Feb. 27, 1968 E. D. BEACHLER 3,370,359

WEB DRYING METHOD AND APPARATUS

Filed May 10, 1965 3 Sheets-Sheet 1

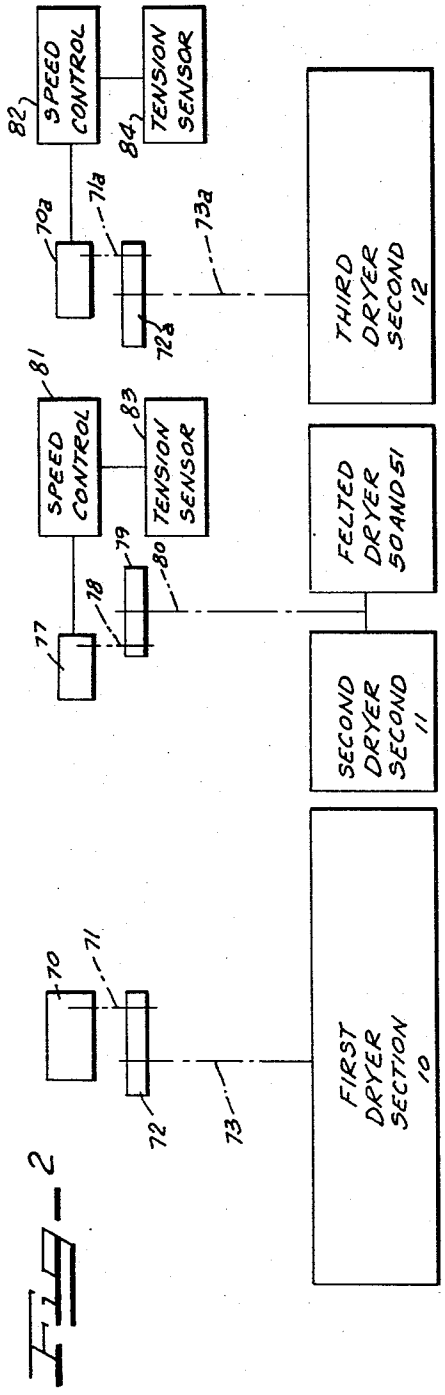


Fig. 2

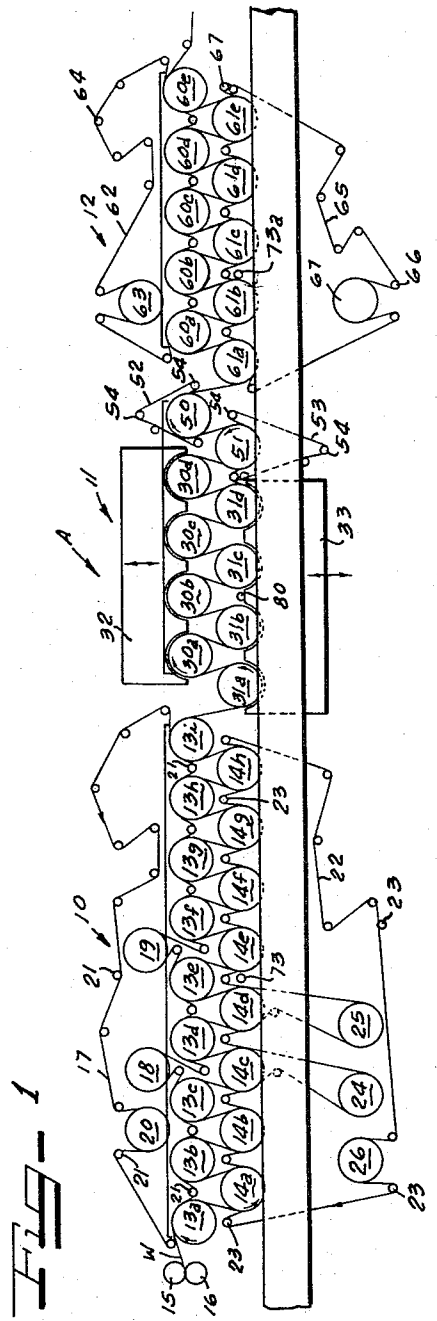


Fig. 1

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WEB DRYING METHOD AND APPARATUS

