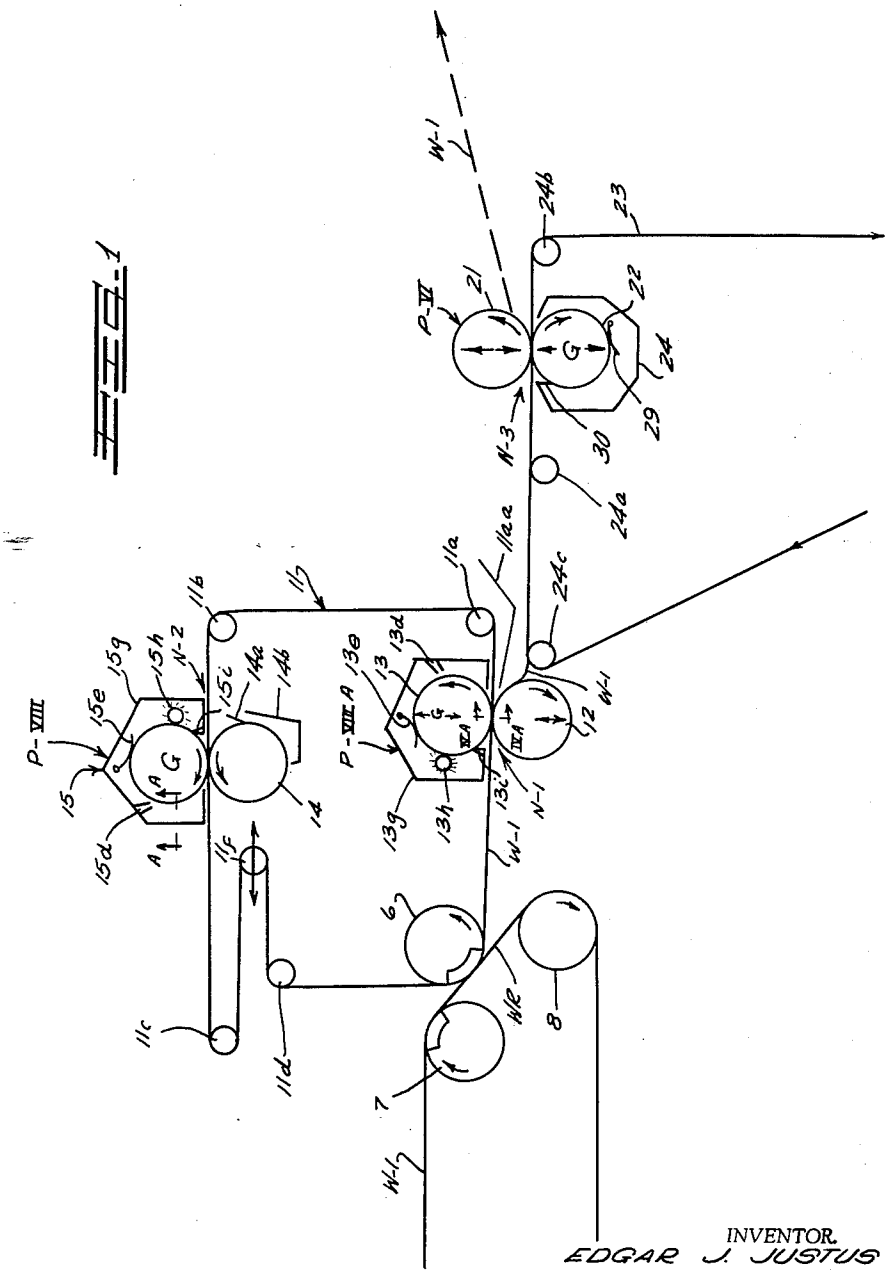
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MULTIPLE GROOVED ROLL PRESS ASSEMBLIES

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FIG. 1



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MULTIPLE GROOVED ROLL PRESS ASSEMBLIES

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FIG. 1A

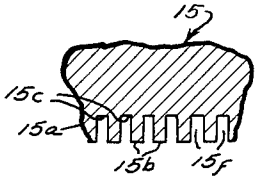


FIG. 2
(PRIOR ART)

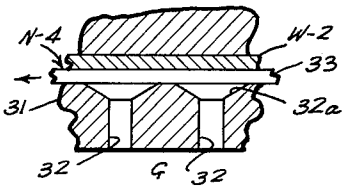


FIG. 3
(PRIOR ART)

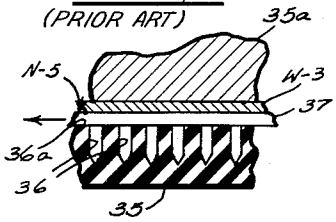


FIG. 4

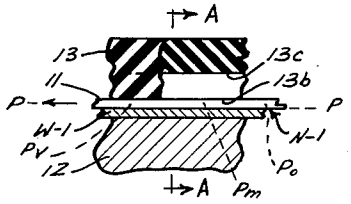


FIG. 4A

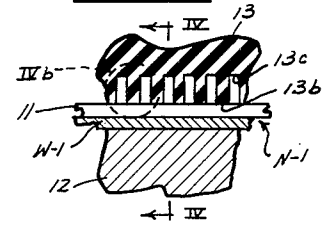


FIG. 4B

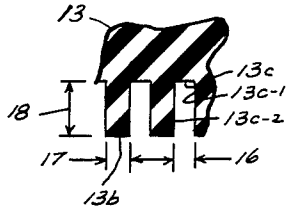


FIG. 5A

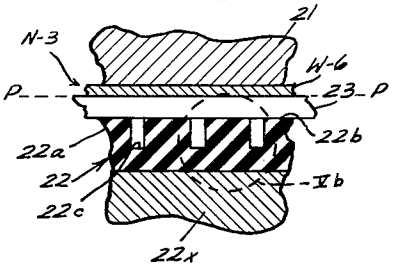
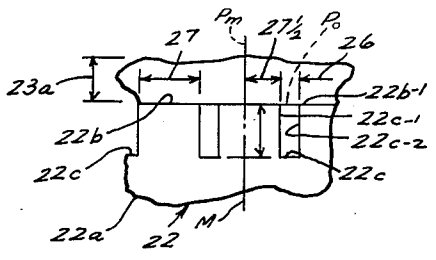


