CONTINUOUS PROCESS OF DRYING UNCOATED FIBROUS WEBS

Filed Nov. 8, 1966 2 Sheets-Sheet 1

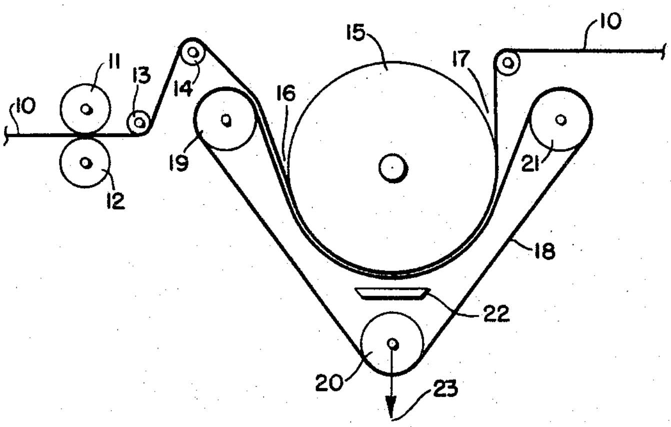

FIG. 1

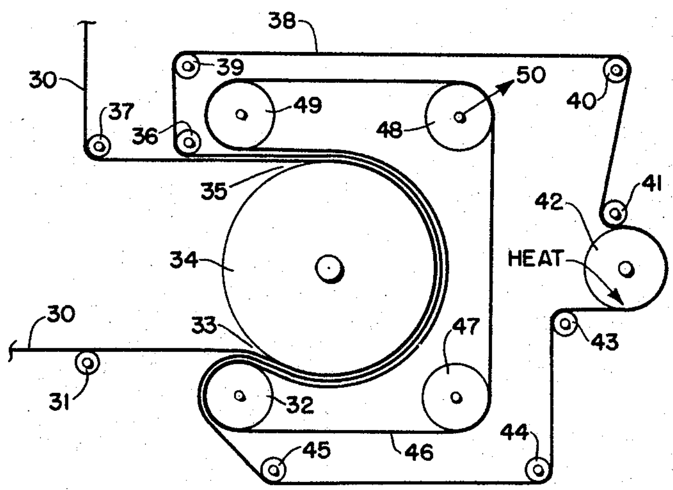

FIG. 2

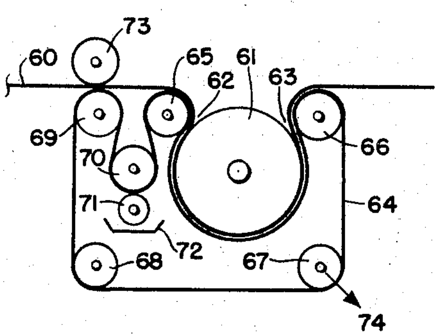

FIG. 3

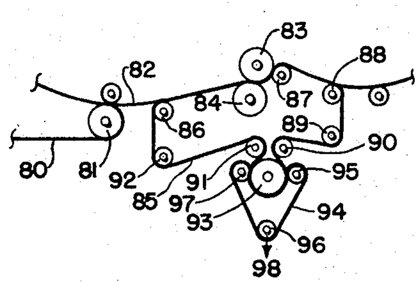

FIG. 4

CONTINUOUS PROCESS OF DRYING UNCOATED FIBROUS WEBS

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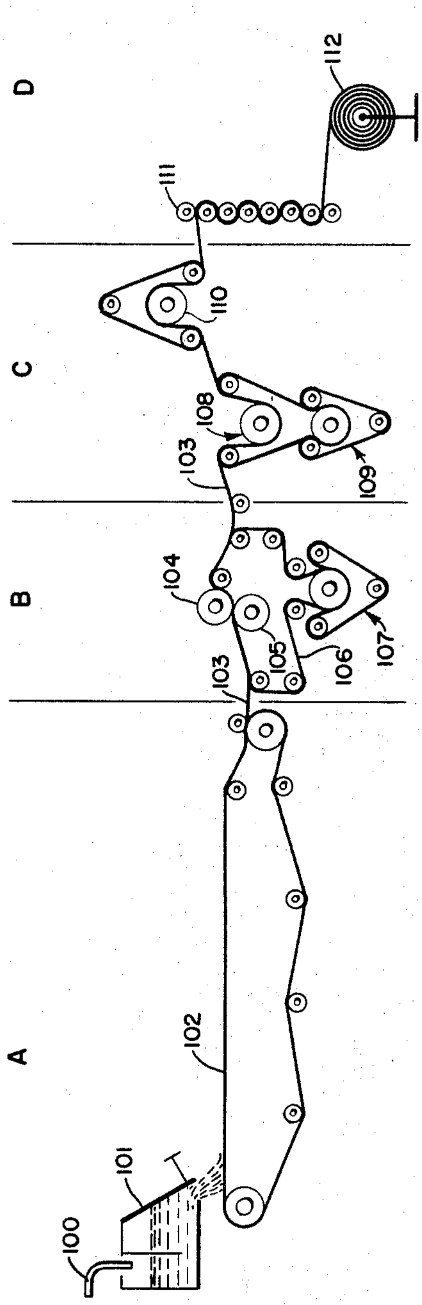