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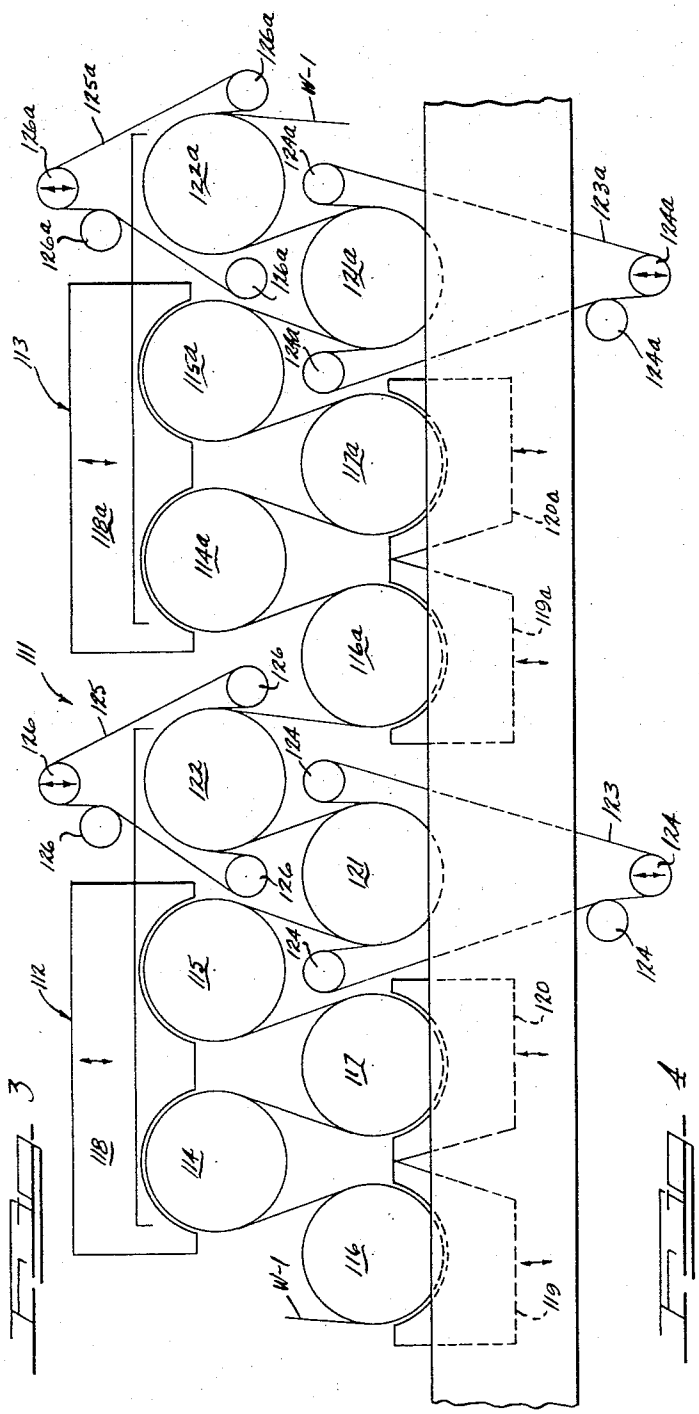


FIG. 3

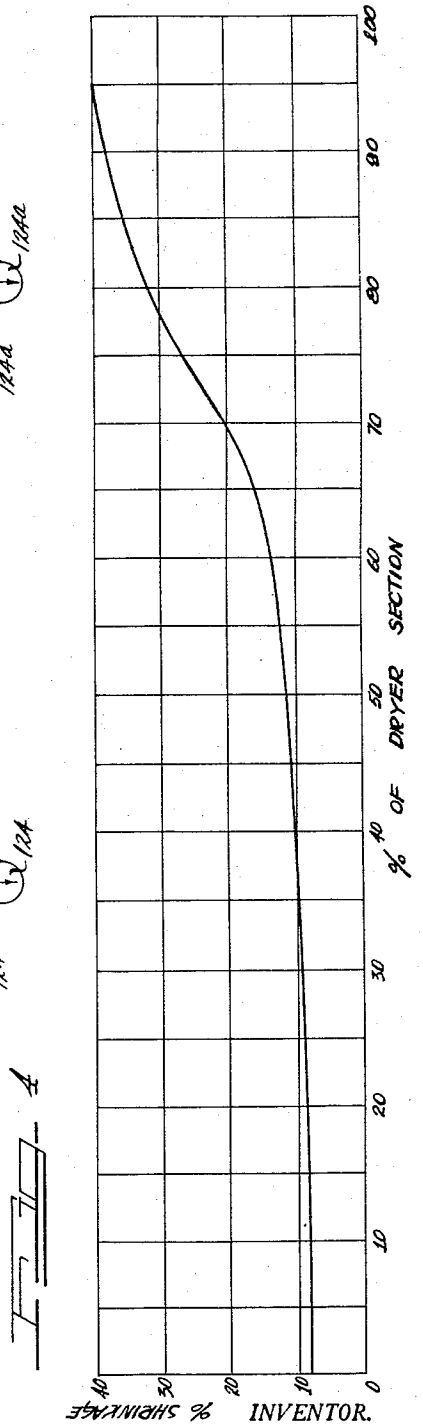


FIG. 4

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WEB DRYING METHOD AND APPARATUS