FIG. 5B



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MULTIPLE GROOVED ROLL PRESS ASSEMBLIES

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FIG. 6

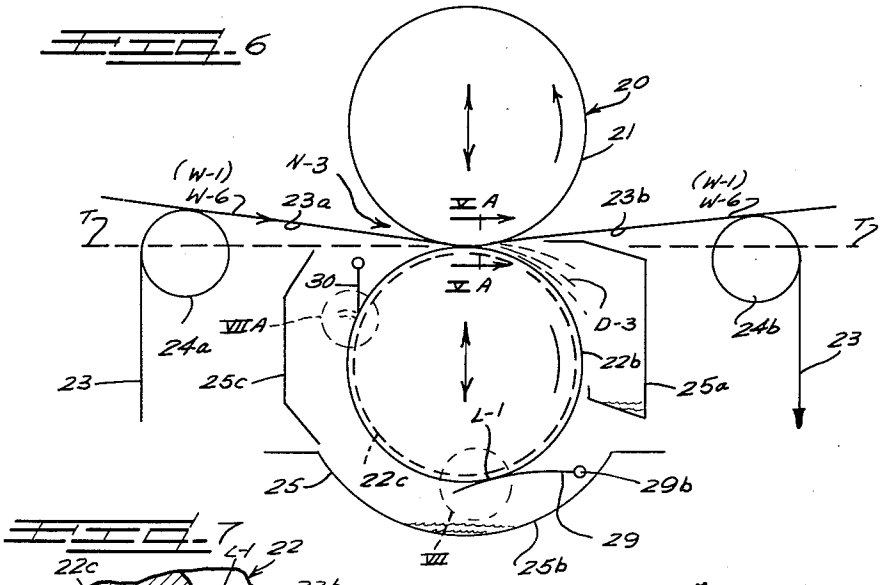


FIG. 7

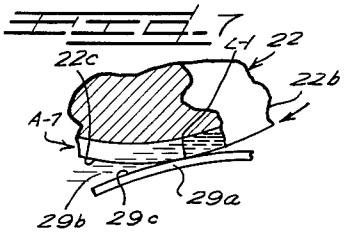


FIG. 7A

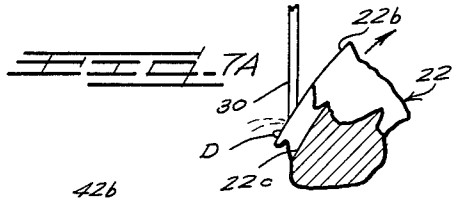
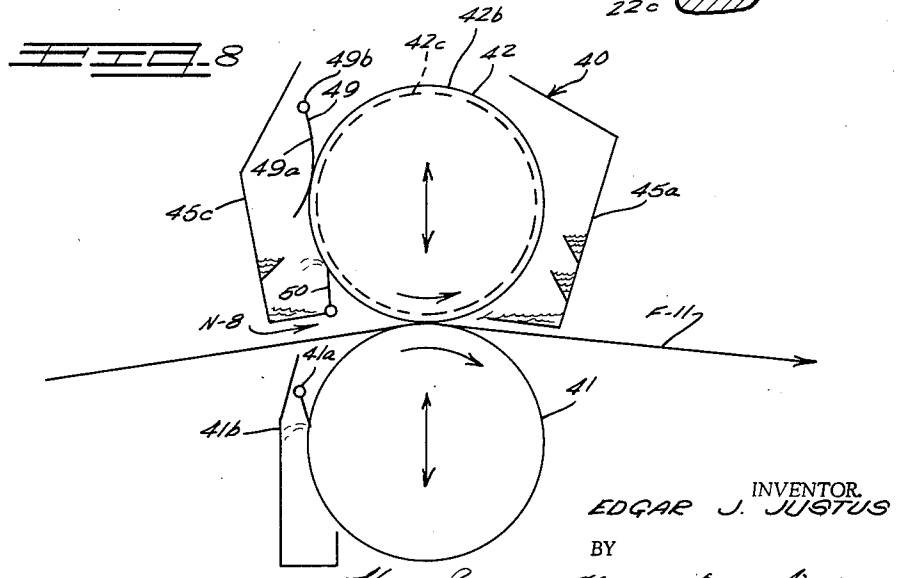


FIG. 8



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MULTIPLE GROOVED ROLL PRESS ASSEMBLIES