FIG. 5

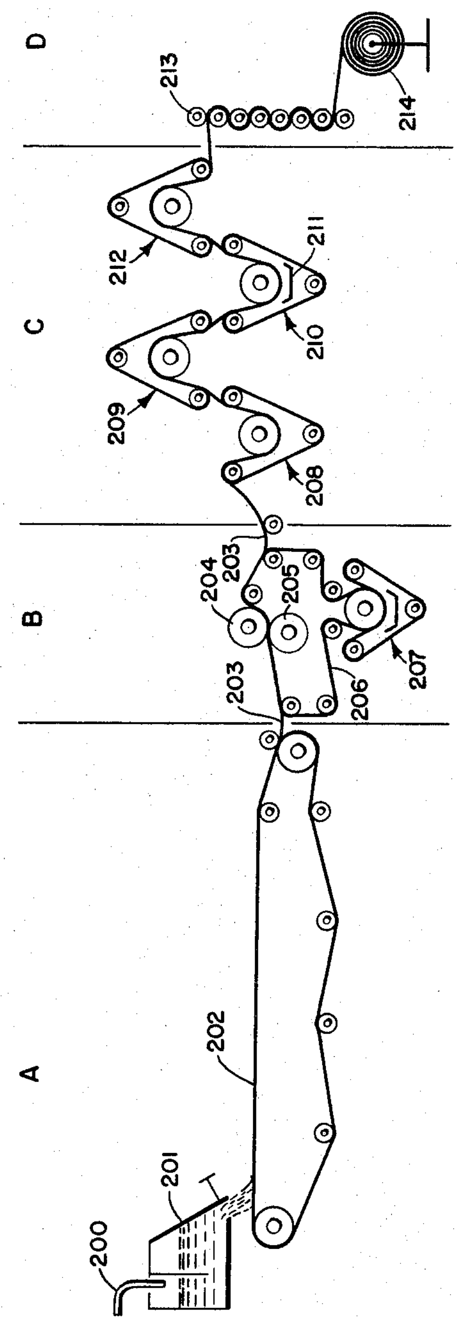

FIG. 6

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CONTINUOUS PROCESS OF DRYING UNCOATED FIBROUS WEBS

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ABSTRACT OF THE DISCLOSURE

This invention relates to a process and apparatus for removing liquid from an uncoated fibrous web material by pressing a substantial portion of a wet uncoated fibrous web against a heating surface with a pliable member more porous than the uncoated fibrous web. The heating surface is at a temperature of at least about 250° F. and the pressure in the pressing step is at least about 5 p.s.i.

Cross reference to related application

This application is a continuation-in-part of copending application Ser. No. 310,222, filed Sept. 20, 1963, now abandoned.

Background of the invention

This invention relates to a process and apparatus for removing liquid from an uncoated fibrous web material in a paper-making process; and more particularly, this invention relates to a novel process for the removal of water at a heretofore unheard of rate from a water saturated uncoated continuous web material such as paper or paperboard web.

Present day machines for the production of paper are principally of two types, the Fourdrinier machine and the cylinder machine, and water removal from paper and paperboard made on conventional Fourdrinier and cylinder paper machines is accomplished in several ways. Initially, the water used in the formation of the web is removed by draining the water from the fibers through a wire screen. In the case of the Fourdrinier machine, this draining process is assisted by the use of table rolls which exert a pumping action beneath the wire screen and also by suction boxes beneath the wire screen. In both types of machines, an uncoated web is subsequently removed from the wire, or felt in the case of a cylinder machine, and then transferred to a press section.

In conventional press systems, the uncoated paper or paperboard web is led into the nip between two pressure rolls simultaneously with the felt. The water is thereby squeezed from the saturated web and is absorbed by the felt with the excess water passing through the felt and onto the roll. In the case of a suction press, any excess water as well as a portion of that contained in the felt is removed by the suction roll. There are numerous variations in conventional press systems, but in substantially all cases the web and felt pass through a very narrow pressure nip where the water is squeezed from the web into the felt. One particular variation of this system employs a series of dryers just prior to the pressure nip whereby the temperature of the web is raised appreciably to reduce the viscosity of the water and promote release of the water from the web in the nip. This particular type of apparatus arrangement is commonly referred to as a "hot press."

On conventional paper machines, an uncoated web leaves the press section containing under the best conditions a minimum of about 60 to 70 percent water and then enters the dryer system. The dryer system generally comprises a series of heated cylinders usually operated in combination with a system of dryer felts. The dryer felts serve a dual function, first, to hold the web in reasonably close contact with the drying cylinders and second, to provide a vehicle for the transfer of water emanating from the web. The dryer felts, which are endless or continuous, are then dried separately by passage over heated cylinders constituting part of the felt conveying means. After contact with the heated cylinders, the semi-dried felt is then reapplied to the web undergoing treatment.

