

July 26, 1966

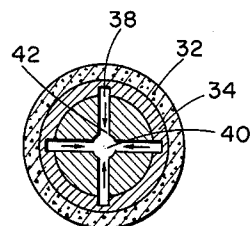
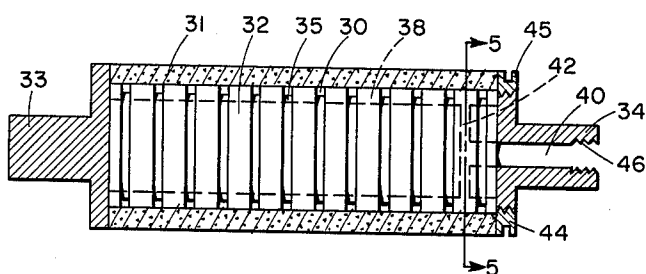
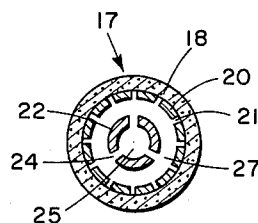
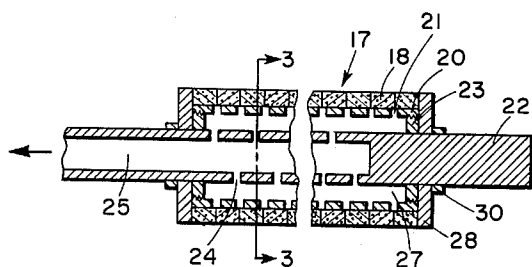
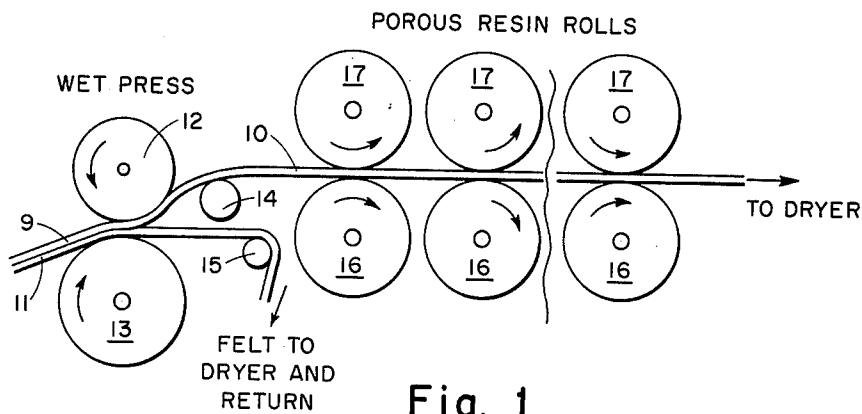
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3,262,840

METHOD AND APPARATUS FOR REMOVING LIQUIDS FROM
FIBROUS ARTICLES USING A POROUS POLYAMIDE BODY

Filed Sept. 20, 1963

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

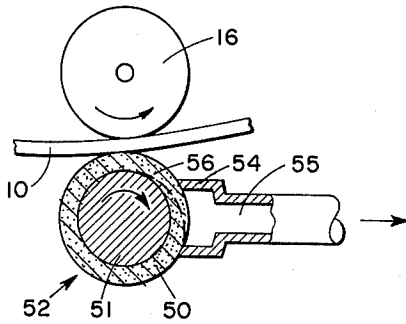


Fig. 6

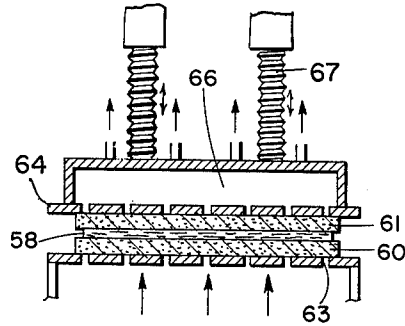


Fig. 7

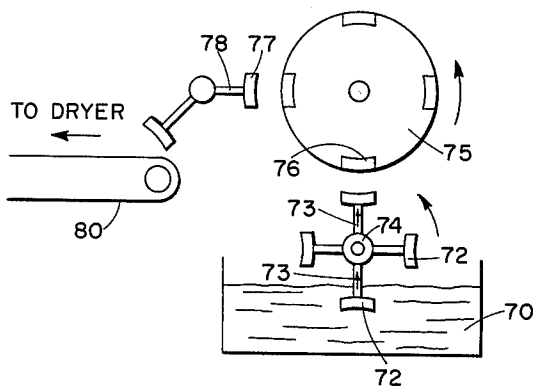


Fig. 8

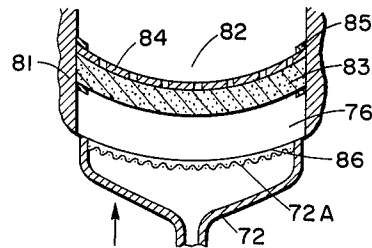


Fig. 9

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3,262,840

METHOD AND APPARATUS FOR REMOVING LIQUIDS FROM FIBROUS ARTICLES USING A POROUS POLYAMIDE BODY

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8 Claims. (Cl. 162-205)

