METHOD AND EQUIPMENT FOR DRYING WEB MATERIAL

Filed Dec. 18, 1967 Sheet 1 of 3

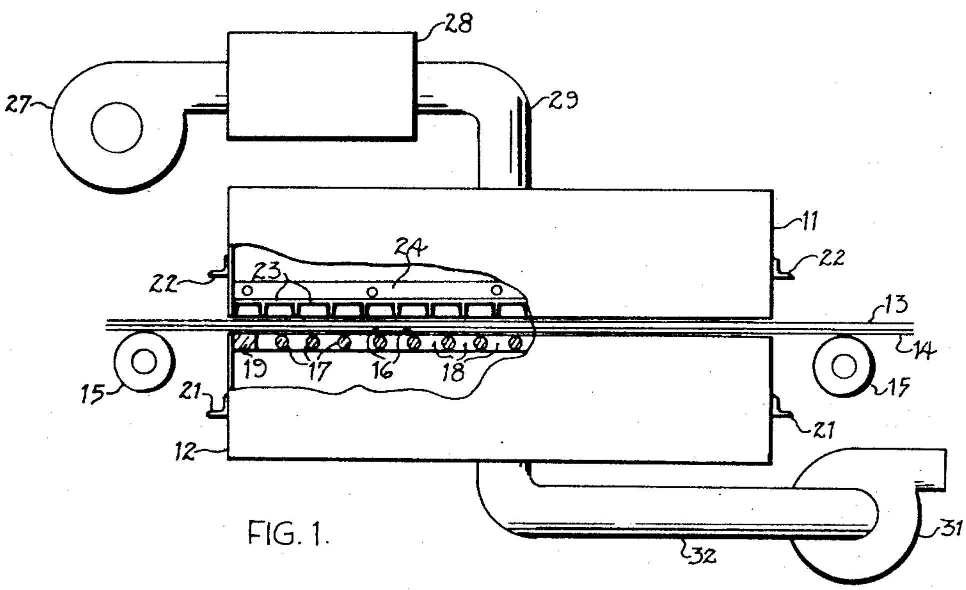

FIG. 1.

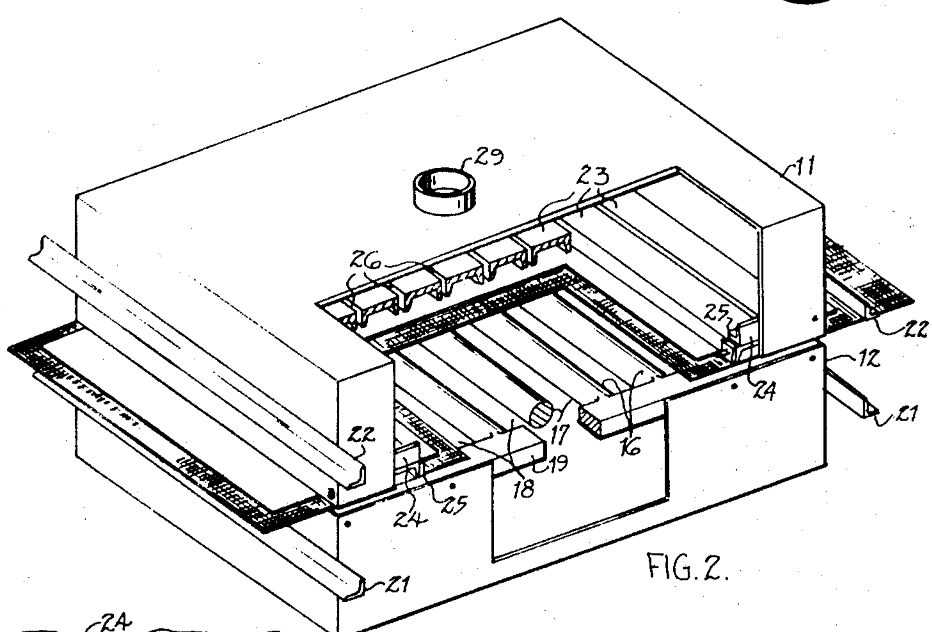

FIG. 2.

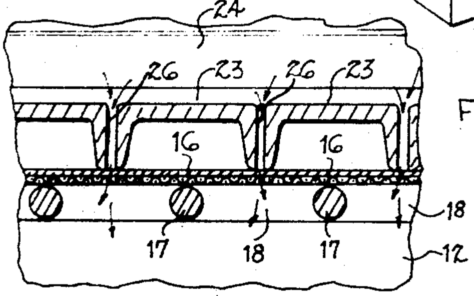

FIG. 3.