Heretofore, the practice in the art has been to apply an amount of tension to the dryer felt corresponding to a pressure normal to the cylinder of about 0.05 pound per square inch. To the best of our knowledge, no felt system has been reported in the literature operating at a pressure normal to a cylinder higher than about 1 pound per square inch. The use of such operating pressures has in turn limited the use of high temperatures for drying, especially in the initial drying stage, since excessive heat will cause the water at the surface of the web to boil thereby blowing the web away from the drying surface.

In present day conventional paper-making machines operating under the above conditions, it has been found also that very little water removal occurs on the first several dryers in the cylinder dryer section even though these dryers are heated to at least the boiling point of water. The water in the web does not begin to evaporate until after the first several dryers because a part of the water recondenses and is absorbed in the felt with the remaining portion being removed from the environment as steam and discharged into the atmosphere.

Thus, in light of the above limitations, it can be understood why the drying rate of an uncoated paper web varies along the length of the drying section of present day paper-making machines. Specifically, the drying rate starts off rather low, usually at about 1 to 2 pounds per hour per square foot of drying surface and gradually increases as the paper serpentines through the section, reaching a maximum of generally from about 7 to 8 pounds per hour per square foot at which point it holds constant for a period whereafter it gradually decreases toward the dry end of the section. Overall drying rates will vary to some extent depending upon the type of stock being manufactured; however, seldom do they exceed more than 5 pounds per hour per square foot even with very effective vapor removal means. For example, average drying rates for kraft paper and paperboard will be usually from about 3 to 5 pounds per hour per square foot under the best conditions.

To overcome the above deficiencies, the practice has been to include more and more dryers in the dryer system to increase production rates. As is generally well known, for a given paper or paperboard machine, there is a maximum production rate which is usually controlled by the capacity of the dryer system. When this production rate is exceeded, paper exceeding the specification level of moisture content is produced. The simple solution of just adding more and more dryers and auxiliary equipment has not been a panacea for all of the paper makers' problems in this regard since other troublesome factors have been introduced. For example, beyond the additional cost, there is the additional amount of control required in operating larger machines, and more operating utilities are required. Therefore, a process for overcoming this problem whereby the drying rate for paper stock can be vastly increased, would be a welcome contribution to the art.

It is an object of this invention to provide a process and apparatus for drying an uncoated web material containing liquid.

It is an object of this invention to provide novel process and apparatus for the removal of moisture from a web material at a rate heretofore unobtainable in present day paper-making machines.

A specific object of this invention is to provide a novel water removal process and apparatus which is capable of being employed in various stages of present day paper-making processes so as to achieve production rates and efficiencies heretofore unobtainable.

A more specific object is to provide a process and apparatus for the manufacture of continuous fibrous web material having greater strength and surface smoothness than heretofore obtainable by present day methods employing similar raw materials.

An even more specific object of this invention is to provide a process for the manufacture of continuous paper stock at a greater degree of efficiency than presently realized in the art.

These and further objects will come to light as the discussion proceeds.

FIGURE 1 in the drawings is a schematic of an apparatus in its most rudimentary form for the process of this invention.

FIGURE 2 is a preferred embodiment of this apparatus in that it depicts a preferred means for pressurizing a web material under treatment.

FIGURE 3 depicts a unique combination made possible by this invention, viz. a combination of the apparatus of this invention with a number of pressing rolls.

FIGURE 4 depicts another arrangement of the apparatus of FIGURE 1 as integrated in the pressing section of a conventional paper-making machine.

FIGURES 5 and 6 illustrate the ramifications to present day paper-making processes made possible by way of this unique invention. In that figure, Section A is a conventional Fourdrinier section, Section B is the pressing section, Section C is the drying section, the latter two sections revolving around the unque precess and apparatus of this invention, and Section D is a conventional calender section.

In accordance with the process of this invention, unexpected increases in drying rates for an uncoated fibrous web material, for example paper stock as produced on a Fourdrinier or cylinder machine, are realized by passing an uncoated web, containing liquid to be removed, continuously around an in direct contact with a substantial portion of rotating drum surface heated to at least a temperature equivalent to the boiling point of the liquid in the web and continuously and simultaneously applying a pressure against the outer surface of the web throughout substantially all of the time the web is in contact with the rotating drum surface, said pressure being at least 5 pounds per square inch and greater than the vapor pressure of the liquid at the temperature employed.

More precisely this invention teaches a continuous process for drying an uncoated fibrous web material containing volatile liquid consisting of the combination of simultaneous steps of,

(a) contacting said uncoated web continuously with a substantial portion of a rotating drum surface heated to at least the boiling point of said volatile liquid, and

(b) forcing with a continuous pliable member more porous than said uncoated fibrous web substantially all of the contacting web against said substantial portion of a rotating drum surface at a pressure at least as great as the vapor pressure of said volatile liquid at the temperature of the heated drum surface.

