Other objects and advantages of the present invention will become apparent from the following description of preferred modes of carrying out the present invention and examples thereof and from the appended claims and the accompanying drawings, wherein:

FIGURE 1 is a partly diagrammatic elevation, partially in section, of one form of heat treating apparatus constructed in accordance with the principles of the present invention;

FIGURE 2 is a diagrammatic side view of a paper forming machine and a preliminary drying section which may be used in conjunction with the apparatus of FIGURE 1;

FIGURE 3 is a top plan view of the duct work of an air supply and exhaust system employed in the apparatus of FIGURE 1;

FIGURE 4 is a left-hand end view of the supply and exhaust system duct work;

FIGURE 5 is a partial right-hand end view of the apparatus of FIGURE 1, illustrating a portion of a heat transfer fluid supply and exhaust system employed in the apparatus; and

FIGURE 6 is a view, similar to FIGURE 1, of a second form of heat treating apparatus constructed in accord with the principles of the present invention.

Referring now to the drawing, an exemplary multiple roll, plural deck drier **88** constructed in accordance with principles of the present invention and equipped with multiple open mesh synthetic felts of the type described above is illustrated in FIGURES 1–5.

Turning first to FIGURE 1, drier **88** includes, generally, a plurality of internally heated drying rolls **90–120** for heating sheet **122** by conduction. Drier **88** also includes radiators **124** and **126** for applying radiant energy to sheet **122** and a ventilating system **127** for heating sheet **122** by convection and for removing from adjacent sheet **122** vapors evolved by the heat applied to it by the heated air, the drying rolls, and the radiators. These components are supported from framework **128** and, in main part, surrounded by an insulated housing or casing **129**.

Drying rolls **90–120** may be of any conventional construction, such as the steam heated rolls illustrated in my British Patent No. 779,326, for example. They are arranged in two vertically spaced apart decks, identified generally by reference characters **130** and **132**, with the rolls **92, 96, 100, 104, 108, 112, 116,** and **120** in upper deck **130** located approximately mid-way between the drying rolls in lower deck **132**. Sheet **122** is guided onto the first drying roll **90** by a guide roller (not shown) and then moves around drying rolls **92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118,** and **120** in that order, so that it alternately passes between rolls in upper deck **130** and lower deck **132**. Sheet **122** is guided from the last drying roll **120** by a guide roller **133**.

An endless felt **134** is employed to press sheet **122** into contact with the drying rolls in lower deck **132** to provide optimum conduction of heat from the drying rolls to sheet **122** and to prevent the formation of wrinkles in the sheet. Felt **134** is guided around the drying rolls in lower deck **132** by guide rollers **136** located between adjacent rolls in the lower deck. These rollers are located at generally the same level as the tops of the drying rolls to provide contact between the felt and the rolls through

an arc which is substantially a semicircle. Felt **134** thereby presses sheet **122** against each of these rolls substantially throughout its arc of contact with each roll.

Felt **134** is also trained around guide rollers **138, 140, 142, 144, 146, 148, 150,** and **152,** which carry the lower run of the felt. Felt **134** is maintained under high tension in any suitable manner so that it will exert pressure in a direction normal to the sheet contacting surface portions of the drying rolls in lower deck **132.**

An endless felt **154,** similar to felt **134,** is guided around the upper portions of the rolls in upper deck **130** by guide rollers **156** located between adjacent rolls in upper deck **130.** Rollers **156** are located at about the same level as the bottoms of the upper deck rolls to maintain sheet **122** in firm engagement with them. Guide rollers **158, 160, 162, 164, 166,** and **168** carry the upper run of felt **154.** Like felt **134,** felt **154** is maintained under tension so that it will exert a pressure on sheet **122** in a direction normal to the sheet contacting surface portions of the rolls in upper deck **130.**