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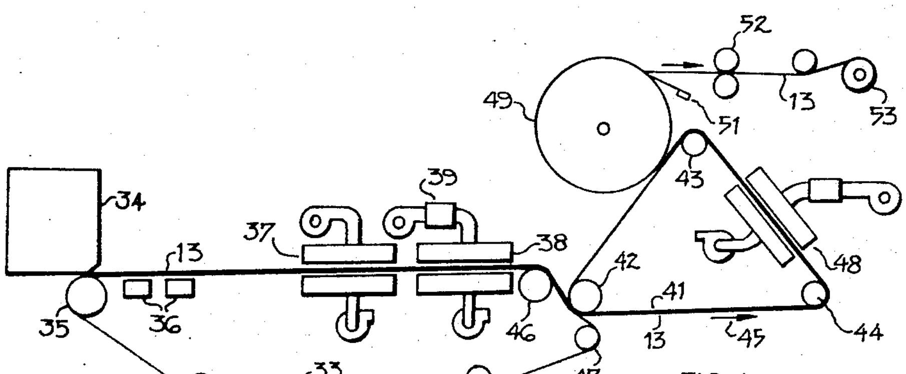

FIG. 4.

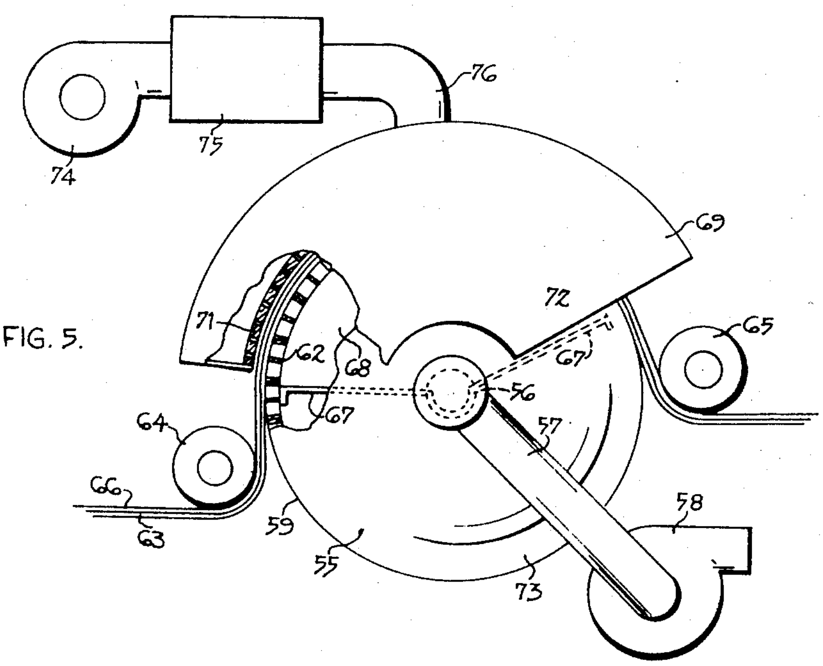

FIG. 5.

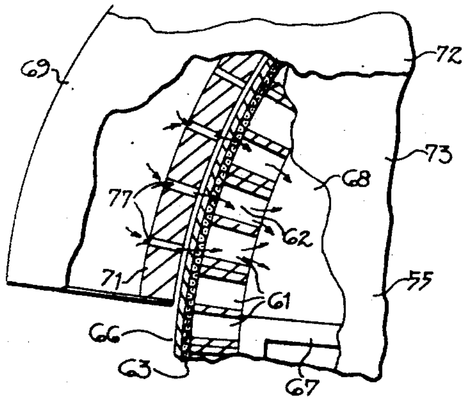

FIG. 6.

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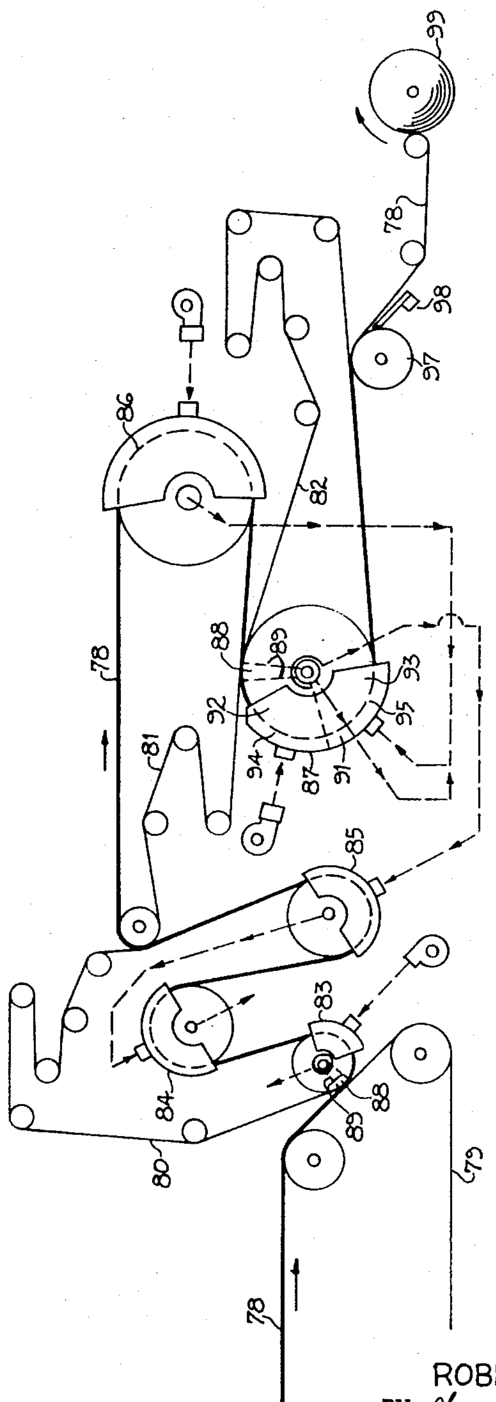