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FIG. 10

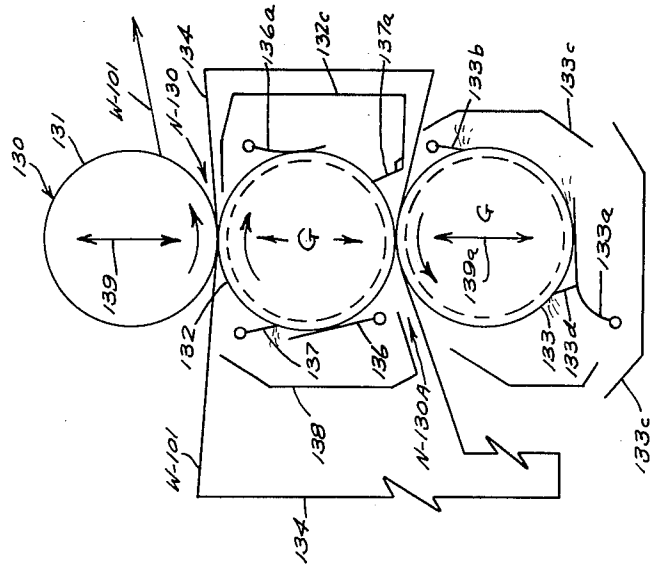
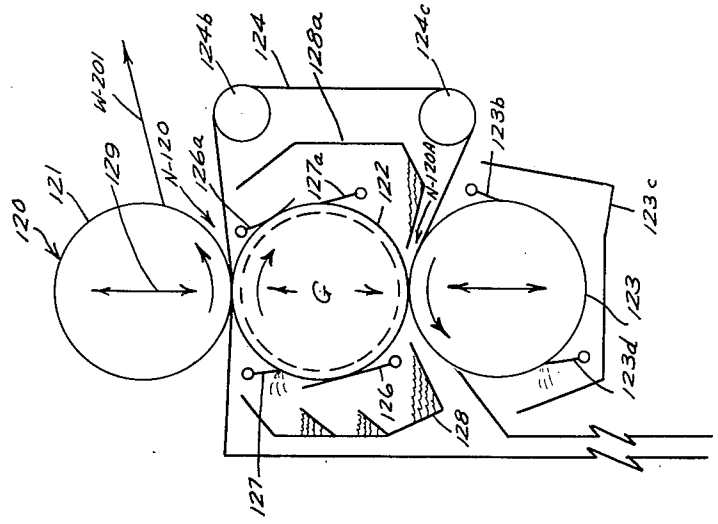


FIG. 9



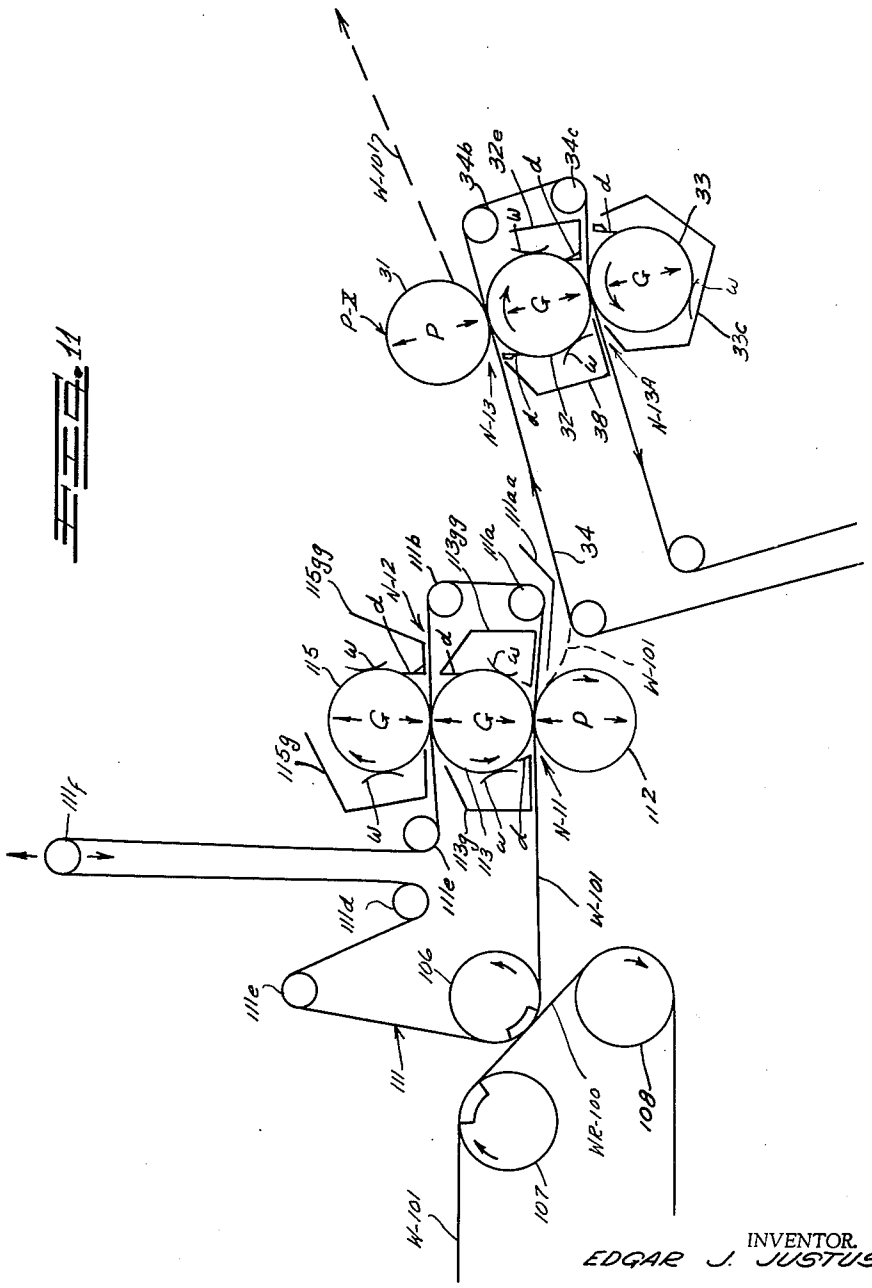
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MULTIPLE GROOVED ROLL PRESS ASSEMBLIES

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FIG. 11



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United States Patent Office 3,198,696 Patented Aug. 3, 1965

3,198,696

MULTIPLE GROOVED ROLL PRESS ASSEMBLIES

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

Filed Aug. 15, 1963, Ser. No. 302,423
1 Claim. (Cl. 162—360)

This is a continuation-in-part of my application, Serial No. 214,589, entitled "Divided Press," filed August 3, 1962, and my application Serial No. 258,391, entitled "Press Roll and Assemblies," filed February 14, 1963, both now abandoned.