The source of pressure is derived from a porous belt means which is caused to press against the outer surface of the uncoated web over essentially the same arc of contact prescribed by the web in contact with the drum surface. Thus, a preferred embodiment of this invention is a process for removing liquid from a wet uncoated fibrous web material comprising passing said wet web around and in direct contact with a substantial portion of a drum surface heated to a temperature at least equivalent to the boiling point of the liquid in the web and continuously applying a pessure against the outer surface of the web throughout substantially all of the time the web is in contact with the drum surface by a porous pressure means acting upon the surface of said wet web in contact with said drum surface, said pressure being at least 5 p.s.i. and greater than the vapor pressure of the liquid at the temperature of the drum surface.

The porous belt pressuring means can comprise any pliable continuous means which is capable of conforming to the surface of the rotating drum and which is more porous than the web material there between. Such pliable continuous means may comprise continuous metallic or non-metallic screen belts, perforated metallic or non-metallic belts and like items; however, it is preferred that either a porous felt-like fibrous belt capable of withstanding the necessary forces or a conventional papermaker's felt reinforced with a foraminous metal mesh or belt, either embedded therein or as a backup member, be used when a substantially uniform surface on the dried web is desired. As will be brought out hereinafter, it is often desirable to employ a combination of these different types of belt pressuring means during the course of a paper-making process; however, for drying an unsaturated paper web at high temperatures, it is generally preferred to employ a belt pressuring means comprising conventional papermaker's felt with or without porous backup member.

It is clear that substantially any belt means may be used in the process of this invention as long as it is capable of withstanding the tension to be applied thereto to force the web against the rotating drum; is sufficiently pliable to be used as a continuous moving belt means; is more porous than the uncoated web material to be dried; and provides the desired surface in contact with the uncoated web material.

In essence, this invention is an exceptionally high pressure-high temperature process and apparatus for drying a fibrous web material, for example water saturated paper stock as formed upon the wire screen of a conventional Fourdrinier paper machine. By exceptionally high pressures is meant an increase over that normally employed in the art by a factor as much as 100, viz. the use of pressures on the order of 5 pounds per square inch and even upwards to 150 pounds per square inch, especially between 10 to 30 pounds per square inch; however, the pressure always being slightly greater than the corresponding vapor pressure of the liquid to be removed for the specific operating temperature of the dryer drum. Pursuant to the process of this invention drying rates of 45 pounds per hour per square foot are obtained easily when working with paper stock having a moisture content of 60 to 40 percent after pressing as compared to drying rates of 5 to 7 pounds per hour per square foot realized today by conventional paper-making machines when drying paper in this moisture content range.

Moreover, this invention now has made it practical to operate at higher temperatures than heretofore employed in the art. Specifically, temperatures above 250° F., preferably between 300 to 500° F. with those around 400° F. being most preferred. Thus, by the combination of higher pressures and temperatures in the practice of this invention, drying rates heretofore unobtainable in the art are realized.

Although the theory by which this invention operates is not understood clearly, it is postulated that in accordance with this invention, vapor generated at the interface between the heated drum surface and the surface of the web in contact therewith is used to drive liquid within the web through the web into or through the porous belt means. In this manner, a major portion, on the order of 50 percent, of the liquid within the web is removed without the need to supply sufficient heat to the liquid to raise the temperature of the liquid to its boiling point and to meet latent heat of vaporization requirements. This is accomplished by supplying sufficient pressure to the web by the porous belt means to maintain the web in close proximity to the drum surface so that most of the vapor formed at the drum-web interface must escape through the web driving the liquid ahead of it. It follows rather clearly that by using higher temperatures and higher pressures, the driving force is increased thereby accomplishing the removal of liquid in a shorter period of time.

The use of higher temperatures and pressures than heretofore were permissible is possible because of the short period of time the web is in contact with the heated surface; the direction of flow of the vapor and liquid, and the direction of pressure application on the web.

In nip roll drying of liquid containing webs, pressure is applied on a narrow cross-section of the web and liquid is removed in a direction substantially opposite to the movement of the web through the nip rolls. The maximum pressure which can be applied in this method is very low in that the pressure tends to crush the web and the flow of exiting liquid and vapor tend to tear or burst the paper.

In the process and apparatus of this invention, the flow of the exiting liquid and vapor is in the same direction in which the fibers of the uncoated web were laid during the formation of the web and in which direction the web has its greatest strength. Further, the pressure is applied over a large area which acts to prevent the web from separating and this pressure is balanced to a large extent by the escaping liquid and vapor among the fibers which helps to prevent the crushing of the fibrous web.

Moreover, it has been found that in the drying of an uncoated fibrous non-woven web material by way of this invention, for example, paper stock, the strength and stiffness of the resultant sheet increases with increasing drying rates, primarily as a function of increasing pressure. These unexpected results are enumerated in Table I below.