Felts **134** and **154** are preferably manufactured from synthetic materials which are at least partially transparent to infrared radiation having wave lengths from about 3.5 to 5.0 microns and are preferably of an open mesh construction. In the preferred embodiment, a weave is employed which will produce from 30 to 50% (or more) open area in the mesh. Suitable felts, having varying degrees of transparency for radiation of the wave length described above and mesh openings in the range of percentages described above, are available from, among others, the Formex Company, a division of Huyck Corporation, and from the Appleton Wire Company. Any one of a number of weaves supplied by these and other companies may be employed although it is deemed preferable to use a material having as high a degree of transparency to infrared radiation as is compatible with the strength and other physical requirements of a particular installation. It is also preferable to employ a felt having as much open area as possible to facilitate the escape of evolved moisture and other volatiles from adjacent the drying product and to facilitate circulation of a scouring gas into contact with the product. A typical example of a suitable weave is Formex Company's Design #41.

Use of such felts as described above permits the radiant energy emitted by radiators **124** and **126** to readily pass through the felt and impinge on sheet **122** at each of the drying rolls **98–118.** Such felts also permit the heated gases delivered by ventilating system **127** to flow through the felts and scour the surfaces of sheet **122,** heating sheet **122** by convection and sweeping away from adjacent the sheet volatiles evolved from it. Thus felts **134** and **154** permit sheet **122** to be heated by the novel synergistic combination of radiation, convection, and conduction heating described above and yet permit felts to be used on all decks of the drier, providing optimum sheet-roll contact at each drying roll. Also, radiant heaters may be used on the decks equipped with felts to dry the sheet, which is impracticable where conventional felts are employed as the latter are opaque to radiant energy.

Radiant energy is supplied to sheet **122** by the radiators **124** and **126** referred to above, which may be of the same type as those employed in the heat treating apparatus disclosed in my copending applications Nos. 254,674 and 338,382.

As shown in FIGURE 1, a single radiator **124** is employed in association with each of the drying rolls **100, 104, 108, 112, 116,** and **120** in upper deck **130.** Each of the radiators **124** subtends substantially that portion of the associated drying roll contacted by the sheet of material **122** being dried. Radiators **124** are supported in any desired manner closely adjacent the surfaces of the associated drying rolls, the distance between the radiators and the drying rolls preferably being the minimum needed to thread sheet **122** around the rolls.

Radiators **126** are mounted in a similar manner adjacent the lower portions of the drying rolls **98, 102, 106, 110, 114,** and **118** in lower deck **132.** These radiators are also preferably dimensioned to subtend substantially the portions of the associated drying rolls contacted by sheet **122.**

Radiators **124** and **126** are preferably heated by circulating through them a high boiling point organic liquid such as "Smitherm A" or "Smitherm D." In the illustrated exemplary dryer **88,** the selected liquid is heated (preferably in a system of the type described in my copending application No. 237,817 filed November 15, 1962, for High Temperature Heating Apparatus (now Patent No. 3,236,292)) and circulated through main supply conduits **170** and **172** and branch supply conduits **174** into radiators **124** and **126.** After circulating through the radiators, the heat exchange fluid flows through branch exhaust conduits **176** and main exhaust conduits **178** and **180** to the heating unit. The details of this delivery and exhaust system are not critical and will vary, depending upon the nature of the particular installation. A more elaborate discussion of this system is therefore not deemed necessary.

Ventilating system **127** includes a blower (not shown) which directs air (or other fluid, if desired) through a suitable air heater (also not shown) into a pair of main supply ducts **182** and **184** located, respectively, above upper roll deck **130** and beneath lower roll deck **132.** From the main ducts, the heated air flows through branch ducts **186** into plenum chambers **188.** Each plenum chamber **188** terminates in an integral nozzle provided with a pair of outlets **190** and **192,** each located adjacent one of the two rolls between which the particular plenum chamber **188** is disposed. For example, the two elongated outlet openings **190** and **192** from the plenum chamber **188** disposed between rolls **98** and **102** in lower deck **132** are located closely adjacent rolls **98** and **102,** respectively, and are oriented to direct the air emerging from them generally parallel and into contact with the sheet **122** on these rolls.