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.

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 potion 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 applications Serial No. 214,589, filed August 3, 1962, and Serial No. 258,391, filed February 14, 1963, 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 light-weight 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.

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 elavational view taken substantially along the line A—A of FIGURE 4;

FIGURE 4B is a sectional fragmentary enlargement taken substantially at the encircled portion designed 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 in FIGURE 5A;

FIGURES 6 and 8 are essentially diagrammatic elevational views of press assemblies embodying the instant invention (with FIGURE 6 being taken from the front side of press assembly and FIGURE 8 being taken from the back side);

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

FIGURES 9 and 10 are essentially diagrammatic elevational views of divided press assemblies embodying the instant invention; and

FIGURE 11 is an essentially diagrammatic elevational view of an improved press assembly embodying the instant invention.

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 pick up press felt **11** mounted on guide rolls **11***a*, **11***b*, **11***c*, **11***d*, and a tensioning roll **11***f*. A first plain press roll **12** and a second upper 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 suction pickup roll **6** within the felt loop **11** picks the web W–1 from a wire run WR between a suction couch roll **7** and a turning roll **8** and transfers the web W–1 to the first nip N–1 so that the wire side of the web W–1 is first pressed against the plain roll **12**, and then goes on to the second press indicated at P–VI. A third press roll **14** and a fourth upper 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 aforesaid 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 relatively 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 wiper **15***e* preferably not fitting into the grooves **15***c* and operating in conjunction with the water jet **15***d* to sweep and/or pump water, etc. out of the grooves **15***c*. 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*, but preferably a plain doctor blade, peripherally spaced from the brush **15***h* completes the removal of moisture from the land areas **15***b*. 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 oncoming 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.

It connection with the roll **13**, it will be seen that there is also provided a water jet **13***d* at the up-running side of the roll **13** preferably cooperating with a wiper **13***e* (at the off-running side thereof) preferably not fitting into the grooves on the surface of the roll **13**. A save-all **13***g* is also provided and at the down-running side of the roll **13**, suitable brush means **13***h* and an air jet or air doctor **13***i* but preferably a mechanical 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 saveall **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 lower roll **12**, the upper 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 lower roll **12**, the upper 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

13c each have a very small or narrow axial dimension 16 at the mouth or peripheral portion thereof aligned with the generally cylindrical exterior surfaces 13b 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 13c at the outer periphery or mouths thereof. It will also be seen that the grooves 13c are defined between generally radial walls 13c–1 and 13c–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, which shows in greater detail the press P–VI of FIGURE 1, it will be seen that (the web runs W–1 and W–6 in the two views are not identical, hence the different reference numerals, and) 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 24a and 24b, which felt 23 travels with the web W–6 in contact therewith at the oncoming 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 25a, 25b and 25c.

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 22a on an imperforate ductile iron shell 22x. The cover 22 may and preferably in certain case is formed of stainless steel which will also permit the cutting of fine grooves 22c between land areas 22b, in the dimension and configuration shown in FIGURES 5A and 5B. Referring more specifically to FIGURE 5B, it will be seen that the cover 22a of the grooved roll 22 is indicated in a view without section lines for ease in detailing the description thereof. The grooves 22c are here shown having a substantially uniform axial dimension 26 that is 0.025 inch between generally cylindrical (smooth) land areas 22b on ridges alternating with the grooves 22c, with such land areas 22b 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 22c 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 22c is defined between generally radially extending, parallel walls 22c–1 and 22c–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 under-cutting the land areas 22b), so that water entering the peripheral mouths of the groove 22c will not be restricted in its flow radially inwardly in the groove 22c.

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 22c 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 25a 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 22c at the immediate off-running side of the nip N–3. The grooves 22c 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 22c to resist the release of water from the roll 22 because of centrifugal force is at least partly overcome and the saveall portion 25a 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 22c 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 29a secured to a transverse cross bar 29b and urged as a continuously transverse sheet against the land areas 22b on the periphery of the roll 22. The wiper sheet 29a thus does not enter into the grooves 22c 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 22c (which is actually swept out of the grooves 22c 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 gravitational forces at the down-running side of the grooved roll 22 is thus substantially swept out of the grooves 22c and to a substantial extent into the second, bottom saveall portion 25b.

Some of the water thus drawn from the grooves 22c remains on the land areas (as a menicus), 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 22b of the uprunning side of the grooved roll 22, and such water on the land areas 22b 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 25c feeding into the bottom saveall portion 25b. 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 coacts with the land areas 22b 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 22b 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 22b into the bottoms of the grooves 22c, 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 22b 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 embodiment 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 Schaaning and was directed to a grooved press roll allegedly intended to replace felt covered rolls and having grooves of such configuration that Schaaning 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.