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FIG. 5

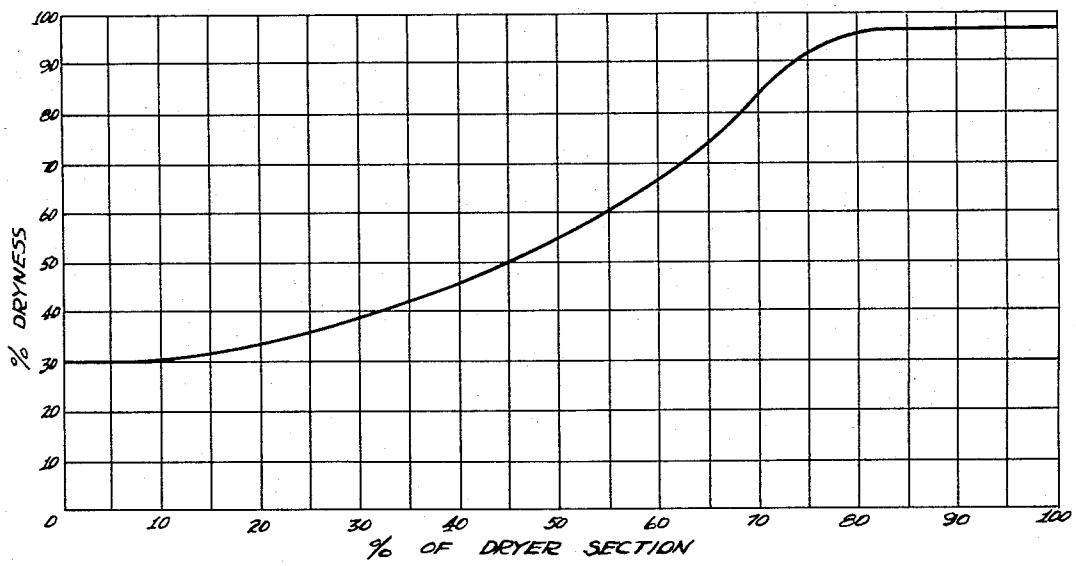


FIG. 6

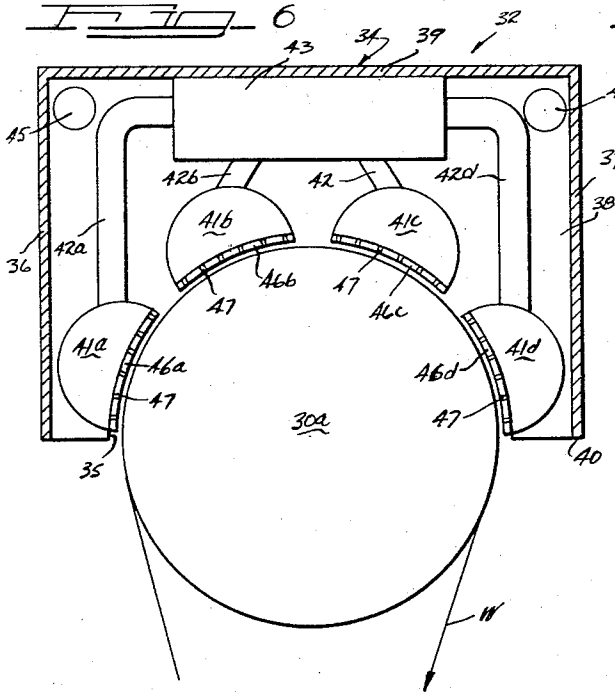
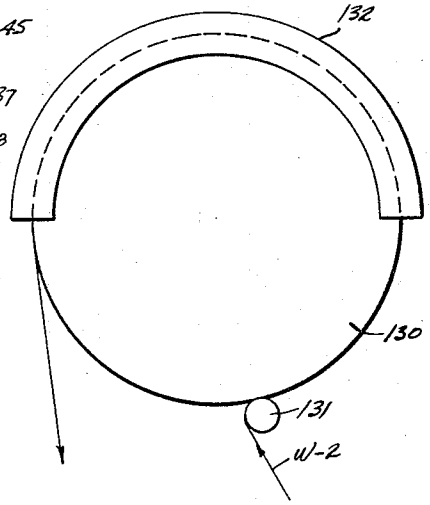


FIG. 7



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United States Patent Office 3,370,359 Patented Feb. 27, 1968

3,370,359

WEB DRYING METHOD AND APPARATUS

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Filed May 10, 1965, Ser. No. 454,575
19 Claims. (Cl. 34—18)

The present invention deals with the drying of web materials in such a manner as to accommodate shrinkage without sacrificing drying efficinecy. More specifically this invention relates to the heated cylinder drying of paper on a papermaking machine wherein the paper is released from adherence to the cylinders during the period of maximum shrinkage of the paper.

While the invention will be specifically hereinafter described as embodied in a process and apparatus for the cylinder drying of paper on a papermaking machine, it should be understood that the principles of this invention are generally applicable to the drying of web materials which shrink during the drying operation. Therefore the scope of this application includes the drying of all such materials.

The conventional drying section of a papermaking machine includes one or more heated drums or cylinders receiving the paper therearound in intimate contact therewith. In the multiple dryer cylinder equipped papermaking machines the paper is lapped around successive cylinders and held in intimate contact with the cylinder surfaces by felts. In single dryer cylinder equipped papermaking machines, such as "Yankee" machines, a pressure roll is generally provided to squeeze the wet web on the dryer surface. This intimate contact between the web and the heated drying surface increases the drying efficiency of the cylinder and prevents steam generated from the moisture in the web from lifting the web out of good heat transfer relation with the heated cylinder surface.

In order to provide intimate contact between the web and the heated drying surface when felts or pressure rolls are employed, the web is usually tensioned at 15 pounds per linear inch. Such tensioning of the web at a particular subsection of the drier is maintained by controlling the speed of a subsequent subsection. A web tension sensor may be employed to automatically control a variable speed drive or inching drive in the subsequent subsection.

It is known that wet paper shrinks considerably before it reaches a fully dried condition and since intimate contact between the drying cylinder and the paper web interferes with such shrinkage, the desired physical properties of the dried paper cannot be obtained unless some provision is made to accommodate shrinkage. Heretofore shrinkage adjustment has only been possible during open draw areas of the web as when it passes, unsupported, between dryer cylinders. This adjustment is effected by varying the relative speeds of the offgoing and oncoming cylinders at the extremities of the open draw. Thus, it has become conventional to divide the dryer section of a papermaking machine into a plurality of subsections each including geared together cylinders. The drying capacities of the sections are regulated so that the paper web will be delivered to the slower driven subsections through open draws at points in the drying process where the paper is about to pass through its maximum shrinkage rate. Since the unsupported draws are non-drying areas, it will be appreciated that compromises must be made in relative speeds of the successive dryer subsections because the draws must have some degree of tautness and the web cannot go through its maximum shrinking range unless it continues to lose moisture.

The present invention now provides for the release of the paper from adherence to the drying cylinder while utilizing the cylinder to dry the paper through its maximum shrinkage range and without interfering with the efficient drying of the paper in intimate contact with drying cylinders outside of the maximum shrinkage range. The present invention makes use of the conventional drying sections of existing papermaking machines to dry the paper up to and beyond the maximum or critical shrinkage range and provides drying cylinders for drying the paper through its maximum or critical shrinkage range with apparatus for releasing the paper from adherence to these cylinders so that the paper can shrink while still under the drying influence of the cylinders. The release of the paper is caused by high velocity air jets impinged against the paper on the cylinders and lifting the paper from adherence to the cylinder surface so that it is free to assume dimensions in accordance with its moisture content.