From nozzle outlet openings **190** and **192,** the heated air flows around the associated rolls between the rolls and the associated curved radiator **124** or **126,** heating sheet **122** by convection and scouring away from adjacent its surface the volatiles evolved from the sheet. The spent air flows through openings **194** and **196** into exhaust plenums **198,** which may be constructed in substantially the same manner as supply plenums **188.** From exhaust plenums **198,** the spent drying air flows through branch exhaust ducts **200** into main exhaust ducts **201** and **202** (see FIGURE 3). The spent drying air in the main exhaust ducts may be discharged or recirculated into contact with sheet **122** to control the final moisture or other volatile content of sheet **122** as discussed in my copending application No. 338,382.

The air employed in drier **88** is preferably heated to a temperature in the range of 250–500° F. and is preferably discharged into contact with sheet **122** in a turbulent condtion at a velocity in the range of about 100–1500 ft. per minute. As pointed out above, the heated air passes readily through the openings in felts **134** and **154,** and therefore efficiently heats sheet **122** by convection and scours away evolved volatiles.

The product to be dried in driers **88** may be formed in any desired manner. For example, as shown in FIGURE 2, a Rotoformer **203** (which is a cylinder type forming machine) may be employed for this purpose. It may also be desirable to preliminary dry sheet **122** before passing it into drier **88** to give it enough strength to permit it to be threaded through the main drier.

FIGURE 2 diagrammatically illustrates a preliminary drying section **204** in which the newly formed sheet **122** is supported on a felt **205,** preferably of the synthetic open mesh type described above. Sheet **122** passes between a pair of horizontally oriented, closely spaced

radiators 206 and 208 (also preferably of the type described above). The sheet then passes between press rolls 210 and 212 and to the main drying apparatus 88.

In the exemplary illustrated preliminary drying section, felt 205 is trained around press roll 212 and guide rolls 214, 216, 218, and 220. Idler rolls 222 and 224 are employed to support the lower run of the felt. Guide rollers 226 and 228 direct the newly formed paper into the preliminary drying section and from this section to the dryer, respectively. These and other details of the paper forming apparatus and the preliminary drying section are not critical in the practice of the present invention and are presented merely for a better understanding of the present invention. Therefore, description of these details is not believed to be necessary.

Refering again to the drawing, FIGURE 6 illustrates a Minton type drier 230 constructed in accord with the principles of the present invention. Drier 230 includes, generally, a plurality of internally heated drying rolls 232–248 for heating sheet 250 by conduction, radiators 252 for applying radiant energy to sheet 250, and a vacuum system 254 for evacuating the casing 256 surrounding the drying rolls and for exhausting from casing 256 vapors evolved from sheet 250 by the heat applied to it from the drying rolls and radiators.

The drying rolls may be of the type discussed above in conjunction with the embodiment of FIGURE 1 or of any other construction desired. They are arranged in two vertically spaced apart decks 258 and 260 with the rolls in upper deck 258 located approximately midway between those in lower deck 260. Sheet 250 is guided from the exterior of casing 256 through an inlet opening 261 in the casing onto the first drying roll 232 by a guide roller 262 and then moves around drying rolls 234, 236, 238, 240, 242, 244, 246, and 248 in that order, so that it alternately passes between rolls in upper deck 258 and those in lower deck 260. Sheet 250 is guided from the last drying roll 248 and through an outlet passage 264 in casing 256 by a guide roller 266. Guide rollers 262 and 266 are incorporated in vacuum seals 268 and 270 of the type disclosed in United States Patent No. 1,595,240 issued August 10, 1926, to O. Minton. As these seals are described in detail in the foregoing patent and as their details are not part of the present invention, it is not considered necessary to describe them further herein.