This invention relates to removing liquids from fibrous articles, whether woven or nonwoven materials, and more particularly to the removing of liquids in the making of paper and paper products, and in the treating of paper and textiles.

In the making of paper after the web has been formed on the wire it is, of course, necessary to remove the water remaining in the web thus formed. This is normally done by transferring the wet web to a felt support and then rolling the wet web with the felt through a set of rolls, one of which is normally constructed of hard rubber, the other of which is made of iron or covered with rubber. This in papermaking is known as the wet press and it is designed to remove water from the capillary structure of the wet web. In wet pressing it is desirable to remove as much water as possible and at the same time to obtain uniform water distribution in order to produce a high quality paper. A similar problem arises in making shaped articles which are formed on molds, such as in slush molding.

In the treating of paper it is normally customary to introduce treating agents in the form of a liquid, and particularly an aqueous liquid. After the paper has been treated with the required amount of material, it is of course necessary to remove the excess liquid. In the same manner in treating textiles, whether they are woven or nonwoven materials, resins and the like are generally introduced in the form of a liquid suspension or solution, and after a sufficient quantity of the treating agent has been introduced into the textiles the liquid must be removed. Inasmuch as it is most economical to use water as the liquid media in these treatments, it is the liquid which is most commonly used rather than a more volatile liquid which is more easily removed with heat. Thus, the liquid removal process is one which desirably begins with some form of mechanical removal of some of the liquid.

Long experience in papermaking and in the treating of fibrous webs with liquid agents has indicated that by the use of wet press rolls it is not possible to reduce the liquid content through pressing below about 70% by weight of water in the web. This is due primarily to the fact that one is working with an incompressible fluid, namely, water, and even with the use of a felt backing it is possible to compress the paper and transfer only so much of the water into the felt. This means that the remaining portion of the liquid must be removed in a drying step which involves heating.

In actual practice, it has been found that the cost of heat drying is about directly proportional to the amount of water or other liquid which must be removed. It therefore becomes apparent that if it is possible to remove more liquid through a pressing step, then the cost of drying is proportionately reduced. When it is realized that the drying operation in the manufacture of paper, for example, makes up a major portion of the paper cost (except perhaps in cases of extremely high-grade paper where the pulp itself is expensive) it will be seen that a reduction in the amount of liquid which must be removed in drying contributes materially to reducing the cost of making the paper. In a like manner where woven and nonwoven fibrous webs are treated with a liquid agent, the cost of

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removing the residual liquid is a major factor in the total cost of the treating process.

I have found that it is possible to greatly increase the amount of liquid which may be removed from a wet fibrous web in the pressing operation by the use of a porous resin roller in a manner such that the liquid is readily transferred to the resin roller and hence removed from the wet web. Although the method of this invention will be hereinafter generally described in terms of removing water from a web, it is to be understood that the term web is used in a broad sense and is meant to include sheets of paper, paperboard, and molded paper configurations as well as woven and nonwoven textiles and the like.

It is therefore a primary object of this invention to provide an improved method of removing liquids from a fibrous web. It is another object of this invention to provide a method of the character described which is capable of removing a greater percent of liquid from a fibrous web than is now possible to remove in the well known wet press operation. It is another object of this invention to provide a method which makes possible a material reduction in cost associated with the heat drying of wet webs. It is still another object of this invention to provide a method of the character described which is adapted to papermaking, including the formation of sheets, boards and molded articles, to paper treating, and to textile treating, whether woven or nonwoven. It is another object of this invention to provide a method of making paper articles possessing improved qualities, including paperboard which exhibits improved strength characteristics, as well as to provide improved articles formed of fibrous webs.