The use of high velocity air jets has heretofore been known and employed for drying a paper web by impinging such jets against the paper on the cylinders. In such drying operations, however, because of the tension normally employed on the paper web, the paper would not be completely lifted from adherence to the cylinder surface. That is, high velocity air jets impinged normally against a paper web on the drying cylinders would tend to lift the paper from adherence to the cylinder surface, but the tension normally employed in drawing such a paper web through a plurality of dryer sections would not allow complete release of the paper from the cylinder surface. As a result, the tensions employed on the paper web in such drying sections were increased to a range of between 20 and 30 pounds per linear inch so as to achieve complete adherence of the paper web to the cylinder surfaces.

In accordance with the present invention, therefore, high velocity air jets are employed to cause a lifting action on the paper web from adherence to the cylinder surface while the tension maintained on the paper web is controlled within a definite range to permit the paper web to lifted.

Since all papers can be partially dried from their "as formed" condition without appreciable shrinkage and since such papers do not appreciably shrink after they have passed through a critical moisture range, the cylinders equipped with the high velocity air jet arrangements according to this invention need only be used in those dryer sections of the machine where the paper goes through its critical moisture range. Generally the critical moisture range for maximum shrinkage of the paper occurs when the paper is from approximately 50% to 85% bone dry.

Therefore, an important feature of this invention is the release of intimate contact of the paper from the drying cylinders of a papermaking machine in a subsection of the paper machine dryer section as by means of high velocity air jets directed normal to the paper for lifting the paper from the drying cylinders.

Another important feature of the present invention resides in the control of the speed of the various subsections of a paper machine dryer section to maintain the proper tension on the paper web passing over the drying cylinders and impinged with high velocity air jets for allowing the paper to be lifted from the drying cylinders.

In a preferred embodiment of this invention felt equipped drying cylinders are provided immediately adjacent the offgoing ends of the air jet equipped drying cylinders to lessen the length of the web which is unsupported by felts for reducing breakage and the tendency of the web to be pulled backwards and wrap around the first cylinder to which it may adhere.

It is then an object of this invention to release web material from adherence to heated drying surfaces as it passes through a critical moisture content in which maxi-

mum shrinkage occurs without, however, resorting to the use of long open draws of the web material.

A further object of this invention is to take advantage of the efficient drying of web material in intimate contact with heated drying surfaces up to and beyond the moisture range where maximum shrinkage occurs and to release the web material from such intimate contact as it is dried through the maximum shrinkage range without, however, resorting to the use of unsupported draws of the paper.

A further object of the invention is to dry paper in a conventional manner on felted drying cylinders only until the moisture content of the paper is reduced to a point where the paper starts to shrink appreciably and to then continue the drying of the paper on feltless drying cylinders equipped with means for lifting the paper out of adhering contact with such cylinders.

A specific object of this invention is to dry paper on conventional felt equipped drying cylinders down to approximately 50% to 60% bone dryness and to then continue the drying on feltless drying cylinders to a bone dryness of about 85% while lifting the paper out of intimate contact with the feltless cylinders by the use of high velocity air jets.

Another specific object of this invention is to interpose feltless drying cylinders in the drying section of a papermaking machine and to equip such cylinders with means for lifting the paper out of adhering contact with the cylinders.

Another and specific object of this invention is to provide a subdryer section in a conventional multiple cylinder dryer section of a papermaking machine with air hoods which lift the paper off the cylinders of the subsection to accommodate shrinkage of the paper only as it passes through a critical moisture content in which maximum shrinkage occurs and to provide felt equipped drying cylinders at the exiting end of the subsection to reduce the unsupported length of the paper.

Still another specific object of the present invention is to provide a subdryer section in a conventional multiple cylinder dryer section of a papermaking machine with air hoods which lift the paper off of the cylinders of the subsection and to control the tension of the paper web to within a specified limit such that the paper will be released from adherence to the cylinder surfaces to allow free shrinkage of the paper web during a period when the paper web passes through a critical moisture content range.

Other and further objects of this invention will become apparent to those skilled in this art from the following detailed description of the annexed sheets of drawings which, by way of preferred examples only, illustrate several embodiments of the invention.

FIGURE 1 is a diagrammatic side elevational view of a dryer section according to this invention equipped with a feltless subsection at the point where the paper web passes through its maximum shrinkage range.

FIGURE 2 is a diagrammatic view illustrating the manner in which the subsections of the dryer section of FIGURE 1 are driven.

FIGURE 3 is a fragmentary side elevational view of an alternate arrangement of a dryer subsection according to this invention.

FIGURE 4 is a graph illustrating the shrinkage rate of paper at various positions in a dryer section such as is shown in FIGURE 1.

FIGURE 5 is a graph illustrating the moisture condition of the paper at various portions of the dryer section of FIGURE 1.

FIGURE 6 is a somewhat diagrammatic side elevational view with parts in section of a hood equipped feltless cylinder according to this invention.

FIGURE 7 is a somewhat diagrammatic elevational view of a Yankee dryer incorporating a hood means according to this invention.

As shown on the drawings:

In FIGURE 1 the dryer section A includes three subsections **10**, **11** and **12** with the subsections **10** and **12** being conventional felt equipped geared together multiple drying cylinder sections and the intermediate section **11** being a hooded feltless section accommodating free shrinkage of the paper.