TABLE I.—STRENGTH AND STIFFNESS AS A FUNCTION OF PRESSUE

Paper Strength			Pressure (lbs./in.^{2})
Tensile	Mullen	Stiffness	
101	81	184	4
101	81	190	9
121	99	197	16
133	106	230	17

In light of these unique results pursuant to the practice of this invention, it can be seen that a new mechanism for water removal is in operation. This new mechanism can best be understood by referring to FIGURE 1 in the drawings which depicts one embodiment of the novel means constituting a part of this invention. In FIGURE 1, a saturated fibrous web material 10 is conveyed into contact with a heating or dryer drum 15 by suitable conveying means **11**, **12**, **13**, and **14**. The fibrous web material **10** is held into intimate contact with the drum and subjected to considerable pressure by the porous pressure belt means **18** which is arranged relative to the heating drum **15** by virtue of the conveyor rollers **19** and **21**. The fibrous web material **10** undergoing treatment is caused to be wrapped around a considerable circumferential portion of the heating drum **15** by these same means, thus creating an incoming nip at **16** and an exit nip at **17**. The porous pressure member **18** is a continuous member which may be driven by and hence move with the same lineal speed as that of the web material **10** which is motivated by the rotating drying drum **15**. The continuous member **18** is arranged relative to the member **15** such that it exerts the requisite pressure against the web material **10** wrapped around the periphery of the drying drum **15** by suitable tensioning means **23** acting upon element **18**.

The arrangement depicted in FIGURE 1 comprising the idler drum **20** which is acted upon by the desired tensioning force would be suitable means for accomplishing such result. The idler drum **20** would also desirably form part of the conveying system for the pressure member **18**. Water collection means **22** can be located beneath the drying drum **15** for reasons which will be brought out below.

With the above unique means in mind, it can now be understood how the method forming a part of this invention can be practiced to achieve this new mechanism for water removal made possible by way of this discovery. As an example of how this process can be conducted with the above means, a web **10** as it enters the nip **16** is subjected to a high pressure, say on the order of 20 pounds per square inch, and at the same time comes into contact with the surface of the drying drum **15** which is at an elevated temperature, preferably around 400° F. The water at the top surface of the web **10**, that is that portion of the web in contact with the drum **15**, immediately rises to a temperature corresponding to the pressure in the system at this point. The pressure on the water will be something less than the normal pressure exerted by the pressure member **18**, in this instance something less than 20 p.s.i., which pressure depends upon the resistance of the water web-felt system to the dissipation of this pressure. In any case, by supplying heat at a sufficient rate concentrated at the interface between the web and drum surface, a vapor pressure greater than atmospheric pressure is generated at the interface. This results in a pressure differential across the web-felt system. During the normal course of this process, namely other than during startup, an equilibrium situation is attained in the porous pressure felt **18** whereby the entire felt is thereafter saturated with at least around 50 percent water. The pressure differential which has been created across the web-felt system causes liquid water to flow through the web **10** and the porous pressure member **18** capillaries and out of the bottom of the latter, gravitating to the lowermost portion of the member **18**. In actual operation, a continuous stream of relatively cool water flows out of the bottom of the felt **18**. This water can be conveniently collected by such means as **22** depicted in FIGURE 1. Thus, it can be seen that the pressure member **18** must have a porous structure in order for this first mechanism to take place to any degree. The relatively cool temperature of the water flowing from the felt or porous member **18** substantiates the fact that this water is not condensed water which was evaporated at the dryer surface and subsequently recondensed in the felt, but rather is largely water driven out of the porous member **18** by the extent of evaporation that does occur.

When the web **10** reaches the exit nip **17**, there is a sudden reduction in pressure which results in a flashing of the major portion of any liquid remaining in the web at this point. This second factor alone has been found to account for as much as 70 to 80 percent of the water removed. The amount of flashing will depend to a considerable extent upon the porosity of the felt-web system.

There is a third factor which operates during the initial phase of the passage of the web **10** through the system and which contributes to this new mechanism for water removal. It is known that the water removal rate W in a paper web under pressure, as in a press, is proportional to the pressure on the web p and the time under pressure t and inversely proportional to the viscosity of the water in the web u which in turn is highly temperature sensitive. This can be expressed as follows:

$$W=K\frac{p}{u}t$$

It can be seen that a web **10** entering the system of FIGURE 1 is subjected to a pressure p over an extended period of time t and that the water in the web is rapidly heated to very high temperatures, thus reducing its viscosity u. The three factors in the above formula work toward a high water removal rate W. The system of this invention permits the use of very high temperatures without any accompanying damage to the sheet or web **10**, thereby reducing the viscosity of the water in the web to a greater extent than heretofore possible by present day drying techniques and apparatus. This third factor functions mainly during the early portion of the web travel through the system because the time factor t is largely effective over a very short period of time, varying with the compressibility of the web. This is especially true where the web **10** is given an initial pressing, such as by the rolls **11** and **12** in FIGURE 1, so that the bulk of the water that can be removed by squeezing alone has been removed. Thus, it can be seen that this new mechanism for water removal is a result of at least four interrelated corollaries, viz. the driving force of the vapor, the pressuring of the web while its fibers are held tightly in position, a reduction in viscosity which aids this mechanism overall, and the subsequent removal of most of the water after pressuring by flashing.