It is another primary object of this invention to provide apparatus for removing liquids from wet fibrous webs which will remove more liquid than is now possible with the present mechanical means. It is another object to provide apparatus of the character described which is adaptable to various papermaking and treating operations as well as to textile treating. Other objects of the invention will in part be obvious and will in part be apparent hereinafter.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the other steps, and the apparatus embodying features of construction, combinations of elements and arrangements of parts which are adapted to effect such steps, all as exemplified in the following detailed disclosure, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings in which:

FIG. 1 is a diagrammatic representation of a portion of a papermaking apparatus showing the use of porous resin rolls after the wet press operation;

FIG. 2 is a longitudinal cross-section of one embodiment of a porous roll constructed in accordance with this invention;

FIG. 3 is a cross-section along line 3-3 of the roll of FIG. 2;

FIG. 4 is a longitudinal view partly in cross-section illustrating another embodiment of a porous roll;

FIG. 5 is a cross-section along line 5-5 of the roll of FIG. 4;

FIG. 6 is a modification of this invention showing the use of a porous roll and means for removing residual liquids;

FIG. 7 illustrates an apparatus showing the adaptation of the process and apparatus of this invention to the making of paperboard;

FIG. 8 illustrates the method and apparatus of this invention adapted to the formation of molded paper shapes formed by slush molding; and

FIG. 9 is a cross-sectional view of apparatus constructed in accordance with this invention and suitable for use in slush molding.

In general, the method of this invention for removing liquid from a fibrous web may be characterized as the step of contacting under pressure the surface of the fibrous web with the surface of a microporous resin body. Since it is necessary to continuously remove the liquid from the porous body, it is preferable to reduce the pressure at the surface opposite to that in contact with the web, thus drawing the liquid through the porous resin. In a preferred embodiment, the resin is a porous polyamide formed by sintering finely-divided particles, the average diameter of which is 40 microns and less.

The apparatus of this invention may be described as comprising a microporous resin body adapted to make surface-to-surface contact with the surface of a web or fibrous body, means for bringing the surface of the resin body in contact with the surface of the fibrous body under pressure, and means for removing the liquid transferred from the fibrous web to the resin body. The porous resin body may be in the form of a roll or a plurality of rolls, a flat surface, or a contoured surface as will be described hereinafter.

Many synthetic resins will prove satisfactory in the practice of this invention. However, the preferred resin is a synthetic fiber-forming polyamide generally known as "nylon." For convenience, the porous structure described herein generally is referred to as being comprised of nylon, though it is to be understood that this includes other suitable synthetic resinous materials as described below. The polyamides are particularly suitable for use as porous structures due to a number of desirable physical properties. For example, they have good structural strength, they have excellent wear properties, and they have a suitable amount of resilience. Still further, porous bodies having the desired degree of porosity can readily be formed from polyamide resins.

The synthetic polyamides may be further described as synthetic resins obtained by the self-polymerization of monoaminomonocarboxylic acids, or by reacting a diamine with a dibasic carboxylic acid in substantially equal molar amounts. In defining the polyamides, it is to be understood that amino acids, diamines and dibasic carboxylic acids are intended to include the equivalent amide forming derivatives of these reactants. The polyamides include also polymers obtained by admixture of other polymer-forming reactants as for instance glycol dibasic acid mixtures in the case of polyester amides. Among the better known synthetic polyamides are polyhexamethylene adipamide, polyhexamethylene sebacamide and polymerized epsilon aminocaproic acid (caprolactam).

Among the other synthetic resins known, the polycarbonates, polyesters, polyethers, polyvinyls and acetal resins also possess the required strength and resiliency, and it is meant to include within the scope of this invention all of the synthetic resins which are capable of being formed into porous bodies having sufficient structural strength to permit them to be contacted under pressure with a wet fibrous web.

Various methods have been developed for forming porous polyamide bodies, among which may be cited the process disclosed in United States Patents 2,695,425 and 3,022,542. Briefly, the process comprises pressing finely-divided nylon powder (which has an average ultimate particle size of less than 40 microns) and sintering to form the porous article. It is preferable first to heat the nylon powder under nonoxidizing conditions prior to pressing to a temperature of from about 250° F. up to about its melting point, then cool, cold press it into the desired configuration, and finely sinter it. The porous polyamide body may also be formed by other methods,

for example, introducing a leachable material into a body formed by pressing and sintering and then subsequent washing the leached material from the porous body thus formed.

In order to function efficiently as a means for removing liquid from a wet fibrous web, the porous nylon body should have a degree of porosity of at least 15% and preferably in a range from about 15% to 40%, that is, the volume of the pores should range between about 15% and 40% of the total volume of the porous resin body. Generally, the greater the porosity, the more efficient is the nylon body in removing liquid. However, porosity must not be gained at the expense of the strength and resiliency required.

In order to better understand the method and apparatus of this invention, several specific embodiments will now be described with reference to the figures.