FIG. 7.

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METHOD AND EQUIPMENT FOR DRYING WEB MATERIAL

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Int. Cl. F26b 13/04, 3/04
U.S. Cl. 34—122 6 Claims

ABSTRACT OF THE DISCLOSURE

To remove moisture from a wet permeable web, particularly during the production of light weight paper, drying air is impinged on the web at high velocities, whereby the momentum of the high velocity air causes it to penetrate the web to improve the efficiency of the drying operation both by increasing the exposure of internal web fibers to the evaporative effect of the aair and also by physically blowing or pushing moisture particle through and out of the web.

The present invention relates generally to drying porous web materials and more particularly to drying a wet porous paper web during a papermaking process by passing drying air through the web.

The basic concept of drying a porous paper web in a papermaking machine by passing drying air through the web has previously been recognized as being more efficient than conventional processes in which the drying air is presented only to the face surfaces of the web. In general, the greater efficiency of this process, as determined by the amount of moisture that can be removed from the web in a given time by a predetermined volume of drying air at a particular temperature and humidity, is the result of two factors; namely, evaporative removal of moisture from the web end mechanical moisture removal effected by the physical pushing and/or entrainment of liquid by the air stream passing through the web.

In a typical known dryer of the type in which drying air is forced through a web of moist fibrous paper material, a vacuum box is located immediately below a moving perforate wire or fabric supporting the wet web, and is connected to an exhaust pump or blower; with an appropriate rib structure or the like being provided across the open top of the vacuum box to support the portion of the wire or fabric spanning the box. Adjacent the top surface of the web a similar inverted pressure box is aligned with the vacuum box and is connected to a source of heated pressurized drying air. Thus, the pressure differential between the pressurized heated air in the pressure box and the partial vacuum created in the vacuum box causes the heated air to pass completely through the web, thereby drying it internally as well as externally by evaporation of moisture from the web and by entrainment of liquid in the air stream moving through the web. Alternatively, the same general type of dryer can comprise a perforated vacuum drum partially encircled by the web along an area of the drum surface opposed by a correspondingly curved open face of the pressure box or cap.

In either of the foregoing types of dryers, which can be designated respectively as linear dryers and drum dryers, the rate at which moisture is removed from any given area of the web by air of a predetermined temperature and humidity is related to the weight and volume of air passing through that web area. Therefore, if the entire area of the web positioned between the pressure and vacuum boxes is of uniform permeability, the flow of air through the web likewise will be substantially uniform, thereby resulting in correspondingly uniform drying. In actual practice, however, the porosity of the web is not entirely uniform, either due to local variations in fiber content or distribution, or, more importantly, due to variations in the amount of water entrapped among the fibers of the web. Hence, since an area of the web having less entrained water than surrounding areas is more permeable to air, a disproportionate volume of air passes preferentially through such an area of the web, thereby accelerating further the drying of that particular area and continuously increasing the diversion of the available drying air from the relatively wetter surrounding areas.

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As previously mentioned, the effectiveness of a dryer system of this general type is attaributable in part to evaporation effected throughout the web by contact between the moist web fibers and the drying air; and also to entrainment and pushing of liquid moisture by the moving air stream. The later factor is particularly significant during the initial web drying operation, in which the web enters the dryer in a very wet condition, and can be visualized in terms of air pressure pushing water out of water-filled spaces between the web fibers and in terms of forcing air through the web with sufficient velocity to literally blow water out from among the web fibers as a result of the momentum of the rapidly moving air stream. While the amount of drying effected by evaporation is related rather directly to the weight and volume of air of a given temperature and humidity conducted through the web, the effectiveness of the liquid entrainment phenomenon varies as a function of the velocity of the air flow.

