Aug. 3, 1965 E. J. JUSTUS 3,198,694

PRESS ROLL ASSEMBLIES IN PAPER MAKING MACHINE

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FIG. 1

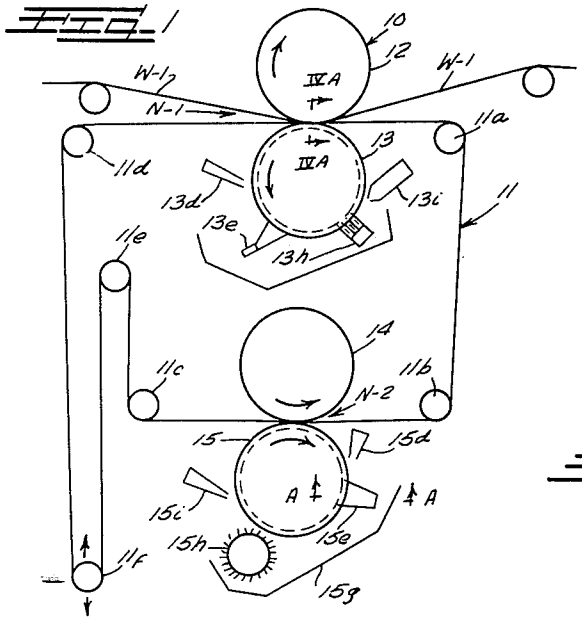


FIG. 1A

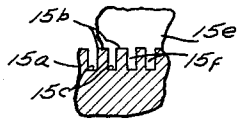


FIG. 2

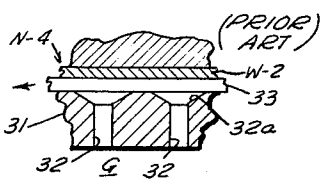


FIG. 3

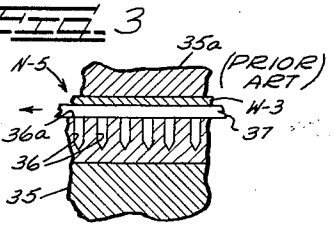


FIG. 4

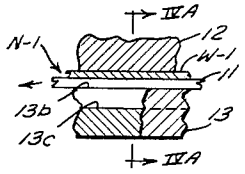


FIG. 4A

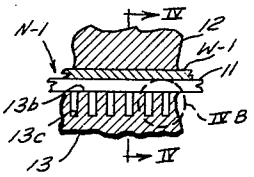


FIG. 4B

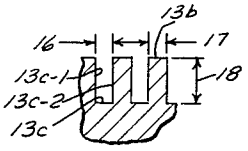


FIG. 5A

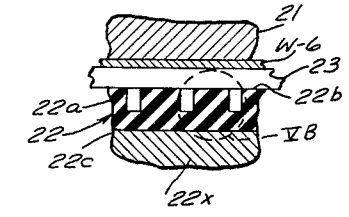
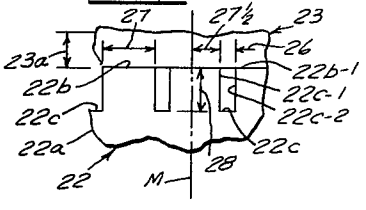


FIG. 5B



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FIG. 6

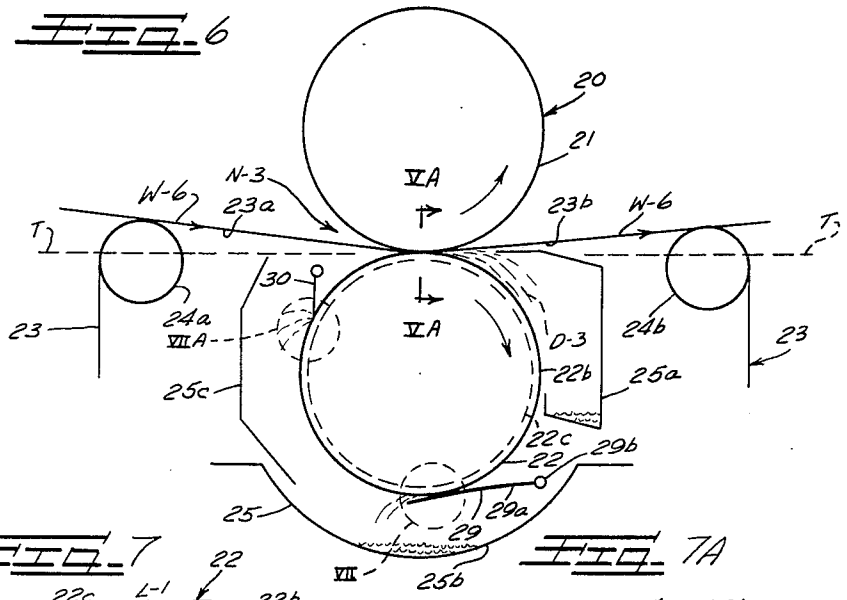


FIG. 7

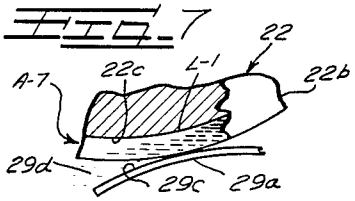


FIG. 7A

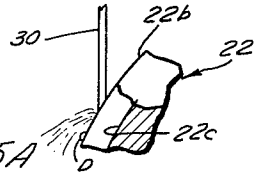


FIG. 15

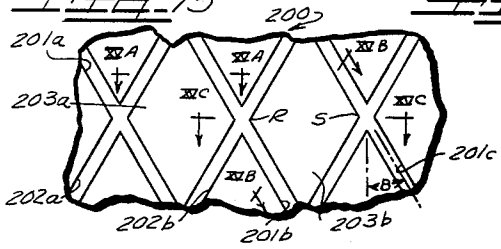


FIG. 15A

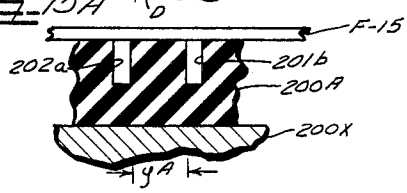


FIG. 15B

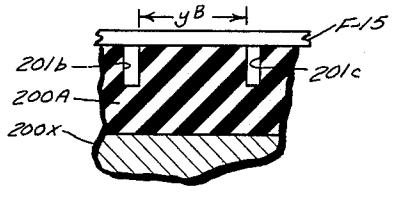
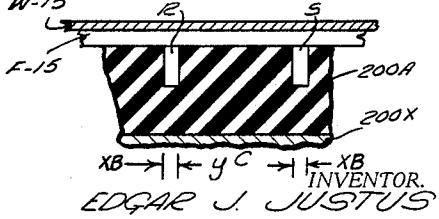


FIG. 15C



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FIG. 8

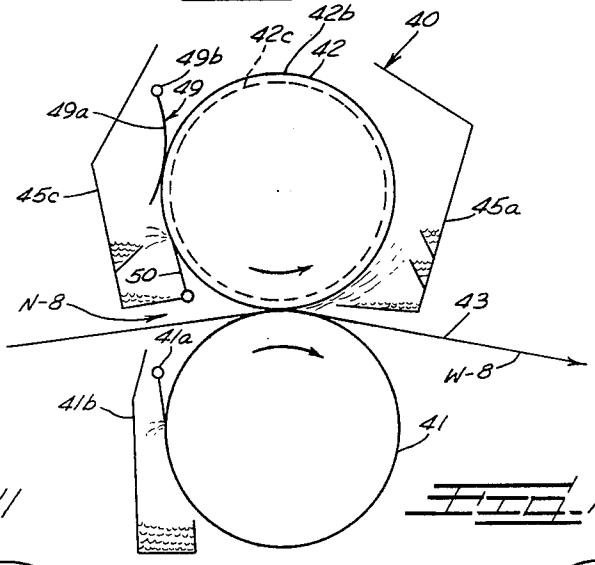


FIG. 11

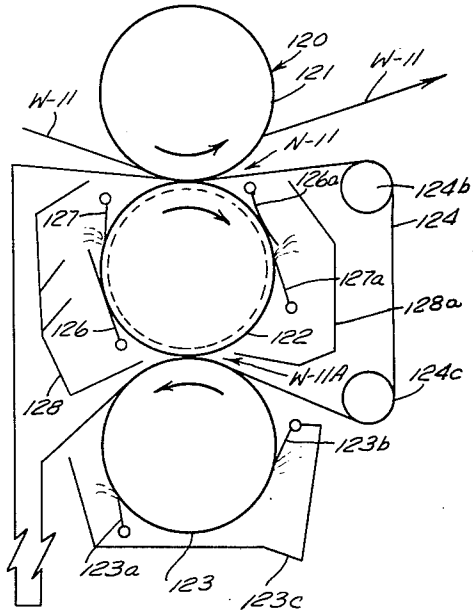
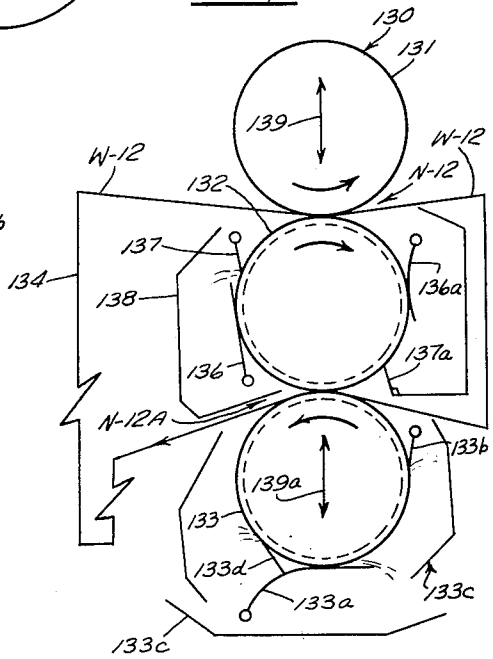


FIG. 12



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Aug. 3, 1965 E. J. JUSTUS 3,198,694

PRESS ROLL ASSEMBLIES IN PAPER MAKING MACHINE

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FIG. 9

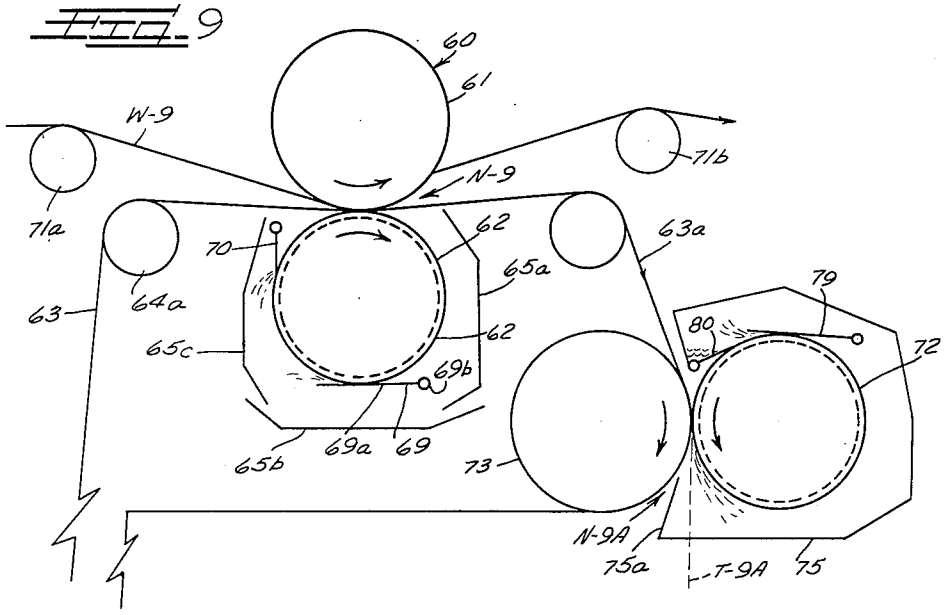
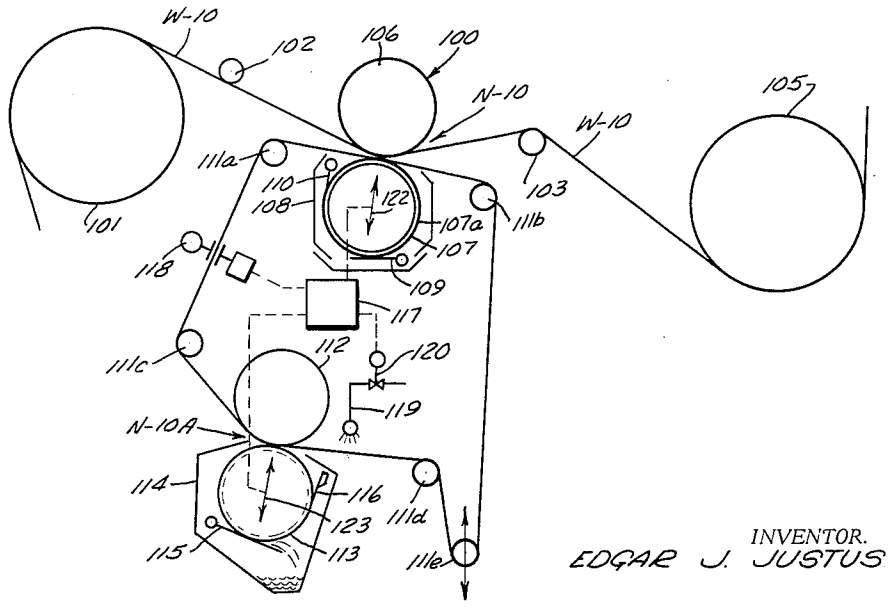


FIG. 10



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Aug. 3, 1965 E. J. JUSTUS 3,198,694

PRESS ROLL ASSEMBLIES IN PAPER MAKING MACHINE

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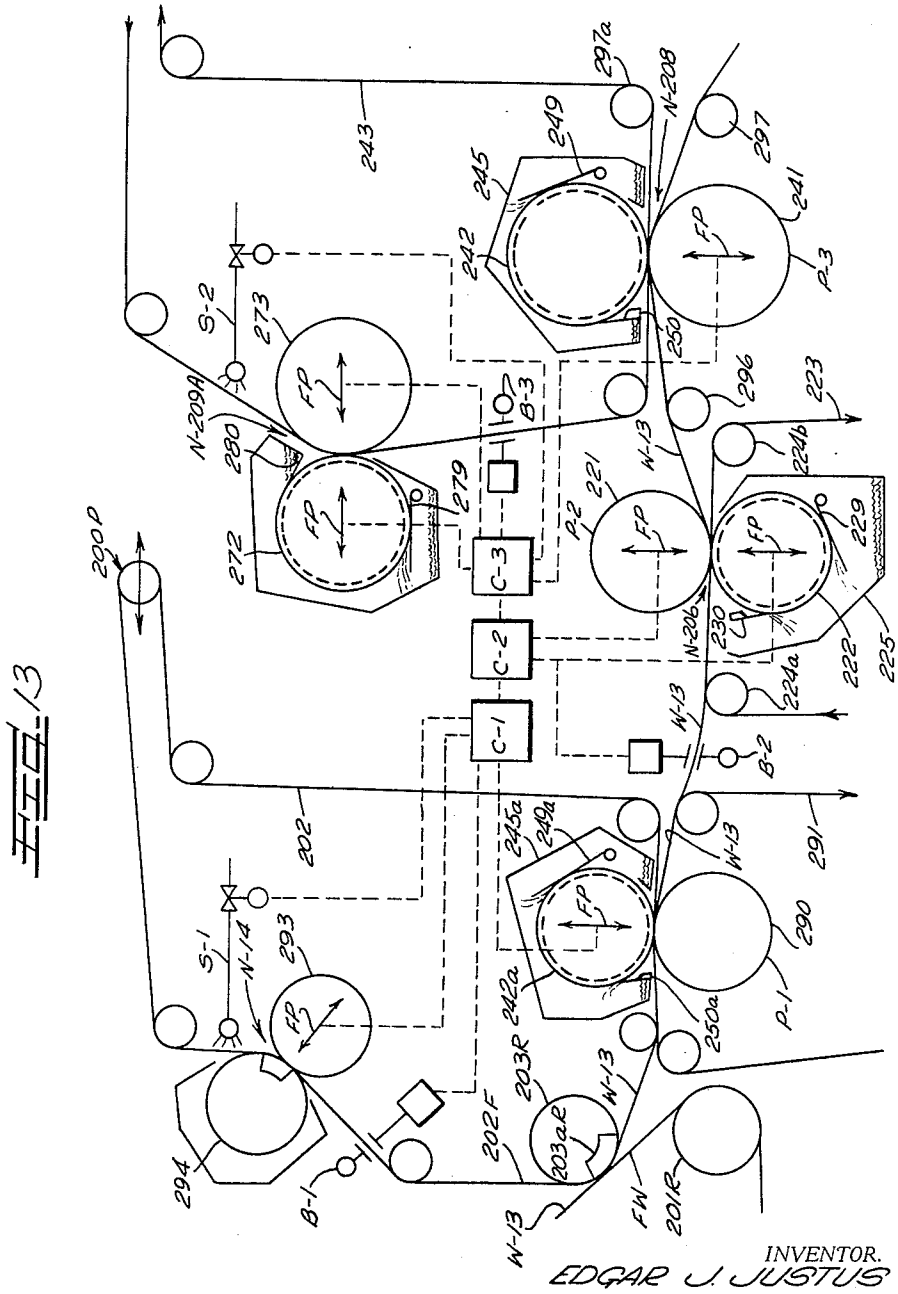