FIG. 1 illustrates a small portion of a typical paper-making machine, beginning with the wet press which generally comprises two rolls, an upper roll 12 and a lower roll 13, defining between them a nip area. Customarily, these rolls are of nonporous material having a smooth surface, for example, steel or hard rubber. In the normal papermaking operation, it is customary to transfer the wet web 9 as it comes from the papermaking machine to a felt 11, and the assembly of the web 9 and felt 11 is then passed through the nip of the rolls making up the wet press. The paper, after pressing, has a tendency to adhere to the smoother of the two surfaces, that is, to the surface of the roll 12 while the felt (normally wool) containing water breaks from the wet web and is passed over a guide roll 15 to be returned after removal of the water therefrom.

In accordance with the teaching of this invention, the paper 10 as it comes from the wet press is directed over a guide roll 14 and passed through one or more presses, each of which has a nonporous roll 16 and a porous nylon roll 17. When the paper 10 leaves the wet press, it typically has about 70% water still remaining in it. By passing through a press constructed as shown in FIG. 1, it is possible to further reduce the quantity of water to 50% in the first press formed by rolls 16 and 17, 47% in the second, and to 35% in the fifteenth roll. These data were obtained using a nylon roll having a degree of porosity of about 40% and an average pore size of about 18 microns. The actual pore size will vary with the degree of porosity. For example, at 25% porosity the average pore size may be from 3 to 5 microns with same pores being larger and some smaller.

Thus, it will be seen in a typical operation such as illustrated in FIG. 1, that the paper coming from the wet press which normally contains about 70% water can be so treated by pressing alone to reduce the amount of water to 35%. Taking for example the making of newsprint, it may be shown that the removal of the additional 35% of water can result in cutting drying costs to about one-half assuming that drying costs are essentially proportional to the amount of water which must be removed. Moreover, in almost all papermaking equipment, the capacity of the dryers controls the speed at which the paper machine can be run. Thus, if one wishes to increase this speed, additional drying capacity is almost mandatory. However, by the use of the porous nylon roll of this invention, such an increase in drying capacity can be avoided while still achieving an increase in speed and hence in the capacity of any given papermaking equipment.

It is also, of course, possible to replace the nonporous rolls 16 of FIG. 1 with a second porous nylon roll and to use one or two porous nylon rolls in the wet press.

The reasons for the efficacy of the porous nylon roll or other porous resin body in this role of liquid removal is probably not completely understood, but it seems reasonable to explain it in the light of what is now known

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about water removal from paper through the use of a papermaking felt and a plastic fabric.

Wahlström (Pulp Paper Mag. Canada, 61, No. 8:T-379 (1960)) developed a theory of water removal in a press section to show that all water is pressed out of the paper sheet during the compression stage in the nip of the press roll. During the recovery stage, on the way out of the nip, the sheet is rewetted to a large extent by the felt because the paper has finer pores than the felt. This theory has been completely confirmed by the experiments of Sweet (Pulp Paper Mag. Canada, 62, No. 7:T-367(1961)). The felt therefore serves two purposes. It provides a compressible pad to increase the width of the nip, and provides a drainage path for the water squeezed out of the sheet. Both of these reduce the longitudinal hydraulic pressure gradient which is responsible for crushing the paper (TAPPI Engineering Conference Papers, pp. 44-48 (October 1962)). The recent addition of a plastic fabric between the felt and the roll increases the drainage and therefore further decreases the crushing tendency. (See Paper Trade Journal, vol. 147, No. 3, pp. 20-22, January 21, 1963.) During the decompression phase in the nip the presence of the felt is highly undesirable since it causes a large amount of rewetting of the paper. The use of plastic fabric does not appreciably help in this respect.

The porous nylon roll or other porous body of this invention retains the beneficial features of the felt and plastic fabric and at the same time eliminates the rewetting problem. Thus, the felt and fabric are replaced by a porous nylon cylinder in FIG. 1 which also acts as one of the rolls of the press. A large gain in water removal efficiency is obtained in this way, as shown above.

The great improvement in drying efficiency of the porous nylon roll over other pressing methods can be explained in terms of Wahlström's theory. In short, the nylon roll combines all the desirable properties of felt plus plastic fabric and, instead of rewetting during the recovery phase in the nip, it actually provides additional drying.

The porous nylon roll is compressible enough to give a wide nip area and permeable enough to give excellent drainage of the water squeezed out of the paper and out of the compressed surface layer of the roll itself. Thus, the nylon roll by itself can supply the compressive and drainage qualities of a combination of felt and plastic fabric.

In the recovery phase, after passing the point of maximum compression in the nip, both the compressed paper sheet and the compressed zone of the nylon roll expand and develop internal water-air interfaces. Under these conditions capillary tension is set up. Since the pores in the nylon roll are much smaller than those in the paper, the capillary tension is greater in the roll than in the paper. Thus water is sucked from the paper into the roll until the paper separates from the roll.