Subsection **10** includes an upper bank or tier of drying cylinders **13***a* to **13***i* inclusive and a lower bank or tier of drying cylinders **14***a* to **14***h* inclusive in staggered relation to the cylinders of the upper tier. A newly formed paper web W emerging from the nip of press rolls **15** and **16** of the press section of a conventional papermaking machine is threaded through the subsection **10** in a serpentine path alternately lapping the tops of the cylinders of the top tier and the bottoms of the cylinders of the bottom tier. An upper tier dryer felt **17** laps a pair of felt dryer or "Feeney" rolls **18** and **19**, and a felt return roll **20**, and is guided in an open looped path by guide rolls **21** with one of the rolls **21** having a felt tensioner attachment. A similar bottom dryer felt **22** is provided and guided by the guide rolls **23** and lapping dryer or Feeney rolls **24** and **25** and a felt return roll **26**. The felts **17** and **18** lap the paper web W as it passes over the drying cylinders and cause it to be maintained in intimate contact with the drying cylinder surfaces to obatin maximum heat transfer from the cylinder to the paper.

The second subsection **11** includes an upper tier of drying cylinders **30***a* to **30***d* and a lower tier of drying cylinders **31***a* to **31***d*. A hood **32** envelops the top halves of the top tier of cylinders **30***a* to **30***d* while a second hood **33** envelops the bottom halves of the lower tier of cylinders **31***a* to **31***d*. As indicated by the arrows the hoods **32** and **33** are adjustable to give access to the cylinders in the event of a web break. The web from the last cylinder **13***i* of the subsection **10** enters the subsection **11** under the roll **31***a* and it will be especially noted that no covering felts such as **17** and **22** are provided for the cylinders **30** and **31**.

FIGURE 6 illustrates a type of hood for the cylinders of the subsection **11** and is shown for convenience only in connection with the single dryer cylinder **30***a*. The hood **32** could thus be a plurality of individual units such as is shown in FIGURE 6 or could encompass a plurality of the cylinders as illustrated in FIGURE 1.

As shown in FIGURE 6 the hood **32** includes an insulated cover **34** coextensive with the width of the web W and having a bottom opening **35** to encompass the top half of the cylinder **30***a* to be generally coextensive with the degree of wrap of the web W on the roll **30***a*. Opposed side walls **36** and **37** and end walls such as **38**, a generally flat top wall **39**, and a bottom wall **40** constitute the housing. The housing contains a plurality of blower heads **41***a* to **41***d* defining interiorly air supply plenums fed by conduits **42***a* to **42***d* respectively from a supply duct **43** connected to a suitable source of heated air. Exhaust openings **45** in the housing remove moisture bearing air from the hood. Nozzles **46***a* to **46***d* inclusive, illustrated in the form of plates have a plurality of holes or perforations **47** therein of from ¼ to ⅝ inch in diameter when the plates are about ¼ of an inch thick and when these plates are spaced from the web about 1 inch.

Heated air streams issue from the nozzle openings **47** at velocities of the order of 10,000 to 20,000 feet per minute to scrub from the web W the boundary layer of moisture carried by the web and to release the web from adherence with the drying cylinder **30***a*. This release is caused by development of an unbalanced pressure condition on opposite sides of the web produced by a greater air velocity along the exposed web surface as contrasted with the pressure on the web surface which wraps the cylinders. In addition, the evaporated moisture between the drying cylinder surface and the web creates a vapor pressure tending to lift the web from the cylinder.

In actual practice, the air which issues from the nozzle openings 47 spreads out over the surface of the paper web and provides a gradient of pressure which decreases from one of the nozzle openings 47 to a midpoint between that and an adjacent nozzle opening. However, as the paper web is being dried, a film of expansible gas is created between the web and the drying surface. This gas, as well as any air that is carried into the space between the web and the drying cylinder by movement of the web and rotation of the cylinder, cause a pressure differential across the web which provides a lift thereto. If the tension on the web is within a prescribed range, the web will be lifted entirely from the cylinder surface allowing free shrink of the paper web. Since the web is released from adherence from the cylinder surface relative free movement between the web and the surface can occur permitting the web to shrink to any dimension natural to its moisture content. Throughout the entire shrinking operation, however, the web continues to be subjected to efficient drying both from the heat of the drying cylinder surface and the heat of the heated air issuing from the nozzles 47. In addition, the moving air sweeps away the moisture laden atmosphere normally surrounding the web in a drying section.

Included in the second drying subsection 11 and driven at the same rate of speed as the cylinders 30 and 31 is a pair of felt wrapped cylinders 50 and 51 equipped with dryer felts 52 and 53 respectively, guided by rolls such as 54. The purpose of these felt equipped cylinders in the subsection 11 is to minimize an open draw length for the web between the sections 11 and 12 and to prevent the web from wrapping around the feltless cylinders in the event of a web break. The felted cylinders 50 and 51 are thus effective to pull the web through the section 11.

The third dryer subsection 12, as shown in FIGURE 1, is similar to the section 10 and includes an upper tier of drying cylinders 60*a* to 60*e* inclusive, a lower tier of drying cylinders 61*a* to 61*e* inclusive, a top felt 62 wrapping a return roll 63 and guided by roll 64, and a bottom felt 65 guided by roll 66 and wrapping a return roll 67. The last cylinders 60*e* and 61*e* are normally "sweat dryers" which are run cold to eliminate moisture irregularities in the dried web.

Upon leaving the third drier section 12 the web W moves to a calender stack (not shown) and is further processed in a conventional manner.

As shown in FIGURE 2 the first dryer subsection 10 is driven by any suitable motive means or prime mover 70 connected by a shaft 71 to a gear reducer 72 having an output shaft 73 connected to the gears which gear together all of the dryer cylinders in the first subsection. The third dryer subsection 13 has substantially identical drive arrangement, and like numerals with the suffix "*a*" have accordingly been applied to like parts. The second dryer subsection 11 includes a prime mover or any suitable motive means 77 connected through a shaft 78 to a gear reducer 79 and then through a shaft 80 to the gears of the rolls 30 and 30*a* as well as the felted rolls 50 and 51.