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; 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. at least about ¼ inch in diameter 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_s extending the full width of the roll shell **31** interiorly opposite the nip N–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_s 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_s 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 N–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_s 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_s 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 known 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 ¼ 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 avoid or eliminate the "shadow marking" characteristic of the performance of certain perforate suction rolls. 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* inbetween 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 ⅛ or ¼ of an inch in diameter 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 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 ⅛ inch) and preferably for substantially the entire groove radial dimension **18, 28**. It will thus be seen that a minimum groove cross sectional area may be computed as $2x^2$ on the basis of the example of 0.025 inch groove width "x" and 0.050 inch groove depth, although a greater area is preferred in the neighborhood of $5x^2$ for a depth of 0.125 inch. This concept would permit interior groove axial dimensons greater than the mouth axial dimension **16, 26**, 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 a taper between the walls of relatively deep grooves, such that the walls would be functionally parallel (for the operating purposes described) in the region of the grove 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 mid-point 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 ½ 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 ⅛ 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* (that is contacted, touched or, in the language of the art "covered" or "wrapped" by the felt **23**). 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 ⅛ 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 undesirable temporary entrance of the felts of most 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 excellent results are obtained using a groove axial dimension of substantially 0.025 inch, although more recent work indicates a distinct preference for 0.020 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 as to 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 aforsaid 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 pheriphery 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 designed 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 unecessary 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 now 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 a 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 de-

vices 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 tendancy 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 FIG. 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 1:1 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%.

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 the minimizing re-wetting of the felt at the off-running side of 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. FIG. 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 maximum of 1:3 to a practical minimum of about 1:20 below 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 0.35 inch width, one obtains an unusually versatile press roll for use throughout a press assembly (e.g. as in FIG. 13). 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 1/4 inch are generally superior to other structures for the combination of strength, cleaning and manufacturing purposes.

Within the foregoing parameters, open areas of 15 to 25% may be used in the first web press of a machine and 10 to 20% in the second press of the machine (e.g. 0.020 inch grooves with 0.105 inch lands typical for 16% and 0.020 inch grooves with 0.080 inch lands typical for 20%), taking off less water in successive presses. 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* and the suction pickup roll 6 maintain the felt at least substantially tangential to the rolls at the nips N–1 and N–2, to obtain the advantages already described. It should be mentioned that at the off-running side of the nip N–1 the web W–1 follows briefly the down-running side of the plain roll 12 whereas the felt 11 is separated therefrom immediately at the off-running side of the nip N–1 by the guide roll 11*a* and in order to avoid any tendency in the felt 11 to re-wet the web W–1 by throw-

ing off water in this region, a conventional save-all **11***aa* is employed between the web W–1 and the felt **11** at the immediate off-running side of the web press nip N–1.

The web W–1 then passes on to the second web nip N–3 which is operated at an open area in the embodiment of FIGURE 1 of approximately 16% for the grooved roll **22**.

Referring now to FIGURE 8, which shows essentially the press P–VIII of FIGURE 1 from the back side of the machine shown in FIGURE 1, with certain parts thereof not being identical to the showing of FIGURE 1, hence the different reference numerals, it will be seen from FIGURE 8 that the press, indicated generally by the reference numeral **40** defines a nip N–8 which receives the felt (here designated F–11) in a felt only press nip N–8. 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 slight amounts of water from the felt F–11 and the bottom roll **41** is cleaned by a doctor **41***a* at the oncoming side of the nip N–8, such doctor **41***a* being mounted in operative association with a saveall **41***b*.

As in the case of the press **20** of FIGURE 6, both the upper and lower rolls **42** and **41**, respectively, in FIGURE 8 are mounted on anti-deflection mounting means and either one is mounted also with fluid pressure actuated moving and/or nip loading means. Such fluid pressure actuated means are well known in the art and need not be described in further detail herein. In general, one of the rolls (preferably in this case the grooved roll and each of the nips N–3 and N–8 which has the additional auxiliary equipment) will be mounted in a relatively fixed position whereas the other will be mounted on the fluid pressure actuated means for movement and control of nip loading.

Both of the rolls are, however, mounted on anti-deflection mounting means (not shown) which are also now well known in the art. For example, such anti-deflection mounting means are shown in U.S. Patents No. 2,648,-122; 2,651,103; and 2,651,241. In addition, in my co-pending applications Serial No. 102,571, filed April 12, 1961 now Patent No. 3,097,590, and Serial No. 154,801, filed November 24, 1961, now Patent No. 3,077,591, preferred embodiments of anti-deflection roll mounting means for such rolls are disclosed, and the antideflection roll mounting means employed in the practice of the instant invention involve the rubber sandwiches on a through shaft as shown in my application Serial No. 102,571 for mounting each of the rolls shown herein with double headed arrows to indicate the same diagrammatically within the circle of the diagrammatic showing of the roll itself. Such double headed arrows also indicate in connection with any given press couple that at least one if not both of the rolls employed in defining the press couple is a roll mounted on fluid actuated moving and pressure loading means of conventional structure.

It will also be seen that in the case of the view such as that of FIGURE 6, the grooves in the roll **22** are indicated by the dashed circular line **22***c*, which merely represents the presence of the grooves diagrammatically; whereas in other views of the invention (e.g. FIGURE 1) the grooved rolls are indicated diagrammatically merely by the use of a G centered on the showing of the roll.

Referring again to FIGURE 8, it will be seen that the felt run F–11 is shown in FIGURE 8 as being guided so as to clearly run at both the oncoming side and the off-running side in planes below what would be a common tangent plane between the rolls **41** and **42**, so that there is minimum contact between the felt **11** and the grooved surface of the roll **42**, all as previously described in greater detail in connection with the press **20** of FIGURE 6. In addition, it will be seen that at the off-running side of the nip N–8 a save-all section **45***a* is mounted in close running relation to the uprunning grooved surface of the roll **42** in order to catch droplets of water thrown therefrom and prevent the same from re-wetting the felt F–11 leaving the nip N–8. At the down-running side of the grooved roll **42**, it will be seen that a pumping type wiper **49** is shown for pumping water out of the grooves into the save-all section **45***c*, and at the immediate oncoming side of the nip N–8 a conventional doctor **50** is shown for wiping the land areas dry. Again, the doctor **50** is positioned as close to the oncoming side of the nip N–8 as is possible, consistent with the practical aspects of mounting the doctor **50**, hence the term "close running relationship" with respect to a doctor **50** and the nip N–8 would presuppose a somewhat greater peripheral dimension than close running relationship between, for example, the save-all section **45***a* and the off-running side of the nip N–8, since save-all mountings do not involve the complications of a doctor mounting. The open area for the grooved roll **42** of FIGURE 8 is approximately 15% in order to minimize rewetting of the off-runing felt F–11.