SUMMARY OF THE INVENTION

The present invention contemplates web dryers related generally tto those discussed above, but in which the drying air is directed onto the sheet at high velocity and in which self-accentuated localized drying of relatively permeable areas of the sheet is reduced, whereby a given volume of drying air effects the removal of a substantially greater amount of moisture than in previously known related devices. Briefly, this is accomplished by providing the pressure box with a nozzle member comprising a plurality of individual nozzles, each of which is adapted to produce a high velocity air jet of relatively small area impinging against the adjacent surface of the web as it traverses the nozzle member. Alternatively, a reticulated barrier member, e.g. formed of sintered metal particles, could be substituted for the nozzle member to minimize accelerated localized drying, but the preferred nozzle plate arrangement defining definite individual air jets affords substantially more economical performance from the standpoint of the power required to achieve the desired high velocity air flow rate to impinge a given weight of air against the web. Regardless of which of these arrangements is employed, however, rather than simply percolating through the web in response primarily to the static pressure differential above and below the web, the drying air is actually blown through the web by virtue of the momentum of the air, with the undesirable preferential channeling of air to a localized area of high web permeability being limited by the flow restriction inherent in the adjacent portion of the nozzle plate or barrier member. Similarly, the momentum of the drying air minimizes its lateral migration along the surface of the web, thereby reducing the importance of maintaining tight seals between the web and the pressure chamber to prevent substantial quantities of air from ineffectively exhausting to the atmosphere without penetrating the web.

In addition to improving the efficiency of the dryer unit as defined by the volume of drying air of predetermined temperature and humidity required to effect a given reduction in the moisture content of the web, the effectiveness of the present invention in exploiting the superior drying capabilities achieved by forcing high velocity air through the web also significantly broadens the range of application of this type of drying equipment in paper machines; thereby allowing such dryers to replace substantially partly or completely more expensive and less efficient types of dryers or presses which often must be used in conjunction with conventional hot air dryers to perform preliminary or final web drying operations.

Various means for practicing the invention and many other advantages and novel features thereof will be apparent from the following detailed description of illustrative embodiments of the invention, reference being made to the accompanying drawings in which like reference numerals refer to like elements.

In the drawings:

FIGURE 1 is a somewhat schematic side elevational view, partially in cross section, of a linear type web dryer according to a preferred embodiment of the invention;

FIGURE 2 is a perspective view of the pressure and vacuum boxes of the dryer depicted in FIGURE 1, with portions of the illustrated construction shown broken away and cross-sectioned to illustrate structural details;

FIGURE 3 is an enlarged cross sectional side elevational view of a portion of the nozzle and web supporting structure illustrated in FIGURES 1 and 2;

FIGURE 4 is a schematic side elevational view of a papermaking machine incorporating several linear dryers of the type illustrated in FIGURES 1 through 3;

FIGURE 5 is a somewhat schematic side elevational view of a rotary type dryer comprising an alternate embodiment of the invention, with portions of the illustrated construction broken away and cross sectioned to depict internal structural features;

FIGURE 6 is an enlarged view of a portion of the rotary dryer shown in FIGURE 5; and

FIGURE 7 is a schematic side elevational view of a paper making machine incorporating a plurality of rotary dryers of the type shown in FIGURE 5.

The linear dryer unit illustrated in FIGURES 1 through 3 comprises a pressure box **11** and a vacuum box **12**, and is adapted to perform a drying operation on a web of moist permeable fibrous material **13** carried through the dryer by a generally horizontal portion of a moveable perforate web support member **14** supported beyond the dryer unit by rollers **15**. Within the dryer, the web support member is slidably supported in a flat plane by the coplanar top surfaces **16** of a plurality of support rods **17** defined by elongated openings **18** in the top wall member **19** of the vacuum box. The entire vacuum box in turn, is rigidly attached to an appropriate stationary frame, not shown, by support rails **21**.

Pressure box **12** is likewise rigidly attached to the same or another stationary frame, not shown, by its support rails **22**, to position it directly above and in predetermined spaced relation to the vacuum box. The lower wall of the pressure box is defined by a plurality of spaced parallel channel members **23** mounted to the side wall members of the box by angle members **24**, with the coplanar lower edges of the channel members being positioned in close proximity to the adjacent top surface of the web. As best shown in FIGURES 2 and 3, the channel members are spaced slightly apart by spacer plates **25** located below angle members **24**, to define a plurality of elongate parallel nozzle openings **26** extending across the web in transverse relation to its direction of movement. Each of the nozzle openings is located in vertical alignment with a corresponding one of the openings **18** in the top wall member of the vacuum box, such openings being considerably wider than the nozzle openings. Alternatively, the nozzles could be defined by staggered or overlapping holes adapted to produce a greater number of jets of air of approximately the same total cross-sectional area.

The air supply system associated with the dryer unit comprises an air compressor pump or blower **27** adapted to force air under pressure through a heater unit **28** and into pressure box **11** through pressure duct **29**. Similarly, an exhaust pump or blower **31** is connected to vacuum box **12** by duct **32**. Accordingly, it will be seen that when both pumps or blowers are in operation, the pressure box is supplied with heated pressurized air which is impinged on the web in elongate narrow high velocity jets defined by the nozzle openings. These jets of air penetrate through the web and through slots **18** in the upper wall member of the vacuum box, from which air is constantly exhausted by the exhaust pump or blower.