While not wishing to be bound by theory, it is felt that this new mechanism as a function of at least these four interrelated corollaries is in effect the discovery that moisture can be removed from a fibrous web material at a very high rate by first subjecting the moisture containing web to high pressures followed by subjection to elevated temperatures sufficient to cause the residual water remaining after pressing to immediately transform into superheated steam upon removal of the pressure. Wherefore the moisture escapes from the web in the form of discrete particles of superheated steam, unlike those of wet steam, whereby collision of the escaping particles with the fibers in the web is minimized. Hence, unlike in present day methods of drying fibrous materials whose fibers have been bonded essentially beforehand and subsequently disrupted during drying, by the unique method and means of this invention, water is removed from a wet web during its drying without damaging the bonding initially built into the web before drying by removing such water in its least disrupting and damaging state. Moreover, for reasons unknown additional interfiber bonding is promoted by drying fibrous material pursuant to this process.

In light of the four mechanisms, it can be understood that in order for them to occur simultaneously, that is, with reference to one separate unit or dryer drum, it is necessary that the pressurizing means be porous to the extent that it allow liquid to flow through it. However, it is to be understood that there are certain stages in the paper-making process pursuant to the practice of this invention, especially when operating at high production rates, where other drying apparatus arrangements can be employed in combination with the unique apparatus of this invention. One stage where it is particularly feasible and attractive to employ a non-porous pressurizing means is in the first part of the drying section. This is because the paper web is no longer dripping wet having passed through the pressing stage where its moisture content is usually reduced to about 65 percent. Hence, its subsequent contact with the initial dryer drum for a relatively short period of time does not result in the generation of sufficient vapor pressure for all of the above four mechanisms to occur to any appreciable degree. That is to say, the moisture in the paper web is not vaporized in the initial stage of a drying section, but rather the water in the paper web is absorbing energy as measured in terms of sensible heat until such time it begins to vaporize whereby the four mechanisms enumerated supra will occur. At which point in the dryer section this transformation takes place will naturally depend upon the production rate. Thus, until such time that the paper web attains that temperature at which point all four mechanisms begin to occur, the advantages of employing a porous pressurizing means are not maximized, and it can be seen why a combination of the various pressurizing belt means will quite often offer the most advantages, such as that shown in FIGURE 6 which is described in detail hereinafter.

To demonstrate the unique results achieved by this invention, the system as depicted in FIGURE 1 was installed on an 80 inch wide Fourdinier paper machine between the press section and the drying section. The rotatably mounted cylinder **15** was 3 feet in diameter and was provided with steam heating means. During the experiment, steam at 200 p.s.i. and 387° F. was injected into the cylinder. The pressing member **18** was constructed of a temperature resistant Dacron fabric capable of withstanding a tension of 1000 pounds per linear inch of width. The tension applied to the belt was 250 pounds per inch resulting in a normal pressure against the drying cylinder of 14 pounds per square inch. A 150 pound kraft paperboard web traveling at 150 feet per minute was fed into the system. The web had an entering moisture content of 62 percent. An overall drying rate of 40.2 pounds per hour per square foot of drying surface was realized. A continuous flow of water was taken off through the drainage means **22** at a rate of 19.2 pounds per hour per square foot of dryer surface. The temperature of this water was 148° F. The web material had a moisture content of 46 percent after flashing at the exit nip. Upon examination, the kraft paperboard web produced by way of this experiment was found to have a mullen strength increase of 30 percent over that obtained while operating this same papermaking machine without employing the unique water removal system of this invention. Additionally, the surface smoothness of the kraft paperboard was also found to be greatly improved over that normally realized under comparable conditions in conventional processes.

To further demonstrate the unique benefits made possible by way of this invention, the apparatus described in detail above was employed between the press section and the drying section of a conventional Fourdrinier paper machine in the production of 40 caliper white high grade blotting paper. The production rate of the machine was increased from its normal 48 feet per minute to 64 feet per minute, an overall increase of 36 percent. The steam pressure in the drum **15** was 75 p.s.i.g. and the pressure exerted by the belt **18** was 19 p.s.i. Under these operating conditions, a total drying rate of 48 pounds per hour per square foot with a liquid water removal rate of 12 pounds per hour per square foot was attained.

In the production of 152 pound special kraft linerboard employing the above apparatus, the normal production rate of 112 feet per minute was increased to 150 feet per minute, viz. a 35 percent increase. In this run, steam was fed to the drum **15** at 210 pounds per square inch and the belt **18** was adjusted to exert a 14 p.s.i. pressure on the linerboard undergoing treatment. Under these conditions, a drying rate of 40.2 pounds per hour per square foot with a liquid water removal rate of 19.2 pounds per hour per square foot was readily obtained.

A 32 percent increase in production rate was realized in the manufacture of 200 pound white blotting paper. The production rate of the Fourdrinier machine employed with the unique apparatus of this invention as above described was increased from a normal 53 feet per minute to 70 feet per minute. Steam at 100 p.s.i.g. was fed to the drum **15** and the belt **18** was adjusted to exert a pressure of 10 p.s.i. upon the blotting paper undergoing treatment. In this instance, a drying rate of 30 pounds per hour per square foot was realized without removal of liquid water.