An endless felt 272 is employed to press sheet 250 into contact with the drying rolls in lower deck 260 to provide optimum conduction of heat from the drying rolls to sheet 250 and to prevent the formation of wrinkles in the sheet. Felt 272 is guided around the drying rolls in lower deck 260 by guide rollers 274 located between adjacent rolls in the lower deck. These rollers are located slightly below the tops of the drying rolls to provide contact between the felt and the rolls through an arc which is substantially a semicircle, thereby pressing sheet 250 against each of these rolls through a major portion of its arc of contact with each roll. Felt 272 is also trained around guide rollers 276, which carry the lower run of the felt. Felt 272 is maintained under high tension in any suitable manner so that it will exert pressure in a direction normal to the sheet contacting surface portoins of the drying rolls in lower deck 260.

An endless felt 278, similar to felt 272, is guided around the upper portions of the rolls in upper deck 258 by guide rollers 280 located between adjacent rolls in the upper deck. Rollers 280 are located at about the same level as the bottoms of the upper deck rolls to maintain sheet 250 in firm engagement with them. Guide rollers 282 carry the upper run of felt 278. Like felt 272, felt 278 is maintained under tension so that it will exert a pressure on sheet 250 in a direction normal to the sheet contacting surface portions of the rolls in upper deck 258.

Felts 272 and 278 are preferably fabricated of the same type of open mesh synthetic material as the felts utilized in the dryer of FIGURE 1 to permit the radiant energy emitted from radiators 252 to pass through the felts and impinge upon the sheet of material 250 being treated and to facilitate the escape of evolved moisture and/or other volatiles from adjacent sheet 250 through the felts.

The use of felts of the type just described materially improves the performance of a Minton type dryer for the reasons discussed below. Minton driers are often utilized for paper drying and similar processes because there is a greater differential between the drying roll temperature and boiling point of the water or other volatile being evolved in a vacuum than there is at atmospheric pressure (this differential may typically be increased from 38° F. in an atmospheric pressure drier to 114° F. in a Minton drier). Consequently, Minton driers are theoretically appreciably more efficient than those which operate at atmospheric pressures.

However, this theoretical increase in efficiency is only partially realized in actual practice because the conventional impervious felts employed prevent evolved substances from escaping from the sheet being treated except in the draw between adjacent drying rolls (shown by A_1 and A_2 in FIGURE 6). Because of this limited opportunity for volatiles to escape from adjacent the sheet being treated, a substantial portion of the evolved volatiles remain in or adjacent the sheet being treated, forming a boundary layer which substantially retards the drying process as discussed above and in my Patent No. 3,208,158 issued September 28, 1965, for Dryers and my copending application No. 254,674.

In a dryer operating at atmospheric pressure such as that illustrated in FIGURE 1, this problem can be at least partially overcome, even when conventional felts are used, by employing high velocity air to scour away the evolved volatiles and thereby increase the rate of vapor removal or by omitting the felts on selected decks as discussed in my copending application No. 254,674. Neither of these approaches can be used in a Minton drier. Felts must be used throughout a Minton drier so that it can be threaded and so that broke will not accumulate inside the drier when the web breaks. Air scouring cannot be used in a Minton drier because of the necessity of maintaining it in vacua (typically 24–26 inches of mercury). Consequently, the use of open mesh felts, which greatly increases the opportunity for evolved volatiles to escape from adjacent the material being treated in a Minton drier materially increases the efficiency of such driers over that heretofore obtainable.

Moreover, the use of this type of felt has the further advantage that it permits the utilization of radiant heaters in Minton driers. This is important because, for the reasons discussed in my copending application No. 254,674, the combined use of conductive and radiant heat transfer mechanisms in drying paper is effective to eliminate "wet streaks" in the paper being dried and thereby prevent the formation of wrinkles and puckers, which wet streaks will cause when paper is dried solely by conduction.

A further advantage obtained by the use of radiant heaters in a Minton drier is that they materially increase the drier capacity because of the additional heat they provide. At the same time, only a negligible amount of space is required for the radiant heaters. This ability to increase capacity without increasing space requirements is particularly important in the case of Minton driers because of their high cost, which is on the order of $50,000 per drying roll so that a typical twenty roll Minton drier costs on the order of one million dollars.