FIG. 13

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PRESS ROLL ASSEMBLIES IN PAPER MAKING MACHINE

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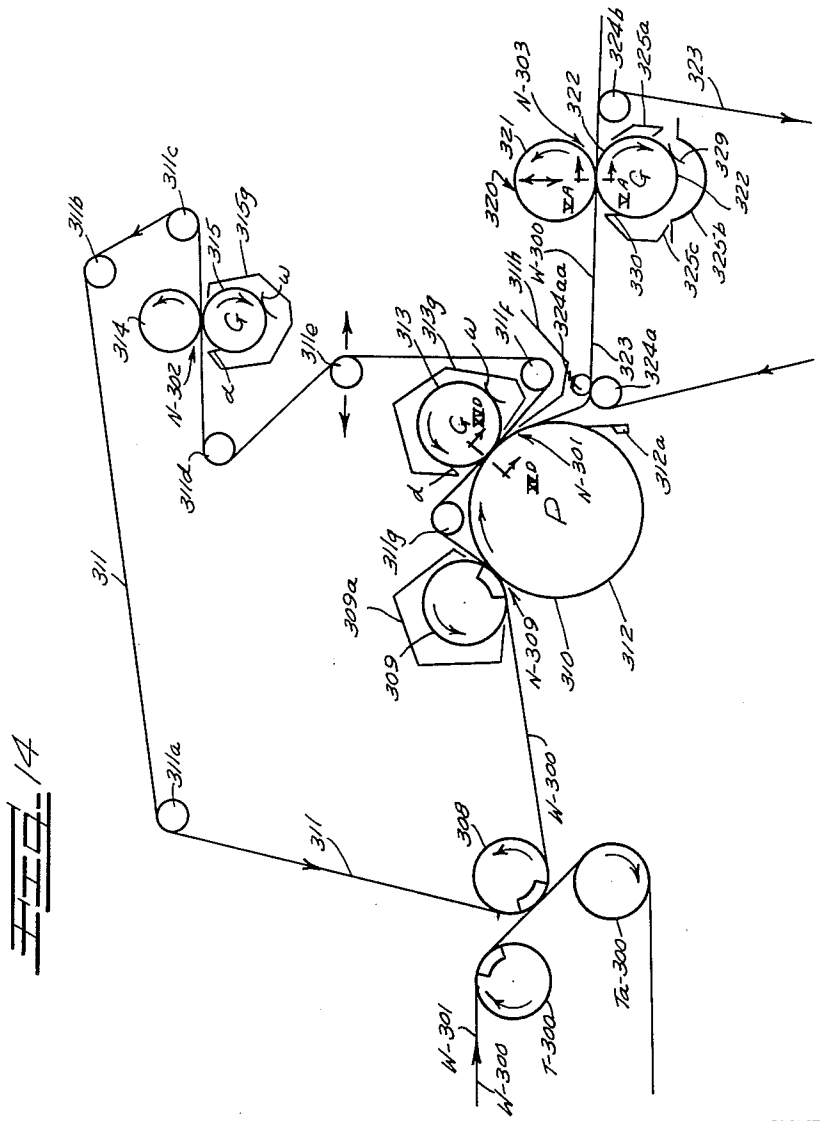


FIG. 14

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PRESS ROLL ASSEMBLIES IN PAPER MAKING MACHINE

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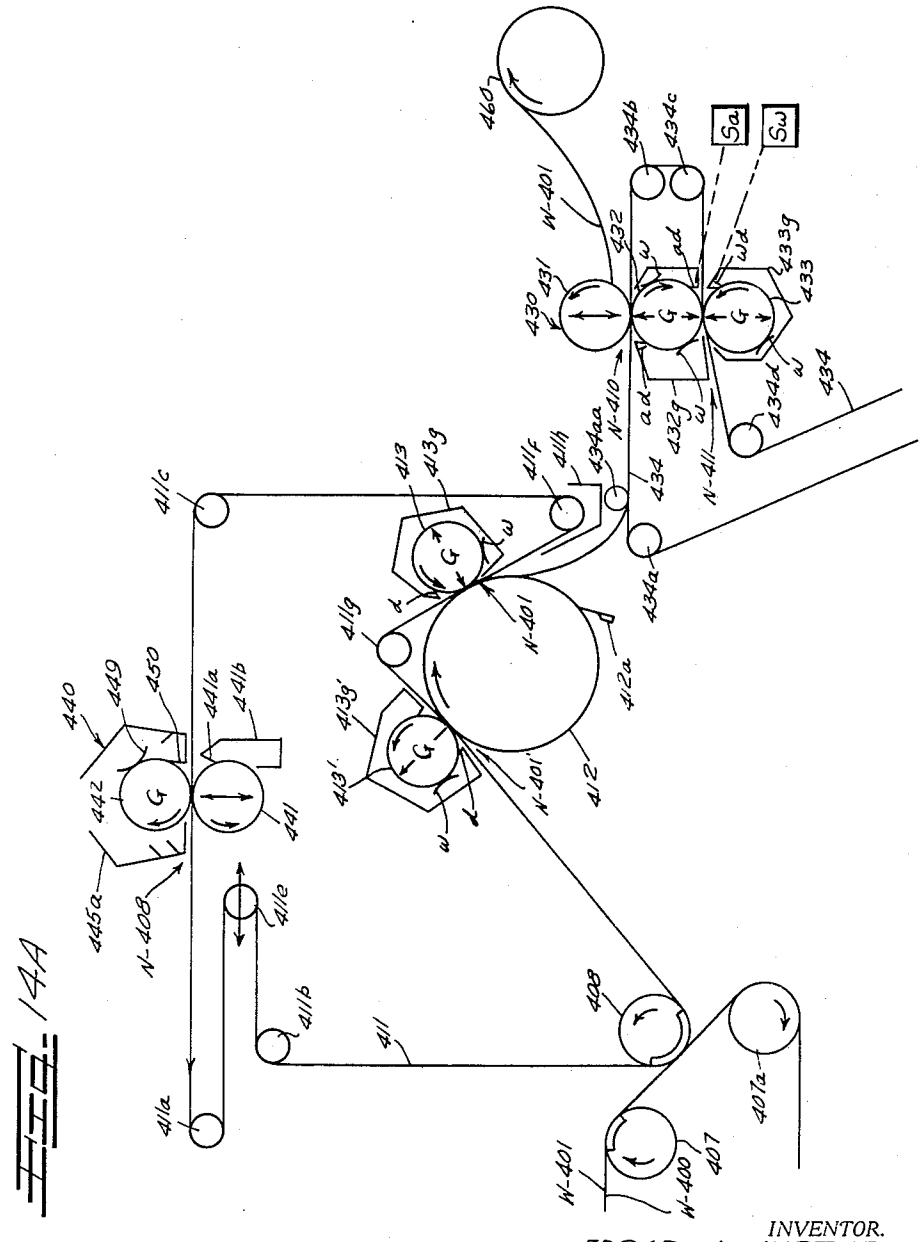


FIG. 14A

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United States Patent Office 3,198,694 Patented Aug. 3, 1965

3,198,694

PRESS ROLL ASSEMBLIES IN PAPER MAKING MACHINE

Edgar J. Justus, Beloit, Wis., assignor to Beloit Corporation, Beloit, Wis., a corporation of Wisconsin

Filed Dec. 10, 1964, Ser. No. 417,325
2 Claims. (Cl. 162—358)

This is a continuation-in-part of my applications Serial No. 214,589, filed August 3, 1962, now abandoned; Serial No. 302,423, filed August 15, 1963; Serial No. 305,713, filed August 30, 1963, now abandoned; Serial No. 302,371, filed August 15, 1963, now abandoned; Serial No. 302,270, filed August 15, 1963, now abandoned; Serial No. 302,422, filed August 15, 1963, now abandoned; Serial No. 302,421, filed August 15, 1963; Serial No. 305,992, filed September 3,1963, now abandoned; Serial No. 378,217, filed June 26, 1964; Serial No. 391,160, filed August 21, 1964, and Serial No. 316,602, filed October 16, 1963 (now abandoned), and this is directed to certain specific aspects of individual press nips embodying the instant grooved press rolls with and without certain essential auxiliary equipment which functions in the unique fashion with the grooved press roll.

The present invention relates to an improvement in devices for removing liquid from a liquid-containing web material, and more particularly, to improved paper machine presses, and press rolls for use therein.

Although the instant invention may have a number of uses in different fields, it is used to particular advantage in the art of paper making and will be described primarily in connection therewith. In a web press, as used in a paper machine, a "web" nip is formed between opposed press rolls, and a traveling paper web in engagement with a felt is passed through the nip. In prior art structures, the press rolls used have been plain, or the roll covered by the felt at the nip may be provided with a perforate shell having a suction gland opposite the nip for aiding in the removal of moisture from the web through the felt, as in the case of the conventional suction press. In other instances, as indicated in Walker U.S. Patent No. 3,023,805, the felt covered press roll may be provided with an imperforate shell having a blind drilled rubber cover thereon for at least temporarily receiving water expressed from the web and through the felt at the web nip. In still other web presses, the felt covered press roll may be provided with other types of "blind" recesses or fine porous structure, or structures in the form of a woven wire or fabric wrap on the roll cover or surface portion of rolls provided with imperforate shells, and in such instances the felt ordinarily functions as a drying felt for the web and carries away a substantial amount if not all of the water that is to be removed from the web at the web nip. This then requires a separate procedure and/or apparatus for dewatering the felt before returning the same to the web press nip. In my copending application Serial No. 214,589, filed August 3, 1962, certain improvements in devices for dewatering the felt at a separate, felt only press nip are described in detail. In addition, certain press roll structures were described in said application for dewatering the felt at the felt only press nip in a divided press and also for assisting in dewatering the felt at the web press (i.e., assisting in removal of water from the felt that has been pressed from the web through the felt at the web press nip).

Heretofore, press arrangements have been used for attempting to remove water from the felt at the web nip. Each of these arrangements has required an alteration of structure as compared with a plain press nip, by either incorporating additional materials in the nip or modifying the plain press roll which supports the felt in the nip, for example, by replacing this roll with a suction roll.

The suction roll is capable of excellent performance in certain uses, but it must be appreciated that the manufacture of the perforated suction roll shells, plus the auxiliary equipment essential to the maintenance of the desired subatmospheric pressures in the suction roll gland, is relatively expensive. Moreover, the use of the suction roll gland within the perforate suction roll shell does not make it possible to use conventional or improved anti-deflection roll means mounted within the interior of the shell for maintenance of the most uniform nip pressures. The relatively large size of the suction roll perforations (plus the pressure differential created by the suction gland at the suction roll periphery) facilitates water removal from the felt, but in situations involving the use of lightweight felts and/or the production of comparatively sensitive paper webs or high quality paper webs, there is a tendency for the webs to develop what is known as "shadow marking" as a result of such suction roll perforations, even though they are covered by a felt at the suction press nip.

In the more recently developed so-called "divided press," efforts have been made to dispense with the use of the suction press roll at the web press nip, by replacing the same with a plain press roll or with rolls of this general type having imperforate press roll shells but covered with a myriad of blind drilled holes, small blind recesses, pores, etc. These rolls with such recesses thereon are employed primarily to avoid overloading the web press nip with water and to permit a portion of the water load to be received in the recesses at the nip, although the water load in the recesses is generally returned substantially to the felt at the off-running side of the web nip. Various other press roll means, including suction press rolls, are then employed at a separate felt only press to dewater the felt to the extent necessary to prepare it for re-entrance into the web press nip in such divided press structure. The instant invention is directed to improvements not only in the web press structure but also in the felt only press structure, which are brought about primarily by the use of certain grooved press rolls in these press structures. A significant advantage of such press rolls, having generally peripherally or circumferentially aligned grooves, is that the roll surfaces at the press nips are vented via the grooves to ambient atmosphere so as to facilitate the dewatering function of the press roll at the press nip. It will be appreciated that in such a grooved press roll, the grooves are applied to an imperforate shell which is capable of mounting with anti-deflection means and without expensive auxiliary suction roll equipment. Still other significant advantages are obtained by the use of specific grooved roll structures and auxiliary equipment which will be described in greater detail herein.

The instant invention thus has as its primary object the provision of an improved press assembly for the removal of liquid from a liquid-containing web material (which might be a moist felt alone or a felt and web combination).

Another object of the instant invention is to provide an improved divided press structure wherein the press rolls at the web press and/or the felt only press have improved structure and function.

Yet another object of the instant invention is to provide an improved press structure wherein the advantages of anti-deflection roll mountings may be used, inexpensive roll structures are used, and simplified structures are provided for water removal from a moist web or felt material and/or from the surface of the press roll itself.

A further object of the instant invention is to provide an improved grooved press assembly embodying the novel grooved press roll structure, that is inexpensive to manufacture, particularly useful and reliable in its water removal function, and readily maintained in functional operation. An additional object of the invention includes

the provision of improved devices for cooperation with such grooved roll to clean and maintain the same, dewater the same during operation, and take advantage of the improved dewatering function of the same.

Other and further objects, features and advantages of the present invention will become apparent to those skilled in the art from the following detailed disclosure thereof and the drawings attached hereto and made a part hereof.

On the drawings:

FIGURE 1 is an essentially diagrammatic side elevational view of a press mechanism embodying the instant invention;

FIGURE 1A is a fragmentary detail view taken substantially along the line A—A of FIGURE 1;

FIGURE 2 is a fragmentary detail sectional view showing a portion of a suction press nip of the prior art;

FIGURE 3 is a view comparable to FIGURE 2 showing a portion of a press nip embodying blind drilled holes in one roll, as used in the prior art;

FIGURE 4 is a view comparable to FIGURES 2 and 3, but showing a portion of a press nip embodying the instant invention;

FIGURE 4A is a fragmentary detail sectional elevational view taken substantially along the line AIV—AIV of FIGURE 4;

FIGURE 4B is a sectional fragmentary enlargement taken substantially at the encircled portion designated IVB in FIGURE 4A;

FIGURE 5A is a fragmentary sectional elevational view comparable to that of FIGURE 4A but showing another embodiment of the instant invention;

FIGURE 5B is a fragmentary enlargement taken from FIGURE 5A at substantially the encircled portion marked VB;

FIGURES 6 and 8 are essentially diagrammatic elevational views of press assemblies embodying the instant invention;

FIGURES 7 and 7A are enlarged fragmentary detail views taken substantially from the encircled portions of FIGURE 6 marked VII and VIIA, respectively;

FIGURE 9 is an essentially diagrammatic elevational view of a divided press assembly embodying the instant invention;

FIGURE 10 is an essentially diagrammatic elevational view of a divided hot press assembly embodying the instant invention;

FIGURES 11 and 12 are essentially diagrammatic elevational views of different divided press assemblies embodying the instant invention;

FIGURES 13, 14 and 14A are essentially diagrammatic elevational views of press sections of paper machines, demonstrating the versatility of the use of the grooved roll of the instant invention;

FIGURE 15 is a fragmentary plan view of still another view of arrangement for a grooved roll embodying the instant invention; and

FIGURES 15A, 15B and 15C are essentially fragmentary views in cross-section taken substantially along the lines XVA—XVA, XVB—XVB, and XVC—XVC, respectively of FIGURE 15.