It is understood of course that the felt-like or pressure member **18** can be any suitable porous material capable of withstanding the forces to which it must be subjected in order to exert sufficient pressure upon the web material wrapped around the drum **15**. While Dacron is a preferred material of construction, other materials such as fiberglass, nylon, and the like can also be employed. Additionally, as brought out above, materials having a much lesser tensile strength, such as conventional 100 percent virgin wool can also be employed as long as they are adequately reinforced. For example, a belt constructed of a porous material having a wire screen embedded therein would be entirely suitable. Another arrangement which is preferred over the above is to employ a belt comprising papermaker's felt with a foraminous backup belt or screen which can be either metal, rubber, or the equivalent thereof. The backup member urges the felt against the web material in the course of exerting the requisite pressure.

Thus, a preferred embodiment of this invention is such as that depicted in FIGURE 2. A continuous saturated web material **30** is conveyed into position and around the peripheral surface of the drying and pressing drum **34** so as to create an inlet nip at **33** and an exit nip at **35**. Roller means **31** and **37** guide the web **30** on and off the member **34**. The wool felt **38** is mounted relative to the drum **34** so as to extend over a considerable circumferential portion thereof as defined by the position of the rollers **32** and **36** which also constitute part of the felt conveying system which further comprises the rollers **39** through **45**. The felt **38** is urged against the web material **30** wrapped around the member **34** by virtue of the foraminous metal belt **46** which also extends over the same circumferential portion of the member **34** as does the felt **38**. Like the felt **38**, the belt **46** is a continuous member that moves with the same lineal speed as the felt and web material undergoing treatment. The metal belt **46** is conveyed upon a separate system constituting the roller means **32**, **47**, **48**, and **49**. The metal belt **46** exerts the requisite pressure upon the felt-web arrangement by suitable belt tensioning means, such as **50** acting upon the roller and belt conveying means **48** in FIGURE 2.

An especially preferred embodiment of the instant invention whereby even greater production rates are realized is to heat the felt-like member at a point in its conveyance system so as to remove moisture contained therein as derived from the web material undergoing treatment. By this arrangement, its efficiency is greatly increased. A suitable apparatus arrangement for accomplishing this desirable objective is depicted in FIGURE 2 wherein element **42** is the source of heat, preferably a drum forming part of the felt **38** conveyance system.

In light of the above, the impact of the instant invention now becomes evident, viz. that much of the multiple components presently employed in conventional papermaking apparatus can be dispensed with by substituting in its place the novel means disclosed herein. For example, it is no longer necessary to have the vast number of dryer rolls in a typical drying section since by way of this apparatus employing a roll of approximately the same diameter, only relatively few rolls are required. The net result is a sizable reduction in the physical space required plus simplicity of operation. Additionally, the apparatus of this invention supercedes the use of separate and special pressing sections, the function of which can easily be combined in the operation of the apparatus of the present invention. Here again, substantial savings of space and ease of operation are realized. It is clear, however, that the apparatus of this invention can be added to conventional paper-making machines, for example between the press and dryer sections, whereby the total apparatus can be operated at much higher speeds than normally employed.

An apparatus arrangement illustrating this very beneficial aspect of the instant invention is shown in FIGURE 3. In that figure, the felt-like or porous pressure member **64** operates in combination with a pressing section comprising the pressing rolls **69** and **73**. In that embodiment, the web material **60** is first given a press between the presser rolls **69** and **73** whereupon it is conveyed into contact with the dryer and pressing drum **61** creating an inlet nip at **62** and an exit nip at **63**. The pressure member **64** which extends over the major portion of the circumferential surface of the drum **61** exerts the requisite pressure upon the web material **60** by a tensioning force **74** which can act upon a conveying member **67** of the pressure member conveyance system, e.g. members **65–70**. Located between the lowermost pressing roll **69** and the drum **61** and forming part of the pressure member **64** conveyance system is suitable heating means **70** for removing a considerable portion of the moisture picked up in the belt **64** in the pressing section. A presser roll **71** can be employed in combination with the heating roll **70** to more effectively remove moisture from the pressure member **64**, which moisture can be collected in suitable means **72**. Operation of the apparatus depicted in FIGURE 3 at speeds commonly employed in the paper-making art today results in a paper stock of the same specifications as that produced in present day machines with elaborate press and dryer sections. However, overall economy can usually be effected by operating the apparatus arrangement of FIGURE 3 at considerably higher speeds and employing in combination therewith a single drying section of this invention, such as that shown in FIGURE 1. In such a combination, the pressure member **64** could be employed to serve the same function for both dryer and presser drums. In which instance, another pressure member dryer drum, such as **70** shown in FIGURE 3, would be positioned between the dryer presser drums such as **61** in FIGURE 3 and **15** in FIGURE 1.