In a typical application, the channel members might be approximately in inch wide and a half inch deep and spaced apart by about $3/100$ of an inch, thereby defining a total nozzle area equal to about three percent of the total area of the portion of the web within the dryer. In performing an initial drying operation on a substantially saturated web, drying air is typically maintained at a nominal gauge pressure of approximately 30 inches of water and at a temperature in excess of 300 degrees F. The ratio of the nozzle area to the area of the web being dried can of course, be altered to suit various conditions but should not exceed 10% of the web area, if efficient performance is to be achieved from the standpoint of heat and power requirements. In selecting the most appropriate combinations of nozzle arrangements and air requirement, the most important consideration is to achieve air velocity through the nozzles or their equivalent at a rate of at least 8000 feet per minute, as opposed to an air velocity of less than 1000 feet per minute in a similar unit devoid of the subject nozzle plate or the like.

Therefore, it will be apparent that the hot drying air impinges on the web at a much greater velocity than in the case of prior art dryers in which the pressure differential in the vacuum and pressure boxes generally does not exceed 10 inches of water pressure and in which the air is emitted onto the web through a reticulated flow resistant barrier of substantially greater area than the combined area of the separate nozzles. Since the penetration of the air through the web results primarily from the velocity of the air passing through the nozzles, the depressurization of the vacuum box is intended primarily only to insure positive exhausting of the unit, rather than to maintain a static pressure differential between the faces of the web. Hence, this vacuum can be relatively moderate, e.g. minus 10 inches of water pressure or less.

In addition to the previously explained advantages afforded by this localized jet impingement system, another very important beneficial feature of such an arrangement is that the problem of leakage along the wall members of the pressure box is substantially reduced inasmuch as the penetration of air through the web is primarily a momentum phenomenon, dependent upon the velocity of the air rather upon maintaining a given air pressure throughout the pressure box. Thus, whereas in the previous type of apparatus even relatively small gaps between the pressure box and the web or drum will result in wasteful loss of relatively large volumes of heated air, such gaps have relatively little diversionary effect on the high velocity jets of drying air provided by the present invention.

In other words, by impinging high velocity air jets on the web surface, the subject dryer produces at the adjacent web surface a layer of air under much higher pressure than that which could be maintained economically in a known type of pressure box without elaborate means for preventing lateral air leakage between the web and the edges of the open end of the box.

This feature therefore results in conservation of the heated drying air by minimizing losses to the surrounding atmosphere, and also simplifies accurate determination of the efficiency of the unit and automatic regulation thereof, by insuring that only a small and relatively constant amount of air is diverted from passing through the web. Therefore, by associating automatic blower and heater control means with known types of sensing devices adapted to sense the temperature, humidity and volumetric rate of flow of the air in ducts **28** and **32**, the moisture content of the web emerging from the dryer can be controlled automatically to a relatively high degree of accuracy.

FIGURE 4 depicts schematically and in greatly simplified form the essential elements of an illustrative papermaking machine incorporating several linear dryer units corresponding to those just described. Although the illustrated machine is of a relatively simple type appropriate for making porous tissue paper or the like, it should be understood that the subject invention is also applicable to more elaborate machines including the various additional machine elements associated with producing various other types of paper of sufficient permeability to allow the passage of air therethrough during the drying operation.

The paper web **13** formed on moving Fourdrinier wire **33** by feeding the so called paper furnish onto the wire from headbox **34** adjacent breast roll **35**. Since the furnish contains considerably more water than can be retained by the capillarity of the fibrous web mass deposited on the wire, a considerable amount of excess water drains through the wire by gravity, such drainage generally being assisted by suction boxes as shown at **36**. As the web passes beyond the suction boxes, therefore, drainage has accounted for the removal of considerable excess water but the web still remains substantially saturated with water absorbed into and entrained by capillarity between the web fibers.