Thus both the compression and recovery phases in the nip remove water from the paper sheet with the result that exceedingly high drying efficiency is achieved.

It will be seen from the above description of the mechanism by which the nylon roll removes liquids from fibrous articles (e.g., paper) that the average pore size of the nylon roll should be less than the average pore size of the wet article from which the water or other liquid is to be removed. The minimum average pore size in the nylon roll or body will depend to a large degree upon the actual operating conditions and cannot be defined in a general manner for all conditions. In removing the liquid from the porous nylon body so that it may serve as a continuous drying means it is necessary to reduce the pressure (pull a vacuum) on one side of the porous body (normally on that side opposite the contacting surface). This method of liquid removal indicates that when the pore size is decreased to the extent that the capillary forces are greater than the forces developed through the pressure differential created in the use of a vacuum, some difficulty may be

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encountered in the removal of liquid from the porous nylon. However, the application of pressure during the period of contact between the wet web and the nylon body may be used to overcome a portion of the capillary forces so that the minimum pore size must be determined for any given system.

Although the smaller pore sizes are generally more desirable for removing liquid from the wet porous webs, they may introduce some difficulties in subsequently removing the liquid from the porous nylon body. The advantages of small pore size may, however, be combined with subsequent efficient liquid removal in a porous nylon body having a pore-size gradient across its thickness. In this embodiment, the small pore sizes are used at that surface which contacts the wet fibrous article and the largest pore sizes at that surface where a vacuum is created. Intermediate pore sizes may, of course, be between the two extreme surfaces. In this modification of the porous nylon body, that portion which has the smallest pore sizes can be relatively thin, depending upon the remaining portion for support and strength. Such a porous nylon body having a pore-size gradient can be formed in layers and sintered, or molded with the desired gradient characteristics.

The capillary-sized pores in the nylon body must be capable of substantially retaining their original characteristics during use by resisting any appreciable swelling or shrinking, or by reacting with the liquid being picked up. Furthermore, the pores must substantially retain their structure and not be subject to any appreciable mechanical breakdown under the pressure to which they are subjected. At the same time the porous structure should exhibit resiliency under this pressure to behave in the manner described above.

One embodiment of a porous nylon roll suitable for use in apparatus such as shown in FIG. 1 is shown in cross-section in FIGS. 2 and 3 in which the numeral 17 is used to generally indicate the roll. In this embodiment, it will be seen that a number of annular porous nylon rings 18 making up a porous sleeve, are mounted upon a hollow cylindrical roll 20 having perforations 21. This roll is mounted on a shaft 22 which, in turn, is positioned on the perforated roll by means of a ring 23. Shaft 22 has ports 24 and is hollow, at least through a portion of it, defining within it a channel 25 which permits a vacuum to be pulled on the roll 17 and provides for the removal of liquid as it is drawn from the wet fibrous web through the porous nylon rings 18, the perforated roll 20 into the annular space 27. The nylon rings 18 are maintained on the shaft 22 in contact with each other by means of the end plates 28 which are held in position by suitable means such as nuts 30. Although FIG. 2 illustrates the use of a series of nylon rings, the nylon sleeve may of course be also formed of a single continuous piece as is illustrated in FIG. 4.

It will be seen in the apparatus of FIG. 1 and in the cross-sectional diagrams of FIGS. 2 and 3 that as the wet fibrous web is pressed between the porous roller 17 and a suitable solid roller 16, some of the liquid originally present in the fibrous web is drawn through the nylon sleeve into the annular space 27 and out through the hollow shaft 22 when a vacuum is pulled through the hollow shaft and the annular ring. In this embodiment the liquid removed from the fibrous web is transmitted through the porous nylon body.

FIGS. 4 and 5 illustrate another embodiment of a porous roll constructed in accordance with this invention and suitable for use in apparatus such as shown in FIG. 1. This roll differs from that of FIG. 2 in that the metal shaft is essentially solid and is provided with appropriate channels for carrying off the liquid which passes through the porous resin sleeve. In the roll of FIG. 4 the porous resin, e.g., nylon, is constructed as a continuous sleeve 31 which is fitted upon a metal shaft 32 having extensions 33 and 34 at either end suitable for mounting in a roller system. The metal

shaft 32 has a series of circumferential grooves 35 defining with the inner wall of the porous nylon sleeve a series of circumferential channels 36. These in turn lead into a series of longitudinal channels 38 (four are shown in FIG. 5). Shaft extension 34 and a small length of main shaft 32 are drilled out to form a central channel 40 which, by means of radial channels 42, communicates with the longitudinal channels 38. Thus, there is provided a path for the liquid which is drawn into the nylon sleeve 31 to be withdrawn from the roller system. This path comprises the circumferential grooves 35, the circumferential channels 36, the longitudinal channels 38, the radial channels 42, and the central channel 40. Extension 34 is adapted to take a threaded ring 45, and by means of threads 46 within the central channel 40 it is adapted to be attached to a conduit leading to a suitable vacuum system (not shown). The roll is easily assembled by unscrewing the threaded ring 45, passing the nylon sleeve 31 over the main metal shaft and then screwing on the threaded ring 45 to hold it into position on the roller assembly. Nylon sleeve 31 can also be made with a pore-size gradient, the smaller pores being on the outside.

In the apparatus modification of FIG. 6 the liquid is absorbed by the porous nylon sleeve 50 which is mounted on a suitable shaft 51. These two components make up the roller 52 which in this case is seen to form the button roller of a press. In this modification, the liquid is not transmitted across the thickness of the porous sleeve, but is removed through the use of a suitable vacuum system such as illustrated in FIG. 6. A vacuum chamber 54 is mounted in close contact with a portion of the roll 52 and is in communication with a vacuum system, not shown, through a duct 55. As the roll 52 rotates in the direction of the arrows, it will pick up a quantity of liquid from the wet fibrous web, and the liquid will then be subsequently removed therefrom by the vacuum system. In FIG. 6 the liquid, diagrammatically represented by the numeral 56, is shown to be contained temporarily in a portion of the nylon sleeve.

Certain associated apparatus may be used in conjunction with the apparatus of this invention as it is illustrated in FIG. 1. For example, a heavy nip may be placed opposite the dewatering nip (i.e., on the top of roll 17) to wring out some water from the porous nylon roll 17. Liquid removal may also be enhanced by the use of alternately applied vacuum and pressure. For example, a roll such as shown in FIG. 2 may be suitably internally compartmentized and valved so that a vacuum is created within that portion of the roll which corresponds to the outer surface which is in contact with the wet web and air under pressure is made available over that internal portion of the porous nylon roll which corresponds to that surface not in contact with the wet web. In this arrangement, the residual water remaining after the vacuum is released is forced out of the porous roll under pressure, thus minimizing difficulties in water removal brought about through the use of small pore sizes. The compartmentizing and valving of the interior of rolls is known in the filtering art.

The apparatus illustrated in FIGS. 1 through 6 are also well adapted to the removal of liquid from porous webs which have been treated. A sheet of paper or a woven or nonwoven textile, for example, which has been immersed or otherwise contacted with a liquid treating agent may be passed through the wet press of FIG. 1 and then into the porous press rolls 16 and 17, or introduced directly to the porous press rolls. In like manner the treated web may be put through the press rolls of the apparatus of FIG. 6.

It is also, of course, within the scope of this invention to make both of the rolls of a pair of rolls such as shown in FIGS. 1 and 6 of the porous type constructed in accordance with this invention. Both of the rolls of a pair may be of the type which requires the

passage of the liquid through the porous resin body (FIGS. 2 and 4), of the type which continuously removes the liquid from the same surface which contacted the wet fibrous web (FIG. 6), or a combination of these two types.

Difficulties have always been encountered in removing water from glassine paper by passing it through the standard pressing rolls. These difficulties appear to be due to the fact that the fibers are so highly hydrated, and it is normally possible to reduce the moisture content to only about 80% by weight by wet pressing. A typical glassine paper which had been partially dried after wet pressing, and having a moisture content of 59% by weight, was pressed between a steel roll and a porous nylon roll. One pass through this roll system reduced the water content to 55% by weight. Another sample of glassine paper containing 80% by weight of water was passed with a papermaking felt through the nip of a steel roll and porous nylon roll, the felt contacting the steel roll. The water content in this sample was reduced to 67% in one pass through these rolls. The felt was used because the glassine paper alone became disrupted in the nip of the rolls. Glassine paper samples given multiple passes through the steel and porous nylon rolls became quite transparent, indicating that this paper should have a higher degree of grease resistance than is normally achieved.

The removal of liquids from all types of textiles has been demonstrated. Nylon, cotton, rayon and wool woven textiles were all dipped in water and thoroughly saturated. Samples of each of these materials were then passed once through a regular clothes wringer and equivalent samples of each were passed once through the wringer, one roll of which was replaced by a porous nylon roll formed as in FIG. 2. The amount of residual water remaining in each of the samples so treated was then measured. The results are given in Table 1.