The use of radiant heaters in accord with the present invention: (1) permits a faster rate of product movement through a given size drier; or (2) permits a smaller drier to be used for a given rate of product movement. Either way, the cost of drying paper or other product in a Min-

ton drier can be appreciably reduced by application of the principles of this invention.

Radiant energy is supplied to sheet **250** by the radiators **252** referred to above, which may be of the same type as those employed in the heat treating apparatus disclosed in my copending applications Nos. 254,674 and 338,382.

As shown in FIGURE 6, a single radiator **252** is employed in association with each of the drying rolls in upper deck **258**. Each of the radiators **252** subtends substantially that portion of the associated drying roll contacted by the sheet of material **250** being dried. Radiators **252** are supported in any desired manner closely adjacent the surfaces of the associated drying rolls, the distance between the radiators and the drying rolls preferably being the minimum needed to thread sheet **250** around the rolls.

Radiators **252** are mounted in a similar manner adjacent the lower portions of the drying rolls in lower deck **260**. These radiators are also preferably dimensioned to subtend substantially the portions of the associated drying rolls contacted by sheet **250**.

Radiators **252** are preferably heated by circulating through them a high boiling point organic liquid such as those mentioned previously. The liquid heating and circulating system may be of the type disclosed in conjunction with the embodiment of FIGURE 1. It is to be understood, however, that the details of these systems are not critical and will be varied, depending upon the nature of the particular installation.

The vacuum system **254** provided for evacuating dryer casing **256** includes a main condenser **284** communicating with the interior of the casing through a duct **286** and a jet pump **287** for removing non-condensables (mostly air) from the vacuum system. Condenser **284** is of conventional construction, including a shell **288** in which a series of perforated baffles or trays **289** (only a few of which are shown) are disposed. The steam flowing into condenser **284** through conduit **286** is contacted by water entering the upper end of the condenser through an inlet line **290** as the water flows down through the condenser over baffles **289**. The condensed steam and cooling water are discharged from the condenser through a tail pipe **292**, which terminates in a vessel **294**, provided with a water discharge conduit **295**, which surrounds the lower end of the tail pipe. The liquid in tail pipe and vessel **294** forms a water seal, which prevents air from entering the vacuum system.

The jet pump **287** employed to remove non-condensable gases from the vacuum system includes a first stage jet air ejector or pump **296** supplied with steam from a suitable source through steam pipe **298** (other motive fluids may of course be employed to operate jet pump **287** if volatiles other than water are being pumped from the system). This type of device is well known (see, for example, U.S. Patents Nos. 571,002 issued November 10, 1896, to L. Schutte for Exhauster and 1,111,541 issued September 22, 1914, to E. Koerting for Injector); and it is, therefore, not considered necessary to describe it herein, especially as its details are not part of the present invention.

Steam jet ejector **296** induces a flow of the noncondensable gases from condenser **284** through off-take conduit **299**, compresses them to a pressure typically on the order of 24 inches of mercury, and pumps them into a jet condenser **300**. In condenser **300**, which may be of any desired construction, the steam passing into the condenser with the non-condensables is condensed by water sprayed or otherwise introduced into the condenser through an inlet line **302**.

The cooling water and condensed steam is discharged from condenser **300** through a tail pipe **304** configured to provide a water seal at its lower end **306**. Tail pipe **304** is connected to the tail pipe **292** from main condenser **284** so that the water discharged from condenser **300** ultimately flows into tail pipe **292**.

The non-condensables remaining in jet condenser **300** are evacuated from it through an off-take conduit **308** by second-stage steam jet pump **310**, which is supplied with steam from steam line **298** and may be of the same construction as jet pump **296**. Jet pump **310** compresses the non-condensables and discharges them through a conduit **312** to the surrounding atmosphere together with the motive fluid supplied to the second stage pump, which it is not necessary to condense.