The first actual drying operations performed on the web are accomplished by linear dryer units **37** and **28** located along the Fourdrinier wire and corresponding in structure to the unit shown in FIGURES 1 through 3. While it is known to provide a conventional hot air dryer unit along the Fourdrinier wire beyond the suction boxes, it is important to note that the subject dryer units at the corresponding location are not merely equivalent to such previously known dryers, but are much more effective and economical due to the employment of high velocity air jets to blow entrained water out of the web as opposed to merely evaporating it by contact with heated air. As previously mentioned, the web is substantially saturated as it enters the dryer units along the Fourdrinier wire, with the open spaces between the web fibers being filled with water held in place by capillary action. Therefore, in known dryers of the type in which only a relatively small static pressure differential can be maintained between the faces of the web, such pressure is insufficient to overcome the capillary forces which retain the unabsorbed water between the web fibers. Consequently, the removal of moisture by such a dryer occurs principally by evaporation at the web surfaces until the moisture content is reduced sufficiently to allow air penetration, whereupon the above described undesirable localized drying phenomena comes into effect. In the arrangement depicted in FIGURE 4, however, the localized high velocity jets of air emitted through the nozzle plate of the pressure boxes impinge on the saturated web with sufficient momentum to push or blow water out of the web and into the vacuum box in opposition to the capillary forces tending to retain such droplets between the web fibers. In other words, the initial drying operation is effected primarily by virtue of the momentum of the drying air rather than by evaporation, for which reason dryer unit **37** can be supplied with unheated air or with exhaust air from the succeeding unit **35** to reduce the expense associated with heating the drying air. When used in conjunction with making tissue paper or other similar highly porous paper, the moisture removal effectiveness of the air jets is of course more pronounced than when a similar dryer is employed in a machine adapted to make paper of higher fiber content which is inherently less

permeable and holds the entrained water under greater capillary forces between the more numerous and densely packed fibers. Therefore, when employed to dry paper of a relatively high fiber content, the first dryer unit may also be provided with its own source of heated air or with a secondary heater to increase the temperature of exhaust air from a succeeding unit, thereby increasing the evaporative effect of the air jets on the web.

The second dryer unit **38** is substantially identical to unit **37** but is provided with an air heater **39** adapted to heat the pressurized air to promote evaporation of the moisture within the web, from which unit **37** has already removed most of the water susceptible to mechanical extraction. Even though evaporation is now the dominant drying process, the same high velocity air jet system is nevertheless employed in this and subsequent dryer units to increase the evaporative capacity of the drying air by insuring that the air comes into intimate moving contact with the moist fibers throughout the web rather than forming stagnant layers of saturated drying air within and at the surfaces of the web.

By the time the web emerges from dryer unit **38**, it has been dried sufficiently to allow it to be transferred from the Fourdrinier wire to a second dryer wire or fabric **41**, which is supported by rollers **42**, **43**, and **44** for movement in the direction indicated by arrow **45**. Such transfer of the web to the dryer belt is accomplished between couch roll **46** and wire return roll **47** of the Fourdrinier and may be assisted by employing a conventional vacuum roll at the location of roll **42**. As the web continues its movement along the dryer belt it encounters a third linear dryer unit **48**, likewise similar to the one shown in FIGURES 1 through 3, by which it is further dried by high velocoity jets of heated air. Since as the web has already lost much of its moisture content in the preceding drying operations and is therefore quite porous, the drying air employed in unit **48** may be maintained at a lower input pressure and/or at higher temperatures than in the preceding units to effect the required drying at this stage of the machine. As previously suggested, the various drying units can be provided conveniently with automatic means not shown, for adjusting such temperatures and pressures automatically to maintain the desired predetermined moisture content within the web at various stages of the paper making operation.

Upon emerging from dryer unit **48**, the web has been dried to a level of moisture content compatible with the performance of a final drying operation on a conventional steam heated "yankee" dryer **49**, which serves to flatten and smooth the web as the remaining excess moisture is removed therefrom under the influence of the heated surface of the dryer drum. As is well known in the art, the dried web is then separated from the drum by a creping doctor blade **51**, whereupon it is passed through straightening rollers **52** and wound onto an appropriate mandrel **53** for removal from the machine.

From the foregoing explanation, it should be apparent that the subject high velocity air dryer units are employed to remove all of the excess water in the paper web with the exception of the relatively slight amount of moisture which is required for proper performance for the final yankee drying operation. In contrast to this system, which is very economical both in terms of structure and operating costs, similar machines employing conventional hot air dryers almost invariably require additional expensive and relatively inefficient heated drum type dryers or the like preceding the final drying operation to offset the previously described localized drying phenomenon. Also, it should be apparent that the subject units need not replace entirely all other types of preliminary and intermediate dryers, but can be installed readily at almost any location along the web to provide efficient and accurately controllable supplemental drying of the web. For example, even in the manufacture of relatively heavy paper which, may be too dense in a highly wet state to be penetrated even by high velocity drying air, a drying unit according to the present invention might be employed beneficially beyond other types of dryers utilized to reduce the moisture content of the web sufficiently to allow its penetration by the high velocity drying jets.