As shown on the drawings:

Referring to FIGURE 1, it will be seen that a press assembly, indicated generally by the reference numeral **10** is shown therein comprising a looped press felt **11** mounted on guide rolls **11***a*, **11***b*, **11***c*, **11***d*, **11***e* and a tensioning roll **11***f*. A first plain press roll **12** and a second lower press roll **13** define a first "web" press nip N–1 receiving the felt **11** and a moist web W–1 for transfer of water from the web W–1 to the felt **11** at such nip N–1. A third press roll **14** and a fourth lower press roll **15** define a second or felt only nip N–2. The press rolls **13** and **14** are within the loop of the felt **11** and the press rolls **12** and **15** are outside of the loop of the felt **11**. The second press roll **13** is formed of a generally imperforate shell or base structure (such as in the case of prior art blind drilled rolls, such as are shown in Walker U.S. Patent No. 3,023,805, and in my aforementioned application Serial No. 214,589, the disclosure of which is incorporated herein by reference). The second press roll **13** is thus contrasted to the conventional perforate suction roll (which has perforations such as are indicated in FIGURE 2 hereof), and the roll **13** has a cover containing a plurality of fine water-retaining recesses between land areas which support the felt **11** at the nip N–1. The roll **15** has a similar cover structure. More specifically, referring to FIGURE 1A, the cover structure for the rolls **13** and **15**, which is indicated in cross-section at **15***a* in FIGURE 1A, comprises a plurality of peripherally (or generally circumferentially) aligned land areas **15***b* with relative fine or narrow grooves **15***c* between the land areas for receiving the water from the felt **11** at the nip (e.g. at the nip N–2 for the roll **15**). It will be appreciated that the land areas **15***b* are of sufficient width and the grooves **15***c* are sufficiently narrow to permit the felt **11** to be readily supported at the nip N–2 (or at the corresponding nip N–1 by the roll **13**), so that water may be expressed from the felt **11** into the grooves **15***c*, but the felt **11** itself will not be pressed into the grooves **15***c* to any significant extent; and in the case of the nip N–1, the felt **11** will not be deformed or otherwise temporarily modified in passing through the nip N–1 so as to cause substantial or significant shadow marking on the web W–1 as a result of the land and groove pattern on the surface of the roll **13**.

Referring specifically to the operation of the press roll **15**, it will be seen that the grooved press roll **15** at a point remote from the off-running side of the nip N–2 is first subjected to a water jet **15***d*, followed by a scraper **15***e* fitting into the grooves **15***c* and operating in conjunction with the water jet **15***d* to sweep and/or scrape fibers, fines, water, etc. out of the grooves **15***c*. As indicated in FIGURE 1A, wherein the scraper **15***e* is indicated fragmentarily but in full view, the scraper **15***e* is provided with a plurality of fingers **15***f* which operate in extremely close running relation to the grooves **15***c*, so as to effectively scrape or seep all solid material from the grooves **15***c*. The water jet **15***d*, of course, serves to assist in this sweeping action and to keep the front face of the scraper **15***e* clean, flushing water into a conventional save-all arrangement **15***g*. A rotary brush **15***h* is also mounted for brushing droplets of water out of the grooves at a region remote from the nip N–2. Brush means **15***h* may be replaced by flexible leaves or similar elements adapted to sweep through the grooves **15***c* and brush droplets therefrom. Finally, an air jet or air doctor **15***i* peripherally spaced from the brush **15***h* completes the removal of moisture from the grooves **15***c*. It will be appreciated that the air doctor **15***i* also serves to wipe and dry completely the land areas **15***b* at substantially the immediate oncoming side of the nip N–2.

In this respect, it should be noted that herein the "longitudinal" direction will always be the direction of travel of the web or felt or other article referred to in connection with this direction; whereas the "transverse" or "cross-machine" direction will be at right angles to the longitudinal direction generally in the plane of the felt or web referred to. With respect to each nip (e.g. N–1 or N–2) the "oncoming" side of the nip is the side of the nip which the traveling web and/or felt approach; whereas the off-running side of the nip is in the longitudinal direction from the encoming side of any given nip and it is at the side of the nip where the web or felt travels longitudinally away from the nip. Likewise, the oncoming and off-running sides of any piece of auxiliary equipment, such as the air doctor **15***i* will be, respectively, the direction from which the rotating surface of the roll approaches and the direction toward which the rotating surface of the roll leaves such air doctor **15***i*. Thus, for example, the brush **15***h* is at the oncoming

side of the air doctor 15*i* and the nip N–2 is at the off-running side of the air doctor 15*i*. In each of the drawings hereof, the arrowheads indicate the direction of travel of elements on which such arrowheads are placed.

In connection with the roll 13, it will be seen that there is also provided a water jet 13*d* at the down-running side of the roll 13 preferably cooperating with a scraper 13*e* (at the off-running side thereof) fitting into the grooves on the surface of the roll 13. A save-all 13*g* is also provided and at the uprunning side of the roll 13, suitable brush means 13*h* and an air jet or air doctor 13*i* (at the off-running side of the brush means 13*h*) are provided to complete the removal of moisture from the grooves and the land areas, and into the save-all 13*g*.

Referring now to FIGURE 4A and FIGURE 4, it will be seen that FIGURE 4A is a detail sectional view comparable to FIGURE 1A, except that it is taken generally along the line IVA—IVA of FIGURE 1 at the nip N–1, so as to show fragmentarily the upper roll 12, the lower roll 13, the web W–1 (all in section) and the felt 11 in full view for simplification of the drawing. It will be seen that the roll 13, like the roll 15 of FIGURE 1A is provided with substantially equally sized and formed grooves 13*c* and land areas 13*b* (which form the generally cylindrical peripheral surfaces of ridges also designated by the reference numeral 13*b*). FIGURE 4 is another fragmentary detail sectional view taken substantially along the line IV—IV of FIGURE 4A and FIGURE 4 shows the upper roll 12, the lower roll 13 (with parts shown in section and parts broken away), the web W–1 and the felt 11 (in full view, with an arrow indicating the longitudinal direction). The groove 13*c* is indicated in FIGURE 4 as part of the alternating generally circumferentially aligned ridges 13*b* and grooves 13*c* on the roll 13, but the detail of FIGURE 4 is taken of such a small overall portion of the press assembly that the curvatures of the rolls 12 and 13, as well as the bottoms of the grooves 13*c* are not emphasized. Referring to FIGURE 4B, however, it will be seen that the grooves 13*c* each have a very small or narrow axial dimension 16 at the mouth or peripheral portion thereof aligned with the generally cylindrical exterior surfaces 13*b* or land areas of the ridges, which ridge land areas have an axial dimension 17 that is shown in FIGURE 4B to be substantially the same as the axial dimension 16 of the grooves 13*c* at the outer periphery or mouths thereof. It will also be seen that the grooves 13*c* are defined between generally radial walls 13*c*–1 and 13*c*–2 which extend in generally parallel relationship spaced apart at least the axial dimension 16 for a substantial radial distance of their depth 18 which is greater than the axial dimension of the mouths of the grooves 16 and the axial dimension 17 of the land areas (in fact, being substantially twice either the axial dimension 16 or 17).

Referring now to FIGURE 6, it will be seen that there is shown a press assembly indicated generally by the reference numeral 20 in FIGURE 6 which is a significant improvement over the embodiments of the invention indicated hereinbefore at the nips N–1 and N–2 of FIGURE 1. The press assembly 20 comprises an upper plain press roll 21 comparable in structure to the plain press roll 12, and a lower grooved press roll 22 comparable in some respects to the grooved press rolls 13 and 15 hereinbefore described. The press rolls 21 and 22 define a press nip N–3 which receives a moist web W–6 engaging the plain press roll 21 carried on a felt 23 trained over guide rolls 24*a* and 24*b*, which felt 23 travels with the web W–6 in contact therewith at the on-coming side, at the pressure area, and at the off-running side of the nip N–3, as here shown. The grooved roll 22 is provided with a saveall indicated generally at 25 and shown with three sections 25*a*, 25*b* and 25*c*.

The grooved roll 22 is shown in fragmentary detail in FIGURES 5A and 5B (FIGURE 5A being taken substantially along the line VA—VA of FIGURE 6), and it will be seen that the grooved roll 22 is provided with a solid elastomer (rubber) cover 22*a* on an imperforate ductile iron shell 22*x*. The cover 22*a* may and preferably in certain cases is formed of stainless steel which will also permit the cutting of fine grooves 22*c* between land areas 22*b*, in the dimension and configuration shown in FIGURES 5A and 5B. Referring more specifically to FIGURE 5B, it will be seen that the cover 22*a* of the grooved roll 22 is indicated in a view without section lines for ease in detailing the description thereof. The grooves 22*c* are here shown having a substantially uniform axial dimension 26 that is 0.025 inch between generally cylindrical (smooth) land areas 22*b* on ridges alternating with the grooves 22*c*, with such land areas 22*b* having an axial dimension 27 that is 0.100 inch, or substantially four times the groove mouth axial dimension 26, thereby giving an open area on the surface of the grooved roll 22 of substantially 20%. The grooves 22*c* extend radially inward to a depth 28 of ⅛ inch (or 0.125 inch) which is greater than both the groove axial dimension 26 and the land area axial dimension 27, and such groove 22*c* thus has a "volume" value expressed in the cross-sectional view of FIGURE 5B as equal to 5 times the square of the groove mouth, i.e. $(5)(0.025)^2=0.003125$ in.^{2} and so does $(0.025)(0.125)=0.003125$ in.^{2}. Such groove 22*c* is defined between generally radially extending, parallel walls 22*c*–1 and 22*c*–2, which are axially spaced the distance 26 of the axial groove mouth dimension or greater than that distance (by not more than about 100% because of the undesirability of undercutting the land areas 22*b*), so that water entering the peripheral mouths of the groove 22*c* will not be restricted in its flow radially inwardly into the groove 22*c*.

Referring again to FIGURE 6, it will be seen that the water expressed from the web W–6 through the felt 23 at the nip N–3 is received in the grooves 22*c* of the grooved roll 20 and to a substantial extent carried away from the felt 23 at the off-running side of the nip N–3. The first saveall section 25*a* is mounted in substantially the closest practical running relation with the off-running felt 23 and the off-running side of the roll 22 so as to capture droplets of water thrown by centrifugal force from the grooves 22*c* at the immediate off-running side of the nip N–3. The grooves 22*c* resist the tendency for centrifugal force to throw such droplets away from the roll 22, however, particularly at slower operating speeds. At higher operating speeds of 500 feet per minute and above, however, the tendency of the narrow grooves 22*c* to resist the release of water from the roll 22 because of centrifugal force is at least partly overcome and the save-all portion 25*a* functions to minimize rewetting of the underside of the web W–6 in this respect.

A substantial amount of water, however, remains entrapped in the narrow grooves 22*c* in the grooved roll 20 until this roll passes past a wiper 29, which is unique in its simplicity, consisting merely of a generally flat sheet of moderately resilient material such as metal sheet 29*a* secured to a transverse cross bar 29*b* and urged as a continuously transverse sheet against the land areas 22*b* on the periphery of the roll 22. The wiper sheet 29*a* thus does not enter into the grooves 22*c* but merely presents a surface that is axially continuous for the transverse peripheral dimension of the roll 22 along the generally transverse line of contact (i.e. actually a limited peripheral area of contact), whereat the wiper 29 extends axially continuously from the off-running side of such line of contact L–1 so as to separate or diverge slowly from the off-running periphery of the grooved roll 22 so as to effect, by pumping action, a drawing of the water in the grooves 22*c* (which is actually swept out of the grooves 22*c* by air rushing in to fill the partial vacuum created by the pumping action of the wiper 29). The water in the grooves which has been held therein in resistance to the combination of centrifugal and gravita-

tional forces at the down-running side of the grooved roll 22 is thus substantially swept out of the grooves 22*c* and to a substantial extent into the second, bottom saveall portion 25*b*.

Some of the water thus drawn from the grooves 22*c* remains on the land areas (as a meniscus), and the mist or droplets of water generally present in the immediate vicinity of high speed press rolls in paper machines will also tend to deposit on the land areas 22*b* of the up-running side of the grooved roll 22, and such water on the land areas 22*b* is then removed by a conventional doctor means, preferably merely in the form of a conventional doctor blade 30, which at high speeds will actually throw water droplets away from the roll surface as indicated in FIGURE 6 and against the third saveall portion 25*c* feeding into the bottom saveall portion 25*b*. The doctor blade 30 thus provides a doctor means in close proximity to the oncoming side of the nip N–3 to dry the land areas. Preferably the doctor means 30 co-acts with the land areas 22*b* within what constitutes at least the last 120°, and preferably the last 90° of travel of the grooved roll 22 approaching the nip N–3, so that the land areas 22*b* will be dry at the immediate oncoming side of the nip N–3. If some droplets of water are driven by the doctor 30 from the land areas 22*b* into the bottom of the grooves 22*c*, it has been found that the particular function of the grooved roll 22 is not significantly impaired, whereas retention of moisture on the land areas 22*b* does make a significant difference in the operation of the grooved roll 22, for reasons which will be described in detail hereinafter.

Theory and advantages of inventions of FIG. 1 and FIG. 6

As previously indicated, certain aspects of the embodiment of the invention shown in FIGURE 6 involve significant and distinct improvements over the embodiments of the invention shown in FIGURE 1; and although it is not desired to limit the invention to any particular theory, it is believed that certain theoretical considerations will explain the superiority of the embodiment of FIGURE 6 over that of FIGURE 1, as well as the superiority of the embodiments of both FIGURES 1 and 6 over the prior art.

Grooved rolls in the art of pressing paper webs were considered and discarded several generations ago. For example, in 1915, U.S. Patent No. 1,123,388 issued to Schaanning and was directed to a grooved press roll allegedly intended to replace felt covered rolls and having grooves of such configuration that Schaanning alleged that they would retain water by capillary action. As early as 1905, Fletcher (U.S. Patent No. 800,845) proposed a grooved roll made of certain segmental portions. In the 1920's, Goodfellow (U.S. Patent No. 1,369,335) proposed a press roll with circumferential grooves as well as generally axial grooves interrupting the circumferential continuity of land areas, which were covered with the felt; and Wagner issued U.S. Patent No. 1,483,562 relating to grooved rolls used with a pair of press felts for cooperation with certain suction mechanisms outside of the press rolls. Wagner U.S. Patent No. 1,321,956 shows grooved rollers in a couching mechanism. Wagner U.S. Patent No. 1,520,489 relates to a grooved jacketed roll. Wagner U.S. Patent No. 1,517,036 relates to a pair of press rollers intended to press a traveling paper web with their bare unprotected surfaces, with one of such rollers having grooves in the surface thereof. Wagner U.S. Patent No. 1,552,098 mentioned that prior teachings have suggested 1 mm. (or about 0.04 inch) as the minimum groove width (although Wagner was primarily concerned with making reasonably dry pulp for shipment rather than unmarked paper); and Wagner U.S. Patent No. 1,552,098 then goes on to suggest that very shallow grooves (e.g. 0.5 mm.) may be used with more narrow grooves (e.g. down to 0.75 mm.) exposed directly to the pulp in order to let the pulp fill such grooves and the subjected to water removing pressure in such grooves.

As late as 1958, however, Wagner issued U.S. Patent No. 2,858,747 which was directed to grooved press rolls functioning with a suction device mounted outside of the roll shell with sealing elements extending into the grooves; but with occasional exceptions such as this in the patent art, it will be found that substantially the entire paper making industry devoted its attention to the perforate shell type of suction roll for water removal at a press nip, once this structure was discovered and introduced in the industry. In fact, for the past thirty or forty years the drilled perforate shell type suction roll has been used predominantly and practically exclusively in the paper making industry for the removal of water in any significant quantities from moist paper webs in paper making machine press assemblies.