FIGURE 4 depicts a manner in which this new mechanism for drying a saturated fibrous web material can be integrated with a conventional pressing section in a papermaking machine. Element **80** represents the wire screen on a Fourdrinier paper machine. Paper stock **82** leaving the wire **80** at the couch roll **81** is conveyed into the press rolls **83** and **84** by felt means **85**. The felt **85** conveying system comprises the rollers **86–93**. The felt **85** is subjected to the novel drying method of the instant invention by conveying it over the dryer drum **93**. The pressure member **94**, similar to element **18** in FIGURE 1, is positioned relative to the drum **93** such that it presses the felt **85** into intimate contact over a considerable circumferential portion of the dryer drum **93**. The same mechanism that occurs as discussed above in regards to FIGURE 1, also occurs in this instance. Namely, the pressure member **94** is caused to exert considerable pressure by virtue of the tensioning means **98** in combination with the pressure member conveying means **95**, **96**, and **97** upon the felt means **85**. By this arrangement, it has been found that the water removal efficiency of a press section in a conventional paper-making machine can be increased upwards to about 500 percent by use of this invention.

FIGURE 5 illustrates the sizable reduction in plant space and simplicity of operation that can be achieved by way of this invention. Section A represents a conventional paper forming section of a Fourdrinier paper machine. A source **100** of paper pulp is fed into the head box **101** from which it is distributed upon the screen **102**. The saturated fibrous web material **103** formed thereupon is then conveyed into a pressing section, in this instance Section B representing the apparatus arrangement detailed in FIGURE 4. In Section B, elements **104** and **105** represent pressing rolls which squeeze moisture from the web material **103**, such moisture being absorbed by the felt means **106**. The water saturated felt means **106** is then conveyed to the felt drying means **107** whereby the felt **106** is dried in accordance with the new mechanism made possible by the instant invention. The fibrous web material **103** leaves this section with a moisture content of about **45** percent, considerably less than normally attained in the pressing section of present day paper machines. The fibrous web material is then conveyed into Section C which constitutes the dryer section. Section C depicts an especially preferred apparatus arrangement whereby exceptionally high drying rates are realizable involving the barest minimum of equipment outlay. The web material **103** is dried by the unit **108** which is similar to that depicted in FIGURE 1. The pressure member forming a part of the drying unit **108** is in turn dried by a similar unit **109**, which unit is similar to that of **107** in the presser Section B. The dried web material **103** is then fed into calender Section D comprising the calender stack **110** and reel **111**.

In FIGURE 6, Section A represents a conventional paper forming section of a Fourdrinier paper machine. A source **200** of paper pulp is fed into the head box **201** from which it is distributed upon the screen **202**. The saturated fibrous web material **203** formed thereupon is then conveyed into a pressing Section B representing the apparatus arrangement detailed in FIGURE 4. In Section B, elements **204** and **205** represent pressing rolls which squeeze moisture from the web material **203**, such moisture being absorbed by the felt means **206**. The water saturated felt means **206** is then conveyed to the felt drying means **207** whereby it is dried in accordance with the new mechanism made possible by the instant invention. The felt drying means **207** represents the structure detailed in FIGURE 1. The pressurizing belt means of the felt drying means **207** can be constructed of either a porous felt-like fibrous belt capable of withstanding the necessary forces, or conventional papermaker's felt reinforced with foraminous metal mesh or belt, either embedded therein or as a backup member. The fibrous web material **203** leaves this section with a moisture content of about 45 percent, considerably less than normally attained in the pressing section of present day paper machines.

The fibrous web material is then conveyed into Section C which constitutes the dryer section. The drying units **208** and **209** comprise non-porous pressurizing belt means since these units are primarily employed to raise the temperature level of the moisture in the paper web to prepare it for the next drying unit **210**. The drying unit **210** comprises pressurizing belt means which is porous and like that employed in the unit **207**. The heated paper web **203** enters the drying unit **210** and is subjected to the mechanisms of water removal discussed above. Water flowing from the paper web is collected in means **211** and conveyed exterior of the drying section. The paper web **203** leaving the drying unit **210** next enters the drying unit **212** wherein its moisture content is finely adjusted

down to about 5 percent. Since most of the moisture in the paper web **203** has been subsequently removed in the drying unit **210**, the unit **212** can comprise a pressurizing belt means of a non-porous nature, the remaining moisture in the paper web being removed by flashing at the exit nip of the unit **212**. The essentially dry web material **203** is then fed into calender Section D comprising the calender stack **213** and reel **214**.

Thus it can be seen that by the novel method and apparatus of this invention, it is now possible to produce paper stock of a higher quality at lower cost and with much less equipment than heretofore employed in the art.

What is claimed is:

1. A continuous process for drying an uncoated fibrous web material containing volatile liquid comprising the combination of simultaneous steps of

(a) contacting said uncoated fibrous web material continuously with a substantial portion of a rotating drum surface heated to a temperature of at least about 250° F., and

(b) pressing, with a continuous pliable member more porous than said uncoated fibrous web material, substantially all of the contacting material against said substantial portion of a rotating drum surface at a pressure of at least about 5 p.s.i. and at least as great as the vapor pressure of said volatile liquid at said temperature of the heated drum surface.

2. The process of claim **1** further characterized by said temperature being from about 300° F. to about 500° F.

3. The process of claim **1** further characterized by said volatile liquid being water.

4. The process of claim **1** further characterized by said pressure being from about 5 p.s.i. to about 150 p.s.i.

5. The process of claim **3** further characterized by said temperature being about 400° F. and said pressure being from about 10 p.s.i. to about 30 p.s.i.

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