Substantial increases in drying capacity may be obtained in both of the driers discussed above, and especially in the drier illustrated in FIGURE 6, by substituting for steamheated rolls, rotatable drum driers of the type disclosed in my U.S. Patents Nos. 3,177,932, issued April 13, 1965, for Drum Type Heat Transfer Apparatus and 3,181,605 isued May 11, 1965, for Uniformly Heated Rotary Drum and in my copending application No. 447,017 filed April 9, 1965, for Apparatus (now Patent No. 3,228,462). These drum driers all employ as heat transfer mediums high boiling point liquids, such as those described above, which can be circulated through the drums at temperatures of up to 750° F. or higher in liquid form. The drying surfaces of these drums can therefore be heated to much higher temperatures than those of steam heated drums because insurance regulations require that the latter use steam which has a relatively low pressure and, therefore, a correspondingly low temperature. This is most important in Minton type driers. In the latter, the steam pressure must be lowered because of the vacuum in the dryer casing so that the differential between the internal and external drum pressures will not increase and exceed the allowable pressure differential. This results in a lower roll temperature and reduced dryer capacity. Maximum capacity is of considerable importance in Minton driers because of the expense of building, operating, and maintaining such driers due to the necessity of using vacuum seals, air tight drives for the drying rolls, and other similarly complex and expensive mechanical features.

Another advantage of using such drier drums is that the same heating and circulating system can be employed for the drums and radiators as the same liquid heat transfer media can be employed in both. This results in major reductions in capital investment and operating costs.

Minton driers constructed in accord with the principles of the present invention also represent an improvement over the heretofore known driers of this type even when conventional felts are employed. Conventional felts absorb and quickly become saturated with evolved volatiles, which substantially retards the drying process. In conventional Minton driers this problem is alleviated to a small extent by providing felt driers, a felt typically passing over 20 drying rolls and then being dried. This solution, however, is only of limited benefit because the felts absorb a maximum load of water or other volatiles long before the last drying roll is reached; and the use of additional felt driers is economically impractical because of the high cost of providing space for them in the vacuum vessel.

In Minton driers constructed in accord with this invention, the radiant heaters can be utilized as felt driers in installations where conventional felts are employed. The radiant heaters require very little space; and, accordingly, can be used at each drying roll to provide substantialy continuous felt drying without any significant increase in space requirements in the vacuum vessel.

As mentioned previously, the principles of the present invention find application in processes other than paper drying. Moreover, it will be obvious to those skilled in the arts to which the present invention pertains that the exemplary embodiments of the present invention disclosed herein can be used with only slight or even no modification for the processing of other materials. The

foregoing discussion is therefore to be considered as illustrative and not as limiting the scope of the present invention, which is intended to be defined solely by the appended claims.

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. Apparatus for heat treating a continuous, moving, sheet of material, comprising:
   (a) a plurality of drying rolls alternately located in vertically spaced apart upper and lower decks and adapted to have a sheet of material contacting, alternately, the upper and lower surface portions of successive rolls in the upper and lower decks;
   (b) radiant heaters spaced from and surrounding the upper portions of at least the majority of the rolls in the upper deck and the lower portions of at least a majority of the rolls in the lower deck;
   (c) first belt means for pressing the sheet material against the rolls in the upper deck, said first belt means extending between said radiant heaters and said upper deck rolls and contacting the upper portions of said upper deck rolls;
   (d) second belt means for pressing the sheet material against the rolls in the lower deck, said second belt means extending between said radiant heaters and said lower deck rolls and contacting the lower portions of said lower deck rolls;
   (e) said first and second belt means being fabricated of open mesh synthetic material capable of passing a substantial proportion of radiant energy impinging thereon with the mesh openings constituting not less than about 30% of the area of said belt means, whereby a substantial portion of the energy emitted from said radiant heaters will pass through said first and second belt means and impinge on said sheet material and volatiles evolved from the sheet being treated can escape from adjacent said sheet through the openings in said belt means.