FIGURE 5 illustrates an alternate embodiment of the invention in which the advantages of high velocity air jet drying are provided in a rotary type dryer unit. In this embodiment a hollow cylindrical drum **55** is supported by appropriate airtight bearings for rotation about a stationary tubular shaft **56** connected by duct **57** to an exhaust pump or blower illustrated at **58**. The cylindrical exterior surface of the drum is perforated by closely spaced uniformly arranged slots or holes, **61**, which in the illustrated drum are defined by a honeycomb shell member **62** of the type known in the prior art. A portion of the endless moving web support member, comprising perforate woven belt **63**, is trained over the drying drum **55** between guide rolls **64** and **65**, so that the moist paper web **66** carried by the belt is supported in spaced relation to the drum surface **59**. A pair of vane members **67**, of the type well known in the paper machine art, are immovably supported within the drum by tubular shaft **56** to define a vacuum chamber **68** adjacent the portion of the cylindrical honeycomb drum surface covered by the web carrier member. This vacuum chamber is in communication with exhaust pump or blower **58** through the tubular shaft and through duct **57**, so that the operation of the pump or blower applies a partial vacuum to the lower surface of the corresponding portion of the web. A pressure cap **69**, corresponding generally to the previously described pressure box **11**, is positioned with its cylindrical nozzle plate **71** closely adjacent the portion of the top surface of the web opposite the vacuum chamber, and with its end wall members **72** in close proximity to the corresponding flat end surfaces **73** of the drum. The pressure cap is connected with pressure pump or blower **74** and with air heater **75** through duct **76**, whereby heated pressurized drying air can be supplied to the cap. Hence, as in the above described linear dryer unit, the compressed heated drying air is impinged perpendicularly on the web in high velocity jets defined by parallel elongate nozzle slots **77** in the nozzle plate.

Whereas in the above described linear type dryer each of the nozzles is opposed by an opening between two of the relatively wide support rods of the vacuum box, the continuous relative movement between the drum and the nozzles precludes such an arrangement in a rotary type unit. Therefore, the drum surface is uniformly perforated, as by the illustrated honeycomb structure, so that the nozzles are at all times opposite substantially open areas of the drum periphery.

FIGURE 7 shows another illustrative papermaking machine adapted to produce tissue paper or the like, which is completely dried by means of five successive rotary dryer units similar to the one just described. In this machine the web **78** is formed on Fourdrinier wire **79**, and is transferred therefrom to successive perforate woven fabric conveyor belts **80**, **81** and **82**, which support the web as it passes in turn through the five successive dryer units identified in sequential order by numerals **82** through **87**. The three endless conveyor belts are moveable in the respective directions indicated by the corresponding arrows and are supported by the dryer drums and by appropriate conventional guide rolls, which are depicted in the drawing but not specifically identified. In general, all of the dryer units are structural similar to the one just described, but in addition to the drying air vacuum chambers, the drums of dryer units **83**, and **87** also include separate high vacuum chambers **88** defined by additional internal vane means **89**, such chambers being connected to appropriate exhaust pumps, not shown, through conduits within the respective tubular drum support shafts. These high vacuum chambers serve only incidentally to

promote the drying of the web, their primary purpose being to encourage the transfer of the web to the adjacent conveyor belt. Similarly, an additional internal intermediate vane member, indicated at **91**, is located within the drum of dryer unit **87** to provide that drum with two drying air vacuum chambers **92** and **93**. The pressure cap of that dryer unit likewise comprises two separate pressure chambers **94** and **95** aligned respectively with the corresponding drying air vacuum chambers, thereby providing two successive dryer stages in the same rotary unit.

When an area of the web enters dryer unit **83** from the Fourdrinier wire, it has already been drained of excess water but is still saturated. Hence, in the web drying operation performed by units **83** and **84**, the mechanical removal of water from the web is much more significant than is evaporation. For this reason, unit **83** is supplied which pressurized by unheated atmospheric air and unit **84** is adapted to utilize the warm moist exhaust air from unit **85**. To simplify the drawing, the air conducting means interconnecting the various dryer units are illustrated schematically by broken lines, with the direction of the air flow being depicted by arrowheads along those lines.

Unlike the other rotary dryer units incorporated in the illustrated machine the second unit **84** is so located as to position the web between the belt **80** and the drum, rather than at the surface of the belt away from the drum. Therefore, to continuously support the face of the web adjacent the drum, the cylindrical honeycomb surface of this unit is wrapped with a layer of perforate fabric akin to that comprising the belts. This sandwiching of the web between two layers of perforate fabric necessarily restricts somewhat the volume of the drying air passing through the web, but this consideration is not of critical importance at this relatively early drying stage particularly in view of the fact that the exhaust air from dryer **85** can be utilized in unit **84** without being reheated.

By the time a portion of the web enters dryer unit **86**, its moisture content has been reduced by the preceding three dryers to the point where further drying is effected primarily by evaporation rather than by mechanical moisture removal. Therefore, to provide maximum evaporation capacity of the drying air, the air cap of dryer unit **86** is supplied with pressurized dry air forced through a heater as shown in FIGURE 5. Similarly, pressure chamber **94** of the final drier unit **87** is also provided with dry air provided by another separate blower and heater system.