As previously mentioned, the tension of the web must be controlled within a predetermined range to allow the web to be lifted from adherence with the cylinder surface. The tension of the web W is preferably maintained between 5 to 15 pounds per linear inch in the section 11, and more precisely at 10 pounds per linear inch. This range of web tension can be maintained by controlling the speed of the sections 10, 11, and 12 with respect to one another. In FIGURE 2, a speed control 81 is diagrammatically illustrated as being connected to the motive means 77 and a speed control 82 as being connected to the motive means 70*a*. In a similar manner, the speed of the section 10 may also be variably controlled if desired.

Since the web W will exhibit both lateral and longitudinal shrink, the section 12 will necessarily have to be operated at a slower speed than that of the section 10 to accommodate for the change in longitudinal dimensions. This requirement is compatible with the requirement of maintaining the web tension within a prescribed range. Therefore, the speed of the sections 11 and 12 may be adequately sensed by tension sensors 83 and 84 connected to the speed controls 81 and 82 respectively. It is to be understood, of course, that other speed control arrangement may be provided to maintain the proper speed and tension on the web W.

If desired the dryer subsection 11 can be divided into a plurality of subsections each with felted dryer cylinders supporting the web between the successive feltless cylinder sections. Thus, as shown in FIGURE 3 the subsection 111 has two successive subsections 112 and 113. The subsection 112 includes the feltless cylinders 114 to 117, the air hoods 118 to 120, and the felted cylinders 121 and 122. A dryer felt 123 for the cylinder 121 is trained around rolls 124 while a dryer felt 125 for the cylinder 122 is trained around the rolls 126. Identical hooded cylinders and felted cylinders are provided in the subsection 113 with corresponding parts bearing the same reference numerals with the suffix *a* added. The web W–1 enters the subsection 112 around the dryer 116 and enters the subsection 113 around the dryer 116*a* and emerges from subsection 113 around the felted cylinder 122*a* from which it can pass into the third dryer section such as 12 of FIGURES 1 and 2. The section 113 can have the cylinders thereof geared together and driven at a slower speed than the cylinders of the section 112 to accommodate shrinkage that might occur in the section 112. Alternately, of course, the two subsections 112 and 113 can have the cylinders driven at the same speed and the interposed felted cylinders can be safety factors to prevent wrap-around of the paper in the event of web breakage. The tension of the web W–1 can be controlled by properly maintaining the speeds of the preceding section and the succeeding section.

As shown by the graph of FIGURE 4 the paper web from the forming and press section of the papermaking machine has undergone approximately 8% shrinkage prior to entry into the first portion of the first dryer section 10. If this dryer subsection 10 forms about 45% of the total drying capacity of the entire drying section of the machine, the web only shrinks about 3% as it passes therethrough. From then on shrinkage occurs at a rapid rate.

It has been discovered that damaging restrained shrinkage of the web does not occur until it is approximately 50% to 60% bone dry. Thus, as shown in the graph of FIGURE 5, when the web enters the first dryer subsection 10 at approximately 30% bone dry very little moisture is removed until the web has traversed approximately 10% of the first dryer subsection whereupon the moisture content is gradually reduced. Assuming that the first dryer subsection 10 comprises about 45% of the total dryer section A, the web is about 50% bone dry when it leaves the first subsection 10.

It has been discovered that a critical amount of shrinkage occurs in the web as it is dried from about a 50% bone dry condition to about an 85% bone dry condition. Thus, as will be seen from the graphs of FIGURES 4 and 5, as an additional 25% to 30% of the dryer section is traveled by the web, the web will shrink from 10% to almost 30%. It will be appreciated of course, that the percentages herein given will vary with the particular type of paper being dried, but the significant point is that an appreciable or major amount of shrinkage occurs as the web is dried from approximately 50% to 85% bone dry. Therefore, in accordance with this invention the feltless and air hooded cylinders are interposed in the drying section of a papermaking machine at the point where the web is about 50% bone dry and have sufficient capacity to dry the web up to about 85% bone dry. A maximum dryness for the web entering the feltless hooded cylinder section is about 60% and a minimum bone dry-

ness for the web emerging from this section is about 80% bone dry. Of course, the feltless hooded cylinder section can have an abundance of drying capacity and the web can be finished dried in this section or dried up to about a 90% bone dry condition. The last dryer section **12** reduces the moisture content of the paper to between 90% to 95% and as shown by the graph of FIGURE 4 the shrinkage of the paper is substantially negligible after it has reached 85% to 90% bone dry conditions.

In general therefore the felted initial dryer subsection or sections reduces the moisture content of the paper to a 50% to 60% bone dry condition while the feltless air hooded subsection or sections reduce the moisture content to commercial dryness, or to 80% to 90% bone dry with a final felted section finishing the drying operation. The feltless cylinder sections of this invention are effective to dry the web through its critical shrinkage range where restraint against shrinkage would materially alter the physical properties of the web.

As illustrated in FIGURE 7, a single drying cylinder equipped Yankee papermaking machine can have the drying cylinder **130** receiving the web W–2 therearound from a pressure roll **131** which causes the web to hug and adhere to the heated drying surface of the cylinder. According to this invention, however, the web W–2 is released from adherence to the cylinder as it passes through its critical shrinkage range by means of the air impingement hood **132** which operates in the same manner as the hood **32** of FIGURE 6. The web tension is maintained within a prescribed range to allow such release of the web W–2 from adherence to the cylinder surface. Thus, the web W–2 is released from adherence to the cylinder **130** through a critical drying range of from 50% to 60% bone dry to commercial dryness of 90% to 95% bone dry because no subsequent dryer section is provided.

From the above description it will be understood that this invention provides for the highly efficient drying of web material which passes through a critical shrinkage range as it is dried and which accommodates free shrinkage through this range without sacrificing drying efficiency. Air jets are used to release the web from adherence to its drying surface as it passes through this critical shrinkage range.

The principles of the invention explained in connection with the specific exemplifications thereon will suggest many other applications and modifications of the same. It is accordingly desired that in construing the breadth of the appended claims they shall not be limited to the specific details shown and described in connection with the exemplifications thereof.

I claim as my invention:

1. The method of drying a wet fibrous web having a moisture content which, if reduced will cause web shrinkage comprising the steps of:

(a) passing the web over a rotating heated cylinder,
(b) impinging a plurality of air streams over the area of the web passing over the heated cylinder on the opposite side of the web from the heated cylinder, to create a film of expansible gas between the web and the surface of the heated cylinder, which in cooperation with the heated air carried to the undersurface of the web causes a lifting action of the web from the cylinder, and
(c) tensioning the web within a prescribed range to allow the gas created and the air carried into the space between the web and the heated cylinder to lift the web from the cylinder only a distance sufficient to eliminate contact of the web with the cylinder.

2. The method of drying wet fibrous material as defined in claim **1** wherein the web is tensioned within a range of from 5 to 15 pounds per linear inch.

3. The method of drying wet material as characterized in claim **1** wherein the web is tensioned to 10 pounds per linear inch.

4. The method of drying wet web material as defined in claim **1** wherein the air streams impinging on the web have a velocity of between 10,000 to 20,000 feet per minute.

5. The method of drying wet web material as defined in claim **4** wherein the web is tensioned within a range of from 5 to 15 pounds per linear inch.

6. The method of drying wet web material as defined in claim **4** wherein the web is tensioned to 10 pounds per linear inch.

7. The method of removing moisture from web materials comprising the steps of

(a) advancing a web into wrapping relationship with a first, second, and third series of drying cylinders,
(b) applying pressure against said web while wrapping the first and third series of drying cylinders to urge the web into intimate contact therewith,
(c) directing against the web while wrapping the second series of drying cylinders a plurality of air streams, and
(d) tensioning the web while wrapping the second series of drying cylinders to within a prescribed range to allow the web to be suspended in close running relationship to the second series of drying cylinders.

8. A method of removing moisture from web material, comprising the steps of

(a) advancing a web into wrapping relation with a first, second and third series of drying cylinders,
(b) applying pressure against said web while wrapping said first and third series of drying cylinders to urge the web into intimate contact therewith,
(c) directing against the web while wrapping said second series of drying cylinders a plurality of high velocity air jets to lift the web from said cylinders whereby said web may shrink freely during the drying thereof,
(d) tensioning the web while wrapping the second series of drying cylinders to a prescribed range to allow lifting of the web, and
(e) positively advancing the web from the second series of drying cylinders to minimize the possibility of backward web movement and wrapping of the web around first series drying cylinders.

9. The method of drying web material which shrinks appreciably as it is dried through a critical moisture content range, which comprises

(a) successively lapping the wet web around a first series of heated dryer cylinders,
(b) pressing the cylinder lapped portions of the web into tight contact with the cylinders,
(c) driving said first series of cylinders at the same speed,
(d) maintaining the drying capacity of said first series of cylinders sufficient to deliver the web with the moisture content just above said critical moisture content range,
(e) lapping the thus delivered web around a second series of heated dryer cylinders,
(f) lifting portions of the lapped web from the second series of heated cylinders to prevent adherence of the web to said second series of cylinders,
(g) maintaining the drying capacity of said second series of cylinders sufficient to deliver the web with a moisture content below said critical moisture range, and
(h) driving said second series of cylinders at a lower rate of speed than said first series of cylinders to accommodate shrinkage of the web in said second series of cylinders.

10. The method of drying web material which shrinks appreciably as it is dried through a critical moisture content range which comprises

(a) successively lapping the wet web around a first series of heated cylinders,

(b) pressing the cylinder lapped portions of the web into tight adhering contact with said first series of cylinders,
(c) driving said first series of cylinders at a first speed,
(d) maintaining the drying capacity of said first series of cylinders sufficient to deliver the web with a moisture content just above said critical moisture content range,
(e) lapping the thus delivered web around a second series of heated cylinders,
(f) directing heated air jets against the lapped portions of the web on said second series of heated cylinders to lift the web and prevent adherence of the web to said second series of cylinders,
(g) maintaining the drying capacity of said second series of cylinders sufficient to deliver the web with a moisture content below said critical moisture content range,
(h) driving said second series of cylinders at a second rate of speed and slower than the speed of said first series of cylinders to accommodate shrinkage of the web through said critical moisture content range and allow lifting of the web, and
(i) continuing the drying of the web to commercial dryness.

11. The method of drying paper which comprises
(a) successively lapping a wet web of newly formed paper around a first series of heated dryer cylinders,
(b) covering the cylinder lapping portions of the web with felts,
(c) pressing the felts against the web to maintain intimate contact between the cylinders and the web,
(d) driving said first series of cylinders at the same speed,
(e) drying the web with said first series of cylinders to about 50% bone dry,
(f) lapping the thus dried web around a second series of heated dryer cylinders,
(g) impinging heated jets of air against the lapped portions of the web on said second series of heated cylinders to lift the web from ahering contact with said second series of heated cylinders and to continuously maintain said web freely suspended over such heated cylinders by continued application of such heated air jets to afford unrestrained shrinkage of the web in all directions at least until it is dried to substantially 85% bone dry, and
(h) driving said second series of heated dryer cylinders at a speed sufficient to maintain the tension of the web passing thereover to within a range of from 5 to 15 pounds per linear inch.