Table 1

Material	Amount of Residual Water, Percent by Weight	
	No Porous Roll	One Porous Roll
Nylon.....	28	18
Cotton.....	54	36
Rayon.....	62	51
Wool.....	51	35

Each of these sets of data for a type of textile illustrates the achievement of a marked increase in water removal with the use of the method and apparatus of this invention.

In treating textiles it is customary to immerse the textile in an aqueous liquid containing the treating agent, e.g., a resin, designed to impart desired properties to the textile. It is advantageous in such treatments to introduce the liquid and hence the treating agents into the fibers rather than between them. This can be accomplished to a greater degree by using a porous roller in the wet press and a more concentrated treating liquid. The removal of more liquid in the pressing step means that less liquid and hence less treating agent will remain between the fibers. Since more liquid is removed in pressing it will generally be desired to use more concentrated liquids in the treating.

The method and apparatus of this invention is also applicable to the forming of flat paperboard which is normally pressed, not by rolling it through two rollers, but by pressing it between two flat platens. A modification showing the application of the porous nylon pressing body of this invention to the manufacture of paperboard is illustrated in FIG. 7. In such an operation, a paperboard 58 made up of a plurality of plies is placed between a bottom porous nylon body 60 and a top porous nylon body 61. In order to apply pressure and remove

liquids simultaneously, it is necessary that the bottom platen support 63 and the top platen pressure applying surface 64 be perforated to permit air to enter through the bottom plate 63 and water to be withdrawn through the top plate 64 by the pulling of a vacuum within the structure 65 which defines a vacuum chamber 66 above the top pressure platen 64. Any suitable means, such as screws 67, may be used to apply pressure to the top platen 64.

By employing the apparatus in FIG. 7, it has been found possible to form paperboard which is materially stronger than paperboard made by pressing the wet web between felts as is now done. A board comprising 10 plies was pressed between felt in accordance with standard practice and subsequently dried by heat, and an equivalent board was pressed using the apparatus of FIG. 7 and placed in surface-to-surface contact with two porous nylon sheets, such as 60 and 61. The two boards were then measured to determine their strength properties. The results are given in Table 2.

Table 2

Test	Pressed Between Felts, p.s.i.	Pressed Between Porous Nylon Platens, p.s.i.
Mullen.....	713	905
Tensile (with grain).....	7,180	10,580
Tensile (across grain).....	4,150	5,910

Although it is not completely understood why the board pressed with the apparatus of FIG. 7 exhibited materially increased strength characteristics, it may be postulated that in the process of removing more liquid initially through mechanical means the fibers making up the web were brought into closer contact before actual drying. It is generally agreed that the closer the fibers are contacted before drying, the stronger the resulting paper will be.

The porous contacting body for removing a liquid is also applicable to slush molding in which process a papermaking furnish is formed on a wire mold form and subsequently dried in this molded form. A typical slush molding apparatus is shown in diagrammatic fashion in FIG. 8, and a typical pressing die is shown in cross-section in FIG. 9. In this apparatus, which is described in detail in United States Patent 2,752,829, the papermaking furnish or slurry is contained in a tank 70. The forming dies 72 are rotatably mounted through retractable arm 73 on a shaft 74. It is possible by means, not shown, to either pull a vacuum through arm 73 or to introduce air under pressure through the arm. In the apparatus illustrated in FIG. 8, as the forming die 72 contacts the slurry in tank 70 a vacuum is pulled through arm 73, thus bringing the fibers in contact and holding them on a foraminous die form 72a (see FIG. 9). The forming die is then removed from the liquid and as it reaches a point directly opposite the complementary form in wheel 75 arm 73 is extended and the fibrous web is transferred under pressure to pressing die 76 through which a vacuum is pulled from back of the pressing die 76. In its travel on the periphery of the wheel 75 and by virtue of the fact that a pressure differential is created a portion of the liquid in the now molded fibrous form is removed so that by the time it is ready to be again transferred to a take-off form 77 mounted on arm 78, it contains about 70% water under normally operating conditions. Finally the molded form is deposited upon conveyor means 80 for transfer to the dryer.

As in the case of making paper sheets or paperboard, it is extremely important to remove as much of the water from the molded fiber shape prior to its introduction into the dryer. In accordance with the practice of this invention, this may be done by employing a porous nylon pressing surface in pressing dies 76 to serve as the sur-

face to which the molded fibrous article is transferred. With the application of pressure the porous nylon surface serves to remove a maximum quantity of water prior to the transfer of the molded article to the dryer. Transfer dies 77 which make the transfer of the partially dried article from the pressing die to a conveyor means such as belt 80 may also have a porous nylon surface to achieve further water removal.

A detailed cross-section of one embodiment of a pressing die suitable for use in slush molding as described in connection with FIG. 8 and constructed in accordance with this invention is illustrated in FIG. 9. The pressing die shown comprises a main housing 81 defining a chamber 82 in which a vacuum may be created or air under pressure introduced, and a die form 83, which in this case is a porous resin body, the surface contour of which corresponds to the contour of one of the surfaces of the structure to be slush molded. Suitable means are provided for positioning the die form 83 in the housing, and in the apparatus of FIG. 9 these include a perforated support 84 and snap rings 85. The fibrous web built up on the foraminous surface 72a of the forming die 72 is indicated by numeral 86.

Plant runs in which a pressing die similar to that shown in FIG. 9 was used in the apparatus of FIG. 8 indicated that it was possible to reduce the moisture content of a molded article to 40% by the time it was delivered to the conveyor 80 (FIG. 8). This is materially less than the normal 70% water present in the molded article as it is transferred to the conveyor. As in the case of papermaking, this reduction in water content prior to the final drying at elevated temperatures is directly reflected in reduction in cost of the molded article. In the formation of molded articles, such as by the apparatus of FIGS. 8 and 9, the use of a porous nylon pressing die in place of the usual wire screen mold not only serves to materially reduce the water content of the molded form prior to drying, but also serves to impart to the molded article a smoother surface than when a wire screen is used. In some cases this may be highly desirable, for example, in the making of paper plates, etc.

It will be seen from the above description, figures and examples, that the method and apparatus of this invention provide an improved way of extracting liquid from a wet fibrous article including fabrics and papers which are treated with liquids. The attendant advantages in this improvement have been indicated and may be summarized as follows. By achieving a lower moisture content the load on the dryers is materially reduced which, in turn, means a material reduction in cost. Moreover, running speeds may be increased without adding drying capacity. It is moreover possible to apply greater pressure to press out the liquid using the rolls of this invention without crushing or disrupting the fibers. It is also possible to form paper products which have greater strength and higher tensile properties.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in carrying out the above method and in the construction set forth without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. A method of reducing the liquid content of a wet fibrous article, comprising the steps of

(a) contacting, with the application of pressure, the surface of a wet fibrous article with a porous, resilient, polyamide body having a degree of porosity of at least 15 percent, the pores of said polyamide body being capillary in size and on an average smaller than those of said fibrous article;

(b) breaking the contact between said fibrous article

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and said porous resin body whereby a portion of said liquid in said article is transferred to said porous resin body; and

(c) removing said liquid from said porous resin body transferred to it from said wet fibrous article. 5

2. A method in accordance with claim 1 wherein said fibrous article is a web from a papermaking machine.

3. A method in accordance with claim 1 wherein said fibrous article is a liquid-treated web.

4. In a method of treating fabric which includes the steps of impregnating said fabric with a liquid and the subsequent removal of said liquid from said fabric, the step of contacting under pressure the liquid-treated fabric with a porous, resilient, polyamide surface having a degree of porosity of at least 15 percent, the pores of said polyamide surface being capillary in size and on an average smaller than those of said fabric thereby removing a portion of said liquid from said fabric. 10 15

5. In the manufacture of a water-laid paper article which includes the formation of a wet fibrous shape on a foraminous mold form and the removal of water from said wet shape, the improvement which comprises as a part of the water-removal step the step of contacting the wet fibrous shape under pressure with the surface of a porous, resilient, polyamide body having a degree of porosity of at least 15 percent; said porous polyamide body being characterized as having pore sizes in the capillary range and smaller than the average pore size of said wet fibrous shape, and said water-removing step being carried out under pressure conditions capable of generating a force on said water in said pores greater than the capillary forces existing within said body whereby said water is removed from said fibrous shape. 20 25 30

6. An apparatus suitable for contacting with a wet fibrous article for removal of liquid therefrom, comprising in combination 35

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(a) a resilient, porous, sintered polyamide body formed of particles the average diameter of which is no greater than 40 microns and having a degree of porosity of at least 15 percent, the pores of said body being capillary in size and on an average smaller than those of said fibrous article, the resilient polyamide body having a surface which is capable of making contact with the surface of said wet fibrous article; and

(b) means for removing liquid from said porous polyamide body transferred to it from said wet fibrous article during pressure contact therewith.

7. An apparatus in accordance with claim 6 wherein said resilient, porous, polyamide body is in the form of a roll suitable for mounting on a rotatable shaft.

8. An apparatus in accordance with claim 6 wherein said resilient, porous, polyamide body is in the form of a plate brought into contact under pressure with said fibrous article.

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