It will be seen also that the auxiliary equipment shown in FIGURE 8 for the grooved roll **42** is much more simple than the auxiliary equipment shown for the grooved roll **15** in FIGURE 1, although the positions of the two rolls are essentially the same in the two views. The embodiment of FIGURES 8 thus actually shows a superior press arrangement not only with respect to the land and groove areas but also with respect to the more simple and reliable elements of the auxiliary equipment which are employed in FIGURE 8 with remarkable success.

Referring now to FIGURE 11, it will be seen that a distinctly improved press assembly is shown in FIGURE 11, embodying improvements over the overall assembly of FIGURE 1 in a number of respects. Parts shown in FIGURE 11 which correspond substantially to parts previously described in FIGURE 1 are designated by the same reference numeral in the 100 series. Thus the web W–**101** is picked up from the wire run WR–**100** by the suction pickup roll **106** wrapped by the suction pick-up felt **111**. The nips shown in FIGURE 11 corresponding substantially to those indicated and previously described in connection with FIGURE 1 are designated by the same reference numerals in the 10 series, thus the suction pickup felt **111** carries the web W–**101** into a first web press nip N–**11**, from which the felt **111** exits around an appropriate guide roll **111***a* so as to be separated from the web W–**101** and the felt **111** is then passed through a felt only nip N–**12**. The first web press nip N–**11** and the first felt only press nip N–**12** are defined by a trio of press rolls which include a lower plain press roll **112**, an upper (middle) grooved press roll **113** and a top grooved press roll **115**, with the grooved press rolls **113** and **115** each having substantially the land area to groove size relationship described hereinbefore in connection with the roll **22**. In addition, doctors (indicated at "*d*") and pumping type wipers (indicated at "*w*") are mounted for operative association with the rolls **113** and **115** in substantially the relationship already described in connection with the corresponding auxiliary equipment for the upper grooved roll **42** of FIGURE 8. The upper grooved roll **115** is provided with separate save-all sections **115***g* and **115***gg*; whereas the lower or middle grooved roll **113** is mounted with separate save-all sections **113***g* and **113***gg*. The save-all **113***g*, pumping type wiper *w* and doctor *d* at the down-running side of the middle grooved roll **113** function essentially the same as the save-all section **45***c*, pumping type wiper **49** and doctor **50** shown in FIGURE 8, whereas, the up-running side of the grooved roll **113** is also provided with a save-all section **113***gg*, a pumping type wiper *w* and a doctor *d* to properly condition the roll surface for the oncoming side of the felt only nip N–**12**.

The felt **111** is thus conditioned at the felt only nip N–**12** so as to be in proper condition for carrying out

its function in conjuction with the suction pickup roll 106, and the overall assembly involving the felt 111 thus is capable of carrying out the functions described as well as initially pressing the wire side of the web W–101 against the plain roll 112 which is preferably granite or Microrok.

The web W–111 is taken from the down-running side of the plain roll 112 and travels onto a felt 34 which carries the web W–101 into a second web press nip N–13 that is again part of a three roll divided press comprising an upper plain roll 31, a middle grooved roll 32 and a lower groved roll 33 provided with appropriate auxiliary equipment which includes save-all sections 32*c* and 38 for the middle groved roll 32 and a save-all indicated generally at 33*c* for the lower grooved roll 33, plus doctors *d* and pumping type wipers *w*.

The second web press nip N–32 indicated as being part of a three roll divided press designated generally by the reference numeral P–X in FIGURE 11 is shown generally in somewhat greater detail in FIGURE 10, wherein the elements having essentially the same function as those described in FIGURE 11 have the same reference numerals in the 100 series. It will thus be seen that the web W–101 passes through the web press nip N–130 and separates immediately from the felt 134 by sticking briefly to the upper plain roll 131. The felt 134 then goes on through the felt only press nip N–130*a* between the two grooved rolls 132 and 133. The grooved roll 132 takes a certain amount of water out of the web 101 and the felt 134 at the web press nip N–30 and retains a substantial amount of the same, and this water is pumped from the grooves of the roll 132 and wiped from the land areas, successively, by the pumping wiper 136*a* and the doctor 137*a*. A certain amount of water is also retained in the off-running felt 134 and this felt 134 is then passed through the felt only nip N–130*a* where it is completely reconditioned and dewatered to the extent desired. The water which tends to remain in the grooves of the roll 132 at the off-running side of the felt only nip N–130*a* is pumped from the grooves by the pumping type wiper 136 at the up-running side of the roll 132 and wiped from the land areas by the doctor 137 at the up-running side, both mounted for operative association with a save-all section 138.

The lower grooved roll 133 also carries off a substantial amount of water from the felt 134 at the felt only nip N–130*a* and this water may be partially thrown from the roll into the save-all indicated generally at 133*c* and some of it will be retained on the land areas and in such instances, it has been found to be preferable to wipe the land areas dry with a preliminary doctor 133*d* associated with the pumping type wiper 133*a*, so that the wiper 133*a* will be able to operate with a little closer running relationship to the surface of the roll 133, so as to obtain a better pumping action. The doctor 133*b* at the oncoming side of the felt only nip N–130*a* carries out the function previously described.

Referring more specifically to the details of the structures of the grooved rolls 132 and 133, it will be appreciated that in FIGURE 10, the top roll 131 is preferably a plain granite or Microrok roll which has a relatively unyielding surface, so the grooved roll 132 associated therewith is preferably provided with a rubber cover in which the grooves are readily cut. This permits the bottom roll 133 to be provided with a stainless steel cover in which the grooves are also readily cut. In paper making press sections, it is generally preferable to have one of the rolls defining a given press couple formed of a generally yieldable surface material such as a solid elastomer, which is usually rubber. It will be appreciated that although the grooves can be readily cut in a rubber cover to provide a roll for use in the invention, rubber covers do wear somewhat more rapidly than, for example, a stainless steel cover or cladding on a given roll, so there are advantages also in the use of a stainless steel clad grooved roll in that this roll is provided with a durable, non-corrosive surface. In the various press couples shown herein, it will be appreciated that the plain rolls 12, 21, 212, 131 and 121 of FIGURE 9) are preferably Microrok rolls, and the grooved rolls defining press nips therewith are preferably rubber covered rolls, whereas certain other grooved rolls such as the grooved rolls 215 and 133 are preferably stainless steel clad grooved rolls.

It will also be appreciated that the open area in the grooved roll 132 is approximately 20%, whereas the open area in the grooved roll 133 is approximately 25% so that water movement at the felt only nip N–130*a* will tend to be greater in the direction of the lower grooved roll 133 which is acting against the working or outer peripheral face of the felt 134 (which is the face of the felt that contacts the web and thus the face of the felt that requires periodic cleaning).

Also, it will be appreciated that in the case of the successive web press nips N–11 and N–13 of FIGURE 11, the nip loads are increased from substantially 200 pounds per lineal inch at the first web press nip N–11 to substantially 350 pounds per lineal inch at the second web press nip N–13. It is thus necessary for the felt only nips associated with each of these web press nips to be operated at at least as great a nip load and preferably about 25 to 50 pounds greater, the nip load at the felt only nip N–12 is thus 250 pounds and the nip load at the felt only nip N–13*a* is thus approximately 400 pounds per lineal inch. Since the rolls employed in defining the nips N–11, N–13, N–12 and N–13*a* are all anti-deflection mounted in the manner hereinbefore described and they are all capable of excellent nip load control because of this, the versatility of the press section shown in FIGURE 11 will be readily appreciated. Preferably in the case of the two three roll divided presses shown in FIGURE 11, in each case the middle or intermediate grooved roll 113 or 32 is generally mounted on anti-deflection means but in a relatively fixed position whereas the upper and lower rolls in each of these divided presses are preferably mounted on fluid actuated load control and moving means in conjunction with the anti-deflection means hereinbefore described. The grooved rolls are thus designated in FIGURE 11 and in certain other views merely by "G" centered on the roll, whereas the plain rolls are designated by the "P" centered on the roll.

Referring briefly to FIGURE 9, it will be seen that the elements shown in FIGURE 9 which correspond to those shown in FIGURE 10 are designated by the same reference numerals in the 120 series. Essentially the three roll divided press assembly of FIGURE 9, designated generally by the reference numeral 120, is used as a replacement for the press P–X indicated in FIGURE 11. The essential difference is that the bottom roll 123 in the press 120 is a plain roll as contrasted to the grooved roll 133 which is the bottom roll in the press 130. The bottom roll 123 is thus provided with a doctor 123*d* at the down-running side and still another doctor 123*b* at the up-running side in close running relation to the oncoming side of the nip N–120*a* for the felt only press nip N–120*a* for the divided press. The middle grooved roll 122 carries out the function of removing water at the web nip N–20 and again removing water at the felt only nip N–20*a* to the extent required in each case to maintain the felt 124 in the desired condition throughout its cycle. In each of these presses 120 and 130 the middle grooved roll is within the loop of the felt and the top and bottom rolls are outside the felt loop. Since anti-deflection mounting means are used in the case of all of the rolls here involved in FIGURES 9 and 10, it will be appreciated that loading control is greatly facilitated at the nips. It will also be appreciated that the invention affords the advantage that the central grooved roll 122 or 132 in the particular embodiments of the invention shown in FIGURES 9 and 10 need not be anti-deflection mounted, because the top and bottom rolls are so mounted and such mounting will afford the desired uniformity of the nip load, except in unusual cases. The anti-deflection mount-

ing for the middle rolls 122 and 132, does afford the additional advantage, however, of assuring better control under extreme or unusual operating conditions.

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 FIG. 4, it will be seen that at the oncoming side of the nip N–1 the pressure P_o in the web W–1 as well as the felt or porous belt 11 is nominal (i.e. about 15 p.s.i. abs.); 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 p.l.i. or greater because the longitudinal dimension of maximum nip load is often less than one inch); and, of course, at the off-running side of the nip N–1 the expanding felt 11 tends to create a subatmospheric (or vacuum) pressure P_v (e.g. 2–5 p.s.i. abs.) 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 evidenced 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 FIG. 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 pressure application at the nip N–3 may appear to be the same (or greater, depending upon the particular press position) nip load in p.l.i. (pounds per lineal inch) but the water flow from the moist web W–6 to the porous felt or belt 23 is essentially (non-crushing and) normal to the plane P—P between the web W–6 and felt 23 (e.g. as shown in FIGS. 4 and 5A). There is no "crushing" flow of water in the web along the plane P—P in the direction $P_m \rightarrow P_o$, nor is there in the nip N–3 of FIGS. 5A and 5B. Moreover, the extremely small axial dimension 27 of the lands 22*b*, 22*b* (FIG. 5B) avoids any cross-machine "crushing" flow of water in the web in the direction $P_m \rightarrow P_o$. Instead, in FIG. 5B, there is presented a felt 23 which has theoretically a low "average" pressure

$$\frac{P_m + P_o}{2}$$

to readily receive water generally normally to the plane P—P at the web-felt interface, followed by flow of water to a limited extent only within the felt 23 and for the limited dimension 27½ in the direction $P_m \rightarrow P_o$. This affords an advantage of extremely high press nip loads (in p.l.i.), when desired, with crushing.

It should also be noted that, even assuming that, in FIG. 5B, P_m is equal to such desired high nip loads as 100, 200, 300 or even 450 p.l.i. (although P_m in p.s.i. will probably be much higher often because the longitudinal dimension of maximum nip pressure P_m is usually less than one inch), the driving force against the water is $P_m - P_o$ which is usually in the range of several hundred p.s.i. The time this driving force is applied is very brief (i.e. for a machine speed of 2000 feet per minute and an oncoming nip side of perhaps one-half inch, being approximately 3×10^{-7} sec.) 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 this physical phenomenon possible. Hence land (axial) widths, particularly for higher speed machines, in the neighborhood of 0.05 to 0.15 (and preferably 0.08 to 0.1) 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 (FIG. 5B) in the same press has been found to produce a distinct reduction (or substantial elimination) of evidence of marking in the certain webs thereby demonstrating the criticality of even superficially very small dimensional changes in this aspect of the structure.

Still another extremely important aspect of groove structure is the cross sectional volume, which has already been expressed in terms of a mouth width (26) 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 such square (i.e. $4x^2$ to $5x^2$). 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 atmosphere and maintain P_o (FIG. 5A) at substantially ambient atmospheric pressure of 15 p.s.i. abs. In pulp making machines, wherein the speeds are relatively slow and the water loads relatively high the grooves actually function very satisfactory as "flow troughs" using the dimensions of 0.02 to 0.025 inch mouth 26 with a normal machine taper (e.g. 7%) to a depth 28 of only 0.06 inch, i.e., a cross sectional area of 2 to $3x^2$. It is important to consider the groove volumes (i.e. 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 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 3×10^{-7} sec. in which the felt expands at the off-running side of the nip (cross-machine) centerline, the driving force of $P_o - P_v$ or 10 to 12 p.s.i. tending to return water from the grooves to the absorbent felt is comparatively much less than the several hundred p.s.i. driving force pushing water into the grooves at the oncoming side (during an 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 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 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 (FIG. 5B) to the center-line of the land area. Water removal is thus effected at conventional higher machine speeds and the 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 vis-à-vis the felt and grooves.

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 receptacles. In any case, water removal is thus effected.

It will thus be seen that shallow and/or sharply tapered grooves, having a semi-circular or a triangular cross-sectional area which is functionally significantly below about twice the square of the groove mouth width (i.e. $2x^2$) 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 "shallow" grooves having the "general" cross section of perhaps an equilateral triangle (i.e. $\frac{1}{3}x^2$) 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 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, etc. 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 brush, water jets or other generally less preferred auxiliary equipment for continuous cleaning.

Throughout the specification and claim, the term "felt" has been used in its generic sense to mean not only the more conventional woolen felts but also all so-called "felts" of different weights, weaves and openness, including reinforced felts, porous fabrics and similar porous

belts which may be composite intergal or separable porous elements.

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:

In a paper machine press assembly, in combination, a first traveling looped felt, a suction pickup roll within the felt loop urging the felt against a traveling wet web on a forming surface for transferring the traveling wet web to the outer peripheral surface of said looped felt, a first plain press roll outside the loop of the felt, a second press roll within the felt loop and defining with said first press roll a first web press nip receiving and dewatering the web carried on said felt and a third press roll outside of the felt loop and defining with said second roll a first felt only nip receiving the felt without the web to dewater and condition the felt, both of said second and third press rolls being grooved rolls formed respectively of imperforate press roll shells presenting each to the felt touching the same a peripheral surface portion having a plurality of alternating generally circumferentially aligned grooves and ridges, said ridges on said second press roll presenting to such felt smooth generally continuously cylindrical closely axially spaced land areas for supporting the felt and permitting the felt to bridge the grooves and thereby protect against substantial marking in the case of the web at the first web press nip defined by such grooved roll, said grooves being vented to ambient atmosphere at the oncoming and off-running sides of the press nip defined by such grooved roll to facilitate reception of water from the felt at such nip, a second looped felt receiving the web from the first web press nip and conveying the web to and through a second web press nip, and a trio of press rolls defining a divided press with one nip defined by a plain fourth roll and a grooved fifth roll being said second web press nip and the other nip being a felt only press nip defined by said fifth grooved roll of said trio within the second felt loop and the sixth grooved roll of said trio outside the second felt loop, each of the aforesaid second, third, fifth and sixth rolls being characterized by the aforesaid grooved roll structure and further having grooves of narrow axial dimension which on the average along each press nip defined by such roll having a land-to-groove ratio of substantially 2:1 to 20:1; with the narrow grooves having axial dimension within the range of 0.005 to 0.035 inch; and having groove depths such that the values for the groove cross-sectional areas at each such nips are at least twice the square of the aforesaid narrow groove axial dimension at the periphery of the respective roll shell, each of such aforesaid grooved rolls also being provided with saveall means for containing and receiving water removed from the roll lands and grooves remote from each press nip defined by each such grooved roll shell.

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