As indicated in FIGURE 2 hereof, in the suction press nip N–4, the roll shell 31 is "perforate," being provided with a multiplicity of holes 32, 32 of substantial size (i.e. usually at least about ¼ inch in diameter but sometimes smaller and usually having flared peripheral mouths 32*a* of greater size) which are drilled entirely through the roll shell 21 (having at least about 1 inch thickness) to communicate with the suction gland G extending the full width of the roll shell 31 interiorly opposite the nip W–4. At the suction press nip N–4, a press felt 33 is interposed between the web W–2 and the perforate suction roll shell 31 (primarily as a water-permeable protective layer for the web W–2), and water expressed from the web W–2 passes completely through the felt 33 and into these holes 32, 32 in the perforate shell 31. Some water continues into the gland G and some is usually retained in these holes 32, 32 at the off-running side of the nip N–4, where the subatmospheric pressure in the gland G tends to counteract centrifugal forces urging water droplets back out of the holes 32, 32 and against the felt 33 under ambient atmospheric pressure. The felt 33 may thus remain in contact with the web W-2 at such off-running side of the nip W–4 without substantial rewetting of the web W–2 (via water thrown back on the felt 33 from the suction roll holes 32, 32). Also, savealls (not shown) are conventionally positioned between the felt 33 and the perforate roll shell 31 at the immediate off-running side of the gland G to catch droplets released from the suction roll holes 32, 32, particularly after these holes pass beyond the limit (i.e., the off-running seal, not shown) of the interior suction gland G so there is no longer a pressure differential holding the droplets in the holes 32, 32. The off-running felt 31 must be guided to avoid such saveall and this often results in guiding the felt with or against the web at the off-running side of the nip N–4. The perforate suction roll with its suction gland, and with or without the saveall, thus functions to carry away substantially all of the water expressed from the web at the nip.

In spite of the excellence of the performance of perforate suction rolls for a number of uses in paper making, it must be conceded that these rolls and their auxiliary equipment are expensive to manufacture. The suction gland therein, also, substantially precludes the use of conventional anti-deflection roll structures for greater versatility and uniformity in nip pressure control. In addition, the substantial size of the perforation mouths 32, coupled with the pressure differential created by the suction gland against the unsupported portions of the felt 33 opposite such perforations 32, has a tendency to cause "shadow marking" of the web in certain instances.

Only in recent times, after many years of commercial use of perforate suction rolls, there has been developed what is referred to by applicant and his associates as the "divided press" type of structure which does not require the use of the perforate suction roll at the web press. In the divided press, the felt alone is cleaned, dewatered

and conditioned at a separate press nip, and then fed with the moist web into what is called a "web" nip which is defined between rolls having imperforate shells (as contrasted to the perforate suction roll shells). As indicated in FIGURE 3, ordinarily the amount of water load at such a "web" nip N–5 is such that at least one of the press rolls 35, 35*a* is provided with recesses 36 on the surface thereof to temporarily take the load of water entering the web nip N–5 to prevent "crushing" of the web W–3 carried by the felt 37. As indicated in FIGURE 3, a preferred form of such recess 36 is provided by a rubber cover on a press roll 35 that contains a myriad of comparatively fine blind drilled holes (i.e., of approximately 1/16 to 1/4 inch or even less diameter, as in the case of Walker U.S. Patent No. 3,023,805); and such fine holes 36, 36 will in the case of most conventional webs W–3 and felts 37 substantially void or eliminate the "shadow marking" characteristic of the performance of certain perforate suction rolls, but sometimes plugging of these holes presents problems. In the divided press, the water removal principle is substantially different. The water is not carried away from the nip N–4 by the suction roll shell 31 and, instead, the water pressed from the web W–3 into the felt 37 is carried away from the web W–3 substantially entirely by the felt 37 at the off-running side of the nip N–5. Excess water at the nip N–5 which is driven into the blind hole perforations 36, 36 to relieve the load at the nip N–5, ordinarily entraps a certain amount of air in the bottom of these blind perforations 36, 36 and this, coupled with the ability of the felt to absorb water when it expands at the off-running side of the nip N–5, results in a substantial removal of water from the system via the felt 37 which, as previously mentioned, is then passed through a felt only press where it is dewatered to the extent desired at a separate press nip. The principle of the water removal at the web press nip N–5 of the divided press also involves what amounts to a comparatively good force balance at the nip itself, whereat the web W–3 is squeezed so that it is dewatered but it is squeezed against a felt 37 that is maintained on a substantial amount of land area 36*a* in between the mouths of the myriad of perforations 36, 36 and the perforations 36, 36 are filled with water under a considerable amount of pressure (particularly when air is entrapped in the bottom of the blind holes 36, 36) so that the bridging or unsupported felt areas at the nip N–5 corresponding to perforation openings of as much as 1/8 or 1/4 of an inch in diameter (or even less than 1/2 inch) are actually very well supported from beneath and there is little significant evidence of lack of support for such felt areas in the resulting pressed web W–3 ordinarily (i.e., little, if any, evidence in the form of "shadow marking"). In addition, the imperforate shells 35, 35*a* effectively defining the web press nip N–5 of such construction that they lend themselves readily to support by various anti-deflection means, so that the web press N–5 is afforded substantial advantages in versatility of nip pressure control and maintenance of generally uniform axial nip loads.

The grooved roll structure employed in the instant invention, however, as exemplified in the embodiments of FIGURES 4, 4A and 4B, as well as the improvements thereon represented in FIGURES 5A, 5B and 8 is based upon still another different and distinct fundamental principle of water removal at press nips. For one thing, the instant invention provides a unique improvement in the divided press assembly (FIG. 1) whereby a grooved roll is used in the place of the roll 35 described in connection with FIGURE 3 (or as will be explained hereinafter at the felt only nip) so as to obtain either a number of distinct advantages over the divided web press structure just described (at some sacrifice in other advantages), or to obtain all of the advantages of the divided press just described, plus a number of additional advantages.

One of the essential concepts of the instant invention involves that of using a grooved roll with land areas 13*b* and 22*b* (of the FIGURE 4 and FIGURE 5 series) that are substantially circumferentially continuous so that the land areas present continuous generally cylindrical, smooth exterior or peripheral outer operating surfaces for engaging the web material or felt 11, 23 and supporting the same. Circumferentially discontinuous land areas are substantially impossible to clean during rotation of the roll. Also essential in consideration of this first concept is the use of such land areas having a very narrow axial dimension 17, 27 between the alternating grooves 13*c*, 22*c* which are also of small axial dimension 16, 26 but which are vented (peripherally) to ambient atmosphere so that water pressed at the press nips, N–1, N–2 and N–3 will have no resistance in this respect to flow through the web material or felt axially as well as radially and into such vented groove mouths (which are wide enough to readily receive the water under pressure). The grooves are provided in a size of sufficient magnitude to receive the water load at the press nip, while being vented to ambient atmosphere and thus in a manner so as not to resist flow into the grooves, by virtue primarily of the groove depth (as comprised to increased groove axial dimensions 16, 26 to accommodate increases in water load). The groove depth 18, 28 in most paper machine uses must thus be substantially greater than the groove opening 16, 26 at the roll periphery, so that the very essential venting function is accommodated. In practical embodiments of the instant invention, the ratio of groove depth 18, 28 to groove axial dimensions 16, 26 at the roll periphery is preferably at least about 2:1 and may be as much as about 10:1 or more depending upon practical, additional consideration such as roll strength, ease of cutting the groove, etc. In addition, it has been found important to make sure that the groove is able to readily receive the water load in that it is provided with side walls 13*c*–1, 13*c*–2 or 22*c*–1, 22*c*–2 which are (generally radially aligned) at least as far apart axially as the groove mouth 16, 26 for at least an initial groove depth substantially equal to the axial dimensions of 16, 26 of the groove mouth (or a minimum of about 0.05 inch, and preferably 1/8 inch) and preferably for substantially the entire groove radial dimension 18, 28. As previously calculated, the groove volume expressed in terms of the preferred groove width "x" of about 0.025 inch and the minimum depth here expressed as 0.05 inch is only $2x^2$ (in cross-section) as compared to a figure of $5x^2$ for the preferred depth of 1/8 inch. This concept would permit interior groove axial dimensions greater than the mouth axial dimensions 16, 26 (also expressed as "x"), if the forming of the same is practical and does not subtract from the strength and other commercial considerations such as cleaning of the roll, but this concept would preclude shallow tapered grooves which would be intended to resist the entrance of water therein (and/or the venting thereof) but an extremely slow taper between the walls of relatively deep grooves, such that the walls would be substantially parallel for operating purposes in the region of the groove mouths would not be precluded.

In addition to the ability of the grooves 13*c* and 22*c* to vent to ambient atmosphere at the press nip and thus readily accommodate the receipt of water, an even more important consideration has now been found to be a part of this concept, and this is the consideration which involves the use of a minimum axial dimension 17, 27 to the smooth generally cylindrical land area on the ridges between the grooves. As indicated in FIGURE 5B, the maximum axial distance which water must travel through the felt 23 (in compressed form) is from approximately the midpoint M of the land area 22*b* to the edge of the groove 22*c* adjacent thereto. Such midpoint M lies in a generally radial plane bisecting the individual ridge and land area 22*b* and the axial distance 27½ to the groove is approximately one-half of the land area 27.

Liquid per se in any medium, such as water in the web type of medium provided by the felt 23, resists flow under

any circumstances, and in the compressed felt 23, which has a dimension within the range of about 1/16 to 1/8 inch (0.0625 to 0.125 inch) the resistance to water flow is sufficiently great to cause considerable care to be taken in defining this dimension 27½ so as to maintain maximum dewatering efficiency at the nip. In this respect, the axial land dimension 17, 27 should be about 25% to 200% of the radial felt thickness 23*a* in compression for the best performance in water flow axially laterally through the compressed felt and into the grooves 22*c* on either side of each land area 22*b*. Preferably the range of axial land dimension 17, 27 to felt thickness 23*a* in compression is within 1:2 to 1:1.

Still another important consideration in the practice of the instant invention with respect to the axial groove dimension 16, 26 at the mouth thereof is that of "shadow marking" in the case of webs passing through the nip. It will be appreciated that shadow marking per se is not of any consequence in connection with a felt only press, nor is it a significant factor in the case of certain types of lower quality webs or in the case of certain paper machines wherein extra heavy felts are used. In such instances, it might be possible to use grooves having substantial axial dimensions 16, 26 up to as much as about 1/8 inch, above which the felt would tend to enter the grooves to too great an extent, causing unnecessary additional wear of the felt, possible plugging of the water flow and/or venting effect, etc. A careful study of this matter has revealed, however, that axial groove dimensions 16, 26, which are significantly greater than about 0.035 inch tend to cause undesirable marking on certain webs and/or the weights into the grooves under the nip load, so as to increase the wear of the felts, and a maximum groove dimension of 0.035 has been found to be a very significant cutoff point for most pressing operations. The minimum practical axial groove dimension 16, 26 which accommodates receipt of water and the essential venting function, is in the neighborhood of about 0.005 inch. As previously indicated the best results are obtained using a groove axial dimension of substantially 0.025 inch.

The foregoing venting concept which is essential to the practice of the instant invention is based upon certain fundamental theories which involve the design of grooves having the best ability to receive water and vent the nip pressure, plus the design of land areas having superior ability to effect axial or transverse flow of water through the compressed felt and into the grooves with a minimum amount of interference and a minimum amount of pressure gradient across the land areas. In the case of a web nip such pressure gradient is a function of the fluid pressure existing at the interface between the felt and the web, and it is important in pressing to vent or relieve such fluid pressure in the felt to as low a level as possible, which is best done by opening up the "back side" of the felt so that water need travel only substantially the thickness of the felt in compression to ambient atmosphere in the grooves.

Another aspect of the instant invention which has been found to be very important is that of minimizing such flow of water through the compressed felt and into such grooves, by preparation of the land areas at the oncoming side of the nip. In this respect, attention is directed to FIGURE 7A, which shows in a transversely directed view the outer peripheral land areas 22*b* alternating between the grooves 22*c* but with droplets D of water (in the form of a meniscus) adhering to the land areas 22*b*. It will be appreciated that in the operation of paper machinery involving press sections, a substantial amount of water is being handled and this water includes droplets in mist in the air as well as the water actually remaining in droplet form on the roll surface, so that the roll surface ordinarily tends to be continuously wet. It must be appreciated, however, that any such droplet D carried on the land areas 22*b* into the nip N–3 (or N-1, N–2) is first immediately pressed into the body of the felt and then must travel the aforesaid axial dimension through the compressed felt and into the vented grooves on either side of the land area 22*b*. This is a phenomenon which is avoided in accordance with the practice of the instant invention by a very simple expedient. In FIGURE 1, the doctor means in the form of the air doctor blow such droplets off the land areas to dry the same at the oncoming side of the nip N–1, N–2 (within at least approximately about 120° at the oncoming side of the nip on the grooved press rolls, and preferably within substantially the last quarter or 90° of rotation of the grooved roll approaching the nip). The press assembly 20 of FIGURE 6 demonstrates the use of a more simple, sturdy, inexpensive and advantageous doctor means for accomplishing the result desired with greater ease, and without the necessity of atomizing or blowing droplets into the ambient atmosphere for redeposit on other operating members. This is done essentially by the use of the doctor blade 30 which is a conventional doctor blade in all other respects and has this advantage. It is mounted, however, at the immediate oncoming side of the nip N–3 so as to make sure that the land areas 22*b* are dry approaching the nip N–3. In this respect, it will be seen that the doctor 30 which presents what constitutes an axially continuous surface urged against (or in very close running relation to) the roll periphery is a greatly simplified structure in that it is not complicated by devices for reaching into the grooves 22*c*.

An important aspect of the invention resides in the fact that devices for reaching into the grooves 22*c* at this particular location are not essential, since the grooves 22*c* are designated with sufficient depth 28 to accommodate the return of at least a small amount of water into the nip N–3 in the grooves without interferring with the overall operation of the press 20. The important point to consider here is that of avoiding an unnecessary additional flow of water axially through the compressed felt by the introduction of water at the land areas 22*b* at the nip N–3.

Still another very important point to consider is that in the press roll 22 which is the preferred embodiment of the instant invention, the generally circumferential, alternating grooves 22*c* and ridges 22*b* are in the form of continuous spirals, as contrasted to *exactly* circumferentially aligned and axially spaced grooves and ridges throughout the entire roll periphery. This latter roll structure can be used in the practice of the instant invention with a number of desirable results, and the spiral grooving is distinctly superior from the point of view of manufacture and use as will be demonstrated hereinafter. Machine tools are available for cutting the desired grooves (in the form of spiral threads) on the surface of such rolls with considerably greater ease and accuracy than can be done in the practical shop operation involving the cutting of grooves that are exactly circumferential. Moreover, the doctor 30 presents an axially continuous surface which is uniquely capable of cooperating with the spiral grooving for dewatering the land areas only, whereas any device reaching into the grooves of spiral grooving could not be retained as a fixed, simple functioning device such as the instant doctor 30.

Referring to FIGURE 7, it will be seen that the wiping device 29 also provides a unique arrangement for dewatering grooved rolls generally, and particularly for dewatering the spiral groove rolls of the type just described. The wiping device 29 does not enter into the grooves 22*c*, but carries out its function of pumping water from the grooves 22*c* by virtue of its unique, simple structure and it carries out this function at the oncoming side of the doctor 30, so that it will not take water from the grooves 22*c* and put it on the land areas 22*b* such that the water will be conveyed into the nip N–3 on such land areas. In essence, the wiper 29 has an axially continuous surface portion 29*a* extending from close proximity to (actually being urged against) the roll surface 22 at

the peripheral surface portions or land areas 22*b* thereof, which surface portion 29*a* extends gradually away from such roll surface or land areas 22*b* (from the region of contact L–1 so as to define with the off-running roll periphery a gradually diverging pair of surfaces for pumping liquid out of the grooves 22*c* as it moves past the wiper means 29. As indicated in FIGURE 7, the combination of centrifugal force, gravitational force and the reduced atmospheric pressure that is created at the underside 29*c* of the sheet 29*a* for the wiper 29 results in the drawing of the water (indicated at 29*d* diagrammatically) out of the grooves 22*c* and off in the general direction of the underside 29*c* of the sheet 29*a*. This is done, of course, to an appreciable extent by the sweeping or inrushing of air A–7, as indicated diagrammatically, along the peripheral surfaces of the grooves 22*c* to compensate for the partial vacuum that is being created by this pumping effect. It will be appreciated that the wiper structure thus shown is unique in its simplicity, ease of assembly, installation, operation, repair, etc., and in addition it is unique in its function with respect to generally spiral grooves 22*c* in that it will dewater the same without reaching into such grooves and thus having the inherent axial travel motion imparted to the wiper device 29 that would result from continuously riding in spiral grooves. It has been found that the fundamental and simple wiper 29 and doctor 30 structures cooperate in a unique manner in connection with the press assembly 20 for obtaining the best operating results. The doctor 30 per se has the unique function of improving the efficiency of the press at the nip N–3, and the wiper 29 per se has the unique function of drawing water out of the grooves 22*c* by a very simple structure and phenomenon. Both of these devices 29 and 30, individually and in combination, are uniquely superior for operation with the preferred spirally grooved press roll in improving the basic operation thereof.