2. The apparatus as defined in claim 1, together with:
   (a) means for introducing a stream of gas between said radiant heaters and the sheet material on the rolls in said upper and lower decks at a velocity sufficiently high to remove from adjacent said sheet volatiles evolved therefrom; and
   (b) means for exhausting the vapor laden gaseous stream from between said sheet material and said heaters.

3. The apparatus as defined in claim 1, wherein said first and second belt means each comprise a belt of material which is at least partially transparent to radiant energy having a wave length in the range of about 3.5 to 5.0 microns.

4. Apparatus for heat treating a continuous, moving sheet of material, comprising:
   (a) a plurality of drying rolls arranged in closely spaced side-by-side relationship in at least one multiple roll deck;
   (b) radiant heaters spaced from and surrounding at least a majority of said rolls; and
   (c) belt means trained around said rolls and extending between the rolls and the radiant heaters to press the sheet material against the rolls, said belt means being fabricated of open mesh synthetic material capable of passing a substantial portion of radiant energy impinging thereon with the mesh openings constituting not less than about 30% of the area of said belt means, whereby a substantial portion of the energy emitted from said radiant heaters will pass through said belt means and impinge on said sheet material and volatiles evolved from the sheet being treated can escape from adjacent said sheet through the openings in said belt means.

5. Apparatus for heat treating a continuous, moving sheet of material, comprising:
   (a) a plurality of drying rolls arranged in closely spaced side-by-side relationship in at least one multiple roll deck;
   (b) radiant heaters spaced from and surrounding at least a majority of said rolls;
   (c) belt means trained around said rolls and extending between the rolls and the radiant heaters to press the sheet material against the rolls, said belt means being fabricated of open mesh synthetic material capable of passing a substantial portion of radiant energy impinging thereon with the mesh openings constituting not less than about 30% of the area of said belt means, whereby a substantial portion of the energy emitted from said radiant heaters will pass through said belt means and impinge on said sheet material and volatiles evolved from the sheet being treated can escape from adjacent said sheet through the openings in said belt means;
   (d) a casing surrounding said rolls; and
   (e) means for evacuating said casing.

6. The apparatus as defined in claim 5, wherein the means for evacuating the casing comprises means for condensing the evolved volatiles and jet pump means for removing non-condensables.

7. Apparatus for heat treating a continuous, moving, sheet of material, comprising:
   (a) multiple drying rolls arranged in a plurality of spaced, generally parallel runs;
   (b) radiant heaters spaced from and partially surrounding at least a majority of the rolls in each of said runs; and
   (c) belt means trained around the rolls in at least one of said runs between the rolls and the radiant heaters to press the sheet material against the rolls, said belt means being fabricated to open mesh synthetic material capable of passing a substantial portion of radiant energy impinging thereon with the mesh openings constituting not less than about 30% of the area of said belt means, whereby a substantial portion of the energy emitted from said radiant heaters will pass through said belt means and impinge on said sheet material and volatiles evolved from the sheet being treated can escape from adjacent said sheet through the openings in said belt means.

8. The apparatus as defined in claim 7, wherein the material from which said belt means is fabricated is at least partially transparent to radiant energy having a wave length in the range of from about 3.5 to about 5.0 microns.

References Cited by the Examiner

UNITED STATES PATENTS

340,335	4/1886	Lindsay	34—116
1,595,240	8/1926	Minton	34—16
2,091,805	8/1937	Chuse	34—18 X
2,621,492	12/1952	Beardsley et al.	34—15 X
2,668,364	2/1954	Colton	34—4

FOREIGN PATENTS

779,326	7/1957	Great Britain.

FREDERICK L. MATTESON, JR., *Primary Examiner.*

A. D. HERRMANN, *Assistant Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,289,315 December 6, 1966

Horace L. Smith, Jr.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 68, for "preliminary" read -- preliminarily --; column 7, line 63, for "portoins" read -- portions --; column 10, line 19, after "these" insert -- novel --; column 12, line 45, for "to" read -- of --.

Signed and sealed this 19th day of September 1967.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents