April 11, 1961 I. BENTOV 2,979,131

METHOD AND APPARATUS FOR TREATING PAPER

Filed June 10, 1959 5 Sheets-Sheet 1

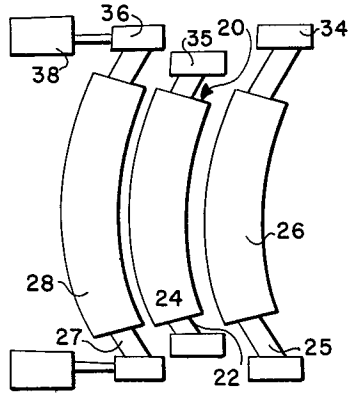


FIG. 1

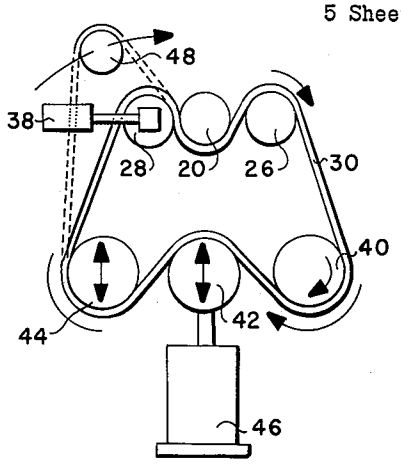


FIG. 2

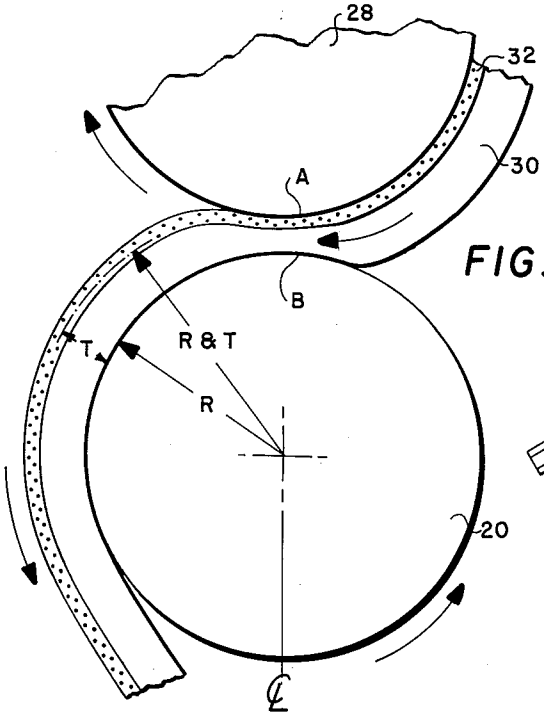


FIG. 3

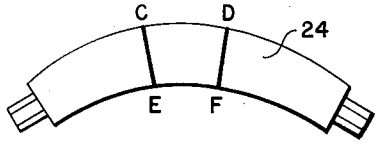


FIG. 4

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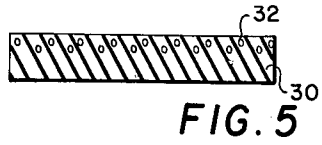


FIG. 5

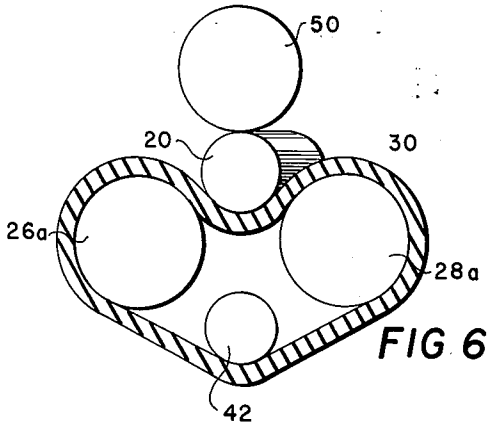


FIG. 6

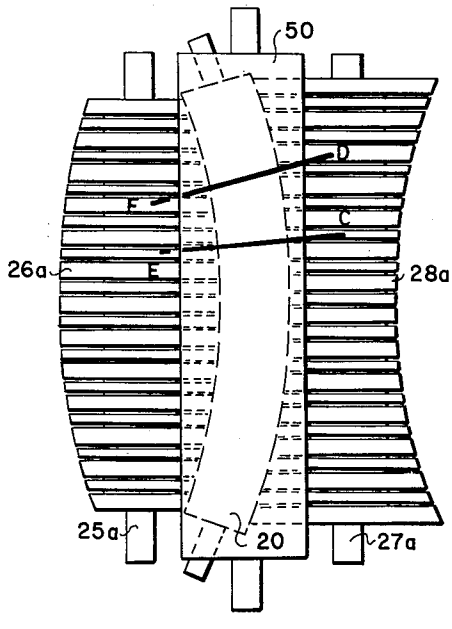


FIG. 7

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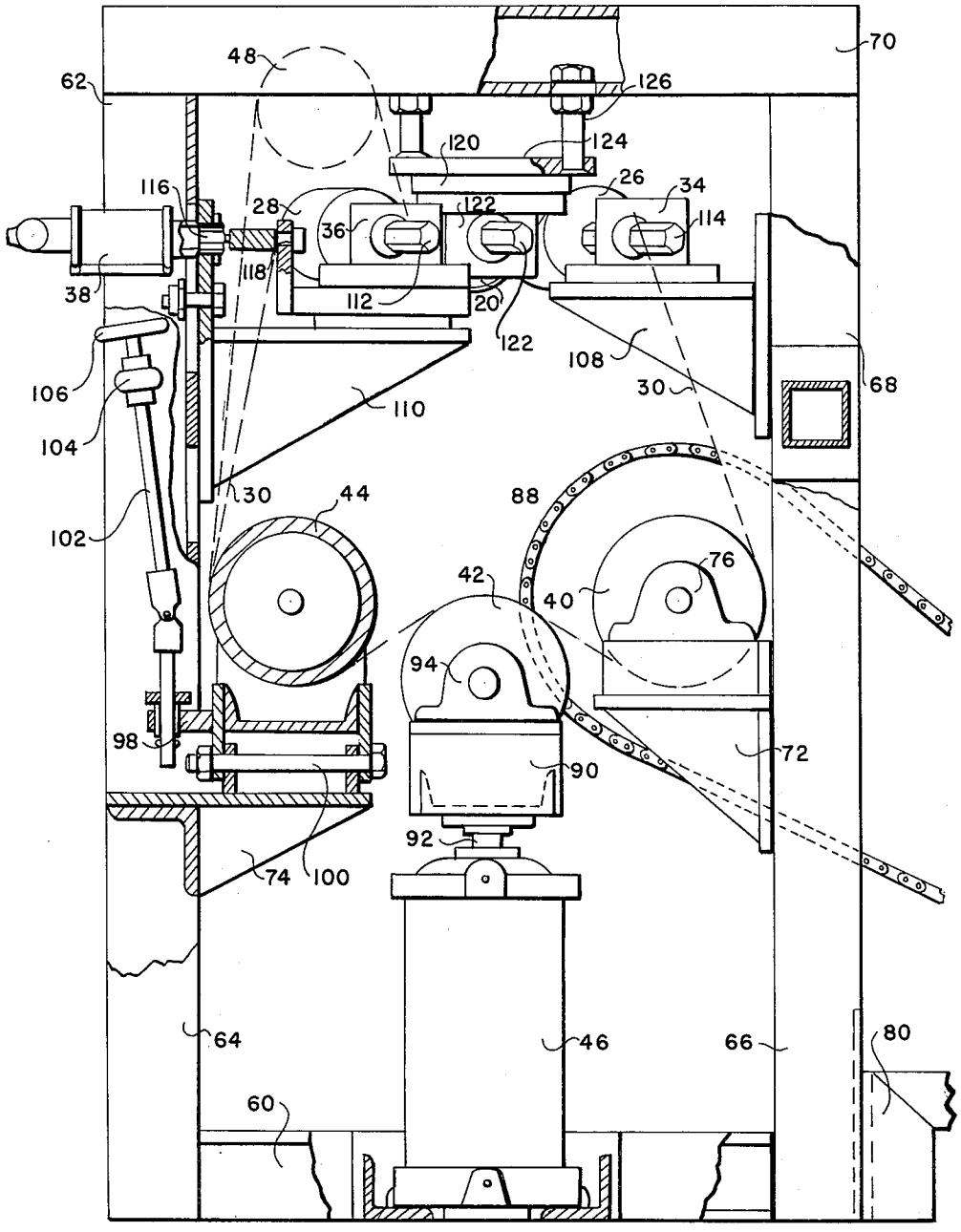


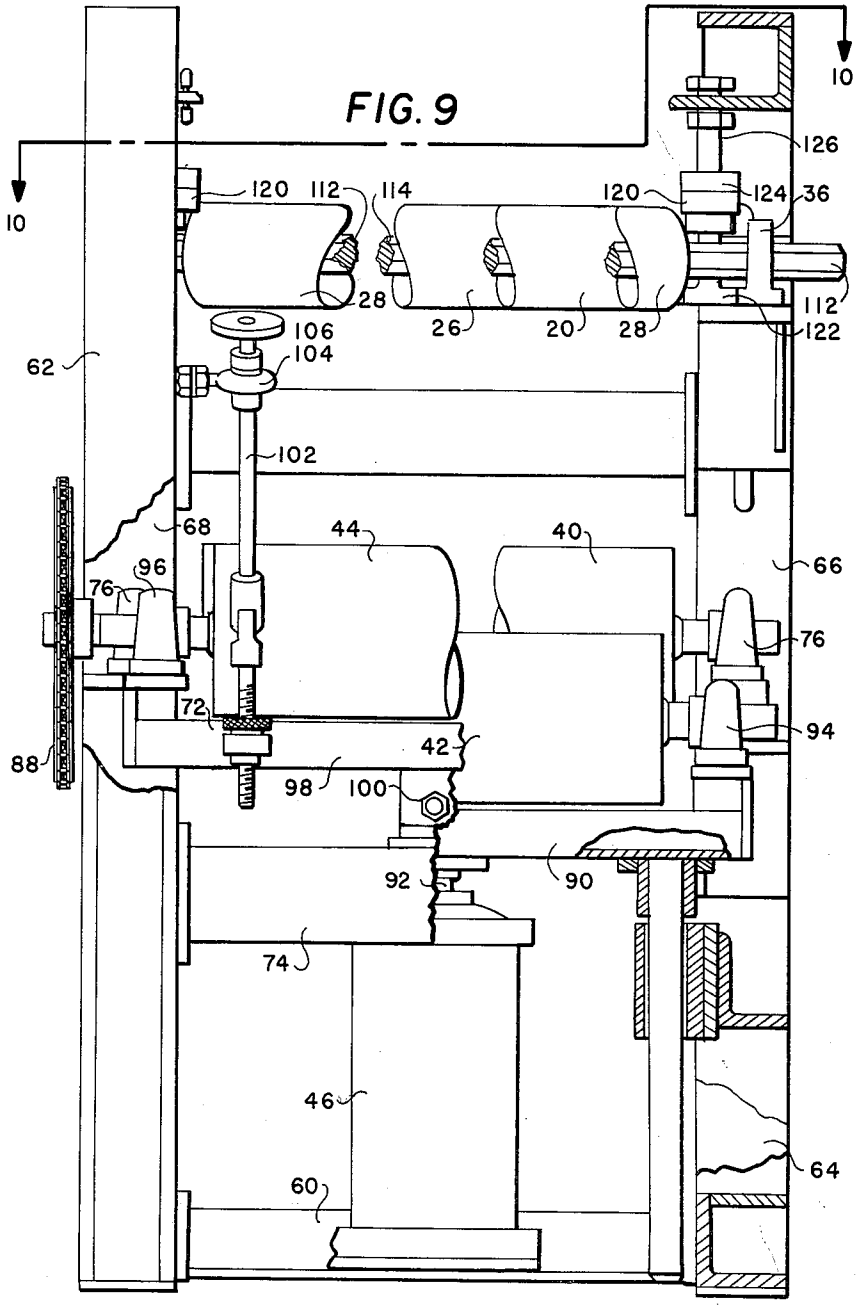
FIG. 8

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FIG. 9



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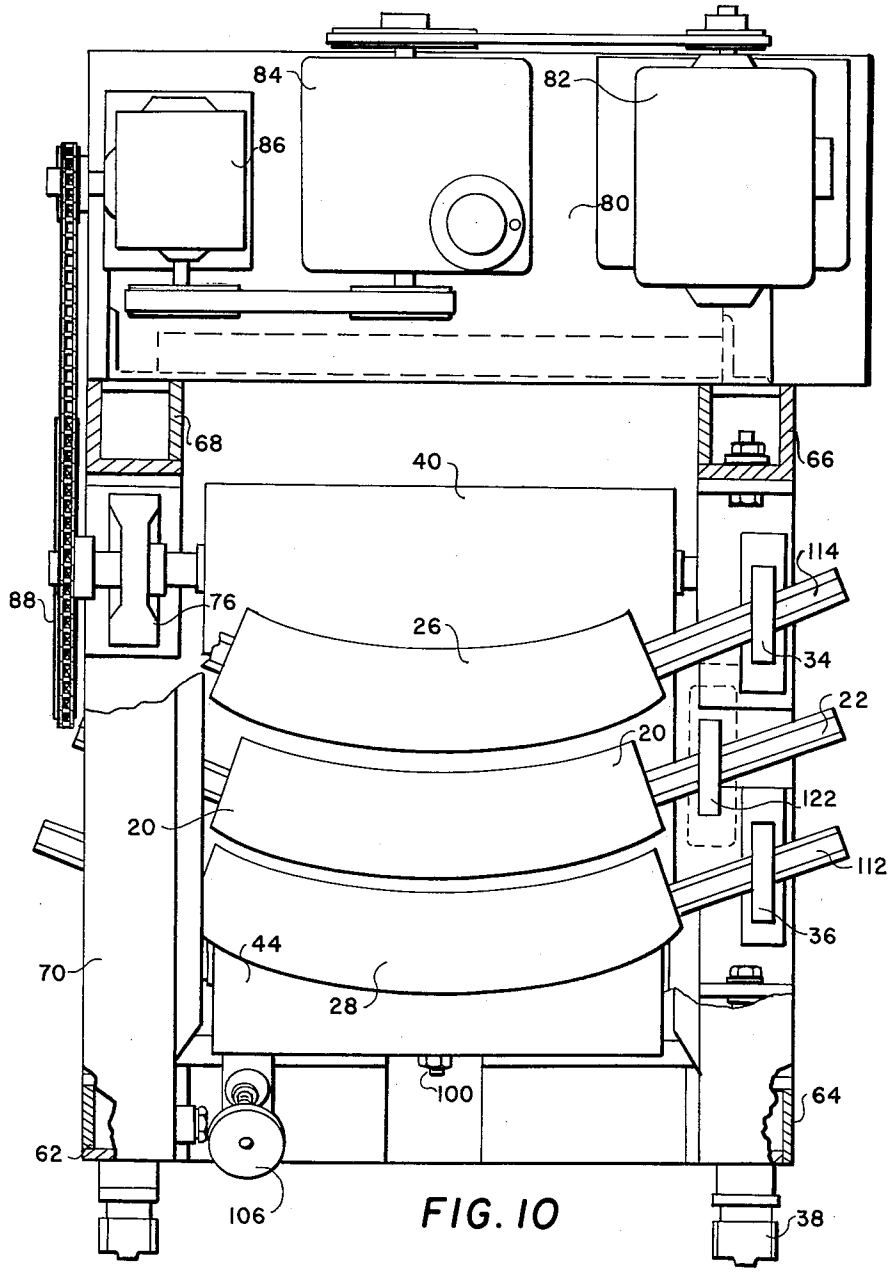


FIG. 10

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2,979,131

METHOD AND APPARATUS FOR TREATING PAPER

Itzhak Bentov, Cambridge, Mass., assignor to W. R. Grace & Co., Cambridge, Mass., a corporation of Connecticut

Filed June 10, 1959, Ser. No. 819,421

7 Claims. (Cl. 162—361)

This invention relates to a method and apparatus for treating paper, and more particularly to a method and apparatus for biaxially shrinking fibrous paper.

Specifically, the present invention is directed to the method and the apparatus to perform the method, of shrinking a length of paper along its longitudinal and horizontal axes simultaneously while at the same time maintaining the faces of the paper substantially free from wrinkling, creeping, or other surface deformations.

The method of the present invention comprises the steps of feeding a piece of paper through an arrangement of pressure and forming rollers, which are so shaped and positioned with respect to each other that compressive forces are applied in the plane of the paper normal to the longitudinal and horizontal axes of the paper. These forces cause the fibers of the moist paper to be pushed or crowded inwardly along both the longitudinal and horizontal axes of the paper so as to reduce the respective longitudinal and horizontal dimensions thereof. During the compression step force is applied perpendicular to the faces of the paper so as to prevent the paper from becoming wrinkled, and heat is applied to help remove moisture from the paper and to set the paper so formed. It is to be understood that the pressures, moisture content, and heat may be varied in accordance with the amount of shrinkage desired and also with respect to the type of paper employed. It has been found that any paper shrunk in accordance with the method of this invention substantially maintains its original thickness and any increase in paper thickness arising from the biaxial compression of the fibers is negligible.

Paper which has been biaxially shrunk and set, in its shrunken state, in accordance with the present invention has a certain amount of extensibility, and may be used for numerous purposes, particularly in the wrapping field. Biaxially pre-shrunk wrapping paper is vastly superior to ordinary wrapping paper because its tendency to tear or rupture is greatly reduced. Any irregularities in the article wrapped will cause the paper to extend about that irregularity and will not put undue stress on the paper so that it becomes readily subject to tearing or puncturing. Other uses and advantages of biaxially shrunk paper will become readily apparent upon its use and an understanding of its characteristics.

It is an object, therefore, of the present invention to provide a new and useful method for biaxially shrinking a piece or web of paper without imparting wrinkles or other surface deformations to the faces thereof, nor increases in thickness, wherein the paper has substantial biaxial extensibility imparted thereto.

It is another object of the present invention to provide new and useful apparatus for biaxially shrinking a length of paper without imparting wrinkles or other surface deformations to the faces thereof, nor increases in thickness wherein the paper so formed has substantial biaxial extensibility imparted thereto.

It is still another object of the present invention to provide biaxially shrunk lengths of paper having no wrinkles or other surface deformations in the faces thereof and which have substantial biaxial extensibility.

These and other advantages and objects will become readily apparent to those skilled in the art upon perusal of the following detailed description taken in conjunction with the drawings appended hereto, in which:

Figure 1 is a diagrammatic plan view of a simple apparatus useful in performing the biaxial shrinking of the present invention.

Figure 2 is a diagrammatic side elevation of the apparatus shown in Figure 1 illustrating the relative adjustments of the individual rollers.

Figure 3 is a cross section of a slice taken in one pair of shrinking rollers illustrating the forces that cause the shrinking along the longitudinal axis according to the present invention.

Figure 4 is a detail of a portion of Figure 1 showing the forces that cause shrinking along the transverse axis according to the present invention.

Figure 5 is a cross-sectional view of the preferred form of endless belt of the present invention.

Figure 6 is a diagrammatic top plan view of another form of simple apparatus useful in performing the biaxial shrinking of the present invention with the belt and one roller removed for clarity.

Figure 7 is a diagrammatic side elevation of the apparatus of Figure 6 indicating the position of the endless belt employed in the present invention.

Figure 8 is a side elevation, partially in section, of the preferred apparatus of the present invention.

Figure 9 is an end view, partially in section, of the preferred apparatus of the present invention.

Figure 10 is a top plan view, partially in section, of the preferred apparatus of the present invention taken along line 10—10 of Figure 9.

Briefly, the method of biaxially shrinkage a piece of moist fibrous paper of the present invention comprises the step of feeding the moist piece of paper between a curved roll and a deformable surface which cooperates with the roll. The paper is fed in between the aforementioned elements at the side of the roll presenting a convex surface and passes about the roller and is removed from between the roller and cooperating deformable surface at a point where the roll presents a concave surface. Due to the relative motion between the deformable surface and the curved roll, paper positioned between the two is caused simultaneously to be compressed along both its longitudinal and its horizontal axes as will be subsequently shown in detail.

In the drawing, Figure 1 diagrammatically shows the position of the forming and pressure rolls of the present invention. A forming roll, indicated generally at 20, comprises fixed non-rotating curved axle 22 about which freely rotates a rubber sleeve 24. Curved rolls 26 and 28 mounted on curved steel shafts 25 and 27 respectively are made the same as roll 20. These rolls are adapted to cooperate with forming roll 20 and are spaced longitudinally thereof on either side. These rolls have a curvature which fits the concave and convex sides of the forming roll, respectively. An endless reinforced deformable belt 30 (Figure 2) passes between the rolls 20, 26 and 28 in the manner and direction indicated in Figure 2. Preferably, the belt 30 is made of rubber, or the like, and is unidirectionally reinforced by parallel cords or fibers 32, as shown in Figure 5. The belt is positioned about rollers 20, 26 and 28 so that the reinforced side is in contact with rolls 26 and 28 as shown in Figures 2 and 3.

Each of the rolls 20, 26, and 28 is suitably mounted, as by the mounting blocks 35, 34, and 36 respectively. Mounting block 36 is slidably mounted and mounting blocks 34 and 35 are fixedly mounted in the same plane. Pressure means such as hydraulically operated cylinder

and piston 38 is affixed to mounting blocks 36 and is adapted to force roll 28 toward forming roll 20. A space is maintained between rolls 20 and 26. The positive pressure on endless belt 30 created in this way prevents the paper from slipping in contact with forming roll 20. Slipping of the paper when it is permitted to occur detracts from the shrinking process.

Figure 2 diagrammatically shows the preferred embodiment of the present invention incorporating pressure means 38 to vary the pressure on the forming roll. In addition to passing between the rolls 20, 26 and 28 as described above, endless belt 30 passes about a drive roll 40, a belt tensioning roll 42, and a guide roll 44. These rolls are suitably heated, as by steam or the like, so that the belt 30 is heated as it passes about them, as indicated. The heated belt then carries the heat obtained up to and through the rolls 20, 26 and 28 as it passes therethrough. The amount of heat imparted to the belt, of course, may be varied to accommodate different types of paper and also to help control the shrinkage taking place. Tensioning roll 42 may be moved vertically up or down to vary the tension on the belt during the operation of the apparatus as by a hydraulically operated piston 46 attached thereto. A guide roll 44 is preferably pivoted about its longitudinal axis so as to properly position the belt 30 as it passes from the heating and tension rolls toward the forming rolls. An additional guide roll 48, which may be either straight or bowed, is positioned above the nip of rolls 26 and 28 to control the angle of feed of the belt 30 into the nip. This roll also serves to prevent lateral pre-compression of the belt before it arrives into the nip. A degree of pre-compression has been found to occur in the belt when fed directly to the nip from guide roll 44 as shown by the dotted line in Figure 2. However, in order to achieve a pre-stretching effect and make it easier for the belt to shrink while in contact with the rolls 20 and 28, the roll 48 should be bowed or curved. The bow of roll 48 should be located in such a manner as to stretch the belt 30 just before it enters the nip of rolls 20 and 28.

Various modifications of the aforementioned forming rolls will be readily apparent to those skilled in the art. One such modification is shown in Figure 6. In this modification convex roll 26*a* is substituted for roll 26 and concave roll 28*a* for roll 28. Roll 20 remains the same as before. Each of rolls 26*a* and 28*a* are formed of a sandwich of independently rotatable circular discs rotatably mounted on non-rotating straight steel shafts 25*a* and 27*a*. The radius of each of the discs making up rolls 26*a* and 28*a* varies to form the convex or concave shape of the rolls. Figure 7 shows the apparatus of Figure 6 with the tension roll 42 located below the forming rolls. A supporting roll 50 is located above forming roll 20 and forces this roll into contact with pressure rolls 26 and 28.

It should be emphasized that the principles involved in biaxially shrinking a piece of paper in accordance with the present invention are the same for each and every embodiment shown and described herein, but are by no means restricted to such arrangements.

The principle under which the method operates is shown in Figures 3 and 4. It will be remembered, from the description above, that belt 30 is made from a deformable rubbery material with parallel longitudinal reinforcing elements near the back surface thereof. It will also be remembered that pressure rolls 26 and 28 and forming roll 20 all consist of curved metal axles with freely rotating deformable rubber collars located on the surface thereof. The reinforced portion of belt 30, as it passes around roll 20, is adjacent to rolls 26 and 28. The paper to be actually shrunk is passed between belt 30 and forming roll 20.

The forward velocity of belt 30 as a whole remains constant throughout its entire path of travel. However since belt 30 has an appreciable thickness, the relative velocity of the top and bottom surfaces of the belt vary as the belt passes around the rollers. Since the reinforcing elements 32 (Figure 5) are under tension at all times, this portion of the belt always remains at the same forward velocity as the belt as a whole. This portion of the belt is represented by letter "A" in Figure 3. Variations in velocity caused by the thickness of the belt as the belt passes around the various rollers, must therefore be taken up by the side of the belt away from the reinforcing elements, which side is noted in Figure 3 by letter "B." When in contact with roll 28, the path traveled by point "B" has a greater circumference than the path traveled by point "A" because of the greater radius of the path of travel of point "B" as compared to the radius of travel of point "A." When however, the blanket changes direction and passes around roll 20, the circumferential length of the path of travel of point "B" becomes less than the circumferential path of travel of point "A" because in this instance the radius of the path of travel of point "B" is less than the radius of the path of travel of point "A." Since the lineal velocity of point "A" remains constant for the reasons explained above, the velocity of point "B" decreases suddenly when the blanket passes from roll 28 to roll 20. Looking at these phenomena in another way and assuming, as one must, because of the reinforcing elements 32, that the length of side "A" remains unchanged, side "B" is stretched relative to side "A' as the blanket passes around roll 28 and is compressed relative to side "A" as the blanket passes around roll 20.

The change in length or the change in speed of side "B" relative to side "A" between the point where belt 30 is moving tangentially to roll 20 and the point where belt 30 has assumed the curvature of roll 20, can be expressed by the following mathematical relation:

$$\text{Differential}=\frac{(R+t)-R}{R+t}$$

where:

R=the radius of the forming roll

t=the distance of the neutral axis of the reinforcing elements in blanket 30 from the face of the forming roll.

In a specific instance where:

R=1.700 inches and t=0.230 inch, the differential in percent is:

$$\frac{(1.700+0.230)-1.700}{1.930}\times 100=12\%$$

thus under these conditions the length of side "B" is reduced by 12% as compared to the constant length of side "A" as the blanket assumes the curvature of forming roll 20. This is approximately the maximum amount of longitudinal shrinkage that may be obtained in the paper in one pass through the machine although there is some additional shrinkage in the nip.

The mechanism behind transverse shrinking is illustrated in Figure 4. It will be remembered that forming roll 20 consists of a freely rotatable rubber collar mounted on a bowed shaft. The axis of the shaft is horizontal and the paper comes into contact with roll 20 from an essentially vertical position on the convex side of roll 20 and leaves in an essentially vertical direction from the concave side of roll 20. The length of the arc on the convex side of roll 20 is necessarily longer than the length of the arc on the concave side. Thus as the rubber sleeve rotates about the roll the length of any given portion of the arc (e.g. C—D) as measured on the convex side is reduced when the same portion of sleeve 24 reaches the concave side (e.g. E—F). Since the blanket is not reinforced against lateral movement, the blanket surface B may be compressed an equal amount. The percentage compression transversely during each path depends upon the relative radii of the convex and concave sides of roll 20 and the theoretical percentage transfer shrinkage may be determined as above.

To obtain the maximum amount of shrinkage in both

the longitudinal and transverse directions it is necessary that there be no slippage between the belt and the paper and the paper and the roll. Since all of the shrinkage in the longitudinal direction occurs almost instantaneously as blanket 30 and the paper pass between the nip between rolls 28 and 20, since it is at this point that blanket 30 assumes the curvature of roll 20, the critical element in preventing slip in this direction is the nip pressure. Unless the pressure exceeds a certain critical amount, slippage may occur and the percentage of compression will be decreased. On the other hand, since shrinkage in the transverse direction occurs gradually during the full travel of the paper about roll 20, the important criterion here is that the tension of the belt 30 be maintained in excess of a certain minimum amount.

Other important elements are heat and moisture. Both heat and moisture help to plasticize the movement of the paper fibers and permit the paper fibers to become compressed relative one to the other. However, obviously excess moisture in the paper must be avoided since water itself is substantially non-compressible and therefore the compression action would cease at any point where the voids in the paper became completely full of water.

The preferred embodiment of the apparatus for carrying out the principles and method to best advantage comprises a base element 60 (Figure 8) having vertical support members 62, 64, 66 and 68 secured at each corner extending upwardly therefrom and a top platform like element 70 supported by said supports. A hydraulically operated cylinder and piston assembly indicated as 46 is disposed substantially centrally on the base 60. Brackets 74 and 72 are secured by suitable means, as by welding, to the supports 62—64 and 66—68, respectively, substantially at the mid points thereof, and extend horizontally therebetween inwardly and transversely of the machine. A cylindrical steam heated drive roll 40 is mounted on the bracket 72, as by the bearings 76 secured to each end thereof. Rotary motion is imparted to the drive roll 40 through a motor and pulley arrangement, mounted on the platform 80, secured to the base element 60 by any suitable means, as by welding or the like. The motor and pulley arrangement (see Figure 10) comprises a motor 82 (preferably electric) drivably connected to a speed changing device 84 which is in turn drivably connected, as by a belt and pulley, to a reduction gearing device 86. Reduction gear device 86 is drivably connected, as by a belt and pulley, to sprocket wheel 88 secured to one end of the axle of drive roll 40, thus causing drive roll 40 to rotate at the desired speed.

A horizontal transversely extending support 90 is secured to the piston 92 of hydraulic cylinder and piston 46. A steam heated belt tension roller 42 is mounted on the support 90, as by the bearings 94, and the support and roll are caused to move upwardly or downwardly by the hydraulic cylinder and piston (actuated by means not shown) so as to increase or reduce the tension on the endless belt 30 passing thereover. A steam heated cylindrical belt guide roll 44 is mounted on the bracket 74, as by the bearing 96 and support 98 adapted to pivot about its longitudinal axis about the stud 100 located at one end thereof. The pivotal motion of the support 98 and roll 44 is accomplished through the action of control rod 102 (Figure 9) threadedly engaging the other end thereof. Rod 102 extends upwardly from the support 98 and passes through guide sleeve 104 secured to the vertical support 62 and is provided with a hand wheel 106 at its upper end. Turning the hand wheel 106 causes the rod 102 to rotate and through the threaded connection with the support 98 causes it to pivot upwardly or downwardly about the pivot stud 100 depending on the direction of rotation of the hand wheel. Thus the belt 30 may be readily guided or adjusted in regard to its travel from the tensioning roll to the shrinking rolls 20, 26 and 28. As previously mentioned the belt may either pass over an additional guide roll 48 mounted on the top platform 70 and thence to the nip of rolls 28 and 20, or it may pass directly to the roll 28.

Support brackets 110 and 108 are secured to the vertical supports 62—64 and 66—68 respectively, as by welding or the like, and extend inwardly therefrom horizontally and transversely of the machine. The bowed roll 28 is mounted on bracket 110 as by the roll mounting blocks 34 which engage the fixed axle 112 thereof. The roll 26 is disposed so that the convex surface thereof faces inwardly of the machine and the concave surface thereof faces the supports 66—68. The bowed roll 26 is mounted on the bracket 108, as by the roll mounting blocks 36 which engage the fixed axle 114 thereof. Mounting blocks 34 are adapted for horizontal reciprocatory movement on the bracket 110 through the action of the hydraulic cylinder and piston 38 mounted in the vertical support 64. Piston 116 is secured at its outer end to the mounting block 34 as by the stud 118 so that when the cylinder and piston 38 are actuated (by means not shown) the mounting blocks 36 and roll 28 carried thereby reciprocate horizontally. The roll 26 is positioned on the bracket 108 so that the convex surface of the roll faces the vertical supports 62—64 and the concave face thereof faces inwardly of the machine. A third roll 20 similarly bowed as the rolls 26 and 28 is positioned between the latter rolls so that the three rolls are in the same horizontal plane. Roll 20 is secured to the plate 120 by means of the roll mounting blocks 122 which engage the fixed axle 22 thereof. Plate 120 is slidingly secured to plate 124 which in turn is secured to top platform 70, as by the studs 126, and plates 120 and 122 extend downwardly therefrom so as to position the roll 20 in the same horizontal plane as the rolls 26 and 28 and in alignment therewith. As previously mentioned, roll 20 is positioned so that the convex surface thereof cooperates with the concave surface of the roll 28 and the concave surface thereof cooperates with the convex surface of the roll 26. Roll 20 is further provided with a rubber sleeve 24, which is adapted to rotate freely about it in the manner described above.

A deformable endless belt 30, reinforced on one surface thereof (Figure 5) is disposed about all the aforementioned rollers so that it passes over guide roll 48 downwardly between the nip of the rolls 28 and 20, under the roll 20 and between the nip of the rolls 20 and 26, thence over the roll 26 downwardly to the heated drive roll 40, over the adjustable tension roll 42, under the guide roll 44 and finally back to the guide roll 48 as shown in Figure 8. As previously mentioned guide roll 48 may be omitted without impairing the operation of the machine, in which event the belt 30 will pass directly from the roll 44 to the bowed roll 28. Pressure on the belt 30 at the nip of the rollers 28 and 20 may be varied by the horizontal reciprocatory movement of the roll 28 toward or away from the roll 20 in the manner described above.

In operation, then, the paper to be biaxially shrunk is fed into the nip of the rolls 28 and 20 between the endless belt 30 and rubber sleeve 24 of roll 20. As the belt 30 moves along the indicated path through the action of drive roll 40, it absorbs heat from the steam heated rolls 40, 42 and 44 as it passes thereabout, and consequently is heated as it passes thereabout the rolls 28, 20 and 26. This heat aids in the shrinking of the paper as it passes between the belt and the aforementioned rolls and may, of course, be varied in accordance with the paper being used and degree of shrinking desired.

The process variables which effect the shrinking efficiency of the machine include the following: nip pressure, moisture content of paper, processing temperature and the coefficient of friction between paper, belt, and roll. There is a certain minimum pressure that has to be maintained in the nip to prevent the belt and paper from slipping. However, pressures considerably above this will interfere with proper paper shrinkage because of excessive reduction in thickness of the paper which causes a higher density and an early wrinkling of the paper.

Moisture content is a critical variable in shrinking paper. The moisture helps to plasticize the paper and reduces wrinkling. At the same time, excessive quantities of liquid limit the shrinkage by taking up space between the fibers. The paper shrinks up to the point where the water in the paper prevents it from shrinking further. In the successive passes, the rate of shrinkage levels off and depends solely on the amount of water evaporated at each pass. The shrinkage rate will increase markedly when a certain moisture content is reached.

Heat will plasticize the paper still further; and since more water is evaporated with each pass, the rate of shrinkage will be higher. A small rise of 10–15° F. above room temperature will have a marked effect on the shrinkage.

In summary, there is no shrinkage without proper nip pressure. For best shrinkage efficiency, as low a nip pressure as possible has to be maintained to keep the paper from being compacted too much in thickness.

The present invention provides a new and useful process for biaxially shrinking any type of fibrous paper without imparting wrinkles or other surface deformations to the faces thereof.

The present invention, moreover, provides a new and useful apparatus for carrying out the principles and steps of process of the present invention. The apparatus is adapted to shrink any type of paper whether heavy or thin or in web or sheet form, and may be readily adapted to provide any desired degree of shrinking to any given piece of paper in accordance with the principles of the process of the present invention.

Various changes and modifications may be made in the details of the structure of the apparatus herein described as well as in the procedure without departing from the scope of the invention or sacrificing the advantages thereof as defined in the claims herein.

I claim:

1. An apparatus for biaxially shrinking a piece of fibrous paper comprising a bowed roll having a resilient surface, a deformable endless belt adapted to cooperate with and in engagement with said roll and defining a nip therebetween, means for moving said belt about a portion of said roll, and means for varying the amount of engagement between said bowed roll and said belt at said nip, said last recited means including a second bowed roll in the same plane as the first bowed roll and in alignment therewith, the concave side of said second roll having the same degree of bow as the convex side of the first roll, said second roll being adapted to be moved toward said endless belt to push toward said first roll.

2. An apparatus for biaxially shrinking a piece of paper comprising three bowed rolls, each of said rolls being in alignment with respect to each other in the same plane and having a degree of bow that adjacent surfaces have the same degree of bow, an endless belt adapted to cooperate with said rolls and to move relative thereabout, means for moving said belt wherein said belt passes over the first of said rolls, under the second of said rolls, and over the third of said rolls, said belt and said second roll defining a nip therebetween, and whereby said belt tends to assume the configuration of said rolls as it moves thereabout.

3. An apparatus as defined in claim 2 having means to move said first roll away from or toward said second roll so as to vary the pressure at said nip defined by said belt and said second roll.

4. An apparatus as defined in claim 2 having means to vary the tension on said endless belt as it moves about the rollers.

5. An apparatus as defined in claim 2 having means to heat said belt.

6. An apparatus as defined in claim 3 having means to heat said belt.

7. An apparatus as defined in claim 4 having means to heat said belt.

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