In addition to the previously mentioned advantages of spiral grooving on the roll 22, which include the more inexpensive and foolproof cutting of such rolls on a lathe, there is a unique cooperation between the spiral land areas 22*b* and the doctor 30 and/or wiper 29 which is not injurious to the felt 23. At the nip N–3 the spiral grooves 22*c* and ridges 22*b* come into momentary contact with the felt 23 under compression (moving truly circumferentially) and for such momentary contact the grooves 22*c* and ridges 22*b* are substantially (and practically) circumferentially aligned in their travel and the axial extent of the travel is so extremely minute that no felt damage is caused thereby. Just the opposite function between the ridges 22*b* and the doctor 30 and/or wiper 29 is obtained, however, because these latter devices remain in fixed position engaging the ridges 22*b* so that their spiral (axial motion) component has the net effect of continuously cleaning, wiping and/or scraping the engaged surfaces of the doctor 30 and/or wiper 29.

In many respects, the foregoing structures of the grooved rolls 13 and 22 are particularly useful even though the groove mouths 16, 26 may be rather substantial in size (e.g. up to 0.1 inch or more at the felt only nip N–2), even to the extent of causing some marking at one of the web nips N–2 or N–3. In the preferred embodiment of the instant invention, however, marking is avoided by the use of very narrow groove openings 16, 26, of an axial dimension that is not greater than about 0.035 inch (and preferably about 1/32 inch). This axial dimension, as a maximum, has been found to be distinctly superior for use in the practice of the instant invention. It has been found that axial dimensions significantly greater than this do not give significantly better performance in any of the ordinary uses of the instant roll, whereas such bigger axial dimensions do have a tendency to cause web marking in most instances. In the manufacture and sale of grooved press rolls for the uses contemplated in the practice of the instant invention, it has thus been found particularly desirable to maintain groove axial dimensions of 0.035 or less. Among other things, this has the advantage of avoiding any special instructions in connection with mill use by the grooved rolls, since such grooved rolls can be used at felt only presses, as well as web presses involving different felt weights and different qualities and types of webs.

Within the limitations hereinbefore set forth, it will be understood that certain relationships between the grooves and ridges in the felt covered press roll (e.g. 15 of FIGURE 1) of a web press in a divided press may not be so critical because the felt 11 is adapted to carry away most of the water expressed from the web W–1 and re-wetting of the web is avoided in FIGURE 1 by guide means separating the web and felt at the immediate off-running side of the nip N–1. The ratio of axial groove dimension 16 to axial land dimension 17 is at least about 1:1 and preferably at least within the range of 1:2 to 1:3 (i.e. 1/32 inch to about 1/16 to 3/32 inch) for satisfactory removal of water from the web, which involves an open area range of 50% to about 25%, with a preferable maximum of 33⅓% (i.e. 1/32 to 1/16 inch ratio).

Extensive research has revealed, however, that distinctly superior performance is obtained using a substantially smaller open area of not more than about 25% (e.g. not more than 1/32 inch grooves with 3/32 inch lands). This is a significant difference between the rolls 13 and 22. This is notwithstanding the fact that an essential aspect of the invention involves ease of reception in the grooves of substantial quantities of water. The reason for the preferred open area upper limit of about 25% (and preferably 20% with the 0.025 inch grooves and 0.100 lands of FIGURE 5B) is that it has been found that this comparatively low open area does not significantly impede water removal from the web (via the felt) at the nip pressures used while it does carry out perhaps the second most important function that provides great versatility for the grooved roll of the invention. This function is that of minimizing re-wetting of the felt at the off-running side of the nip N–3. Although this function greatly assists the dewatering operation in the web (divided) press nip and reduces or minimizes the water load carried away by the felt from the web in the divided press, it is actually capable of effecting substantially all water removal (via the grooved roll at a web press nip) so as to replace a conventional suction roll web press, as indicated in FIGURE 6, particularly at a second or third press in a press assembly (e.g. FIGURE 13).

In FIGURE 6, it will be noted that the felt 23 is aligned substantially at (or preferably slightly above) a nip-tangent plane T—T at both the oncoming 23*a* and off-running 23*b* sides by means of the upper surfaces of the guide rolls 24*a*, 24*b* which are positioned on the side of the tangent plane T—T opposite the roll 22 so that the felt 23 will have minimum contact with the roll 22 (only at the nip N–3), will not tend to have portions entrapped in the grooves 22*c*, will not tend to close off ambient atmosphere at the oncoming or off-running sides of the nip N–3, will undergo minimum wear from contact with the land edges (e.g. at 22*b*–1 of FIGURE 5B which are preferably rather sharply cut to obtain the other advantages described herein), will undergo minimum wear from the limited axial movement of the spiral lands 22*b* at the nip N–3, will permit the proper positioning of the saveall 25, and will withdraw or receive a minimum amount of water from the grooves 22*c* at the off-running side 23*b* of the nip N–3. The grooves 22*c*, of course, resist release of water by centrifugal force (particularly more at the uprunning or top of the roll 22 than at the down-running side when gravity adds to the centrifugal force) but whatever is released (at D–3) is substantially thrown against the upper part of the saveall 25*a* at the immediate off-running side of the nip N–3 between the roll 22 and the felt 23*b*.

Although the travel of the felt 23*b* at the off-running

side is important for many uses, the open area is still very important because some re-wetting of the felt 23*b* at the off-running side of the nip N–3 is almost instantaneous as the felt expands when the nip pressure is released and the felt is then very absorptive. At this instant the water "path" is reversed back out of the grooves 22*c* toward the most remote portion of the absorptive felt 23, which would be along the center line or plane M (FIGURE 5B) above each land 22*b*. It has now been found that in the preferred structure of the roll 22 this reversal of water travel is minimized by the use of a ratio of groove width 26 to land width 27 of a practical minimum of 1:3 to a practical maximum of about 1:20 above which dewatering of the web and/or felt is unduly hampered at the press nip N–3 (and preferably an open area from about 25% to about 10% for practical purposes).

Particularly using the combination of the foregoing (groove-to-land) ratio of 1:3 to 1:20, lands of substantially 0.05 to 0.15 inch width, and grooves of 0.01 to 0.035 inch width, one obtains an unusually versatile press roll for use throughout a press assembly (e.g. as in FIGURE 13). The best results have been obtained using substantially the exact dimensions disclosed for the roll 22. Groove depths 28 at least sufficient to carry the water load are used, and preferably the foregoing combination includes (substantially radial) groove depths of at least about 2 to 10 times the groove width (which is expressed in cross section as a value equal to at least about 2 to 10 times the square of the groove mouth or width dimension), at least about equal to the land width, and at least about 0.1 inch, with maximum groove depth being defined primarily by practical considerations, although square or rounded groove bottoms not substantially deeper than about ¼ inch are generally superior to other structures for the combination of strength, cleaning and manufacturing purposes.

Within the foregoing parameters, open areas of 25%, 20% and 15% (successively) may be used in the first, second and third web presses of a machine, taking off less water at each press. Using the press roll 22 of the invention in a divided press (e.g. at the positions of the rolls 13 and 15 of FIGURE 1), one obtains superior control of the web condition entering the web press nip and guide means 11*a*, 11*b*, 11*c*, 11*d* maintaining the felt at least substantially tangential with the nips N–1, N–2 can be used to advantage with additional guide means 19, 19 separating the web W–1 from the felt 11 at the immediate oncoming and off-running sides of the web press nip N–1 for better control of the water transfer from the web W–1 to the felt 11 and vice versa.

Additional embodiments of the invention

Referring now to FIGURE 8, it will be seen that this embodiment of the invention indicated generally by the reference numeral 40 shows a wet press wherein the press nip N–8 is defined between an upper grooved roll 42 and a lower plain roll 41, which engages the web W–8 traveling on the underside of the felt 43. Elements in FIGURE 8 corresponding to those shown in FIGURE 6 have been designated with the same reference numeral in the 40 series. It will be seen that the bottom plain roll 41 may have a tendency to carry away a slight amount of water from the web W–8 and the roll 41 is cleaned by a doctor 41*a* at the oncoming side of the nip N–8, with the doctor dumping water and the like into a saveall 41*b*. The grooved roll 42 has substantially the same structure as the previously described roll 22, except that the groove width is preferably only 0.015 inch for an open area of 15%, and the press 40 is used as a third press for removing a relatively nominal amount of water. The reduced open area minimizes rewetting of the felt 43 at the off-running side of the nip N–8. The saveall portion 45*a* at the off-running side of the nip N–8 extends between the felt 43 and the surface of the roll 42 to substantially the immediate off-running region of the nip N–8, and collects some droplets of water as indicated diagrammatically.

At the down-running side of the grooved roll 42 a wiper 49 having substantially the structure of the wiper 29 and a doctor 50 having substantially the structure of the doctor 39 are mounted for cooperation, with a saveall portion 45*c*. The saveall 45*c* carries the doctor 50 as close to the oncoming side of the nip N–8 as is practical for permitting the saveall 45*c* to collect and withdraw water wiped from the lands 42*b* of the roll 42 by the doctor 50.

Referring now to FIGURE 9, it will be seen that a divided press is indicated generally by the reference numeral 60, with a web press nip N–9 between a plain upper roll 61 and a lower grooved roll 62, wherein the elements are arranged substantially as shown and described in connection with FIGURE 6, except that the web W–9 is guided by rolls 71*a* and 71*b* at the oncoming and off-running sides of the nip N–9 so that the web W–9 contacts the felt 63 substantially only at the nip N–9 (and the web W–9 tends to adhere to the uprunning side of the upper (granite) roll 61 at the off-running side of the nip N–9, which assists in separation of the web W–9 and felt 63 at the immediate off-running side of the nip N–9, even though the felt 63 is mounted on guide rolls 64*a* and 64*b* which maintain the felt 63 just slightly above the tangent plane passing through the nip N–9). Dewatering and cleaning of the grooved roll 62 is accomplished by elements corresponding in structure and function to those already described in connection with FIGURE 6 and designated by the corresponding reference numerals in the 60 series, the doctor being designated 70.

In FIGURE 9, there is also provided a felt only press nip indicated generally at N–9A which is defined by a plain press roll 73 within the loop of the felt 63 and a grooved press roll 72, having the same structure as the grooved press roll 62 and the previously described grooved press roll 22, positioned outside the loop of the felt 63 for acting upon the "operating" outer peripheral surface 63*a* of the felt 63 to clean, condition and dewater the same. The grooved roll 72 is provided with a saveall 75 mounting a wiper 79 having substantially the same structure and function as the previously described wipers 29 and 69, plus a doctor 80 having substantially the same structure and function as the doctor 50 of FIGURE 8 which also coacts with a down-running side of a grooved roll. The doctor 80 is positioned close to the oncoming side of the felt only nip N–9A for better efficiency in water removal at such nip N–9A and it is mounted in cooperation with the saveall 75 for entrapping water removed thereby and water thrown from the periphery of the roll 72 by the action of the wiper 79. The felt 63 is so mounted that it travels substantially beyond a tangent plane indicated generally at T–9A, for minimum contact with the surface of the grooved roll 72, and quick separation therefrom at the off-running side of the nip N–9A (and for advantageous positioning of the leading edge 75*a* of the saveall 75 at the immediate off-running side of the felt only nip N–9A between the felt 63 and the surface of the grooved roll 72. The divided press 60 is employed for obtaining extremely good control of the water movement at both nips N–9 and N–9A.

Referring now to FIGURE 10, it will be seen that the embodiment of the invention shown in FIGURE 10 comprises a hot press 100 which receives a heated web W–10 coming from the last dryer 101, past a guide roll 102 and into the nip N–10, from which the warm web W–10 passes over a guide roll 103 separating the web W–10 and the press felt 104 at the immediate off-running side of the nip N–10, and passing the web W–10 on to the first dryer 105 of the next dryer section. The hot press 100 has a web press nip defined by an upper plain roll 106 and a lower press roll 107 which has substantially the same structure as the previously described roll 22 with a saveall 108 corresponding to the overall saveall 25, a wiper 109 corre-

sponding to the wiper **29** and a doctor **110** corresponding to the doctor **30**, all as described in greater detail in connection with the roll **22**. The roll **107** is, however, provided with a stainless steel cover **107***a* which is grooved in the manner described in connection with the grooves **22***c* and land areas **22***b* of the roll **22**; but the stainless steel structure **107***a* is used advantageously in the hot press nip N–**10**.

The felt **104** is mounted on felt guide rolls **111***a*, **111***b*, **111***c*, and **111***d* plus a tensioning roll **111***e* in conventional manner, and the felt only press nip N–**10**A is defined between a plain press roll **112** within the loop of the felt **104** and a grooved press roll **113** outside the loop of the felt **104**. The grooved press roll **113** is provided with an overall saveall structure **114** comparable in function to the saveall structure **108**, with a wiper **115** and a doctor **116** corresponding to the wiper **109** and doctor **110**, except that the parts are reversed because the doctor **116** is mounted at the uprunning side of the roll **113** for cleaning of the same immediately ahead of the oncoming side of the nip N–**10**A.

In the press assembly of FIGURE 10 a control box **117** is indicated diagrammatically for receiving a signal from a conventional moisture detecting (beta gauge) device. A shower **119** controlled by a control valve **120** is positioned within the loop of the felt **104** for applying the desired amount of water to the felt **104** at the oncoming side of the felt only nip N–**10**A. The control valve **120** may be controlled manually, or it may be controlled and preferably is controlled through the control panel **117** either automatically or by an operator who may observe the moisture content reading at the control panel **117**. In addition, it will be seen that conventional fluid actuated nip pressure control means indicated by the two-headed arrows at **122** and **123** for the lower press rolls **107** and **113**, respectively, are provided with conventional controls which are connected to the control panel **117**. It will thus be seen that the grooved rolls **107** and **113** are readily employed in the pressure controlled divided press assemblies, wherein the pressure at the felt only nip N–**10**A is controlled so that it may be at least as great as and preferably slightly greater than the pressure at the web nip N–**10** for cleaning, conditioning and dewatering the felt **104** passing therethrough, and the overall operation of the press assembly **100** may be carried out automatically through the control box **117** wherein the elements **122**, **123** and/or **120** may be controlled in response to signals received by the control box **117** from the moisture sensing device **118**, or they may be controlled by the operator actuating conventional pneumatic signals at the control box **117** in accordance with his own observation of the moisture content reading.

Another feature of the instant invention involves the use of anti-deflection mounting means, which are here indicated diagrammatically as a part of the pneumatic loading means **122** and **123** for the rolls **107** and **113**. It will be appreciated that anti-deflection roll mounting means are now known in the art and are illustrated in such patents as U.S. Patent Nos. 2,648,122; 2,651,103 and 2,651,241. In addition, in my copending Patent Nos. 3,097,590, issued July 16, 1963; 3,097,591, issued July 16, 1963; 3,119,324, issued January 28, 1964; and Serial No. 339,998, filed January 24, 1964 (all of which disclosures pending or issued to me, hereinbefore mentioned, are incorporated herein by reference), preferred embodimnts of the anti-deflection mounting means for such rolls are disclosed, and anti-deflection means of the type disclosed therein are employed in the mounting for the rolls **107** and **113**, as well as all other rolls shown hereinafter with the diagrammatic showing of a two-headed arrow for nip pressure control or loading. The aforesaid disclosures are incorporated herein by reference, and the specific disclosure used herein is that involving mounting on rubber sandwiches on a through shaft as shown in my Patent No. 3,097,590 for FIGURES 9 and 10 hereof and the anti-deflection roll used is that of my Patent No. 3,119,324.

A common feature of all such anti-deflection rolls of my Patent Nos. 3,097,590 and 3,119,324 is that the rolls are provided with imperforate shell structures which are supported substantially or appreciably axially inwardly from the shell ends by support means within the shell carried on shaft means for rotation of the shell. A feature of the roll of my Patent No. 3,119,324 is that the imperforate roll shell is carried on an oil or other liquid film (supported by a substantially non-deflected shoe) such that deflection is minimized (and in FIGURE 13 hereof this is the deflection control structure for the roll **222**). As used herein, the term "anti-deflection roll" means a roll having such structure, which structure is not possible with conventional suction roll shells (having the necessary gland mounted therein).

Referring now to FIGURE 11, it will be seen that the press shown therein indicated generally by the reference numeral **120** is a divided press formed by only three rolls **121**, **122** and **123**, with the central roll **122** being a grooved roll having a structure that is substantially identical to that already described for the roll **22**. As indicated in the press **120**, the web W–**11** passes through the web nip N–**11** contacting the felt **124** substantially only at the nip pressure area for removal of the desired amount of water from the web W–**11** and transfer the same partially to the felt **124** and partially to the grooves in the grooved roll **122**. The felt **124** then passes around guide rolls **124***b* and **124***c* and through a felt only nip N–**11**A. Water is removed by doctors **123***a* and **123***b* cooperating with a saveall **123***c* in conventional manner.

The grooved press roll **122**, however, carries out the dual function of removing water from the felt only at the felt only nip N–**11**A and such water is removed from the uprunning side of the grooved roll **122** by the cooperation of a wiper **126**, a doctor **127** and a saveall **128**, having the functions already described herein. At the down-running side of the grooved roll **122**, water removed from the web press nip N–**11** is removed from the roll, likewise, by a wiper **126***a*, a doctor **127***a* and a saveall **128***a* which function in the manner already described, except that their positions are reversed compared to those of the elements **126**, **127** and **128**.

Referring now to FIGURE 12, it will be seen that the elements shown therein correspond to a substantial extent to elements shown in the press assembly **120** of FIGURE 11, and elements having the same structure and function as those of FIGURE 11, are designated by the same reference numeral in the 130 series in FIGURE 12. A significant difference in the divided press assembly **130** is that the bottom press roll **123** is a grooved roll having a structure substantially identical to that of the middle grooved roll **132** (which in turn is identical to that of the roll **122** of FIGURE 11). The lower grooved roll **123** serves to effect greater removal of water from the felt **134** at the felt only nip N–**12**A, so that better control of the water content of the felt may be obtained and this permits the web W–**12** to travel in and out of the web press nip N–**12** on the felt **134**. Water removal from the web press nip N–**12** is accomplished substantially by the grooved press roll **132**, which may be operated without the down-running wiper **136***a* and doctor **137***a*, if desired, for the reason that it can transfer substantially all of the water removed from the web nip N–**12** to the felt only nip N–**12**A, where it is ultimately transferred into the grooves of the bottom roll **123**. The felt only press nip N–**12**A thus has the additional function of effecting the substantial removal of water from the grooved roll **132** as well as from the felt **134**, to the extent desired, at the felt only nip N–**12**A. The grooves in the two rolls **132** and **133** are preferably offset axially slightly. The wiper **133***a* (which is here combined with a doctor **133***d* co-acting therewith) and doctor **133***b*, plus the saveall elements **133***c* serve to remove the water from the grooves of the bottom grooved roll **133** in the manner hereinbefore described. Anti-deflection and fluid

actuated mounting means indicated generally at **139** and **139***a* for the top and bottom rolls **131** and **133** are also employed in the divided press **130** to control the nip loads in the manner already described.

FIGURE 13 shows diagrammatically an overall press assembly indicated generally by the reference numeral **200P**, for the purpose of showing the versatility of the grooved rolls of the instant invention. In the assembly **200P**, the web W–**13** is picked up from a forming wire FW (returning about a turning roll **201R**) by a pickup felt **202F** wrapped around a conventional suction pickup roll **203R**, with the suction area indicated diagrammatically at **203***a*R, and the web W–**13** is then passed through a first press P–**1**, a second press P–**2** and a third press P–**3**, using successively 200, 300 and 400 pounds per lineal inch of nip pressure for carrying out dewatering of the web W–**13**. Each of the press rolls **222**, **242** and **272** has essentially the same structure and function as the previously described grooved press rolls **22**, **42** and **72**; and the grooved press roll **242***a* has a structure and function comparable to that of the roll **242**, except that it is provided with grooves of approximately 0.035 inch width and an open area of approximately 25%, in order to accommodate a maximum water load and function as a transfer press roll in the first press P–**1** in cooperation with a conventional suction roll **290** for transferring the web W–**13** to the lower press felt **291**. The pickup felt **202** then passes around conventional guide rolls as indicated and into a divided press felt only nip N–**14** defined by an anti-deflection roll **293** and a suction roll **294**.

The second press P–**2** has substantially the press structure of the press **20** of FIGURE 6 and elements corresponding thereto are designated in the 200 series in FIGURE 13. The web W–**13** is taken from the second press P–**2** over a web guide roll **296** and into the nip N–**208** of the third press P–**3**, which is composed of elements corresponding substantially in structure and function to those described in FIGURE 8, and having the same reference numerals in the **200** series. As in the case of the previously mentioned grooved roll **242***a*, the grooved roll **242** is provided with a saveall **245** mounting a doctor **250** close to the oncoming side of the nip and a wiper **249**, here shown functioning on the uprunning side of the grooved roll for drawing water out of the grooves (primarily for convenience of showing in the drawing, since the wiper **49** of FIGURE 8 is better operated at the downrunning side of the roll).

The third press P–**3** also differs from the press **40** of FIGURE 8 in that it is part of a divided press assembly with a felt only nip N–**209**A which corresponds substantially in function and structure to the previously described felt only (vertical) nip N–**9**A of FIGURE 9, and elements shown in connection with the felt only nip N–**209**A which correspond substantially in structure and function to those associated with the previously described nip N–**9**A have the same number in the 200 series. In addition, it will be seen that the felt **243** passing through the third press nip N–**208** is mounted on guide rolls **296***a*, **297***a*, etc. which cooperate with the paper guide rolls **296** and **297** to effect separation of the web W–**13** from the felt **243** at both the oncoming and off-running sides of the nip N–**208**.

In the press assembly **200P** of FIGURE 13, it will be appreciated that the suction rolls **290** and **294** may both be grooved press rolls having the structure previously described in connection with the press roll **22**. In fact, the versatility of the invention will be appreciated best, in FIGURE 13, for the reason that the press roll **22** could be used in the press roll positions **242**, **242***a*, **222**, **272**, **290** and/or **294**. In addition, such grooved press rolls with imperforate shells, and mounted on anti-deflection means hereinbefore described, may be employed in automatic, semi-automatic or operator controlled press assemblies, such as the assembly **200P**, which it will be seen is provided with operating panels C**1**, C**2**, C**3**, of conventional type, which may receive one or more moisture content signals from moisture measuring (beta gauge) devices positioned at B**1**, B**2**, and/or B**3**, for selectively actuating the various fluid pressure actuated anti-deflection roll mounting means indicated at the double headed arrows designated FP on the drawing. The showers indicated diagrammatically at S–**1** and S–**2** also function substantially as described in connection with the shower **119** of FIGURE 10, and are, likewise, capable of control from the control panels C–**1** through C–**3**, in accordance with known control methods and with known control devices. The various control signal lines are indicated in dotted lines on FIGURE 13.

Referring to the grooves **22***c* shown in FIGURE 7C to be substantially vertical in parallel alignment in the small portion of the roll surface shown in this view, it will be appreciated that the spiral angle or the angle of these grooves **22***c* to the centroidal axis of the roll shell should be comparatively small angle, alpha, which might be expressed for a 20 inch diameter (i.e. 10 inch radius) press roll as tangent alpha equals approximately 0.125 divided by 10, or 0.0125. The range for tangent alpha should be within about 0.003 to about 0.03, preferably. It will be appreciated that spiral angles β (beta) up to 20° or 30° may be used, particularly if it is desired to have the spiral grooves intersect from time to time, as explained hereinafter with reference to FIGURE 15 and the FIGURE 15 series.

In general, the simple generally circumferential grooves (with a slight helix) have already been described as being preferred for use in the practice of the invention and grooves of this type are distinctly superior for a number of reasons. Nevertheless, there may be instances when it might be desirable to use other grooved structures and such other grooved structures are indicated in FIGURE 15, in top plan view of a fragmentary, small portion of a roll surface, with the views **15**A, **15**B and **15**C indicating fragmentary sections taken in these structures.

For example, in the view of FIGURE 15, it will be seen that the roll surface indicated generally by the reference numeral **200** is provided with a first plurality of helical grooves **201***a*, **201***b*, **201***c*, etc., which are shown as having a helix angle substantially greater than that previously described in connection with the preferred generally circumferentially aligned grooves and ridges. Likewise, the structure of the roll **200** is provided with a second set of generally helical grooves indicated in part at **202***a*, **202***b*, **202***c* which have a comparable helix angle to the grooves of the 201 series, but are reversed in direction so as to intersect the grooves of the 201 series thereby obtaining generally diamond-shaped land areas indicated at **203***a* and **203***b*. It will be appreciated that the maximum axial dimension of such land areas is represented in FIGURE 15C as extending from a groove intersection R to a groove intersection S shown in plan view in FIGURE 15. The groove width of xB compared to the land axial dimension yC shown in FIGURE 15C is still within the scope of the instant invention, being on the average about a ratio of x:y to 1:6 or 1:7, and the groove width x that is adapted for use in a web press in the practice of the instant invention will still be within the groove width range hereinbefore specified (i.e. about 0.005 to about 0.035 inch). The land width yC in FIGURE 15C is, of course, closer to the upper limit of about 0.25 inch hereinbefore specified for the land width, in order to minimize cross-machine flow in the plane of the web, here indicated diagrammatically at W–**15** and thus minimize cross-machine crushing flow. The grooves of the intersections R and S are thus sufficiently close together to avoid the necessity (of using means other than the grooves **201** and **202** for) venting to ambient atmosphere at the underside of the felt F–**15** for the purposes already described herein.

In FIGURE 15B, it will be seen that the generally parallel (although slowly helical) grooves **201***b* and **201***c* have

a more narrow land width *y*B therebetween in the section shown in FIGURE 15B, so that crushing flow in the web is avoided in the direction of the section line XVB—XVB for the reasons hereinbefore described. In the section of FIGURE 15A, it will further be seen that a still more narrow land area *y*A even in the cross-machine direction of the section line XVA—XVA is afforded between the grooves **202***a* and **201***b*, as there shown. It will thus be seen that the overall average land width *y* is within the parameters already set forth, and the grooves of the 201 and 202 series may thus function in the manner hereinbefore set forth, i.e. the overall open area does not exceed 33⅓% and/or the overall average land to groove ratio is 2:1 or more in the cross-machine direction. The previously described pumping wiper may also be used to remove water from the grooves of this type also, but a rotary brush such as the brush **133***x* in FIGURE 10 of my application Serial No. 378,217, filed June 26, 1964, would also be preferred for use in conjunction with the pumping type wiper in order to maintain the grooves in a relatively clean condition for best operation. Also, it will be noted that the roll itself is provided with a rubber cover **200**A on a ductile iron shell **200***x*; and in forming the surface structure indicated in FIGURE 15, it is normally necessary to run the rubber covered roll **200** through a first cutting operation to cut, for example, the helical grooves of the 201 series in one direction and then process the roll **200** a second time to cut the helical grooves of the 202 series in the opposite direction.

The grooves of the 201 and 202 series of FIGURE 15 are actually vented peripherally before and after any nip and on the underside of the felt indicated diagrammatically at F–**15** at such nip and they are sufficiently narrow to carry out many of the other functions hereinbefore described. Having such a large helix angle, however, these grooves **201** and **202** are not vented to ambient atmosphere through the shortest distance, as would be the case in the previously described generally circumferential grooves.

Also, assuming that the dimensions *y*B between the generally parallel helical grooves **201***b* and **201***c* is approximately 0.1 inch and the grooves are 0.020 inch, it will be appreciated that this would (in the absence of the other set of helical grooves **202**) form a basis for an open area of 16%; but the inclusion of the other set of grooves **202** increases the open area to at least about 20%, using grooves **202** of the same size as the grooves **201**. Actually, the open area in patterns such as that of FIGURE 15 may be as much as about 33%, particularly if the machine is to be operated relatively slowly and the grooves are themselves cut with substantial volume (i.e. depth) so that they may function as water troughs. In such instances, land areas of approximately ⅔ of the total area may effect the desired pressing and the substantial open area for grooves receiving water flowing away from the nip may be useful. Likewise, the land areas of maximum dimension, such as the land area *y*C of FIGURE 15C may be as much as 0.3 inch in its maximum dimension. It will be appreciated that this maximum happens to be in only one particular direction (i.e. exactly the cross-machine direction) whereas the land sizes here are so small compared to the overall nip size that in a relatively slowly operating machine, the escape routes for the water to the grooves **201** or **202** may well be much shorter, as indicated in FIGURES 15A and 15B, and satisfactory venting of the upper side of the felt W–**15** is readily accomplished to afford the function of water troughs for the groove system here described.

In FIGURE 6, it will be noted that the felt **23** is aligned substantially at (or preferably slightly above) a nip-tangent plane T—T at both the oncoming **23***a* and off-running **23***b* sides by means of the upper surfaces of the guide rolls **24***a*, **24***b* which are positioned on the side of the tangent plane T—T opposite the roll **22** so that the felt **23** will have minimum contact with the roll **22** (only at the nip N–**23**), will not tend to have portions entrapped in the grooves **22***c*, will not tend to close off ambient atmosphere at the oncoming or off-running sides of the nip N–**3**, will undergo minimum wear from contact with the land edges (e.g. at **22***b*–**1** of FIGURE 5B which are preferably rather sharply cut to obtain the other advantages described herein), will undergo minimum wear from the limited axial movement of the spiral lands **22***b* at the nip N–**3**, will permit the proper positioning of the saveall **25**, and will withdraw or receive a minimum amount of water from the grooves **22***c* at the off-running side **23***b* of the nip N–**3**. The grooves **22***c*, of course, resist release of water by centrifugal force (particularly more at the uprunning or top of the roll **22** than at the downrunning side when gravity adds to the centrifugal force) but whatever is released (at D–**3**) is substantially thrown against the upper part of the saveall **25***a* at the immediate off-running side of the nip N–**3** between the roll **22** and the felt **23***b*.

Although the travel of the felt **23***b* at the off-running side is important for many uses, the open area is still very important because some re-wetting of the felt **23***b* at the off-running side of the nip N–**3** is almost instantaneous as the felt expands when the nip pressure is released and the felt is then very absorptive. At this instant the water "path" is reversed back out of the grooves **22***c* toward the most remote portion of the absorptive felt **23**, which would be along the center line or plane M (FIGURE 5B) above each land **22***b*. It has now been found that in the preferred structure of the roll **22** this reversal of water travel is minimized by the use of a ratio of groove width **26** to land width **27** of a practical minimum of 1:2, and preferably 1:3 to a practical maximum of about 1:20 below which dewatering of the web and/or felt is unduly hampered at the press nip N–**3** (and permits a maximum practical open area of 33⅓%, but preferably an open area from about 25% to about 10% for practical purposes).

Particularly using the combination of the foregoing (groove-to-land) ratio of 1:2 or 1:3 to 1:20, lands of substantially 0.05 to 0.15 or 0.25 inch width, and grooves of 0.01 to 0.035 inch width, one obtains an unusually versatile press roll for use throughout a press assembly (e.g. at any and preferably all of the grooved roll positions indicated in the drawings hereof). Excellent results have been obtained using substantially the exact dimensions disclosed for the roll **22** (i.e. 0.025 but preferably about 0.02 inch grooves with about 0.1 inch lands). Groove depths **28** at least sufficient to carry the water load are used, and preferably the foregoing combination includes (substantially radial) groove depths of at least about 2 to 10 times the groove width, at least about equal to the land width, and at least about 0.1 inch, with maximum groove depth being defined primarily by practical considerations, although square or rounded groove bottoms not substantially deeper than about ¼ inch are generally superior to other structures for the combination of strength, cleaning and manufacturing purposes.

Within the foregoing parameters, open areas of 33⅓% (but preferably 25%), 20% and 15% (successively) may be used in the first, second, and third web presses of a machine, taking off less water at each press (e.g. 0.020 inch grooves with 0.030 inch lands typical for 20% and 0.020 inch grooves with 0.105 inch lands typical for about 16%). Using the press roll **22** of the invention in a divided press (e.g. at the positions of the rolls **13** and **15** of FIGURE 1 with a resulting nip cross section of FIGURE 9A with corresponding parts indicated by the same reference numerals in the 100 series), one obtains advantages in moisture content control and minimized felt wear, among others. One obtains superior control of the felt condition entering the web press nip with guide means **11***a*, **11***b*, **11***c* and **11***d* maintaining the felt at least substantially tangential with the nips N–**1**, N–**2**, and with additional guide means **24***b*, **14***c* separating the web W–**1** from the felt **11** at the immedi-

ate oncoming and off-running sides of the web press nip N–1 for better control of the water transfer from the web W–1 to the felt 11 and vice versa.

Another important feature of the invention, involves the use of anti-deflection mounting means, which may be used in the practice of the instant invention to advantage in the mounting of either movable or fixed rolls, although there are certain advantages in mounting the fixed rolls on anti-deflection arrangements or means. Hence, fixed rolls indicated at 13 and 22, etc. may be advantageously mounted on anti-deflecting means such as are shown in U.S. Patents, Nos. 2,648,122; 2,651,103; and 2,651,241. In addition, in my copending applications Serial No. 102,571, filed April 12, 1961, and Serial No. 154,801, filed November 24, 1961 (now, respectively, U.S. Patents Nos. 3,097,590 and 3,097,591), and also in my U.S. Patent No. 3,119,324 preferred embodiments of anti-deflection roll mounting means for such rolls are disclosed, and the anti-deflection roll mounting means involving mounting on rubber sandwiches on a through shaft as shown in my application Serial No. 102,571 are employed for mounting the rolls 13 and 22, etc. in the embodiments illustrated herein. The deflection control oil-cover shoe system of my U.S. Patent No. 3,119,324 may instead be used in the rolls 13 and 22, etc. and such structure is used in subsequently described grooved rolls 315, 313, 322, 413 433, 432 and 442 which deflection control subject matter is incorporated herein by reference.

In addition, such grooved press rolls with imperforate shells and mounted on anti-deflection means hereinbefore described, may be employed in automatic, semi-automatic or operator controlled press assemblies for varying the pressures of the various press nips and such controls may include conventional moisture content sensing devices such as the known moisture measuring (beta gauge) devices.

Referring to the grooves 22*c* which are indicated, for example, in FIGURES 5A and 5B as having a generally helical or spiral configuration (which cannot actually be shown in the views of FIGURES 5A and 5B), it will be appreciated that the spiral angle or the angle of these grooves 22 with the centroidal axis of the roll shell should be a comparatively small angle, alpha, which might be expressed for a 20 inch diameter (i.e., 10 inch radius) press roll as tangeant alpha equals approximately 0.125 divided by 10, or 0.0125. The range for tangent alpha should be within about 0.003 to about 0.03, preferably. This is also the approximate range for a plurality of (continuously parallel) helical grooves which may be conveniently cut in the roll surface simultaneously (such that the cross section would still look like that of the FIGURE 5 series); but as previously mentioned greater helical angles can be used (not only for the just mentioned purpose but also) when it is desired to have the grooves intersect from time to time as in the FIGURE 15 series.

It will be noted that in certain views herein (e.g. FIGURE 6) the grooves in a grooved roll are indicated diagrammatically by dashed lines whereas in other views (e.g. FIGURE 1) grooved rolls are indicated merely by a G centered or within the diagrammatic showing of the roll itself.

Also, in connection with the discussion of the rolls 13 and 22 and their relative covers, as described in connection with FIGURES 4 and 5, it will be appreciated that the versatility of the invention is represented therein in that the grooved covers or surfaces for rolls used in the practice of the instant invention are shown as being composed of either the resilient yieldable solid elastomer (i.e. rubber) cover for the roll 13 as well as the non-resilient, non-yieldable, durable, non-corossive stainless steel cover for the roll 13. It will be appreciated that in the case of any of the rolls used in the practice of the instant invention, which are the so-called "grooved rolls," the manufacture of such rolls involves expense substantially less than that ordinarily associated with the manufacture and installation of a suction roll, but it is still a manufacturing expense that is somewhat greater than the expense involved in the manufacture of a plain roll which is to be used as a press roll. In fact, the manufacturing expense of the instant "grooved" rolls is substantially less expensive than that of the blind drilled rolls, such as the structure indicated in FIGURE 3 hereof, even the structures are comparable in this respect in that the cover for the roll is, in each case, applied to a generally imperforate roll shell structure which is mounted on anti-deflection means and which may be mounted also with fluid actuated mounting means or other essential equipment for press roll operation. The cutting of grooves is simply less expensive and less complicated than the drilling of the blind drilled holes.

On the other hand, it will be appreciated that, in paper making press assemblies, it is ordinarily considered practical to define press nips with at least one of the rolls having a yieldable surface, so that damage to the two rolls is minimized during operation, in the event of some operating accident which might involve passage of foreign material or even a sudden change in web or felt thickness through the nip. On the other hand, it will be appreciated that the stainless steel cladding on the surface of a normal imperforate roll shell is ordinarily more expensive than a conventional rubber cover; but the stainless steel cladding is much more durable and the somewhat greater expense which might be involved in machining the grooving therein is ordinarily more than compensated for in the practice of the instant invention by the much greater wearing life of the grooved stainless steel clad roll as compared to a grooved or rubber covered roll. Thus, the grooved roll 13 would be expected to be (and, in fact, is) much more durable in its wearing characteristics and much longer lasting in life in the operation of the press assembly than the corresponding rubber covered roll 22; but the rubber covered roll 22 affords the distinct advantage of being the so-called yieldable or yielding roll that is between two rolls 21 and 22 which have comparatively non-yielding surfaces. This affords the additional advantage of the use of the grooved roll 22 in conjunction with a granite or Microrok roll 21.

Referring to FIGURE 14, it will be seen that this view shows generally what is sometimes referred to as a dual press, wherein the web W–301 is pressed first with its "wire side" against a plain roll 312 at two successive press nips defined by the successive press rolls 309 and 313 shown in FIGURE 14. An advantage of this particular type of press is that the web W–301 traveling on the wire W–300 over the suction couch roll 307 and on the wire reach between the couch roll 307 and the turning roll 307*a* has a tendency to "staple" at least partially some of the fibers of the web to the wire W–300. When the web W–301 is then removed from the wire W–300 by virtue of the suction pickup roll 308 wrapped by a suction pickup felt 311, there is a tendency for some surface irregularities to form on the underside of the web W–301, which is the side previously exposed to the wire W–300 and is referred to in the trade as the "wire side" of the web W–301. This would then be the exposed side of the web W–301 as it travels away from the suction pickup roll 308 on the suction felt 311.

In considering the movement of the suction pickup felt 311, it will be seen that it is mounted on a plurality of guide and tensioning felt rolls 311*a*, 311*b*, 311*c*, 311*d*, 311*e*, 311*f*, 311*g* and, of course, the suction pickup roll 308 already described.

The paper web W–301 is thus carried on the underside of the pickup felt 11 from the forming wire W–300 to an initial suction press nip N–309 defined by a conventional suction press roll 309 (with conventional saveall 309*a*). The suction press nip N–309 is defined between an upper suction press roll 309 and a lower but large (i.e. having a diameter substantially 1.5 to 4 times that

of the rolls 309 or 313) plain press roll 312 which may be one of granite or Micrordk, or similar porous material which has the desired degree of porosity to receive the web W–301 in the suction press nip as well as a second press nip here indicated generally at N–301, and then release the web W–301 from the downrunning side of the plain roll 312, with or without the necessity of using the so-called self-dumping doctor 312*a*. It will be appreciated that the fragmentary section, indicated at XVD—XVD through the nip N–301 is actually an upside down view of FIGURE 15A wherein the grooved roll 313 corresponds to the previously discussed (intersecting) grooved roll 200 of the FIGURE 15 series cooperating with the plain roll 310 (not shown in the FIGURE 15 series).

It will be seen that the two felt guide rolls 311*g* and 311*f* effect separation of the felt 311 from the web W–301 on the plain roll 312 except at the two nips N–309 and N–301, and these felt guide rolls 311*g* and 311*f* maintain the felt substantially tangential to the rolls 312 and 313 at the nip N–301.

Since the conventional suction roll 309 will have the effect of withdrawing some water from the web W–301 and through the felt 311, and this suction roll 309 will have the effect of retaining some of the water thus withdrawn from the felt 311, the felt 311 will exit from the suction nip N–309 in a suitable condition for operation in the following press nip N–301 which embodies in part a concept of the invention (e.g. FIGURE 15).

The press roll 313 is provided with a rubber covered surface (or a surface of equivalent solid synthetic or natural elastomer) having a plurality of axially alternating and intersecting circumferentially aligned grooves and land areas which are illustrated in the various views of FIGURES 15, 15A, 15B and 15C. The web W–301 follows the moving surface of the plain roll 312 at the off-running side of the nip N–301, while the felt 311 is quickly separated from the web W–301 at the off-running side of the nip N–301 via the felt guide roll 311*f*, and an additional saveall, indicated diagrammatically at 311*h* is associated with the felt and felt guide roll 311*f* to prevent the felt from throwing water back on to the web W–301 at the off-running side of the nip N–301.

To a substantial extent water expressed from the web W–301 and through the felt 311 at the nip N–301 will be temporarily retained in the grooves of the grooved press roll 313 and this water may then be captured in a conventional saveall 313*g* immediately after the grooved surface of the roll 313 leaves the nip N–301. In addition, a pumping type wiper *w* (here shown diagrammatically) is used to assist in further wiping or pumping water from the grooved surface of the roll 313 and into the saveall 313*g*. Also a conventional doctor *d* is mounted for operative association with the grooved surface of the roll 313 at the oncoming side of the nip N–301 to wipe the land areas clean of water just before the grooved surface of the roll enters into the nip N–301.

In the embodiment of the press nip N–301, in the practice of the invention, it will be found that there is an appreciable transfer of water from the web W–301 to the felt 311 at the nip N–301 and the felt 311 will carry a considerable amount of this water away from the nip N–301. The felt 311 thus leaving the nip N–301 contains a considerable amount of moisture and should be "reconditioned" to the extent that its moisture content is properly adjusted so that it may function most favorably during suction pickup at the roll 308.

This reconditioning of the felt is accomplished by passing the felt 311 between the two felt guide rolls 311*d* and 311*c* so that the felt will be aligned substantially tangentially with a felt only nip N–302 defined by an upper plain roll 314 and a lower grooved roll 315. The grooved roll 315 also has generally circumferentially aligned alternating grooves and land areas, such as are indicated in FIGURE 5A, and such as the roll 22 has. The grooved roll 315 is equipped with a saveall 315*g*, a pumping type of wiper *w* for drawing water out of the grooves and into the saveall 315*g*, and a conventional doctor *d* at the immediate oncoming side of the felt only nip N–302, to wipe the land areas clean immediately before entrance into the felt only nip N–302. In this arrangement, it will be seen that the felt may be reconditioned at the felt only nip N–302 and thus placed in the desired condition of moisture content and the like so that it will function in the proper manner at the suction pick-up roll 308.

The web W–301 is taken off the downrunning side of the large plain roll 312 through a very short open draw, beneath a guide roll 324*aa* and pasted or run on to a traveling felt 323 spanned between guide rolls 324*a* and 324*b*, so that the felt 323 may carry the web W–301 through a third press nip N–303 defined by a press indicated generally by the reference numeral 320 but shown in substantial detail in FIGURE 14 hereof (and using reference numerals in the 300 series to indicate parts corresponding to those described in FIGURE 6 in the twenty series of reference numerals). It should be noted that the paper guide roll 324*aa*, however, performs an important function in guiding the web, without damage through fluttering, etc. directly onto the felt 323.

The press 320 is defined by a plain roll 321 and the indicated lower roll 322, which is a grooved roll having a distinctly improved and superior groove to land relationship, as indicated in FIGURES 5A and 5B.

Referring now to FIGURE 14A, it will be seen that there is shown therein an arrangement differing from that of FIGURE 14 in a number of significant respects, but elements having the same or substantially the same functions as those shown and described in connection with FIGURE 14 are indicated in FIGURE 14A with the same reference numerals in the 400 series. It will be seen that the felt arrangement is designated by the 411 series. It will also be noted that the large plain press roll 412 now defines successive press nips N–401′ and N–401 with successive grooved rolls 413′ and 413, which grooved rolls in this instance have the general groove-to-land relationship hereinbefore discussed in detail in connection with the roll 22. The only difference in this instance being that the first grooved press roll 413′ has approximately a 25% open area and the second grooved press roll 413 has approximately a 20% open area, while a third press indicated generally by the reference numeral 430 is defined by an upper plain roll 431 and a lower grooved roll 432 wrapped by a felt 434, with this lower grooved roll 432 having again the general land-to-groove relationship hereinbefore described in connection with the roll 22 and the FIGURES 5A and 5B, but in this case having an open area of only 15%, since it is necessary to remove less water at this last nip here designated N–410. It will further be seen that FIGURE 12 hereof shows in detail the press 430. The press 430 may be completely substituted by a press 120 which is shown in greater detail in FIGURE 11 hereof.

It should also be noted that the return run of the felt 411 at the oncoming side of the suction roll 408 is reconditioned by still another grooved roll press 440, wherein the grooved roll 442 is the upper roll of the press. In this instance the upper side of the felt 411 passing through the felt only nip N–408 of this press 440 is the side of the felt which has been in contact with the paper web W–400 and this is the side of the felt which may contain fibers, clay, filler, etc. and it is this side of the felt 411 which is preferably cleaned and conditioned most advantageously by exposure to the grooved surface 442 of the grooved roll in the felt only press nip N–408. FIGURE 8 hereof shows in substantially greater detail the felt only press nip N–8 corresponding to the nip N–408, but it will be seen that FIGURE 8 shows a view taken from the opposite or back side of the machine as com-

pared to the view shown in FIGURE 14A. In other words, the direction of roll rotation and felt travel shown in FIGURE 8 is opposite to that indicated in FIGURE 14A only because the view of FIGURE 8 is taken from the opposite side of the machine.

The movement of water in the direction thus indicated is preferred for the reason that the roll 442 is operating against the outer peripheral surface of the felt and thus the surface of the felt 411 which actually engaged the web at the earlier web nip and may thus have a tendency to pick up clay, fibers and the like. Conditioning as well as dewatering of the felt is thus accomplished most advantageously by movement of water at least to a substantial extent from the interior of the felt 411 peripherally outwardly to the grooves of the roll 442, to wash the outer peripheral face of the felt clean. A limited amount of dewatering in the opposite direction is, of course, not harmful (e.g. at N–411 of FIGURE 14A) and has advantages in that a certain amount of conditioning of the inner peripheral surface of the felt loop is also desired.

Another aspect of the instant invention resides in the control of nip pressures not only at the first, second and third web press nips (i.e. N–405, N–401 and N–410, respectively of FIGURE 14A) but also in control of the nip loads between a web press and the felt only press associated therewith in a divided press structure. Thus, it is preferred in the practice of the instant invention to employ an initial nip load at the nip N–405 (of FIGURE 14A) of about 200 pounds per lineal inch, and using an open area of about 25% on the roll 413', so that maximum dewatering takes place without the use of maximum nip loads on the initial relatively delicate web. Next, at the second web press nip N–401, a higher nip load of 300 pounds per inch is used. Likewise, an open area of only about 20% in the grooved roll 413 is preferably used, as indicated in the arrangement described in connection with FIGURE 9. It has previously been pointed out that the arrangement of FIGURE 9, which was described initially in connection with the roll 13, was described for purposes of showing one aspect of a grooved roll divided press arrangement embodying the instant invention and it was described initially for purposes of comparison with the superior operation of rolls having superior land to groove relationships such as the rolls 22, etc. Nevertheless, the nip loads at the nips N–401 and N–408 will require that the felt only nip load N–408 should be at least as great as the nip load N–401 and preferably greater. The nip load used at N–408 is 325 pounds per inch. In FIGURE 14, the nip load at N–302 is also 325 pounds per lineal inch (using a nip load of 300 pounds per lineal inch for the corresponding web press nip N–301); whereas the load at the nip N–401 in the divided press of FIGURE 14A is about 450 pounds per inch, using a web press nip load of 425 pounds per inch at N–410, for the reason that all of the ultimate mechanical dewatering must take place via the grooved roll 432, using about 15%, or even 10%, open area to minimize rewetting, and the entire felt dewatering and reconditioning takes place partially by virtue of the presence of the grooves on the face of the roll 432, but primarily by virtue of the grooves on the roll 433, which is employed with an open area of 20%. In such instances, the third web press nip N–303 of FIGURE 14 may be operated using about 400 p.l.i. and 16%–18% open area as the sole means for removing water from the web and felt, or this third press nip N–303 may be operated using a structure that is identical to the press structure 420 hereinbefore described in detail.

The advantages of the present invention, in that a grooved roll may be substituted (position-wise) for a suction roll in a number of different positions (but with a vast number of unique and distinct advantages), will be readily appreciated when one considers that the suction roll, because of the perforate suction roll shell and the necessary auxiliary equipment for suction rolls can be mounted for the purposes of resisting deflection only by complicated and expensive mounting mechanism, if at all. Thus, in particular, in the case of the press couple 20, a perforate suction roll in the position of the grooved roll 22 would necessarily have limitations in its operation with respect to the application of a uniform (axially applied) nip load, even though the average nip load employed at the first web press nip N–3 is comparatively low. It will further be appreciated that as the nip loads are increased, the advantages of the grooved roll become more and more apparent, for the reason that the suction roll has definite limitations in connection with the application of uniform nip loads axially at high average nip loads. Thus, if a grooved roll is used to replace the roll 322 at the underside of the third nip N–303 of FIGURE 14, in the manner already described, the distinct advantage of the grooved roll over a suction roll will become readily apparent at the high nip loads used. Additionally the grooved roll 322 is used with the previously described anti-deflection and/or deflection control means acting against the interior of its sturdy impermeable roll shell (in a manner not feasible with the perforate suction roll shell) so as to obtain unique uniformity of cross-machine nip load, even at extremely high nip loads.

Referring again to FIGURE 14A, it will be seen that a third web press N–410 is shown as being defined by substantially the same elements as are used for the first press 130 in FIGURE 12 and elements corresponding in structure and function to those shown in the press 130 of FIGURE 12 are designated in FIGURE 14A by the same reference numerals in the 400 series except, of course, that the web nip is designated N–410 and the felt only nip is designated N–411. The function and operation of the third press 230 is substantially the same as that previously described for the press 130 of FIGURE 12, except for the anti-deflection mounting applying couples at the quarter points for the rolls 432 and 433, and the structures of the doctors. In the usual position for mechanical doctors for the middle roll 432, there are air-doctors *ad* or axially continuous air-blast "knives" which wipe the water from the land areas. These air-doctors *ad* are connected to sources of compressed air, for example, as indicated diagrammatically at S_a. In addition, still another fluid pressure or fluid blast knife *wd* is used in the mechanical doctor position for the roll 433, but this axially continuous fluid blast is in the form of a high pressure water blast (connected diagrammatically to a high pressure water source S_w) which when aimed as shown, much like an air knife, actually drives water droplets from the lands and leaves the lands on the roll 433 substantially dry going into the nip N–411. The saveall 433*g* readily handles the water blast, or may be enlarged to do so.

One difference with respect to the roll 325 in FIGURE 14 is that this roll is equipped with the anti-deflection or deflection control means of my U.S. Patent No. 3,119,-324, which affords excellent nip load control across the width of the machine. Also it has been found helpful to employ a paper guide roll 324*aa* to minimize web movement or "fluttering" at high speeds by controlling web movement directly from the bare roll 312 onto the felt 323, in the region of the felt guide roll 324*a*; but such paper guide rolls 324*aa* function essentially to guide the web and do not carry out any press nip function with the associated felt guide roll (in this case 324*a*).

One of the problems in web pressing is avoidance of "crushing" of the web which is perhaps a poorly chosen but very meaningful word of the art—actually meaning "incipient fracture" of the web—caused by excessive, poorly directed water flow in the web at the nip. Thus, referring to FIGURE 4, it will be seen that at the oncoming side of the nip N–1 the pressure Po in the web as well as the felt or porous belt 11 is nominal (i.e. about 15 pounds per square inch absolute); whereas at the middle

(or cross-machine center line) of the nip N–1 the pressure P*m* is at a maximum (usually at least as great as the nip load in pounds per lineal inch or greater because the longitudinal dimension of the maximum nip load is often less than 1 inch); and, of course, at the off-running side of the nip N–1 the expanding felt **11** tends to create a sub-atmospheric (or vacuum) pressure P*v* (e.g. from about 2 to 5 pounds per square inch absolute) depending to a great extent on the ability of the porous felt or belt **11** to receive ambient atmosphere (since the pressed web W–1 is substantially non-porous in this condition).

Generally in "crushing" P*m* is so much greater than P*o* that in the case of a substantial total water load entering the nip N–1 there is created a flow of water in the web from P*m* toward P*o* and this results not only in the visible collection of water as a pool at the oncoming side of the nip but also in a web product which will have many small cross-machine "cracks" or incipient fractures that can be observed in the final product. The grooves **13***c*, however, being vented to ambient atmosphere afford the easiest water flow path (backward and forward) in the nip, so even though the pools of water may be evidence in the present press nips, crushing of the web can be avoided because there is an avoidance of undesirable water flow in the web itself.

Referring to FIGURE 5B, it will thus be seen that the maximum pressure P*m* actually occurs only at the machine direction center line M of each land area **22***b* (generally along the cross-machine center line of the nip N–3) and the minimum or nominal pressure P*o* is actually very closely adjacent thereto (along the cross-machine center line of the nip N–3) so that the net effect of the pressure application at the nip N–3 may appear to be the same (or greater, depending upon the particular press position) nip load in pounds per lineal inch but the water flow from the moist web W–6 to the porous felt or belt **23** is essentially a non-crushing, normal or perpendicular to the plane P—P flow, with reference to the plane P—P between the web W–6 and the felt **23** (for example as shown in FIGURES 4 and 5A). There is no "crushing" flow of water in the web along the plane P—P in the direction P*m* toward P*o*, nor is there in the nip N–3 of FIGURES 5A and 5B. Moreover, the extremely small axial dimension **27** of the lands **22***b*, **22***b* of FIGURE 5B avoids any cross-machine "crushing" flow of water in the web in the direction indicated as P*m* toward P*o*. Instead, in FIGURE 5B, there is presented a felt **23** which has theoretically a low "average" pressure of ½ of the total of P*m* plus P*o* to readily receive water generally normal to the plane P—P at the web-felt interface, followed by a flow of water to a limited extent only within the felt **23** and for the limited dimension **27½** in the direction previously indicated. This affords an advantage of extremely high press nip loads, in pounds per lineal inch, when desired, without crushing.

It should also be noted that, even assuming that, in FIGURE 5B, P*m* is equal to such desired high nip loads as 100, 200, 300 or even 450 pounds per lineal inch (although P*m* in pounds per square inch will probably be much higher often because the longitudinal dimension of maximum nip pressure P*m* is usually less than 1 inch), the driving force against the water is P*m* minus P*o* which is usually in the range of several hundred pounds per square inch. The time this driving force is applied is very brief (i.e., for a machine speed of about 3000 feet per minute and an oncoming nip side of perhaps ½ inch, such time being approximately 6×10^{-4} second) but the driving force is so great and the maximum water travel path **27½** so small that substantially all of the water is almost instantly driven into the deep grooves **22***c*, with substantial avoidance of a web crushing pressure gradient in the nip plane P—P either longitudinally or in the cross-machine direction. In particular, the very narrow (axially) lands **13***b* and **22***b* between narrow (but appropriately large) grooves **13***c* and **22***c* make the physical phenomenon possible. Hence axial land widths particularly for higher speed machines, in the neighborhood of 0.05 to 0.15 up to 0.25 (and preferably 0.08 to 0.1 inch) are important.

The groove dimensions are also important in that 0.025 may be ideal for a given press whereas a reduction to 0.02 for the width **26** in FIGURE 5B in the same press has actually been found to produce a distinct reduction (or substantial elimination) of evidence of marking in certain webs, thereby demonstrating the criticality of superficially very small dimensional changes in this aspect of the structure.

Still another extremely important aspect of groove structure is the cross-sectional area or volume, which has already been expressed in terms of the mouth width of "*x*" as a practical minimum of twice the square of the mouth width (i.e. at least $2x^2$) and preferably four to five times the square of the mouth width. This volume is not necessarily so much for merely the desired capacity to receive water but more for the necessary ability to vent to the ambient atmosphere and maintain P*o* at substantially ambient atmospheric pressure of 15 pounds per square inch absolute. In pulp making machines, wherein the speeds are relatively slow and the water loads relatively high, the grooves actually function very satisfactorily as "flow troughs" using the dimensions of 0.02 to 0.25 inch groove mouths with a normal machine taper (e.g. about 7%) to a depth **28** of only 0.06 inch, i.e., a cross sectional area of two to three times the square of the mouth width (whereas the groove dimension in the machine direction is theoretically infinite). It is important to consider the groove volumes (i.e. which are conveniently given a numerical value in terms of cross sectional areas) on the basis of the groove mouth width "*x*" because shallow tapered grooves may be incapable of the necessary venting function and/or the necessary ability to resist the tendency for the felt to reabsorb all of the water in the grooves at the off-running side of the press nip.

The groove mouth width **26** has still another very important function, often expressed in terms of open area, and this pertains to the overall resistance to water return from the grooves to the subatmospheric felt at the off-running side of the nip. Again, using the previously described operating conditions, it will be appreciated that, during the very brief period of approximately 6×10^{-4} second in which the felt expands at the off-running side of the nip (cross-machine center line), the driving force P*o* minus P*v* or about 10 to 12 pounds per square inch tending to return water from the grooves to the absorbent felt is comparatively mush less than the several hundred pounds per square inch driving force pushing the water into the grooves of the oncoming side of the nip during a substantially equal time interval. Additional unfavorable factors include the effect of centrifugal force and the effect of perhaps a longer time interval (since it is difficult to separate the felt from the grooved roll surface at the very instant that the nip pressure is relieved); but all of these unfavorable factors are more than counteracted by (a) the very great difference in actual driving forces, (b) the reasonably rapid removal of the felt from the grooved roll surface, and (c) the water travel path, since the water must travel (1) first generally normally to the felt plane toward the groove mouth for (2) a rather substantial distance, particularly in the case of the water at the bottom of the deeper grooves, past closely adjacent groove walls tending to resist water movement both by (3) frictional drag and (4) molecular or capillary-like attraction between the water and the groove wall material and then through (5) a right-angle turn for (6) still another substantial distance **27½** shown in FIGURE 5B to the center line of the land area. Water removal is thus effected at conventional higher machine speeds and lower open areas here specified simply because the off-running time interval is wholly insufficient to permit the felt to withdraw all of the water from the grooves—or even, for that matter, to permit creation of equilibrium or balanced

water conditions between the felt and grooves (which would allow for the retention of some water in the grooves anyway).

At slower operating conditions using the same structures, even if equilibrium conditions were reached, the grooves must hold and carry off substantial quantities of water. And at even slower conditions such as were indicated as a possibility with a pulp machine the comparatively larger land areas afford the necessary nip pressure application whereas the comparatively (axially) smaller grooves afford vented, free flow of water away from the nip and out of the system into conventional receptatcles in any case, water removal is thus effected.

It will thus be seen that the shallow and/or sharply tapered grooves, having semicircular or triangular cross sectional areas which are functionally significantly below about twice the square of the groove mouth width in cross sectional area are either incapable of satisfactory venting, satisfactory resistance of return of water to the absorbent felt at the off-running side of the nip, or both. The suggested minimum of $2x^2$ is practical as well as functional, since it is conceivable that certain principles of the invention could be followed, for example, using so-called "shallow" grooves having the "general" cross section of perhaps an equilateral triangle (and hence a cross sectional area of only $\frac{1}{3}x^2$) but with a relatively deep but very narrow and hence small volume slot of only perhaps 0.002 inch width extending radially inwardly from the apex of such triangle; but such slot would have to have some functional volume because this would constitute essentially the only volume of water not reabsorbed by the felt from such shallow grooves in the normal operation, and again in slow operation the slot would still require some volume to afford the required venting function (and to this end continuous cleaning to keep the slot functional would be difficult or impractical). The grooves have already been described as requiring substantial depth to accommodate these essential functions.

Occasional cross-machine slots on the lands (and/or conduits beneath the land surfaces) interconnecting the generally circumferential grooves would not be precluded by the basic principles of the invention, but such structures are not preferred primarily because whatever useful function they might have would ordinarily be impaired by practical considerations relative to maintaining such structures clean. In ordinary operation, for example, the cross-machine slots on the lands would probably fill up quickly and unless continuously cleaned by additional auxiliary equipment such as brushes, water jets and the like, functionally continuously cylindrical lands would result. In any event, whatever type of groove structure attempted (other than the hereinbefore described substantially circumferential structure) would be subject to the same basic limitations of groove width, open area, depth, cross sectional area and general contour hereinbefore described, plus the added requirement of rotary brushes, water jets or other generally less preferred auxiliary equipment for continuous cleaning.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of the present invention.

I claim as my invention:

1. In a paper machine press section, in combination, a looped traveling moist felt, a first press roll, a second press roll engaging the felt defining with said first press roll a press nip for receiving the felt, said second press roll having a generally cylindrical press roll shell mounted for rotation about its centroidal axis and positioned to press a peripheral rotary surface portion thereof against said felt, said surface portion having alternating generally circumferentially aligned grooves and ridges, said grooves having a narrow axial dimension at the roll periphery for receiving water pressed from the felt but also tending to resist flow of water out of the grooves, said ridges each presenting a generally cylindrical outer peripheral land area, generally axially continuous doctor means close to the nip for removing water from said land areas at the oncoming side of the nip during rotation of the roll, and guide means positioned relative to a common tangent plane for the first and second rolls for maintaining the moist felt on the side of said plane of the first roll at both the oncoming and off-running sides of the press nip, whereby the felt may have a minimum amount of travel within said grooves, the grooves having an axial dimension at the roll periphery of 0.005 to 0.035 inch and extending radially inwardly to impart to the cross sectional area of each groove a value substantially equal to at least twice the square of the aforesaid groove axial dimension, and the peripheral land areas on said grooved press roll having an average axial dimension that is at least twice the groove axial dimension.

2. In a paper machine press section, in combination, a looped traveling moist felt, a first press roll, a second press roll engaging the felt defining with said first press roll a press nip for receiving the felt, said second press roll having a generally cylindrical press roll shell mounted for rotation about its centroidal axis and positioned to press a peripheral rotary surface portion thereof against said felt, said surface portion having alternating generally circumferentially aligned grooves and ridges, said grooves having a narrow axial dimension at the roll periphery for receiving water pressed from the felt but also tending to resist flow of water out of the grooves, said ridges each presenting a generally diamond-shaped outer peripheral land area, generally axially continuous doctor means close to the nip for removing water from said land area at the on-coming side of the nip during the rotation of the roll, and guide means positioned relative to a common tangent plane for the first and second rolls for maintaining the moist felt on a side of said plane of the first roll at both the on-coming and off-running sides of the press nip, whereby the felt may have a minimum amount of travel within said grooves, the grooves having an axial dimension at the roll periphery of 0.005 to 0.035 inch and extending radially inwardly to impart to the cross-sectional area of each groove a value substantially equal to at least twice the square of the aforesaid groove axial dimension, the peripheral land areas on said grooved press roll having an average axial dimension that is at least twice the groove axial dimension, thereby presenting a rotary surface portion with an average effective open area of not more than substantially 33⅓%.

References Cited by the Examiner

UNITED STATES PATENTS

1,321,956	11/19	Wagner	100—112
1,483,562	2/24	Wagner	162—358
1,517,036	11/24	Wagner	29—121
1,520,489	12/24	Wagner	29—121
1,552,098	9/25	Wagner	29—121
2,858,747	11/58	Wagner	162—361

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