12. The method of drying a paper web on a papermaking mahcine which comprises
(a) successively lapping the wet web around a first series of felt-covered heated dry cylinders,
(b) driving said first series of cylinders at a first rate of speed,
(c) maintaining the drying capacity of said first series of cylinders sufficient to deliver the web with a moisture content just above the critical moisture content range for the paper where the maximum shrinkage of paper occurs,
(d) lapping the thus delivered web around a second series of heated dryer cylinders including an initial group of feltless cylinders and a final group of felt covered cylinders,
(e) impinging heated air jets against the web on the feltless cylinders to lift the web from said feltless cylinders,
(f) maintaining the drying capacity of said second series of cylinders sufficient to dry the web through its critical moisture range, and
(g) driving said second series of cylinders at a speed sufficiently slower than said first series of cylinders to accommodate shrinkage of the web as it passes over the feltless cylinders of said second series of cylinders and sufficiently to allow lifting of the web.

13. Apparatus for drying web material which shrinks appreciably as it is dried through a critical moisture content range which comprises
(a) a first series of geared together dryer cylinders for successively receiving the wet web in lapped relation therearound,
(b) covering felts for said first series of cylinders to hold the web in intimate contact with the cylinders,
(c) means driving said first series of cylinders at a first speed,
(d) a second series of geared together dryer cylinders for receiving the web from said first series of cylinders, said second series of cylinders including a first group of feltless cylinders and a second group of felt covered cylinders receiving the web from said first group,
(e) air impingement means for said first group of feltless cylinders in said second series of cylinders effective to prevent adherence of the web to the feltless cylinders, and
(f) means driving said second series of cylinders at a slower rate of speed than said first series of cylinders for accommodating shrinkage of the web and for tensioning the web to within a range to allow nonadherence of the web to the feltless cylinders.

14. Apparatus for removing moisture from web material which comprises:
(a) a first dryer section including a plurality of drying cylinders geared together for equal peripheral surface speeds and arranged for receiving a web in wrapping relation thereon,
(b) means urging the web into intimate contact with the cylinders of said first dryer section to reduce the moisture content of the web to a predetermined level,
(c) a second dryer section including a second plurality of drying cylinders geared together independently from said first plurality for equal peripheral surface speeds adjustable with respect to the peripheral speeds of said cylinders of the first dryer section and effective to dry the web from the first section to a moisture level below which appreciable shrinkage of the web will not occur,
(d) means urging the web into intimate contact with at least the final cylinder of said second dryer section to prevent major movement of the web relative to the surface of said final cylinder,
(e) air impingement means in close proximity to the remaining cylinders in said second dryer section for directing high velocity air jets to lift the web out of adhering contact with said cylinders whereby the web is free to shrink as it is dried in said second dryer section, and
(f) means for controlling the tension of the web in said second dryer section.

15. Apparatus for drying paper webs and the like which comprises
(a) first, second and third dryer sections, said first and third dryer sections each including a series of geared together felt covered dryer cylinders, said second dryer section including a series of uncovered dryer cylinders,
(b) means associated with said uncovered dryer cylinders to prevent adherence of the web to said cylinders, and
(c) means driving the cylinders of said second section at a different rate of speed than the cylinders of said first section to accommodate free shrinkage of the web and non-adherence of the web to said cylinder.

16. Apparatus for removing moisture from web materials, comprising
(a) a first dryer section including a plurality of drying cylinders receiving a web in wrapping relation thereon,

(b) means urging the web into intimate contact with the cylinders in the first section to reduce the moisture content of the web to a predetermined level,

(c) a second dryer section including a plurality of drying cylinders receiving the web from the first section and at said predetermined moisture level, and

(d) air impingement means positioned in close proximity to the cylinders in the second section and directing against the web while in said second section air jets of a velocity sufficient to generate lift in the web, whereby during the drying of the web said web is released from said cylinders and may undergo maximum shrinkage.

17. Apparatus for removing moisture from web materials, comprising

(a) a first dryer section including a plurality of drying cylinders receiving a web in wrapping relation thereon,

(b) means urging the web into intimate contact with the cylinders in the first section to reduce the moisture content of the web to a predetermined level,

(c) means driving the cylinders in the first dryer section at a first speed,

(d) a second dryer section including a plurality of drying cylinders receiving the web from the first section and at said predetermined moisture level,

(e) air impingement means positioned in close proximity to the cylinders in the second section and directing against the web while in said second section air jets of a velocity sufficient to generate lift in the web, whereby during the drying of the web said web is released from said cylinders and may undergo maximum shrinkage,

(f) means driving the cylinders in the second dryer section at a second speed,

(g) a third dryer section including a plurality of drying cylinders receiving the web from the second section,

(h) means urging the web into intimate contact with the cylinders in the third dryer section to remove further moisture from the web,

(i) means driving the cylinders in the third dryer section at a third speed, and

(j) means for independently adjusting said first, second and third speeds through a limited range.

18. Apparatus of the character defined in claim **16** in which there is provided means to hold the web against backward movement.

19. Apparatus for drying web material, comprising

(a) first travelling heating surface means contacting the wet web and removing moisture therefrom until its moisture content is at a point at which further drying will cause appreciable web shrinkage,

(b) felt means maintaining the web in engagement with said heating surface means,

(c) second travelling heating surface means receiving said web from said first travelling heating surface means, and

(d) means releasing said web from adhering contact with said second heating surface means during the drying thereof, whereby said web may freely shrink and assume dimensions natural to its moisture content comprising:

(e) means ejecting heated air on the surface of the web opposite from said heating surface means and creating a film of expansible gas between said heating means and the web and cooperating with the air carried into the space between the web and the heating surface means, to lift the web from said heating surface means, and

(f) means maintaining sufficient tension on the web to limit lifting of the web to only the extent necessary to eliminate contact of the web with the cylinder.

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