Upon emerging from the first stage of the final drier unit, the web material has been dried sufficiently to reduce its moisture content to a level acceptable in the finished paper sheet, and could be removed from the machine without further processing. Therefore, the second stage of the final dryer unit defined by pressure chamber **95** and vacuum chamber **93** does not actually perform a further drying operation. Instead, this stage of the machine provides an equilibrium zone in which the web is penetrated by high velocity air derived from the exhaust of the first stage of that unit and from the preceding unit **86**, and repressurized by an appropriate blower or the like, not shown. This air, therefore, is warm and relatively humid, and tends to improve the overall uniformity of the web moisture content by allowing overly dry web areas to reabsorb a slight amount of moisture while small amounts of moisture are further evaporated from local web areas that may still be too moist. Thereafter, the finished paper web is separated from the belt **82** by roller **97** and doctor blade **98** and is wound onto mandrel **99**, on which it is removed from the machine.

Although the most effective temperature and pressure of the drying air at the various drying units is dependent upon a number of factors including the nature of the web material and design factors inherent in a particular papermaking machine, in a typical application the air pressure differential across the web might decrease progressively from about 30 inches of water at the first dryer unit to only three or four inches of water at the final dryer, to maintain the required high velocity of the drying air through the nozzle structure while compensating for the corresponding increased porosity of the web as water is progressively removed therefrom. Similarly, as previously mentioned, the temperature of the drying air in the final two dryer units may be in the neighborhood of 600° F., such temperature being lower in the preceding units which operate merely at the exhaust temperature of the succeeding units or at ambient atmospheric temperature. It should,, of course, be obvious that supplemental heater units could be employed as desired to increase the air temperature in the earlier drying stages and that systems other than the one specificially described could be employed to circulate drying air between the various units. Similarly, it should be equally apparent that such rotary dryer units can be adapted readily to other types of paper making machines, which might employ both rotary and linear dryer units according to the present invention as well as other types of conventional dryer devices.

Although the foregoing description relates to specific embodiments of the invention, it should be apparent that variations and modifications thereof can be effected within the spirit and scope of the invention. Accordingly, the present disclosure is to be considered as illustrative and not as limiting the scope of the invention which is defined by the following claims.

What is claimed is:

1. An apparatus for drying a permeable web travelling along a predetermined path on a moving foraminous support member in contact with one surface of said web, said apparatus comprising:

(a) a barrier member supported along said path with one face of said barrier member in spaced generally parallel adjacency to the other surface of a portion of said web,

(b) nozzle means defining in said barrier member a plurality of openings extending therethrough between said one face thereof and the opposite face thereof, said openings having a total cross sectional area less than ten percent of the area of said portion of said web.

(c) pressure box means defining a pressure chamber in communication with said opposite face of said barrier member,

(d) air supply means for supplying heated pressurized air to said pressure chamber at a rate which produces a flow of air through said barrier member at an average velocity exceeding 8000 per minute,

(e) vacuum box means defining a vacuum chamber in communication with said one surface of said portion of said web through said foraminous support member, and

(f) exhaust means for constantly maintaining a partial vacuum in said vacuum chamber to exhaust the air forced through said portion of said web by high velocity impingement upon said other surface thereof.

2. The apparatus defined by claim 1 in which said openings are defined by said nozzle means in the form of a plurality of uniformly distributed holes extending through said barrier member in generally perpendicular relation to said portion of said web.

3. The apparatus defined by claim 1 in which said openings are defined by said nozzle means in the form of a plurality of narrow parallel slots extending through said barrier member in generally perpendicular relation to said portion of said web and in transverse relation to the direction of movement of said support member.

4. The apparatus defined by claim 3 in which the width of said slots does not exceed one tenth of an inch.

5. The apparatus defined by claim 1 in which said portion of said web is moved along a semi-cylindrical path defined by a rotatable drum, said vacuum box means comprising means defining said vacuum chamber internally of said drum.

6. A web dryer system comprising:

(a) means for moving an elongate web longitudinally along a predetermined movement path,

(b) a first dryer unit located at a first position along said path and comprising:

(1) air supply means for impinging high velocity heated pressurized air against one face of a portion of said web adjacent said first dryer unit by directing such air through a plurality of nozzle means adjacent said one face at a velocity in excess of 8000 feet per minute,

(2) exhaust means for creating a partial vacuum at the opposite face of said portion of said web to exhaust air driven through principally by said web by said air supply means,

(c) a second dryer unit corresponding to said first dryer unit, said second dryer unit being located at a second position beyond said first dryer unit along said movement path to perform a second drying operation on said portion of said web, and

(d) means for supplying said air supply means of said first dryer unit with air exhausted from said second dryer unit by said exhaust means thereof.

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KENNETH W. SPRAGUE, *Primary Examiner.*

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,447,247 Dated June 3, 1969

Inventor(s) Robert A. Daane

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

In column 9, line 50, the phrase "8000 per" should read --8000 feet per--.

SIGNED AND
SEALED
FEB 17 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents