



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

| | | |
|---|-----------|---|
| (51) International Patent Classification ⁷ : D21F 3/02, 11/14 | A1 | (11) International Publication Number: WO 00/29667 (43) International Publication Date: 25 May 2000 (25.05.00) |
| (21) International Application Number: PCT/US99/27097 (22) International Filing Date: 12 November 1999 (12.11.99) (30) Priority Data: 09/191,376 13 November 1998 (13.11.98) US (71) Applicant: FORT JAMES CORPORATION [US/US]; 1650 Lake Cook Road, Deerfield, IL 60015 (US). (72) Inventors: MARINACK, Robert, J.; 4483 Country Road G, Oshkosh, WI 54904 (US). McDOWELL, Jeffrey, Charles; 3200 Twin Willow Court, Appleton, WI 54914 (US). WORRY, Gary, L.; 3040 West Spencer Street, Appleton, WI 54914 (US). EDWARDS, Steven, L.; 9539 Tri-County Road, Fremont, WI 54940 (US). (74) Agents: GARRETT, Arthur, S. et al.; Finnegan, Henderson, Farabow, Garrett & Dunner, L.L.P., 1300 I Street, N.W., Washington, DC 20005-3315 (US). | | (81) Designated States: CA, TR, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> |
| (54) Title: METHOD FOR MAXIMIZING WATER REMOVAL IN A PRESS NIP (57) Abstract <p>The present invention is a method for maximizing water removal from an absorbent web in a press nip. The present invention uses a pressing unit having a blanket with a void volume and with a pressure profile that maximizes water removal in the press section or on the Yankee dryer of a paper machine. The pressure profile of the pressing unit according to the present invention has a very steep pressure drop at and/or following the exit of a pressure distribution curve in order to maximize water removal by minimizing rewet of the web. The improved pressure profile according to the present invention results in increased water removal and/or improved line speed. The void volume further increases water removal and/or improves line speed.</p> | | |

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

| | | | | | | | |
|----|--------------------------|----|--|----|--|----|--------------------------|
| AL | Albania | ES | Spain | LS | Lesotho | SI | Slovenia |
| AM | Armenia | FI | Finland | LT | Lithuania | SK | Slovakia |
| AT | Austria | FR | France | LU | Luxembourg | SN | Senegal |
| AU | Australia | GA | Gabon | LV | Latvia | SZ | Swaziland |
| AZ | Azerbaijan | GB | United Kingdom | MC | Monaco | TD | Chad |
| BA | Bosnia and Herzegovina | GE | Georgia | MD | Republic of Moldova | TG | Togo |
| BB | Barbados | GH | Ghana | MG | Madagascar | TJ | Tajikistan |
| BE | Belgium | GN | Guinea | MK | The former Yugoslav Republic of Macedonia | TM | Turkmenistan |
| BF | Burkina Faso | GR | Greece | ML | Mali | TR | Turkey |
| BG | Bulgaria | HU | Hungary | MN | Mongolia | TT | Trinidad and Tobago |
| BJ | Benin | IE | Ireland | MR | Mauritania | UA | Ukraine |
| BR | Brazil | IL | Israel | MW | Malawi | UG | Uganda |
| BY | Belarus | IS | Iceland | MX | Mexico | US | United States of America |
| CA | Canada | IT | Italy | NE | Niger | UZ | Uzbekistan |
| CF | Central African Republic | JP | Japan | NL | Netherlands | VN | Viet Nam |
| CG | Congo | KE | Kenya | NO | Norway | YU | Yugoslavia |
| CH | Switzerland | KG | Kyrgyzstan | NZ | New Zealand | ZW | Zimbabwe |
| CI | Côte d'Ivoire | KP | Democratic People's Republic of Korea | PL | Poland | | |
| CM | Cameroon | KR | Republic of Korea | PT | Portugal | | |
| CN | China | KZ | Kazakhstan | RO | Romania | | |
| CU | Cuba | LC | Saint Lucia | RU | Russian Federation | | |
| CZ | Czech Republic | LI | Liechtenstein | SD | Sudan | | |
| DE | Germany | LK | Sri Lanka | SE | Sweden | | |
| DK | Denmark | LR | Liberia | SG | Singapore | | |
| EE | Estonia | | | | | | |

METHOD FOR MAXIMIZING WATER REMOVAL IN A PRESS NIP

5 RELATED CASES

 This application is a continuation-in-part of copending application
Serial No. 09/191,376, filed November 13, 1998.

FIELD OF INVENTION

10 The invention relates to a method for maximizing water removal from
an absorbent paper web in a press nip. More particularly, the present
invention relates to the use of a shoe press on the Yankee dryer with a
pressure profile that maximizes water removal. Still more particularly, the
present invention relates to a method for utilizing a very steep pressure drop
at and/or following the exit of a nip curve in order to maximize water removal
15 by minimizing rewet. Finally, the present invention relates to a method for
increasing paper machine speed by utilizing a press section that maximizes
water removal.

BACKGROUND OF THE INVENTION

20 In modern society, bath tissue, paper towels, facial tissue, and paper
napkins (hereinafter referred to as packaged paper products) have been
remarkably successfully consumer products. The success of these paper
products stems from the ability of manufacturers to consistently enhance
product attributes at lower cost and to meet volume demands on a timely
basis. Packaged paper products offer consumers an array of attributes
25 necessary to such jobs as performing the daily tasks of wiping up spills,
personal cleansing, and cleaning household goods. For example, paper
towels are engineered to be absorbent and strong while wet whereas bath
tissue products are expected to be soft to the touch yet strong while in use.
Absorbency and softness are inversely related to strength, often making it
30 difficult to obtain the right balance of attributes. Accordingly, significant
research and development efforts are routinely expended to enhance the
quality of these products while continuing to reduce cost by, for example,
improving the production of these products. Although numerous schemes
have been developed and patented, the search by R&D departments
35 continues to seek out new and innovative methods for improving these

5 products.

There are numerous methods described in the patent literature for improving the quality of packaged paper products. One of the earliest known methods to enhance the quality of consumer paper products is described in U. S. Patent No. 3,301,746 by Sanford and Sisson, assigned to Procter and Gamble Corporation, and incorporated herein by reference in its entirety.
10 This patent describes a papermaking scheme for enhancing product quality by avoiding overall web compression and by using a pattern array of densified regions in the xy plane of the sheet to enhance product strength.

Other early methods for improving the quality of packaged paper products are described in U.S. Patent No. 3,812,000 by Salvucci and Yiannos and U.S. Patent No. 3,821,068 by Shaw. These patents are assigned to Scott Paper Company, each of which is incorporated herein by reference in its entirety. Shaw discloses a papermaking scheme for producing soft tissue by avoiding mechanical compression until the sheet has been dried to at least
15 80% solids. Salvucci and Yiannos disclose a technique for producing a soft tissue structure by avoiding mechanical compression of an elastomeric containing fiber furnish until the consistency of the web is at least 80% solids.

Thicker more absorbent structures can be made using a low batting papermaking felt as described in U.S. Patent No. 4,533,457 by Curran et al., assigned to Scott Paper Company, and incorporated herein by reference in its
25 entirety. U.S. Patent Nos. 5,591,305 and 5,569,358 by Cameron, assigned to James River Corporation, and incorporated herein by reference in their entirety, disclose a low-batting, high-bulk-generating felt with improved dewatering capabilities.

30 A more recent method for improving the quality of a through-air-dried sheet is described in U.S. Patent No. 4,440,597 by Wells and Hensler, assigned to Procter and Gamble Company, and incorporated herein by reference in its entirety. This patent describes a method for increasing the stretch of a paper web by operating the forming section of a paper machine
35 faster than the through air dryer section of the paper machine. As a result of

5 the speed differential, the paper web is inundated into the through air-dryer-fabric leading to enhanced stretch and absorbency properties in the base sheet and resulting product.

Fibers and chemicals can be used to enhance the quality of packaged paper products. For example, U.S. Patent No. 5,320,710 by Reeves et al.,
10 assigned to Fort James Corporation, and incorporated herein by reference in its entirety, describes a new furnish combination extracted from the species *Funifera* of the genus *Hesporaloe* in the *Agavaceae* family. This furnish has fibers which are very long and which have very fine-geometrical attributes known to enhance tissue and towel performance. U.S. Patent No. 3,755,220
15 by Freimark and Schaftlein, assigned to Scott Paper Company, and incorporated herein by reference in its entirety, describes a debonding scheme for maintaining wet strength while reducing product dry strength-a method known to enhance the handfeel of towel products.

The use of bulking fibers can improve the quality of the final end
20 product. U.S. Patent No. 3,434,918 by Bernardin, U.S. Patent No. 4,204,504 by Lesas et al., U.S. Patent No. 4,431,481 by Drach et al., U.S. Patent No. 3,819,470 by Shaw et al., and U.S. Patent No. 5,087,324 by Awofeso et al. disclose the use of bulking fibers in papermaking webs to improve product attributes like thickness, absorbency, and softness. These aforementioned
25 patents are incorporated herein by reference in their entirety.

U.S. Patent No. 5,348,620 by Hermans et al., assigned to Kimberly-Clark Worldwide Inc., and incorporated herein by reference discusses a high consistency/high temperature fiber-treatment-process using a disperser to improve product attributes. To improve tissue softness, several approaches
30 are available to the papermaker such as using certain species of hardwood like eucalyptus in stratified webs as disclosed in U.S. Patent No. 4,300,981 by Carstens and U.S. Patent No. 3,994,771 by Morgan et al. The last two patents are incorporated herein by reference in their entirety. These aforementioned patents describe just a few of the many methods developed
35 over the last thirty years to enhance the quality of packaged paper products.

5 There are also numerous schemes for enhancing the productivity of paper machines. For example, gap formers have been developed to enhance sheet drainage ultimately leading to increased machine speed. New developments in Yankee hood design and Yankee cylinder design have allowed improvements in heat transfer coefficients and mass transfer
10 coefficients, ultimately leading to enhanced machine speeds. New developments in forming fabrics, e.g., multi-layer and triple-layer forming fabrics, have resulted in improved drainage, better fabric life, and enhanced fiber support. These factors translate into enhanced machine speed and productivity. Improvements in press felts, e.g. Scapa's SPECTRA™ felt
15 concept of using a soft polyurethane sandwich near the base of the felt or the use of stratified batting, have led to improvements in felt life, reductions in break-in time, and improvements in water removal at wet presses. These improved press-felt developments have ultimately translated into improved machine speed and productivity. Improvements in Yankee creping adhesives
20 have been helpful to enhance blade wear and reduce sheet plugging. Continuous creping doctors have alleviated the need to frequently change doctor blades. The last two aforementioned developments have led to improvements in machine speed, reductions in down time, and reductions in paper waste. In spite of all these advances, methods are sought to enhance
25 productivity.

 The present invention improves the efficiency of known water removal methods by adding one or more pressing units to the production paper machine, in place of or in conjunction with a suction pressure roll. "Pressing units" according to the present invention include those units that physically
30 engage a belt or pressing blanket, which contacts the impression fabric or felt upon which the web travels. "Foraminous endless fabric" as defined in accordance with the present invention includes either an impression fabric or felt. "Pressing unit" as defined in accordance with the present invention includes any press members allowing deformation of the pressing
35 blanket/impression fabric and/or felt/web sandwich to result in asymmetric

5 pressure profiles. These pressing units including pressing blankets are generally discussed in the literature as "shoe presses." Pressing units according to the present invention do not include suction pressure rolls since they lead to symmetrical pressure distributions frequently mathematically described by sine or haversine functions.

10 Shoe presses have been used to increase water removal at wet presses, ultimately leading to increased machine speed for linerboard grades and more recently, newsprint and fine paper grades. The idea of extending the time in a press nip as a means to enhance water removal is not a new idea. Nissan in 1954 published a paper in Tappi, Vol. 37, No.12, p.597
15 (1954) suggesting that the use of extended time in a press nip would enhance the water removal performance of a press. Over twenty-five years, ago Busker published an early paper in Tappi, Vol. 54, No.3, p.373 (1971) on the use of extended nip times, as a means to enhance water removal. Beloit Corporation commercialized the first open belt wide shoe press on a
20 linerboard machine in 1980 as described in an article by J. Blackledge presented during the 2nd International Pira Conference, entitled 'Modern Technologies in Pressing and Drying', Nov 6-8, 1990, p. 1. The aforementioned three articles are herein incorporated by reference in their entirety.

25 Figure 1 shows a typical closed belt wide shoe press (see Figure 2 in an article entitled "New Pressing Technologies for Multiply Board" by J. Breiten in 81st Annual Meeting, Technical Section, CPPA, p. A137 for a more detailed drawing). A wide shoe press as described in the literature is essentially a controlled crown roll with a flexible shell and a concave shoe
30 hydrodynamically loaded against each other. The belt or blanket is usually a fabric reinforced polyurethane-coated structure that can be grooved or blind drilled for more efficient water removal. The inside of the belt is generally lubricated with oil, which develops a hydrodynamic film as it passes over the shoe and reduces wear/friction in both surfaces. Wide shoe press nips are on
35 average 5 to 10 times longer than conventional roll press nips (generally, 5" -

5 10" versus 1" - 2"). Water deflectors (not shown) on the outside surface will dewater the blanket. By utilizing such a wide nip, loads up to 10,000 pli are possible without the risk of damaging blankets and felts or crushing the sheet. The exit side of the shoe features a sharply curved nose designed to pull the sheet directly out of the nip and away from the felt, thus reducing rewet and
10 improving sheet dryness. U.S. Patent No. 4,931,142 describes certain advantages to this type of take off angle in conjunction with long press nips. Rolls do not normally support the belt loop of the wide shoe press. The loop generally is closed off with special head assemblies for containing the oil.

Numerous schemes for improving the operation of shoe presses have
15 been developed over the years. For example, in U.S. Patent No. 5,043,046 by Laapotti and assigned to Valmet Corporation, U.S. Patent No. 4,625,376 by Schiel et al. and assigned to Voith Corporation, and U.S. Patent No. 4,673,461 by Roerig and assigned to Beloit Corporation, methods are described to enclose the shoe press in order to contain the oil within the unit.
20 The previous three patents are incorporated herein by reference. U.S. Patent No. 5,167,768 by Cronin and Roerig and assigned to Beloit Corporation and U.S. Patent No. 5,582,689 by Rolf Van Haag and Hans-Rolf Conard and assigned to Voith Corporation describe methods for varying the pressure distribution in a shoe press. This capability avoids the need to offset the
25 center of loading or reshape the shoe to change the pressure distribution. These last two patents are also incorporated herein by reference. U.S. Patent No. 5,693,186 by Vallius, assigned to Valmet Corporation, and incorporated herein by reference describes a tension link scheme for containing the loading within the framing of the shoe press apparatus. This
30 scheme ultimately avoids the need to fortify flooring when operating at high line loads. These are just a few of the many developments that have led to improved operating shoe presses.

In the art of pressing linerboard, newsprint, and fine paper webs with a shoe press, a long shoe with a gradual pressure rise is desirable for good
35 dewatering and enhanced bulk properties. This is especially true for flow

controlled webs. Linerboard and to a certain extent newsprint and fine paper have flow controlled pressing conditions. Flow controlled pressing conditions occur when the time in the nip becomes an important factor determining the amount of water removed from the web. High pressure can be attained with these long shoes but it requires high line loads. Figure 2 shows the relationship between peak pressure (i.e., the maximum pressure in the nip) and line load (i.e., the total force divided by linear width) for shoe press nips compiled from an extensive but not exhaustive search of the literature. Table I describes the literature references used to develop Figure 2.

Table I: References Used to Generate Figure 2.

| Reference Number | Source |
|------------------|--|
| 1 | U.S. Patent No. 5,167,768 |
| 2 | W. Schuwerk, Paper Age, September, 1997, p.18. |
| 3 | N. Anderson, Journal of Tappik, Vol. 21, No. 1, 1998, p.52. |
| 4 | J. Kinnunen and A. Kiviranta, Paperi Ja Puu-Paper and Timber Vol. 74, No. 4, 1992, p. 314. |
| 5 | J. Kivimaa, M. Laurikainen, and K. Pansu, PITA Water Removal Conference 1997 York, Paper Technology, April, 1998. |
| 6 | J. Blacklege and D. Lange, 2 nd International Pira Conference, "Modern Technologies in Pressing and Drying", Nov. 6-8, 1990, p.1. |
| 7 | M. Radtke, 79 th Annual Meeting, Technical Section, CPPA, p. A221. |
| 8 | J. Breiten, 81 st Annual Meeting, Technical Section, CPPA, p. A137. |
| 9 | E. Tenfalt, J. Wilmenius, and O. Swanberg, Nordic Pulp and Paper Research Journal, 1998, p.16. |
| 10 | D. Lange and M. Radtke, Papermaker, July 1996, p. 16. |
| 11 | "Chemical Systems Boost Dry Content", PPI, February, 1989, p. 41. |

The graph in Figure 2 shows that shoe presses normally operate at high line load conditions, usually greater than 270kN/m and at high peak

5 pressures. It also shows that shoe presses are not operated at low line loads and at high peak pressures (e.g., see the crosshatched region in Figure 2).

10 In the art of making tissue by the conventional wet pressing operation, Yankee dryers are loaded with suction pressure rolls to remove water from the tissue web and attach the web to the dryer for further processing by the creping operation. The pressure distribution in the suction pressure roll nip is symmetrical in shape and is described mathematically by a sine or a haversine curve. Suction pressure rolls loaded to a Yankee dryer are routinely run at line loads less than 100 kN/m and at peak pressures of less than 4500 kN/m². In the lower left-hand corner of Figure 2 some typical peak pressure versus line load data for suction pressure rolls are shown. The deflection of large, conventional Yankee dryers due to hoop stress levels limits the line load to less than about 100 kN/m. As a result, it is very difficult to attain high peak pressures in the nip at these low line loads, since the pressure distribution cannot be altered. This limitation has extreme consequences for tissue grades since they are pressure controlled, i.e., the flow resistance in the web is low due to the use of high freeness furnishes and low basis weight webs, thus it is believed that peak pressure, not time in the nip, controls press dewatering. These suction pressure rolls suffer from other disadvantages. For example, since the nip diverges after the maximum pressure is achieved, rewet can occur for a large part of the press nip. A typical suction pressure roll curve appears in Figure 3, where nip divergence is apparent. Also, the suction pressure roll unit is not flexible so that the line

15
20
25

5 load needs to be fixed and matched to a given Yankee crown condition in order to obtain a uniform nip profile across the machine. Furthermore, since the loading cylinders are located at each end of the pressure roll, profiling capabilities are very limited.

10 The use of conventional shoe presses on a Yankee dryer at the maximum hoop stress limit of 100kN/m would lead to very low peak pressures as Figures 2 and 3 demonstrate. For example, with a 120 mm shoe at 100 kN/m, the typical peak pressure is on the order of 1700 kN/m as Figure 3 demonstrates. Since the press nip for low weight tissue and towel grades is pressure controlled, the very low peak pressure could cause a decrease in post press dryness, ultimately causing a loss in production. The counter roll
15 in a conventional shoe press is small by comparison to the diameter of a Yankee dryer. As a result, the use of a conventional shoe shape would make it very difficult to remove the felt/fabric from the sheet at the nip exit. Therefore, conventional shoe shapes and conventional felt/fabric takeoff
20 angles would exacerbate rewet for low weight absorbent products.

25 Currently, there are no commercial uses of shoe press technology in the production of absorbent paper products. U.S. Patent No. 5,795,440 by Ampulski et al., and U.S. Patent No. 5,776,307 by Ampulski et al.-both assigned to Procter and Gamble Corporation and both incorporated herein by reference, describe a scheme for making a shaped web by pressing an embryonic web into an imprinting fabric between two felts. These patents use a shoe press assembly in the preparation of a wet pressed paper web.

5 Ampulski et al., like others using pressing units, teaches the use of longer conventional press nips. Ampulski et al. discloses that the nip length is greater than 3.0 inches and may be as long as 20.0 inches. Ampulski et al. achieves this extended nip length through the use of a shoe press. Ampulski et al., like all previous users of shoe presses, fails to consider the use of
10 increased peak pressure.

 International patent application WO 97/43483 by Hermans and Friedbaurer, assigned to Kimberly-Clark Worldwide, Inc., and incorporated herein by reference discloses that extended nip presses, while having been successfully used for making paperboard, have not been used to make low
15 density paper products such as tissue because the high pressure and longer dwell times in an extended nip press serve to densify the sheet beyond that experienced by conventional tissue wet pressing methods. Hermans and Friedbaurer overcome the increased density due to extended nip pressing by incorporating modified resilient fibers (e.g., chemically cross-linked cellulosic
20 fibers) in the web and by wet micro-shaping the web. They also disclose shoe lengths typically in the range of 5 to 10 inches. Like Ampulski et al., Hermans and Friedbaurer do not consider critical peak pressures or line loads as important.

 U.S. Patent No. 5,393,384 by Steiner et al., and assigned to J.M. Voith, GmbH (hereinafter "the '384 patent") generally describes the use of a
25 shoe press in the production of a tissue web. The '384 patent describes the use of a shoe press preceding or contacting a Yankee drying cylinder. The

5 shoe press is used in conjunction with an impermeable belt to reduce
remoistening of the sheet by the felt. These authors used the impermeable
belt since they state: "the prevailing opinion in selecting suitable drying
presses in contingency on the web thickness so far has been that for drying
thin webs there are only simple roll presses suited which generate a
10 sufficiently high contact pressure for a short time, thus optimally removing the
water from a thin web (tissue web) due to the short path, whereas shoe type
presses are suited essentially for drying thick, heavy webs, since they
generate a persistent pressure which allows the water sufficient time for the
considerable longer path in leaving the web." Critical peak pressure and line
15 loads are not discussed in the disclosure. Since the shoe press described in
this disclosure is conventional, a pressure curve for this type of shoe press is
most likely similar to the "typical shoe press curve" illustrated in Figure 3.

Voith, the assignee of the '384 patent, continues to develop the use of
a shoe press for the production of paper products. U.S. Patent No. 5,500,092
20 by Schiel describes a tissue making machine using a triple press nip where
the second nip is a shoe press nip. The criticality of pressure distribution
shape and peak pressure/line load magnitudes are not disclosed in the '092
patent. In the September 1997 article W. Schuwerk, "Shoe Presses and
Sleeves for Newsprint-Concepts and Initial Operating Experience," PaperAge,
25 Pp. 18-23, Voith described the advantages of their NIPCOFLEX shoe press.
According to that article, "[T]o obtain optimum product characteristics,
dewatering in the press must [therefore] show as flat a pressure gradient as

5 possible." In fact, the shoe press described in the article refers to the third section of a newsprint paper machine operating at a line loading of 850 kN/m and a peak pressure of ~5.6 MPa, typical of standard conventional shoe designs and well outside the range of the present invention.

10 U.S. Patent No. 4,931,142 by Steiner, Muller, Schiel, and Flamig, assigned to Voith Corporation and incorporated herein by reference in its entirety describes a method of eccentrically arranging a press blanket with respect to the press plane. This arrangement enables the blanket upon leaving the press nip to immediately move steeply downward and away from the sheet in order to reduce remoistening of the web. Methods of varying the
15 felt angle with respect to the traveling web in a double felted press nip were disclosed to avoid remoistening the sheet and for quick release of the sheet from the felt. Steiner et al. also discloses that the joint path of travel of the paper web, felt, and blanket can be made substantially shorter than prior art. By utilizing the Steiner et al. invention, the joint travel of the felt, web, and
20 blanket can be made equal to zero, i.e., the web can detach itself from the felt directly at the emergence from the press nip. Steiner et al. does not address low line loads and high peak pressures needed for optimum shoe press performance on Yankee dryers. It also does not disclose the need to taper the press shoe to achieve minimized rewet.

25 U.S. Patent No. 5,556,511 by Bluhm and Gotz, assigned to Sulzer-Escher Wyss, and incorporated herein by reference describes a process for making toilet tissue webs whereby a web is wet pressed in a heated pressing

5 arrangement. The heated pressing arrangement can be a shoe press. This disclosure does not address the importance of proper choice of peak pressure, line load, and shoe shape for making absorbent products at high speeds. In fact, the critically of line loads and peak pressures is not discussed. Bluhm and Gotz like all previous users of shoe presses, fails to
10 consider the use of increased peak pressure at low line loads as a means to improve water removal.

U.S. Patent No. 4,973,384 by Crouse, Pulkowski, and Porter, assigned to Beloit Corporation, and incorporated herein by reference describes a process for using a heated extended nip press for optimizing sheet properties
15 without lamination. To accomplish the aforementioned task Crouse et al. found that by application of pressure for an increased period of time, the increased residence time enables the removal of more water from the formed web. As a result, these authors teach toward the use of a conventional long shoe design. They also found that for a heated extended nip press by
20 "gradually decreasing pressure in machine direction toward the trailing edge of the shoe, rapid flashing of steam from the emerging pressed web was avoided." As a result these authors teach away from the use of a heavy peaked pressure distribution at the exit side of a shoe press nip.

WO 97/16593 by Wedel and Worcester incorporated herein by
25 reference discloses an impulse drying method for tissue structures using a shoe press and an induction heater. This disclosed impulse-drying method is intended to replace the Yankee dryer with its associated problems. These

5 authors list the issues with Yankee dryers as being limited in surface
temperature to 185°F, as being limited in line load to 500 pli due to shell
thickness limitations, and as being limited in roll diameter. These authors
state that shoe length is typically ten inches for the impulse drying unit. The
line loads disclosed are 1000 pli to 10,000 pli. As a result, this application
10 teaches away from the combined use of a low line load with a substantial
peak pressure.

Contrary to the current state of the art, the present inventors have,
quite unexpectedly, found that in the production of absorbent paper products,
the use of a steep, sharp pressure gradient and controlled separation when
15 producing absorbent paper can improve dewatering efficiency without
adversely affecting product properties. An example of the pressure profile of
the new shoe design for absorbent paper production according to the present
invention is illustrated in Figure 3.

The present inventors unexpectedly discovered that good sheet
20 dewatering and appropriate bulk/strength properties for low weight absorbent
products could be attained with this pressure optimized shoe press. The
optimized pressure conditions can be achieved according to the present
invention by shaping the shoe, tilting the shoe in the shoe press, reducing the
length of the shoe in the shoe press, and/or tapering the exit side of the shoe.
25 In addition, these conditions can also be achieved by deflecting the pressing
blanket from the web carrying foraminous-endless-fabric at a point nearly
simultaneous with separation of the foraminous-endless-fabric from the

5 nascent web, thereby reducing rewet. These techniques enable the pressure optimized shoe press according to the present invention to achieve improved dewatering while maintaining bulk with line loads less than about 240kN/m and peak pressures greater than about 2000 kN/m².

SUMMARY OF THE INVENTION

10 Further advantages of the invention will be set forth in part in the description, which follows and in part will be apparent from the description. The advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

15 To achieve the foregoing advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, there is disclosed:

 An apparatus for forming an absorbent paper sheet product comprising:

20 a moving foraminous endless fabric;
 means for depositing a nascent web for the absorbent paper sheet on the foraminous endless fabric;
 a moving endless pressing blanket;
 a Yankee drying cylinder; and
25 a pressing unit engaging the pressing blanket adapted to urge the nascent web for the absorbent paper sheet on the foraminous endless fabric into engagement with the Yankee drying cylinder thereby forming a nip, the

5 pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m.

 There is further disclosed:

 An apparatus for forming an absorbent paper sheet product comprising:

10 a moving foraminous endless fabric;

 means for depositing a nascent web for the absorbent paper sheet on the foraminous endless fabric;

 a moving endless pressing blanket;

 a Yankee drying cylinder; and

15 a pressing unit engaging the pressing blanket adapted to urge the nascent web for the absorbent paper sheet on the foraminous endless fabric into engagement with the Yankee drying cylinder thereby forming a nip, the pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m,

20 the pressing unit being configured to disengage the web from the foraminous endless fabric such that rewet of the nascent web by the foraminous endless fabric is less than about 50% of the rewet predicted by the Sweet equations based upon the properties of the foraminous endless fabric and the nascent web.

25 There is still further disclosed:

 An apparatus for forming an absorbent paper sheet product comprising:

- 5 a moving foraminous endless fabric;
- means for depositing a nascent web for the absorbent paper sheet on
- the foraminous endless fabric;
- a moving endless pressing blanket;
- a Yankee drying cylinder; and
- 10 a pressing unit engaging the pressing blanket adapted to urge the
- nascent web for the absorbent paper sheet on the foraminous endless fabric
- into engagement with the Yankee drying cylinder thereby forming a nip, the
- pressing unit being configured to create a peak engagement pressure of at
- least about 2000 kN/m² at an overall line load of less than about 240 kN/m,
- 15 the pressing unit being configured to both disengage the web from the
- foraminous endless fabric and disengage the foraminous endless fabric from
- the pressing blanket at a nip length of less than about one inch from the point
- the nip pressure reaches zero.
- There is still further disclosed:
- 20 An apparatus for forming an absorbent paper sheet product
- comprising:
- a moving foraminous endless fabric;
- means for depositing a nascent web for the absorbent paper sheet on
- the foraminous endless fabric;
- 25 a moving endless pressing blanket;
- a transfer cylinder; and
- a pressing unit engaging the pressing blanket adapted to urge the

5 nascent web for the absorbent paper sheet on the foraminous endless fabric into engagement with the transfer cylinder thereby forming a nip, the pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m.

 There is still further disclosed:

10 An apparatus for forming an absorbent paper sheet product comprising:

 a moving foraminous endless fabric;

 means for depositing a nascent web for the absorbent paper sheet on the foraminous endless fabric;

15 a moving endless pressing blanket;

 a transfer cylinder; and

 a pressing unit engaging the pressing blanket adapted to urge the nascent web for the absorbent paper sheet on the foraminous endless fabric into engagement with the transfer cylinder thereby forming a nip, the pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m².

 There is still further disclosed:

 An apparatus for forming an absorbent paper sheet product comprising:

25 a moving foraminous endless fabric;

 means for depositing a nascent web for the absorbent paper sheet on the foraminous endless fabric;

5 a moving endless pressing blanket;
 a backing roll; and
 a pressing unit engaging the pressing blanket adapted to urge the
nascent web for the absorbent paper sheet on the foraminous endless fabric
into engagement with the backing roll thereby forming a nip, the pressing unit
10 being configured to create a peak engagement pressure of at least about
2000 kN/m² at an overall line load of less than about 240 kN/m.

There is still further disclosed:

A method of making an absorbent paper sheet product comprising:

15 depositing a nascent web for the absorbent paper sheet product on a
moving foraminous endless fabric; and

 contacting the moving foraminous endless fabric bearing the deposited
nascent web with a moving endless pressing blanket engaged with a pressing
unit thereby forming a nip, the pressing unit being configured to create a peak
engagement pressure of at least about 2000 kN/m² at an overall line load of
20 less than about 240 kN/m.

There is also disclosed:

A method of making an absorbent paper sheet product comprising:

 depositing a nascent web for the absorbent paper sheet product on a
moving foraminous endless fabric;

25 contacting the moving foraminous endless fabric bearing the deposited
nascent web with a moving endless pressing blanket engaged with a pressing
unit thereby forming a nip, the pressing unit being configured to create a peak

5 engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m;

transferring the web to a Yankee drying cylinder; and

creping the web from the Yankee drying cylinder.

There is finally disclosed:

10 A method of making an absorbent paper sheet product comprising:

depositing a nascent web for the absorbent paper sheet product on a moving foraminous endless fabric;

contacting the moving foraminous endless fabric bearing the deposited nascent web with a shoe press thereby forming a nip between the shoe press

15 and a Yankee drying cylinder, the shoe press being configured to create a peak engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m;

disengaging the web from the foraminous endless fabric in the nip onto a Yankee drying cylinder;

20 drying the web on the Yankee drying cylinder; and

creping the web from the Yankee drying cylinder.

The accompanying drawings are included to provide a further understanding of the invention and are incorporated in and constitute a part of the specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

25

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a side view of a typical stand alone shoe press.

5 Figure 2 illustrates the relationship between peak pressure and line load for a variety of shoe press arrangements found in the literature, as well as for Yankee suction pressure rolls.

 Figure 3 illustrates nip pressure profiles for a suction pressure roll, a typical shoe press, and a shoe press made according to the present
10 invention.

 Figure 4 illustrates one conventional wet press processing apparatus.

 Figure 5 illustrates one conventional through-air-drying processing apparatus.

 Figure 6 illustrates a typical pressure profile in the nip of a suction
15 pressure roll, backing roll, or transfer cylinder according to the prior art.

 Figure 7 illustrates a pressure profile in the nip of a shoe press.

 Figure 8 illustrates a preferred pressure profile in the nip of a shoe press where the negative pressure corresponds to the vacuum level in the felt.

20 Figure 9 illustrates a shoe press with a large diameter transfer cylinder where the felt rides the web causing rewet after the press nip.

 Figure 10 illustrates a tapered shoe in a shoe press with a large diameter transfer cylinder where the felt is rapidly separated from the web but not from the pressing blanket.

25 Figure 11 illustrates a tapered shoe in a shoe press with a large diameter transfer cylinder where the felt is simultaneously stripped from the sheet and from the pressing blanket on the exit side of the nip.

5 Figure 12 shows a plot of cold Yankee press solids versus line loading for a conventional 120 mm shoe, for a 50 mm shoe made according to the present invention, and for a suction pressure roll.

 Figure 13 illustrates a side view of a typical stand alone shoe press with a blanket having void space.

10 Figure 14 illustrates a blind drilled blanket or belt.

 Figure 15 illustrates a grooved blanket or belt.

DETAILED DESCRIPTION

 In the production of absorbent paper products, paper web drying efficiency and paper web moisture removal directly affect machine speed, and
15 therefore have a significant effect on the productivity that can be attained on a papermachine. The present invention improves paper web moisture removal through the controlled use of a pressing unit in conjunction with a backing roll and/or a transfer cylinder or Yankee drying cylinder. An absorbent paper web as defined herein includes bath tissue, paper towels, paper napkins, wipers,
20 and facial tissue. The basis weight of such products and their base sheets are in the range of about 8 lb/3000ft² to about 50 lb/3000ft².

 According to the present invention, absorbent paper may be produced using any known method or papermaking scheme. The most common papermaking methods are (I) conventional wet pressing (CWP) and (II)
25 through-air-drying (TAD). In a conventional wet press process, i.e., apparatus (10), as exemplified in Figure 4, a furnish is fed by means not shown through conduits (40, 41) to headbox chambers (20, 20'). A web (W) is formed on a

5 conventional wire former on fabric (12), supported by rolls (18, 19), from a liquid slurry of pulp, water and other chemicals. Materials removed from the web through fabric (12) in the forming zone are returned to silo (50), from saveall (22) through conduit (24). The web is then transferred to a moving felt (14), supported by roll (11) for pressing and drying. Materials removed from
10 the web during pressing or from the Uhle box (29) are collected in saveall (44) and fed to white water conduit (45). The web is pressed by suction pressure roll (16) against the surface of a rotating Yankee dryer cylinder (26), which is heated to cause the paper to substantially dry on the cylinder surface. The moisture within the web as it is laid on the Yankee surface causes the web to
15 transfer to the surface. Liquid adhesive may be applied to the surface of the dryer to provide substantial adherence of the web to the creping surface. The web is then creped from the surface with a creping blade (27). The creped web is then usually passed between calender rollers (not shown) and rolled up on reel (28) prior to further converting operations, for example, embossing.

20 A web may alternatively be subjected to vacuum deformation on an impression fabric, alone or in conjunction with other physical deformation processes, and a dewatering step which removes water from the web to a solids content of at least about 30% without the need for overall physical compression. This type of process is conventionally referred to as a through-
25 air-drying process or TAD process. This process is generally described in U.S. Patent Nos. 3,301,746 to Sanford et al. and 3,905,863 to Ayers, which are incorporated herein by reference in their entirety.

5 As an example, one conventional TAD process is illustrated in Figure 5. In this process, fibers are fed from a headbox (10) to a converging set of forming wires (20,30). In this twin wire forming arrangement water is removed from the web by centrifugal forces and by vacuum means. The wet nascent web is cleanly transferred to forming wire (30) via Uhle box (40). The web
10 can be optionally processed to remove water by vacuum box (50) and steam shroud (60). The web is carried along forming fabric (30) until it is transferred to a TAD fabric (70) at junction (80) by means of a vacuum pickup shoe (90). The web is further dewatered at dewatering box (100) to increase web solids. Besides removing water from the web, vacuum pickup shoe (90) and
15 dewatering box (100) inundate the web into TAD fabric (70) causing bulk and absorbency improvements.

 Further enhancements in bulk and absorbency can be obtained by operating the speed of the forming section (i.e., the speeds of forming fabrics 20 and 30) faster than the speed of TAD fabric (70). This is referred to as
20 fabric/fabric creping. In this manner the web is inundated and wet shaped into the fabric creating bulk and absorbency. Thickness created by wet shaping is more effective in generating absorbency (i.e. less structural collapse) than thickness created in the dry state, e.g., by conventional embossing. The web is then carried on TAD fabric (70) to drying unit (110)
25 where heated air is passed through both the web and the fabric to increase the solids content of the web. Generally, the web is 30 to 95% dry after exiting drying unit (110). In one process, the web may be removed directly

5 from TAD fabric (70) in an uncreped state. In the embodiment shown in Figure 5, the web is transferred from TAD fabric (70) to Yankee dryer cylinder (130) and is creped from dryer cylinder (130) via creping blade (150). The creped web is then usually passed between calender rollers (160) and rolled up on reel (170) prior to further converting operations, for example,
10 embossing to make roll products.

According to the present invention, an absorbent paper web can be made by dispersing fibers into aqueous slurry and depositing the aqueous slurry onto the forming wire of a paper making machine. Any art recognized forming scheme might be used. For example, an extensive but non-
15 exhaustive list includes a crescent former, a C-wrap twin wire former, an S-wrap twin wire former, a suction breast roll former, a fourdrinier former, or any art recognized forming configuration. The particular forming apparatus is not critical to the success of the present invention. The forming fabric can be any art recognized foraminous member including single layer fabrics, double layer
20 fabrics, triple layer fabrics, photopolymer fabrics, and the like. Non-exhaustive background art in the forming fabric area include U.S. Patent Nos. 4,157,276; 4,605,585; 4,161,195; 3,545,705; 3,549,742; 3,858,623; 4,041,989; 4,071,050; 4,112,982; 4,149,571; 4,182,381; 4,184,519; 4,314,589; 4,359,069; 4,376,455; 4,379,735; 4,453,573; 4,564,052; 4,592, 395; 4,611,639; 4,640,741; 4,709,732; 4,759,391; 4,759,976; 4,942,077; 4,967,085; 4,998,568; 5,016,678; 5,054,525; 5,066,532; 5,098,519; 5,103,874; 5,114,777; 5,167,261; 5,199,467; 5,211,815; 5,219,004;

5 5,245,025; 5,277,761; 5,328,565; and 5,379,808 all of which are incorporated herein by reference in their entirety. The particular forming fabric is not critical to the success of the present invention. One forming fabric found particularly useful with the present invention is Appleton Mills Forming Fabric 2184 made by Appleton Mills Forming Fabric Corporation, Florence, MS.

10 Papermaking fibers used to form the absorbent products of the present invention include cellulosic fibers commonly referred to as wood pulp fibers, liberated in the pulping process from softwood (gymnosperms or coniferous trees) and hardwoods (angiosperms or deciduous trees). Cellulosic fibers from diverse material origins may be used to form the web of
15 the present invention. These fibers include non-woody fibers liberated from sugar cane, bagasse, sabai grass, rice straw, banana leaves, paper mulberry (i.e., bast fiber), abaca leaves, pineapple leaves, esparto grass leaves, and fibers from the genus *Hesperaloe* in the family *Agavaceae*. Also recycled fibers which may contain any of the above fiber sources in different
20 percentages, can be used in the present invention. Suitable fibers are disclosed in U.S. Patent Nos., 5,320,710 and 3,620,911, both of which are incorporated herein by reference.

25 Papermaking fibers can be liberated from their source material by any one of the number of chemical pulping processes familiar to one experienced in the art including sulfate, sulfite, polysulfide, soda pulping, etc. The pulp can be bleached if desired by chemical means including the use of chlorine, chlorine dioxide, oxygen, etc. Furthermore, papermaking fibers can be

5 liberated from source material by any one of a number of
mechanical/chemical pulping processes familiar to anyone experienced in the
art including mechanical pulping, thermomechanical pulping, and chemi-
thermomechanical pulping. These mechanical pulps can be bleached, if
necessary, by a number of familiar bleaching schemes including alkaline
10 peroxide and ozone bleaching.

 The suspension of fibers or furnish may contain chemical additives to
alter the physical properties of the paper produced. These chemistries are
well understood by the skilled artisan and may be used in any known
combination.

15 The pulp can be mixed with strength adjusting agents such as wet
strength agents, dry strength agents and debonders/softeners. Suitable wet
strength agents will be readily apparent to the skilled artisan. A
comprehensive but non-exhaustive list of useful wet strength aids include
urea-formaldehyde resins, melamine formaldehyde resins, glyoxylated
20 polyacrylamide resins, polyamide-epichlorhydrin resins and the like.
Thermosetting polyacrylamides are produced by reacting acrylamide with
diallyl dimethyl ammonium chloride (DADMAC) to produce a cationic
polyacrylamide copolymer which is ultimately reacted with glyoxal to produce
a cationic cross-linking wet strength resin, glyoxylated polyacrylamide. These
25 materials are generally described in U.S. Patent Nos. 3,556,932 to Coscia et
al. and 3,556,933 to Williams et al., both of which are incorporated herein by
reference in their entirety. Resins of this type are commercially available

5 under the tradename of PAREZ 631NC by Cytec Industries. Different mole ratios of acrylamide/DADMAC/glyoxal can be used to produce cross-linking resins, which are useful as wet strength agents. Furthermore, other dialdehydes can be substituted for glyoxal to produce thermosetting wet strength characteristics. Of particular utility are the polyamide-epichlorhydrin resins, an example of which is sold under the tradenames Kymene 557LX and Kymene 557H by Hercules Incorporated of Wilmington, Delaware and CASCAMID® from Borden Chemical Inc. These resins and the process for making the resins are described in U.S. Patent No. 3,700,623 and U.S. Patent No. 3,772,076 each of which is incorporated herein by reference in its entirety. An extensive description of polymeric-epihalohydrin resins is given in Chapter 2: Alkaline -Curing Polymeric Amine-Epichlorohydrin by Espy in *Wet-Strength Resins and Their Application* (L. Chan, Editor, 1994), herein incorporated by reference in its entirety. A reasonably comprehensive list of wet strength resins is described by Westfelt in Cellulose Chemistry and Technology, Volume 13, p. 813, 1979, which is incorporated herein by reference. The pulp, when making towel grades according to the present invention, preferably contains up to about 30 lbs/ton, more preferably from 10 to 20 lbs/ton of wet strength aids. Wet strength resins are not normally added to tissue grades.

25 Suitable dry strength agents will be readily apparent to one skilled in the art. A comprehensive but non-exhaustive list of useful dry strength aids includes starch, guar gum, polyacrylamides, carboxymethyl cellulose and the

5 like. Of particular utility is carboxymethyl cellulose, an example of which is sold under the tradename Hercules CMC by Hercules Incorporated of Wilmington, Delaware. The pulp preferably contains from 0 to 10 lbs/ton, more preferably from 1 to 5 lbs/ton of dry strength aid.

 Suitable debonders will be readily apparent to the skilled artisan.

10 Debonders or softeners may also be incorporated into the pulp or sprayed upon the web after its formation. The pulp preferably contains from 0 to 10 lbs/ton, more preferably from 1 to 5 lbs/ton of debonder/softener.

 The present invention may be used with a particular class of softener materials - amido amine salts derived from partially acid neutralized amines.

15 Such materials are disclosed in U.S. Patent No. 4,720,383. Evans, Chemistry and Industry, 5 July 1969, Pp. 893-903; Egan, J. Am. Oil Chemist's Soc., Vol. 55 (1978), Pp. 118-121; and Trivedi et al., J. Am. Oil Chemist's Soc., June 1981, Pp. 754-756, incorporated by reference in their entirety, indicate that softeners are often available commercially only as complex mixtures rather
20 than as single compounds. While the following discussion will focus on the predominant species, it should be understood that commercially available mixtures would generally be used in practice.

 Quasoft 202-JR is a suitable softener material, which may be derived by alkylating a condensation product of oleic acid and diethylenetriamine.

25 Synthesis conditions using a deficiency of alkylation agent (e.g., diethyl sulfate) and only one alkylating step, followed by pH adjustment to protonate the non-ethylated species, result in a mixture consisting of cationic ethylated

5 and cationic non-ethylated species. A minor proportion (e.g., about 10%) of the resulting amido amine cyclize to imidazoline compounds. Since only the imidazoline portions of these material are quaternary ammonium compounds, the compositions as a whole are pH-sensitive. Therefore, in the practice of the present invention with this class of chemicals, the pH in the headbox
10 should be approximately 6 to 8, more preferably 6 to 7 and most preferably 6.5 to 7.

Quaternary ammonium compounds, such as dialkyl dimethyl quaternary ammonium salts are also suitable particularly when the alkyl groups contain from about 14 to 20 carbon atoms. These compounds have
15 the advantage of being relatively insensitive to pH.

Biodegradable softeners can be utilized. Representative biodegradable cationic softeners/debonders are disclosed in U.S. Patent Nos. 5,312,522; 5,415,737; 5,262,007; 5,264,082; and 5,223,096, all of which are incorporated herein by reference in their entirety. These compounds are
20 biodegradable diesters of quaternary ammonia compounds, quaternized amine-esters, and biodegradable vegetable oil based esters functional with quaternary ammonium chloride and diester dierucyldimethyl ammonium chloride and are representative biodegradable softeners.

The fibrous web is then either deposited on an impression drying
25 fabric, in the case of the TAD process or on a dewatering felt for the CWP process. Any art recognized fabrics or felts could be used with the present invention. For example, a non-exhaustive list of impression fabrics would

5 include plain weave fabrics described in U.S. Patent No. 3,301,746; semitwill fabrics described in U.S. Patent Nos. 3,974,025 and 3,905,863; bilaterally-staggered-wicker-basket-cavity type fabrics described in U.S. Patent Nos. 4,239,065 and 4,191,609; sculptured/load bearing layer type fabrics described in U.S. Patent No. 5,429,686; photopolymer fabrics described in
10 U.S. Patent Nos. 4,529,480, 4,637,859, 4,514,345, 4,528,339, 5,364,504, 5,334,289, 5,275,799, and 5,260,171; and fabrics containing diagonal pockets described in U.S. Patent No. 5,456,293. The aforementioned patents are incorporated herein by reference, in their entirety. Any art-recognized-felt can be used with the present invention. For example, felts can have double-
15 layer base weaves, triple-layer base weaves, or laminated base weaves. Preferred felts according to the present invention are those having the laminated base weave design. A wet-press-felt found particularly useful with the present invention is AMFlex 3 made by Appleton Mills Corporation. Non-exhaustive background art in the press felt area includes U.S. Patent Nos.
20 5,657,797; 5,368,696; 4,973,512; 5,023,132; 5,225,269; 5,182,164; 5,372,876; and 5,618,612 all-of-which are incorporated herein by reference in their entirety. After the web made by the conventional wet press process has reached a solids content of about 15 %, more preferably about 20 %, the web/foraminous fabric sandwich is contacted with a pressing blanket engaged
25 with a pressing unit, one embodiment in the art referred to as a shoe press. In a similar web made by through air drying, the web/foraminous fabric sandwich is preferably contacted with the pressing blanket engaged with a

5 pressing unit after the web has reached a solids content of at least about 20%, more preferably at least about 25%.

 The pressing unit including a pressing blanket according to the present invention can have any art-recognized configuration. The nip can be created between the pressing unit and a backing roll, in the case of a stand-alone
10 pressing unit, or can be created between the pressing unit and a transfer cylinder. As used in the present invention, backing roll refers to a roll that contacts the web but does not remove the fibrous web from the carrier fabric or felt. Backing rolls for use according to the present invention may be heated or cold. The backing roll can be made of hard rubber or metal. When
15 the rolls are heated with an induction heater the roll is preferably constructed or coated with high diffusivity material, such as copper, to aid in increasing heat transfer.

 As used in the present invention, transfer cylinder refers to a roll that picks up the fibrous web thereby transferring the fibrous web from the
20 foraminous carrier fabric upon which it had been carried. Typical transfer cylinders according to the present invention can include a steel roll, a metal coated roll, a granite roll, a Yankee drying cylinder, and a gas fired drying cylinder. Transfer cylinders for use according to the present method may be heated or cold. When the transfer cylinder is heated with an induction heater
25 the cylinder is preferably constructed or coated with high diffusivity material, such as copper, to aid in increasing heat transfer. One or more transfer cylinders may be used in the process according to the present invention.

5 Heat is preferably applied to the transfer cylinder and/or backing roll.
Heat can be applied by any art-known scheme including induction heating, oil heating and steam heating. Commercial available induction heaters can generate very high energy-transfer rates. An induction heater induces electrical current to the conducting roll surface. Since the induced current can
10 be quite large, this factor produces a substantial amount of resistive heating in the conducting roll. Backing roll or transfer cylinder temperature can be anywhere from ambient to 700 ° F but are more preferably from 180 ° F to 500 ° F. Preferred heating schemes according to the present invention are induction heating and steam-heating.

15 Increased temperature in the backing roll or transfer cylinder decreases the viscosity of the water and makes the sheet more deformable hence improving water removal. Also, increased temperature and operating pressure bring the sheet into intimate contact with the transfer cylinder or backing roll, which improves heat transfer to the web. Furthermore, high
20 steam pressure in the web within the nip can aid in rapidly displacing water from the sheet to the felt.

The pressing unit including a pressing blanket according to the present invention is preferably a shoe press. A shoe press includes a shoe element(s), which is pressed against the backing roll or transfer cylinder. The
25 shoe element is loaded hydrodynamically against the backing roll or transfer cylinder causing a nip to be formed. A pressing belt or blanket traverses the shoe press nip with the fibrous web in contact with the foraminous fabric.

5 Pressing blankets can be smooth, or to enhance water removal at the
press they can be grooved or blind drilled. Conventional pressing blanket
designs contain a fabric coated with polyurethane where the fabric is used as
reinforcement. Other pressing blanket designs use yarns embedded in the
polyurethane to provide reinforcement. One preferred pressing blanket
10 according to the present invention is a yarn reinforced blanket design under
the tradename QualiFlex B, which is supplied by Voith Sulzer Corporation.

 The shoe element length can be less than about 7 inches but is more
preferably less than about 3 inches for the present invention. According to
the present invention the shoe element will also be referred to as a hydraulic
15 engagement member. Shoe designs can be hydrodynamic, hydrodynamic
pocket, or hydrostatic. In the hydrodynamic shoe design, the oil lubricant
forms a wedge at the ingoing side of the nip ultimately causing the formation
of a thin oil film that protects the blanket and the shoe. The hydrodynamic
pocket design incorporates a machined full width pocket in the shoe used for
20 emptying the oil in the pressurized zone of the shoe. The final design is the
hydrostatic design where oil is fed into the center region of the shoe. The
preferred shoe design according to the present invention is hydrodynamic.

 Shoe presses for use according to the present invention can be open
or closed. Early shoe press designs were the open belt configurations where
25 an impermeable pressing blanket encircled a series of rollers similar to that of
a fabric or felt run. These open designs suffered from papermachine system
contamination by oil. The oil loss was at one time, up to 20 liters per day on

5 some systems. The open shoe design is also inferior to a closed design since it cannot be operated in the inverted mode. The closed shoe design alleviates the oil contamination issue and is therefore preferred for use in the present invention.

10 According to one embodiment of the present invention, the peak pressure in the shoe press is preferably greater than about 2000 kN/m², with a line load of preferably less than about 240 kN/m. In another embodiment of the present invention, for conventionally made wide-Yankee-dryers the peak pressure is preferably greater than about 2000 kN/m², while the line load is preferably less than about 175 kN/m and more preferably less than about 100
15 kN/m. For the purposes of the present invention, kN/m is an abbreviation for kilonewtons per meter and kN/m² is an abbreviation for kilonewtons per square meter.

 The sheet can be creped from the transfer cylinder by any art-recognized methods using any art recognized creping aid.

20 The maximum line load a current standard Yankee can sustain is on the order of 100kN/m. When a Yankee is used in conjunction with a suction pressure roll, the Yankee needs to be precisely crowned at the prevailing load to obtain a uniform nip. This procedure is necessary due to the inflexibility of the suction pressure roll arrangement and also due to loading at only the
25 ends of the suction pressure roll. For the case of a shoe press, loading occurs at multiple points across the cross machine direction; individual shoe elements can be installed across the machine to give more precise cross

5 machine direction pressing flexibility; and the shoe press is flexible and capable of conforming to the Yankee dryer surface. As a result, the precision to which the Yankee is ground for crowning will be less.

Figure 6 shows a schematic sketch of a typical pressure distribution curve for a suction pressure roll described by symmetrical mathematical
10 functions like the sine and haversine curves. Since the nip pressure is relieved when the nip diverges, rewet is exacerbated for the suction pressure roll. Figure 7 shows a schematic sketch of a pressure distribution curve for a shoe press with a steep drop off where the felt is stripped from the sheet and later from the pressing blanket. Such a steep drop-off in pressure reduces
15 the amount of rewet. Figure 8 shows a schematic sketch of a pressure distribution curve for a shoe press with a steeper drop off and where suction occurs in the felt at the point of simultaneous separation of the felt, sheet, and blanket when the nip pressure reaches about zero. The negative pressure in the felt, when the blanket and felt are stripped apart, is caused by capillary
20 forces and should aid in holding water in the felt and should help further dewater the web.

Previous shoe, belt or blanket, and felt designs in wide nip presses do not permit optimum separation of these members. For instance, present designs allow for quick separation of the felt and blanket since the felt cannot
25 "wrap" the unsupported blanket. But the drawback is that the felt stays in contact with the sheet allowing capillary flow back into the sheet, i.e., rewet (see Figure 9). Figure 9 is a schematic sketch of a shoe press nip showing

5 sheet, felt, and blanket. Point A in Figure 9 is the point of zero pressure on the pressure distribution curve at the exit side of the nip.

Rewet is determined in the literature by plotting moisture ratio versus the reciprocal of the basis weight using the following equation:

$$K_p = K_o + R/W$$

10 where K_p is the moisture ratio of the paper after the wet press in grams of water per gram of fiber; K_o is the moisture ratio of paper for $1/W = 0$; W is the basis weight in g/m^2 ; and R is the magnitude of the rewet of paper in g/m^2 and corresponds to the slope of the straight line used to fit moisture ratio versus reciprocal basis weight data. The aforementioned equation was first
15 established by John Sweet. Data plotted according to the above equation is frequently referred to in the literature as a Sweet plot. The original work can be found in Sweet, J.S., Pulp and Paper Mag. Can., 62, No. 7: T267 (1961) and a review article can be found in Heller, H., MacGregor, M., and Bliesner, W., Paper Technology and Industry, p.154, June, 1975. Rewet is much more
20 significant for lightweight tissue grades than heavy weight linerboard grades. Rewet has been estimated to be from 5 to 50 g/m^2 of water, depending on the felt, furnish, etc. Rewet for a conventional shoe press can be determined from the above equation. The amount of rewet for the optimum shoe press is preferably less than about 50 % of the amount determined from Sweet's
25 theory using a conventional shoe press system. Rewet is preferably from 0 to 10 g/m^2 of water, more preferably from 0 to 5 g/m^2 of water.

According to another embodiment of the present invention, a pressing

5 felt wraps the blanket and, therefore, pulls away quickly from the sheet
reducing the time for possible rewetting. This design, as depicted in Figure
10, can be achieved by altering the take-away angle of the felt from the nip
and tapering the exit side of the shoe. To aid in blanket deflection from the felt
at the exit side of the shoe, the blanket diameter can be reduced; the blanket
10 can be eccentrically arranged with respects to the press plane; or a roll (not
shown in Figure 10) positioned against the blanket can deflect the belt
further.

Figure 11 shows another embodiment according to the present
invention. In Figure 11, a schematic sketch of a shoe press showing a sheet,
15 felt, and blanket is displayed. This shoe press utilizes a very steep pressure
drop at and following the exit of a nip curve of the press while simultaneously,
separating the felt from the blanket and from the sheet. In this manner, the
negative pressure generated by surface tension forces as the felt and blanket
separate are effective in reducing the flow of water back into the sheet as the
20 felt and sheet are separated. The drawing shows a sharp drop off of the
blanket near the shoe which in turn permits a quick separation of the felt from
both the blanket and the sheet. The outgoing felt would be pulled at an angle
that equally bisected the Yankee and blanket surfaces. Then by adjusting the
tension on the felt, the exact point of separation can be controlled to affect the
25 minimum in rewet. A felt drive roll located immediately following the shoe
press can control the tension level on the felt. The objective of this
embodiment according to the present invention is to affect the transfer of the

5 sheet from the felt at the same time that the negative pulse caused by the separation of the felt and blanket occurs. This design not only minimizes the time the felt is in contact with the sheet; the added vacuum pulse will significantly reduce the amount of water that can flow, even over the short time. Point A in Figure 11 is the point of zero pressure on the pressure
10 distribution curve at the exit side of the nip. The nip pressure curve for the sheet/felt in Figure 11 would most likely approach that shown in Figure 8.

The web is preferably either adhered to the Yankee dryer by nip transfer with a pressing unit including a pressing blanket or is after pressing adhered to the Yankee dryer. The web is dried by steam and hot air
15 impingement hoods. Any suitable art recognized adhesive might be used on the Yankee dryer. Preferred adhesives include polyvinyl alcohol with suitable plasticizers, glyoxylated polyacrylamide with or without polyvinyl alcohol, and polyamide epichlorohydrin resins such as Quacoat A-252 (QA252), Betzcreplus 97 (Betz+97) and Calgon 675 B. Suitable adhesives are widely
20 described in the patent literature. A comprehensive but non-exhaustive list includes U.S. Patent Nos. 5,246,544; 4,304,625; 4,064,213; 3,926,716; 4,501,640; 4,528,316; 4,788,243; 4,883,564; 4,684,439; 5,326,434; 4,886,579; 5,374,334; 4,440,898; 5,382,323; 4,094,718; 5,025,046; and 5,281,307. Typical release agents can be used in accordance with the
25 present invention.

The final product may be calendered or uncalendered and is usually reeled to await further converting processes. The products according to the

5 present invention may be subjected to any art recognized converting operations, including embossing, printing, etc.

The following example is illustrative of the invention embodied herein.

EXAMPLE 1

10 A nascent web was formed on a Crescent-forming machine using a blend of 50/50 long fiber/short fiber refined to 23° SR freeness. Chemicals like wet strength agents or dry strength agents were not added to the stock. The basis weight of the sheet on the Yankee dryer was 8.5 lbs/3000 ft². Two pressing arrangements were used on the paper machine. In the first pressing arrangement, the sheet was pressed onto a Yankee dryer with a suction
15 pressure roll. The vacuum in the suction roll was nominally 0.22 bar. In the second pressing arrangement, the suction pressure roll was replaced by a Yankee shoe press. The sheet was conditioned before the shoe press with a suction turning roll having the same size and open area as the suction pressure roll. The suction turning roll vacuum was nominally equivalent to the
20 level used during the suction pressure roll experiments. After sheet conditioning, the web was pressed onto the Yankee with a shoe press. In order to obtain precise sheet solids data after the shoe press or the suction pressure roll, the Yankee dryer was run cold. Blotters were used to collect flatsheets for physical property determination. Two types of shoes were run:
25 a typical 120 mm shoe and a 50 mm shoe. Figure 3 shows the pressure distribution of the shoes and the suction pressure roll. Figure 12 depicts a plot of sheet solids versus line loading. The typical 120 mm shoe shows no

5 solids benefit versus the suction pressure roll at present operating line load
limits of current Yankee dryers (i.e., approximately, 87.5 kN/m), while the 50
mm pressure optimized shoe press shows an advantage of several
percentage points of solids. Furthermore, the strength and specific volume
properties of a web made with the 50 mm pressure optimized shoe press
10 were equivalent to the strength and specific volume properties of a web made
by the suction pressure roll.

Figures 13-15 illustrate a method for maximizing water removal in a
press nip in accordance with another embodiment of the present invention.
The present embodiment involves a conventional wet pressing (CWP)
15 process. For consistency, like numbers have been used to indicate the
corresponding portions of the apparatus depicted in Figures 13-15 with those
of Figures 1-12. The description of the apparatus of Figures 1-12 thus
applies equally to this embodiment, unless stated otherwise.

Referring to Figure 13, the present embodiment uses a shoe press,
20 preferably a controlled crown roll with a flexible shell and a concave shoe
hydrodynamically loaded against one another. The present embodiment
further includes a belt or blanket (100) having a void volume that enhances
sheet solids after the shoe press to further improve water removal in the
press nip. Appropriate void volume can be achieved by a number of blanket
25 configurations, including, but not limited to, those made by grooving, blind
drilling and the like. The total void volume of the belt or blanket for use
according to the present invention is preferably about 50 to about 3000

5 cm³/m², more preferably about 100 to about 1000 cm³/m², most preferably from about 200 to about 500 cm³/m³.

Blankets for use according to the present invention can include any art recognized blanket having, or which can be modified to have, the required void volume.

10 For example, blankets disclosed by E.J. Justus and D. Cronin in Tappi, August 1964, Vol. 47, No. 8, p. 493, which is incorporated herein by reference, include grooved belts that improve water removal in a press nip where the groove width is about 0.01 to about 0.03 in., the land width is about 2 to about 20 times the groove width and the groove depth is about 2 to about 15 10 times the groove width.

For another example, blankets disclosed by Bo-Christer Aberg in Das Papier No.6, 1996, which is incorporated herein by reference, include grooved belts that work at higher line loads and machine speeds than smooth belts. The belts have groove widths of about 0.5 to about 1 mm and a void 20 volume of about 100 cc/m² to about 500 cc/m².

For yet another example, blankets disclosed by P. Slater and K. Fitzpatrick in the 84th Annual Meeting of the Technical Section, CPPA, January 1998, which is incorporated herein by reference, include grooved belts that provide a press dryness about 1% to about 3% greater than the 25 press dryness obtained with a similar smooth belt. The belts have groove widths of about 0.58 to about 0.79 mm and a void volume of about 200 cc/m² to about 365 cc/m².

5 For still another example, blankets disclosed by D. Madden et al. in the
Tappi 1998 Engineering Conference, which is incorporated herein by
reference, include grooved belts that provide a press dryness about 1%
greater than the dryness obtained with a blind drilled belt. The grooved belt
has an open area of about a 20.3% and a void volume of about 260 cc/m²,
10 and the blind drilled belt has an open area of about 21% and a void volume of
about 380 cc/m² void volume.

Referring to Figure 14, blind drilling involves drilling holes into a
smooth blanket, as will be understood by one of skill in the art. Nip
compression between a blind drilled blanket and the felt causes a hydraulic
15 pressure gradient between the holes in the blanket and the felt which
improves water flow and removal.

The blind drilled blanket preferably has a plurality of holes sequentially
arranged in the machine direction and a plurality of rows sequentially
arranged in the cross-machine direction to cause a hydraulic pressure
20 gradient. The blind drilled blanket can take a variety of configurations. For
example, the hole depth, hole diameter, hole spacing, hole angle, hole
geometry, row spacing and/or row pattern can be varied.

In particular, the hole depth can range from about 0.2 to about 10 mm,
more preferably about 0.5 to about 5 mm, most preferably from about 0.5 to
25 about 3 mm. Also, the hole depth can extend partially or completely through
the blanket.

The hole diameter can range from about 0.2 to about 10 mm, more

5 preferably about 0.5 to about 5 mm, most preferably from about 1 to about 3 mm.

 The hole spacing can range from about 1 to about 20 mm between holes arranged within the same row, more preferably about 1 to about 10 mm, most preferably from about 1 to about 5 mm.

10 The hole angle (i.e., the angle measured from the surface of the belt material counterclockwise to the side of the hole) can range from about 45 to about 135 degrees along any wall in either the machine or cross-machine, more preferably about 70 to about 110 degrees, most preferably from about 80 to about 100 degrees.

15 The row spacing can range from about 1 to about 20 mm, more preferably about 1 to about 10 mm, most preferably from about 1 to about 5 mm.

 The hole geometry can be curved, linear or curvilinear, e.g. round, square, elliptical, polygonal, and the row pattern can be such that the holes in
20 each row are aligned in the cross-machine direction, offset in the cross-machine direction, aligned in the machine direction, offset in the machine direction and the like.

 There is no requirement that all holes have the same configuration, rather, each of the holes can have a different configuration, or one or more
25 individual or set of holes can have the same configuration as one or more other individual or set of holes. Further, there is no requirement that the hole pattern form any type of geometric or other pattern, for example, the pattern

5 can be random.

Referring to Figure 15, forming grooves in the blanket involves removing elongated sections, as will be understood by one of skill in the art. Nip compression of the grooved blanket and the press felt causes a hydraulic pressure gradient in the machine direction, which improves water flow and
10 removal.

The grooved blanket preferably has a plurality of grooved sections sequentially arranged in the cross-machine direction that circumscribe the blanket to cause machine direction water movement. The grooved blanket can take a variety of configurations. For example, the groove depth, groove
15 width, groove bevel, groove angle, land width, open area and groove pattern can all be varied.

In particular, the groove depth can range from about 0.1 to about 8 mm, more preferably about 0.2 to about 5 mm, most preferably from about 0.4 to about 3mm.

20 The groove width can range from about 0.1 to about 6 mm, more preferably about 0.2 to about 4 mm, most preferably from about 0.4 to about 3 mm.

The groove bevel (i.e., the angle measured from the surface of the belt material counterclockwise to the side of the groove minus 90°) can range
25 from about 0 to about 45°, more preferably about 0 to about 30°, most preferably from about 0 to about 20°.

The groove angle can range from about 45 to about 135 degrees (with

5 90 degrees being orthogonal to the cross-machine direction), more preferably about 65 to about 115°, most preferably from about 80 to about 100°.

 The land width can range from about 0.2 to about 25 mm, more preferably about 0.4 to about 10 mm, most preferably from about 0.6 to about 4 mm.

10 The open area can range up to 80% of the total blanket area, more preferably about 15 to about 50%, most preferably from about 20 to about 40%.

 The groove pattern can be such that the grooves in each row are aligned in the cross-machine direction, offset in the cross-machine direction,
15 aligned in the machine direction, offset in the machine direction and the like. Also, for blankets for use in the present invention, grooves need not have the same configuration, rather, all the grooves can have a different configuration, or one or more individual or set of grooves can have the same configuration as one or more other individual or set of grooves. Further, there is no
20 requirement that the groove pattern form any type of geometric or other pattern, for example, the groove placement can also be random.

 Blankets having the disclosed void volume will be readily apparent to the skilled artisan. Such blankets can include any physical arrangement as long as the void space requirements are satisfied. Blankets for use in the
25 present invention may be manufactured by any art recognized process, including but not limited to, casting molding, laser engraving, etc.

EXAMPLE 2

5

A punch press was used to perform dewatering experiments with different belt structures. An AMFlex 3S felt manufactured by Appleton Mills Corporation was used to dewater the paper web. The web basis weight was 8.9 lbs/rm. The felt dryness was controlled to 69.3% dryness by using blotters and a couch roll to remove excess water. Web moisture was controlled to 19.3% dryness by rewetting moist webs using a water spray. The webs were made from a 50/50 blend of northern softwood kraft and eucalyptus refined in a PFI mill to 510 ml CSF.

10

15

A smooth belt, a blind drilled belt and a grooved belt were used in the punch press experiment. The blind drilled belt had a bore area of 3.82 mm², a bore depth of 1.76 mm, an open area of 22.73% and a void volume of 402.9 cc/m². The grooved belt had a groove width of 0.66 mm, a groove depth of 1.41 mm, a pitch of 0.33 grooves/mm, an open area of 21.78%, and a void volume of 270.6 cc/m².

20

The punch press was operated such that the average nip pressure was fixed at 400 psi and the average nip dwell time was fixed at 1.8 ms. The experimental post press dryness results for the experiment were:

smooth belt 31.0 +/- 0.30%

blind drilled belt 39.2 +/- 0.28%

grooved belt 40.3 +/- 0.42%

25

with the +/- percentage being the 95% confidence limit for the test.

These results indicate that pressing with either a blind drilled or grooved belt leads to enhanced sheet solids when compared to a smooth

5 belt. These results also indicate that pressing with a grooved belt leads to enhanced sheet solids over a blind drilled belt.

Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be
10 considered as exemplary only, with the true scope and spirit of the invention being indicated by the following claims.

We Claim:

1. An apparatus for forming an absorbent paper sheet product comprising:
 - a moving foraminous endless fabric;
 - means for depositing a nascent web for said absorbent paper sheet on said foraminous endless fabric;
 - a moving endless pressing blanket;
 - a Yankee drying cylinder; and
 - a pressing unit engaging said pressing blanket adapted to urge said nascent web for said absorbent paper sheet on said foraminous endless fabric into engagement with said Yankee drying cylinder thereby forming a nip, said pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m^2 at an overall line load of less than about 240 kN/m .
2. The apparatus of claim 1, wherein said pressing unit is additionally configured to impose an asymmetrical pressure distribution upon said nascent web, said asymmetrical pressure distribution being skewed such that the pressure declines from a peak pressure to a value of 20% of said peak pressure over a nip length which is no more than about half of the nip length over which it rose to said peak pressure from 20% of said peak pressure.
3. The apparatus of claim 1, wherein said pressing unit comprises at least one hydraulic engagement member.

4. The apparatus of claim 3, wherein said at least one hydraulic engagement member has a length of less than about 3 inches.
5. The apparatus of claim 4, wherein said at least one hydraulic engagement member has a length of less than about 2 inches.
6. The apparatus of claim 1, wherein said foraminous endless fabric is a press felt or an impression fabric.
7. The apparatus of claim 1, wherein the means for forming a nascent web is selected from a crescent former, a twin wire former, a suction breast roll former, or a fourdrinier former.
8. The apparatus of claim 1, wherein said pressing unit is configured to have a line load of less than about 175 kN/m.
9. The apparatus of claim 1, wherein said pressing unit is configured to have a line load of less than about 100 kN/m.
10. The apparatus of claim 1, wherein the peak pressure in said nip is at least about 2500 kN/m².
11. The apparatus of claim 1, wherein the peak pressure in said nip is at least about 3000 kN/m².
12. The apparatus of claim 1, wherein the peak pressure in said nip is at least about 3150 kN/m².
13. The apparatus of claim 1, further comprising a creping blade for removing said absorbent paper sheet from said Yankee dryer.
14. The apparatus of claim 1, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric such

that rewet of said nascent web by said foraminous endless fabric is less than about 50% of the rewet predicted by the Sweet equations based upon the properties of said foraminous endless fabric and said nascent web.

15. The apparatus of claim 14, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric at a nip length of less than about one inch from the point the nip pressure reaches zero.

16. The apparatus of claim 14, wherein said pressing unit is configured to both disengage said web from said foraminous endless fabric and disengage said foraminous endless fabric from said pressing blanket at a nip length of less than about one inch from the point the nip pressure reaches zero.

17. An apparatus for forming an absorbent paper sheet product comprising:

a moving foraminous endless fabric;

means for depositing a nascent web for said absorbent paper sheet on said foraminous endless fabric;

a moving endless pressing blanket;

a Yankee drying cylinder; and

a pressing unit engaging said pressing blanket adapted to urge said nascent web for said absorbent paper sheet on said foraminous endless fabric into engagement with said Yankee drying cylinder thereby forming a nip, said pressing unit being configured to create a peak engagement

pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m,

said pressing unit being configured to disengage said web from said foraminous endless fabric such that rewet of said nascent web by said foraminous endless fabric is less than about 50% of the rewet predicted by the Sweet equations based upon the properties of said foraminous endless fabric and said nascent web.

18. The apparatus of claim 17, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric at a nip length of less than about one inch from the point the nip pressure reaches zero.

19. The apparatus of claim 17, wherein said pressing unit is configured to both disengage said web from said foraminous endless fabric and disengage said foraminous endless fabric from said pressing blanket at a nip length of less than about one inch from the point the nip pressure reaches zero.

20. The apparatus of claim 17, wherein said pressing unit is additionally configured to impose an asymmetrical pressure distribution upon said nascent web, said asymmetrical pressure distribution being skewed such that the pressure declines from a peak pressure to a value of 20% of said peak pressure over a nip length which is no more than about half of the nip length over which it rose to said peak pressure from 20% of said peak pressure.

21. The apparatus of claim 17, wherein said pressing unit comprises at least one hydraulic engagement member.

22. The apparatus of claim 21, wherein said at least one hydraulic engagement member has a length of less than about 3 inches.

23. The apparatus of claim 22, wherein said at least one hydraulic engagement member has a length of less than about 2 inches.

24. The apparatus of claim 17, wherein said foraminous endless fabric is a press felt or an impression fabric.

25. The apparatus of claim 17, wherein the means for forming a nascent web is selected from a crescent former, a twin wire former, a suction breast roll former, or a fourdrinier former.

26. The apparatus of claim 17, wherein said pressing unit is configured to have a line load of less than about 175 kN/m.

27. The apparatus of claim 17, wherein said pressing unit is configured to have a line load of less than about 100 kN/m.

28. The apparatus of claim 17, wherein the peak pressure in said nip is at least about 2500 kN/m².

29. The apparatus of claim 17, wherein the peak pressure in said nip is at least about 3000 kN/m².

30. The apparatus of claim 17, wherein the peak pressure in said nip is at least about 3150 kN/m².

31. The apparatus of claim 17, further comprising a creping blade for removing said absorbent paper sheet from said Yankee dryer.

32. An apparatus for forming an absorbent paper sheet product comprising:

- a moving foraminous endless fabric;
- means for depositing a nascent web for said absorbent paper sheet on said foraminous endless fabric;
- a moving endless pressing blanket;
- a Yankee drying cylinder; and
- a pressing unit engaging said pressing blanket adapted to urge said nascent web for said absorbent paper sheet on said foraminous endless fabric into engagement with said Yankee drying cylinder thereby forming a nip, said pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m^2 at an overall line load of less than about 240 kN/m ,

said pressing unit being configured to both disengage said web from said foraminous endless fabric and disengage said foraminous endless fabric from said pressing blanket at a nip length of less than about one inch from the point the nip pressure reaches zero.

33. The apparatus of claim 32, wherein said pressing unit is additionally configured to impose an asymmetrical pressure distribution upon said nascent web, said asymmetrical pressure distribution being skewed such that the pressure declines from a peak pressure to a value of 20% of said peak pressure over a nip length which is no more than about half of the nip length over which it rose to said peak pressure from 20% of said peak

pressure.

34. The apparatus of claim 32, wherein said pressing unit comprises at least one hydraulic engagement member.

35. The apparatus of claim 34, wherein said at least one hydraulic engagement member has a length of less than about 3 inches.

36. The apparatus of claim 35, wherein said at least one hydraulic engagement member has a length of less than about 2 inches.

37. The apparatus of claim 32, wherein said foraminous endless fabric is a press felt or an impression fabric.

38. The apparatus of claim 32, wherein the means for forming a nascent web is selected from a crescent former, a twin wire former, a suction breast roll former, or a fourdrinier former.

39. The apparatus of claim 32, wherein said pressing unit is configured to have a line load of less than about 175 kN/m.

40. The apparatus of claim 32, wherein said pressing unit is configured to have a line load of less than about 100 kN/m.

41. The apparatus of claim 32, wherein the peak pressure in said nip is at least about 2500 kN/m².

42. The apparatus of claim 32, wherein the peak pressure in said nip is at least about 3000 kN/m².

43. The apparatus of claim 32, wherein the peak pressure in said nip is at least about 3150 kN/m².

44. The apparatus of claim 32, further comprising a creping blade

for removing said absorbent paper sheet from said Yankee dryer.

45. The apparatus of claim 32, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric such that rewet of said nascent web by said foraminous endless fabric is less than about 50% of the rewet predicted by the Sweet equations based upon the properties of said foraminous endless fabric and said nascent web.

46. An apparatus for forming an absorbent paper sheet product comprising:

a moving foraminous endless fabric;

means for depositing a nascent web for said absorbent paper sheet on said foraminous endless fabric;

a moving endless pressing blanket;

a transfer cylinder; and

a pressing unit engaging said pressing blanket adapted to urge said nascent web for said absorbent paper sheet on said foraminous endless fabric into engagement with said transfer cylinder thereby forming a nip, said pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m.

47. The apparatus of claim 46, wherein said pressing unit is additionally configured to impose an asymmetrical pressure distribution upon said nascent web, said asymmetrical pressure distribution being skewed such that the pressure declines from a peak pressure to a value of 20% of said peak pressure over a nip length which is no more than about half of the nip

length over which it rose to said peak pressure from 20% of said peak pressure.

48. The apparatus of claim 46, wherein said pressing unit comprises at least one hydraulic engagement member.

49. The apparatus of claim 48, wherein said at least one hydraulic engagement member has a length of less than about 3 inches.

50. The apparatus of claim 49, wherein said at least one hydraulic engagement member has a length of less than about 2 inches.

51. The apparatus of claim 46, wherein said foraminous endless fabric is a press felt or an impression fabric.

52. The apparatus of claim 46, wherein the means for forming a nascent web is selected from a crescent former, a twin wire former, a suction breast roll former, or a fourdrinier former.

53. The apparatus of claim 46, wherein said pressing unit is configured to have a line load of less than about 175 kN/m.

54. The apparatus of claim 46, wherein said pressing unit is configured to have a line load of less than about 100 kN/m.

55. The apparatus of claim 46, wherein the peak pressure in said nip is at least about 2500 kN/m².

56. The apparatus of claim 46, wherein the peak pressure in said nip is at least about 3000 kN/m².

57. The apparatus of claim 46, wherein the peak pressure in said

nip is at least about 3150 kN/m².

58. The apparatus of claim 46, further comprising a creping blade for removing said absorbent paper sheet from said transfer cylinder.

59. The apparatus of claim 46, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric such that rewet of said nascent web by said foraminous endless fabric is less than about 50% of the rewet predicted by the Sweet equations based upon the properties of said foraminous endless fabric and said nascent web.

60. The apparatus of claim 59, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric at a nip length of less than about one inch from the point the nip pressure reaches zero.

61. The apparatus of claim 59, wherein said pressing unit is configured to both disengage said web from said foraminous endless fabric and disengage said foraminous endless fabric from said pressing blanket at a nip length of less than about one inch from the point the nip pressure reaches zero.

62. The apparatus of claim 46, wherein said transfer cylinder is heated.

63. The apparatus of claim 46, wherein said transfer cylinder is selected from a granite roll, a cold steel roll, a gas fired heater, or a Yankee drying cylinder.

64. The apparatus of claim 63, wherein said transfer cylinder is a

Yankee drying cylinder.

65. The apparatus of claim 64, further comprising a creping blade for removing said absorbent paper sheet from said Yankee drying cylinder.

66. The apparatus of claim 62, wherein said transfer cylinder is heated by an induction heater.

67. An apparatus for forming an absorbent paper sheet product comprising:

a moving foraminous endless fabric;

means for depositing a nascent web for said absorbent paper sheet on said foraminous endless fabric;

a moving endless pressing blanket;

a transfer cylinder; and

a pressing unit engaging said pressing blanket adapted to urge said nascent web for said absorbent paper sheet on said foraminous endless fabric into engagement with said transfer cylinder thereby forming a nip, said pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m².

68. The apparatus of claim 67, wherein said pressing unit is additionally configured to impose an asymmetrical pressure distribution upon said nascent web, said asymmetrical pressure distribution being skewed such that the pressure declines from a peak pressure to a value of 20% of said peak pressure over a nip length which is no more than about half of the nip length over which it rose to said peak pressure from 20% of the said peak

pressure.

69. The apparatus of claim 67, wherein said pressing unit comprises at least one hydraulic engagement member.

70. The apparatus of claim 69, wherein said at least one hydraulic engagement member has a length of less than about 3 inches.

71. The apparatus of claim 70, wherein said at least one hydraulic engagement member has a length of less than about 2 inches.

72. The apparatus of claim 67, wherein said foraminous endless fabric is a press felt or an impression fabric.

73. The apparatus of claim 67, wherein the means for forming a nascent web is selected from a crescent former, a twin wire former, a suction breast roll former, or a fourdrinier former.

74. The apparatus of claim 67, wherein said pressing unit is configured to have a line load of less than about 240 kN/m.

75. The apparatus of claim 67, wherein said pressing unit is configured to have a line load of less than about 175 kN/m.

76. The apparatus of claim 67, wherein said pressing unit is configured to have a line load of less than about 100 kN/m.

77. The apparatus of claim 67, wherein the peak pressure in said nip is at least about 2500 kN/m².

78. The apparatus of claim 67, wherein the peak pressure in said nip is at least about 3000 kN/m².

79. The apparatus of claim 67, wherein the peak pressure in said

nip is at least about 3150 kN/m².

80. The apparatus of claim 67, wherein said transfer cylinder is heated.

81. The apparatus of claim 67, wherein said transfer cylinder is selected from a granite roll, a cold steel roll, a gas fired heater or a Yankee drying cylinder.

82. The apparatus of claim 81, wherein said transfer cylinder is a Yankee drying cylinder.

83. The apparatus of claim 82, further comprising a creping blade for removing said absorbent paper sheet from said Yankee drying cylinder.

84. The apparatus of claim 67, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric such that rewet of said nascent web by said foraminous endless fabric is less than about 50% of the rewet predicted by the Sweet equations based upon the properties of said foraminous endless fabric and said nascent web.

85. The apparatus of claim 67, further comprising a creping blade for removing said absorbent paper sheet from said transfer cylinder.

86. The apparatus of claim 80, wherein said transfer cylinder is heated by an induction heater.

87. The apparatus of claim 84, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric at a nip length of less than about one inch from the point the nip pressure reaches zero.

88. The apparatus of claim 84, wherein said pressing unit is configured to both disengage said web from said foraminous endless fabric and disengage said foraminous endless fabric from said pressing blanket at a nip length of less than about one inch from the point the nip pressure reaches zero.

89. An apparatus for forming an absorbent paper sheet product comprising:
a moving foraminous endless fabric;
means for depositing a nascent web for said absorbent paper sheet on said foraminous endless fabric;
a moving endless pressing blanket;
a backing roll; and
a pressing unit engaging said pressing blanket adapted to urge said nascent web for said absorbent paper sheet on said foraminous endless fabric into engagement with said backing roll thereby forming a nip, said pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m.

90. The apparatus of claim 89, wherein said pressing unit is additionally configured to impose an asymmetrical pressure distribution upon

said nascent web, said asymmetrical pressure distribution being skewed such that the pressure declines from a peak pressure to a value of 20% of said peak pressure over a nip length which is no more than about half of the nip length over which it rose to said peak pressure from 20% of said peak pressure.

91. The apparatus of claim 89, wherein said pressing unit comprises at least one hydraulic engagement member.

92. The apparatus of claim 91, wherein said at least one hydraulic engagement member has a length of less than about 3 inches.

93. The apparatus of claim 92, wherein said at least one hydraulic engagement member has a length of less than about 2 inches.

94. The apparatus of claim 89, wherein said foraminous endless fabric is a press felt or an impression fabric.

95. The apparatus of claim 89, wherein the means for forming a nascent web is selected from a crescent former, a twin wire former, a suction breast roll former, or a fourdrinier former.

96. The apparatus of claim 89, wherein said backing roll is heated.

97. The apparatus of claim 96, wherein said backing roll is heated by steam.

98. The apparatus of claim 96, wherein said baking roll is heated by an induction heater.

99. The apparatus of claim 89, wherein said pressing unit is configured to have a line load of less than about 175 kN/m.

100. The apparatus of claim 89, wherein said pressing unit is configured to have a line load of less than about 100 kN/m.

101. The apparatus of claim 89, wherein the peak pressure in said nip is at least about 2500 kN/m².

102. The apparatus of claim 89, wherein the peak pressure in said nip is at least about 3000 kN/m².

103. The apparatus of claim 89, wherein the peak pressure in said nip is at least about 3150 kN/m².

104. A method of making an absorbent paper sheet product comprising: depositing a nascent web for said absorbent paper sheet product on a moving foraminous endless fabric; and

contacting said moving foraminous endless fabric bearing said deposited nascent web with a moving endless pressing blanket engaged with a pressing unit thereby forming a nip, said pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m.

105. The method of claim 104, wherein said pressing unit is additionally configured to impose an asymmetrical pressure distribution upon said nascent web, said asymmetrical pressure distribution being skewed such that the pressure declines from a peak pressure to a value of 20% of said peak pressure over a nip length which is no more than about half of the nip length over which it rose to said peak pressure from 20% of said peak pressure.

106. The method of claim 104, wherein said pressing unit comprises at least one hydraulic engagement member.

107. The method of claim 106, wherein said at least one hydraulic engagement member has a length of less than about 3 inches.

108. The method of claim 107, wherein said at least one hydraulic engagement member has a length of less than about 2 inches.

109. The method of claim 104, wherein said foraminous endless fabric is a press felt or an impression fabric.

110. The method of claim 104, wherein said pressing unit is configured to have a line load of less than about 175 kN/m.

111. The method of claim 104, wherein said pressing unit is configured to have a line load of less than about 100 kN/m.

112. The method of claim 104, wherein the peak pressure in said nip is at least about 2500 kN/m².

113. The method of claim 104, wherein the peak pressure in said nip is at least about 3000 kN/m².

114. The method of claim 104, wherein the peak pressure in said nip is at least about 3150 kN/m².

115. The method of claim 104, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric such that rewet of said nascent web by said foraminous endless fabric is less than about 50% of the rewet predicted by the Sweet equations based upon the properties of said foraminous endless fabric and said nascent web.

116. The method of claim 115, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric at a nip length of less than about one inch from the point the nip pressure reaches zero.

117. The method of claim 115, wherein said pressing unit is configured to both disengage said web from said foraminous endless fabric and disengage said foraminous endless fabric from said pressing blanket at a nip length of less than about one inch from the point the nip pressure reaches zero.

118. The method of claim 104, wherein said nascent web contacts a transfer cylinder.

119. The method of claim 118, wherein said transfer cylinder is heated.

120. The method of claim 104, wherein said nascent web contacts a backing roll.

121. The method of claim 120, wherein said backing roll is heated.

122. The method of claim 119, wherein said transfer cylinder is heated by an induction heater.

123. The method of claim 121, wherein said backing roll is heated by an induction heater.

124. The method of claim 118, further comprising a creping blade for removing said absorbent sheet from said transfer cylinder.

125. The method of claim 104, wherein said moving endless blanket

engaged with said pressing unit forms said nip with a Yankee drying cylinder.

126. The method of claim 125, wherein said web is dried on said Yankee drying cylinder.

127. The method of claim 126, wherein said dried web is creped from said Yankee drying cylinder.

128. The method of claim 104, wherein said pressing unit is a shoe press.

129. The method of claim 121, wherein said nascent web contacts said backing roll.

130. The method of claim 104, wherein said nascent web is compactively dewatered on said foraminous endless fabric prior to entering said nip.

131. The method of 104, wherein said pressing unit includes a hydraulic engagement member and said hydraulic engagement member is shaped and positioned to substantially align the separation of said foraminous endless fabric from said web and the separation of said foraminous endless fabric from said endless pressing blanket.

132. A method of making an absorbent paper sheet product comprising:

depositing a nascent web for said absorbent paper sheet product on a moving foraminous endless fabric;

contacting said moving foraminous endless fabric bearing said deposited nascent web with a moving endless pressing blanket engaged with

a pressing unit thereby forming a nip, said pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m;

transferring said web to a Yankee drying cylinder; and
creping said web from said Yankee drying cylinder.

133. The method of claim 132, wherein said pressing unit is additionally configured to impose an asymmetrical pressure distribution upon said nascent web, said asymmetrical pressure distribution being skewed such that the pressure declines from a peak pressure to a value of 20% of said peak pressure over a nip length which is no more than about half of the nip length over which it rose to said peak pressure from 20% of said peak pressure.

134. The method of claim 132, wherein said moving endless pressing blanket engaged with said pressing unit is configured to form said nip with said Yankee drying cylinder.

135. The method of claim 132, wherein said moving endless pressing blanket engaged with said pressing unit is configured to form said nip with a backing roll.

136. The method of claim 132, wherein said nascent web is compactively dewatered on said foraminous endless fabric prior to entering said nip.

137. The method of claim 132, wherein said pressing unit includes a hydraulic engagement member and said hydraulic engagement member is shaped and positioned to substantially align the separation of said foraminous endless fabric from said web and the separation of said foraminous endless fabric from said endless pressing blanket.

138. The method of claim 132, wherein said pressing unit is configured to both disengage said web from said foraminous endless fabric and disengage said foraminous endless fabric from said pressing blanket at a nip length of less than about one inch from the point the nip pressure reaches zero.

139. The method of claim 132, wherein said pressing unit is configured to have a line load of less than about 175 kN/m.

140. The method of claim 132, wherein said pressing unit is configured to have a line load of less than about 100 kN/m.

141. The method of claim 132, wherein said pressing unit comprises at least one hydraulic engagement member.

142. The method of claim 141, wherein said at least one hydraulic engagement member has a length of less than about 3 inches.

143. The method of claim 142, wherein said at least one hydraulic engagement member has a length of less than about 2 inches.

144. The method of claim 132, wherein the peak pressure in said nip is at least about 2500 kN/m².

145. The method of claim 132, wherein the peak pressure in said nip is at least about 3000 kN/m².

146. The method of claim 132, wherein the peak pressure in said nip is at least about 3150 kN/m².

147. A method of making an absorbent paper sheet product comprising:

depositing a nascent web for said absorbent paper sheet product on a moving foraminous endless fabric;

contacting said moving foraminous endless fabric bearing said deposited nascent web with a shoe press thereby forming a nip between said shoe press and a Yankee drying cylinder, said shoe press being configured to create a peak engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m;

disengaging said web from said foraminous endless fabric in said nip onto said Yankee drying cylinder; and

drying said web on said Yankee drying cylinder; and

creping said web from said Yankee drying cylinder.

148. The method of claim 147, wherein said shoe press is configured to have a line load of less than about 175 kN/m.

149. The method of claim 147, wherein said shoe press is configured to have a line load of less than about 100 kN/m.

150. The method of claim 147, wherein said shoe press comprises at least one hydraulic engagement member.

151. The method of claim 150, wherein said at least one hydraulic engagement member has a length of less than about 3 inches.

152. The method of claim 151, wherein said at least one hydraulic engagement member has a length of less than about 2 inches.

153. The method of claim 147, wherein the peak pressure in said nip is at least about 2500 kN/m².

154. The method of claim 147, wherein the peak pressure in said nip is at least about 3000 kN/m².

155. The method of claim 147, wherein the peak pressure in said nip is at least about 3150 kN/m².

156. The method of claim 147, wherein said shoe press is additionally configured to impose an asymmetrical pressure distribution upon said nascent web, said asymmetrical pressure distribution being skewed such that the pressure declines from a peak pressure to a value of 20% of said peak pressure over a nip length which is no more than about half of the nip length over which it rose to said peak pressure from 20% of said peak pressure.

157. An apparatus for forming an absorbent paper sheet product comprising:

a moving foraminous endless fabric;

means for depositing a nascent web for said absorbent paper sheet on said foraminous endless fabric;

a moving endless pressing blanket having a void volume;

a Yankee drying cylinder; and

a pressing unit engaging said pressing blanket adapted to urge said nascent web for said absorbent paper sheet on said foraminous endless fabric into engagement with said Yankee drying cylinder thereby forming a nip, said pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m.

158. The apparatus of claim 157, wherein said pressing unit is additionally configured to impose an asymmetrical pressure distribution upon said nascent web, said asymmetrical pressure distribution being skewed such that the pressure declines from a peak pressure to a value of 20% of said peak pressure over a nip length which is no more than about half of the nip length over which it rose to said peak pressure from 20% of said peak pressure.

159. The apparatus of claim 157, wherein said foraminous endless fabric is a press felt or an impression fabric.

160. The apparatus of claim 157, wherein the means for forming a nascent web is selected from a crescent former, a twin wire former, a suction breast roll former, or a fourdrinier former.

161. The apparatus of claim 157, further comprising a creping blade for removing said absorbent paper sheet from said Yankee dryer.

162. The apparatus of claim 157, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric such that rewet of said nascent web by said foraminous endless fabric is less than about 50% of the rewet predicted by the Sweet equations based upon the properties of said foraminous endless fabric and said nascent web.

163. The apparatus of claim 162, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric at a nip length of less than about one inch from the point the nip pressure reaches zero.

164. The apparatus of claim 163, wherein said pressing unit is configured to both disengage said web from said foraminous endless fabric and disengage said foraminous endless fabric from said pressing blanket at a nip length of less than about one inch from the point the nip pressure reaches zero.

165. The apparatus of claim 157, wherein the pressing blanket is a blind drilled blanket.

166. The apparatus of claim 165, wherein the blind drilled blanket has a plurality of holes formed thereon.

167. The apparatus of claim 166, wherein the holes are sequentially arranged in the machine direction.

168. The apparatus of claim 166, wherein the diameter of the holes is about 0.2 to about 10 mm.

169. The apparatus of claim 166, wherein the holes extend into but not through the blanket.

170. The apparatus of claim 166, wherein the angle of the holes as measured along a hole wall vertically extending in the machine direction ranges from about 45 to about 135 degrees.

171. The apparatus of claim 166, wherein the angle of the holes as measured along a hole wall vertically extending in the cross-machine direction can range from about 45 to about 135 degrees.

172. The apparatus of claim 166, wherein the spacing between adjacent holes is about 1 to about 20 mm.

173. The apparatus of claim 167, wherein a plurality of rows of holes are sequentially arranged in the cross-machine direction.

174. The apparatus of claim 173, wherein the spacing between rows is about 1 to about 20 mm.

175. The apparatus of claim 173, wherein the rows of holes are arranged in a geometric pattern.

176. The apparatus of claim 175, wherein the geometric pattern is arranged so that the holes in each row are aligned in the cross-machine direction.

177. The apparatus of claim 175, wherein the geometric pattern is arranged so that the holes in each row are offset in the cross-machine direction.

178. The apparatus of claim 175, wherein the geometric pattern is arranged so that the holes in each row are aligned in the machine direction.

179. The apparatus of claim 175, wherein the geometric pattern is arranged so that the holes in each row are offset in the machine direction.

180. The apparatus of claim 173, wherein or one or more individual hole or row of holes has the same configuration as one or more other individual hole or row of holes.

181. The apparatus of claim 157, wherein the blanket is a grooved blanket.

182. The apparatus of claim 181, wherein the grooved blanket has at least one groove that extends in the machine direction.

183. The apparatus of claim 182, wherein the width of the widest portion of a groove is about 0.1 to about 6 mm.

184. The apparatus of claim 182, wherein the groove extends into but not through the blanket and has a depth of about 0.1 to about 8 mm.

185. The apparatus of claim 182, wherein the groove bevel is about 0 to about 45 degrees.

186. The apparatus of claim 182, wherein the groove angle is about 45 to about 135 degrees, with 90 degrees being orthogonal to the cross-machine direction.

187. The apparatus of claim 182, wherein a plurality of grooves are sequentially arranged in the cross-machine direction of the blanket.

188. The apparatus of claim 187, wherein each of the plurality of grooves circumscribe the blanket.

189. The apparatus of claim 187, wherein the groove width is about 0.4 to about 3 mm.

190. The apparatus of claim 187, wherein the rows of grooves are arranged in a geometric pattern.

191. The apparatus of claim 187, wherein one or more individual groove has the same configuration as one or more other individual groove.

192. The apparatus of claim 187, wherein the land width is about 0.2 to about 25 mm.

193. The apparatus of claim 187, wherein the open area is up to about 80% of the total blanket area.

194. A moving endless pressing blanket for forming an absorbent paper sheet product produced by a pressing unit engaging said pressing blanket adapted to urge a nascent web on a foraminous endless fabric into engagement with a Yankee drying cylinder, said pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m, said pressing blanket comprising a void volume less than about 1500 cm³/m².

195. The apparatus of claim 194, wherein the void volume is achieved by a blind drilled blanket.

196. The apparatus of claim 195, wherein the blind drilled blanket has a plurality of holes arranged in a predetermined geometric pattern.

197. The apparatus of claim 194, wherein the void volume is achieved by a grooved blanket.

198. The apparatus of claim 197, wherein the grooved blanket has a plurality of grooves arranged in a predetermined geometric pattern.

199. A method of making an absorbent paper sheet product comprising:

depositing a nascent web for said absorbent paper sheet product on a moving foraminous endless fabric; and

contacting said moving foraminous endless fabric bearing said deposited nascent web with a moving endless pressing void volume containing a pressing blanket engaged with a pressing unit thereby forming a nip, said pressing unit being configured to create a peak engagement pressure of at least about 2000 kN/m² at an overall line load of less than about 240 kN/m.

200. The method of claim 199, wherein said pressing unit is additionally configured to impose an asymmetrical pressure distribution upon said nascent web, said asymmetrical pressure distribution being skewed such that the pressure declines from a peak pressure to a value of 20% of said peak pressure over a nip length which is no more than about half of the nip length over which it rose to said peak pressure from 20% of said peak pressure.

201. The method of claim 199, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric such

that rewet of said nascent web by said foraminous endless fabric is less than about 50% of the rewet predicted by the Sweet equations based upon the properties of said foraminous endless fabric and said nascent web.

202. The method of claim 201, wherein said pressing unit is configured to disengage said web from said foraminous endless fabric at a nip length of less than about one inch from the point the nip pressure reaches zero.

203. The method of claim 201, wherein said pressing unit is configured to both disengage said web from said foraminous endless fabric and disengage said foraminous endless fabric from said pressing blanket at a nip length of less than about one inch from the point the nip pressure reaches zero.

204. The method of claim 199, wherein said nascent web contacts a heated transfer cylinder.

205. The method of claim 204, further comprising a creping blade for removing said absorbent sheet from said heated transfer cylinder.

206. The method of claim 199, wherein said moving void volume containing endless blanket engaged with said pressing unit forms said nip with a Yankee drying cylinder.

207. The method of claim 199, wherein said pressing unit is a shoe press.

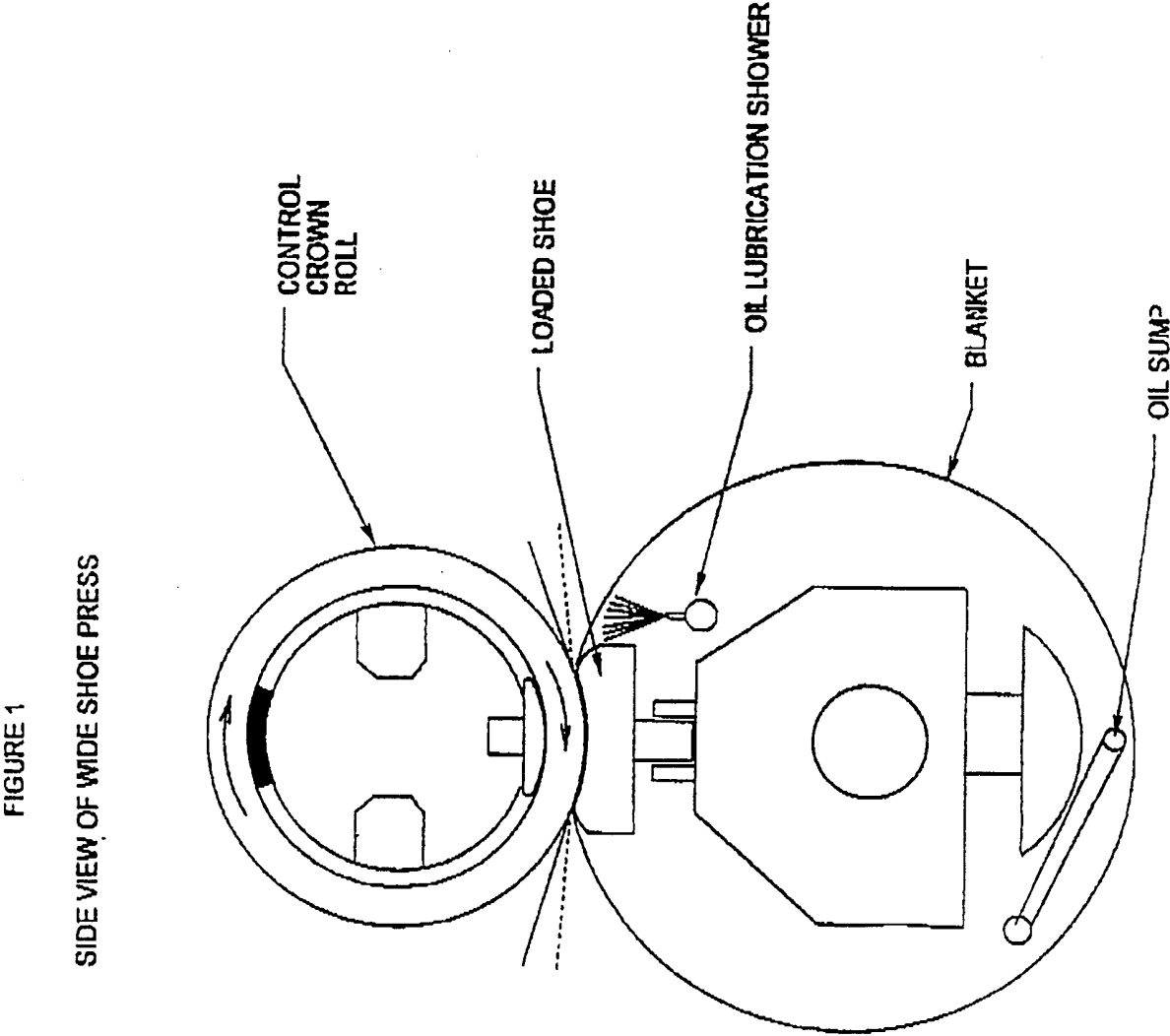


Figure 2: Relationship Between Peak Pressure and Line Load

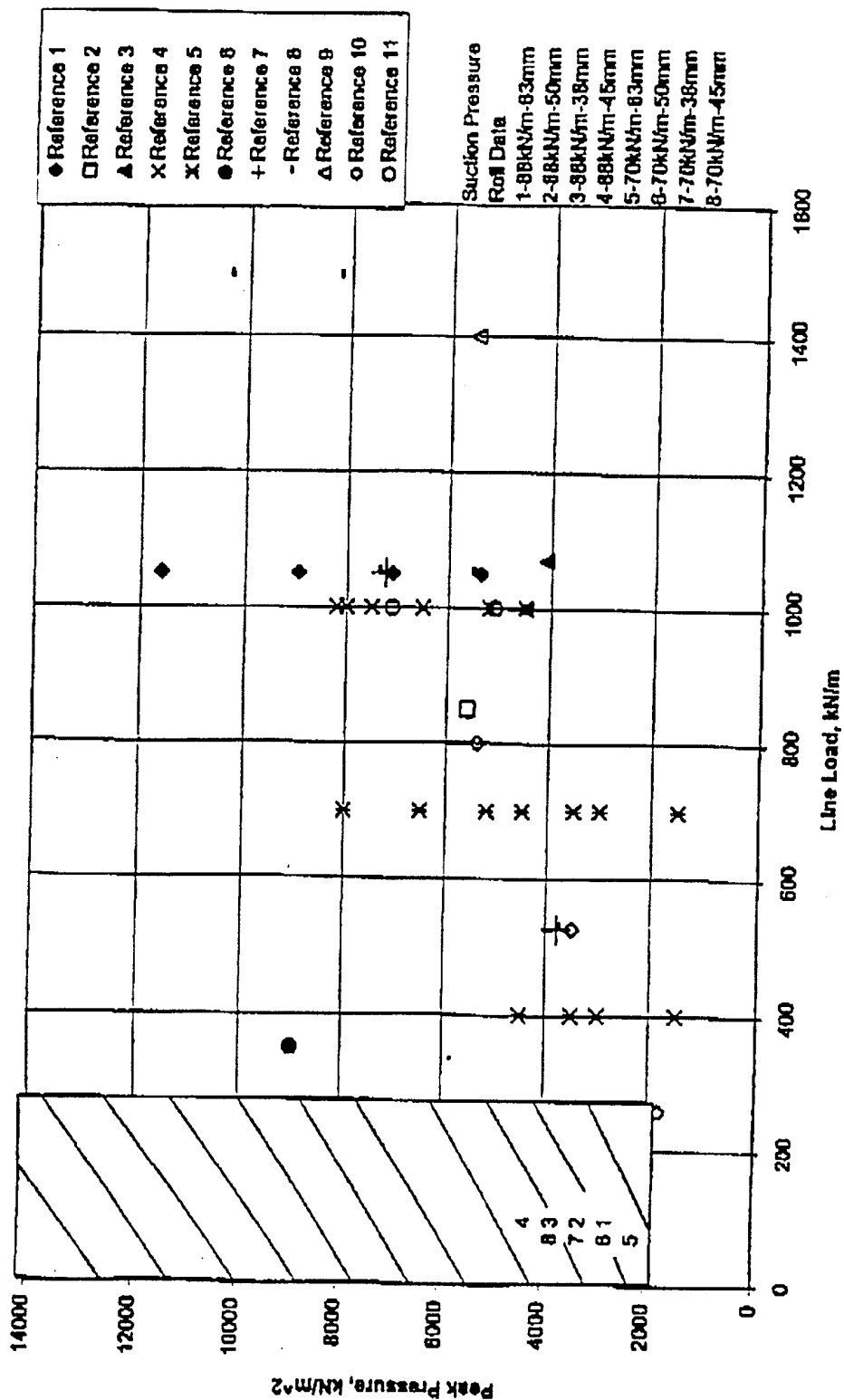


FIGURE 3

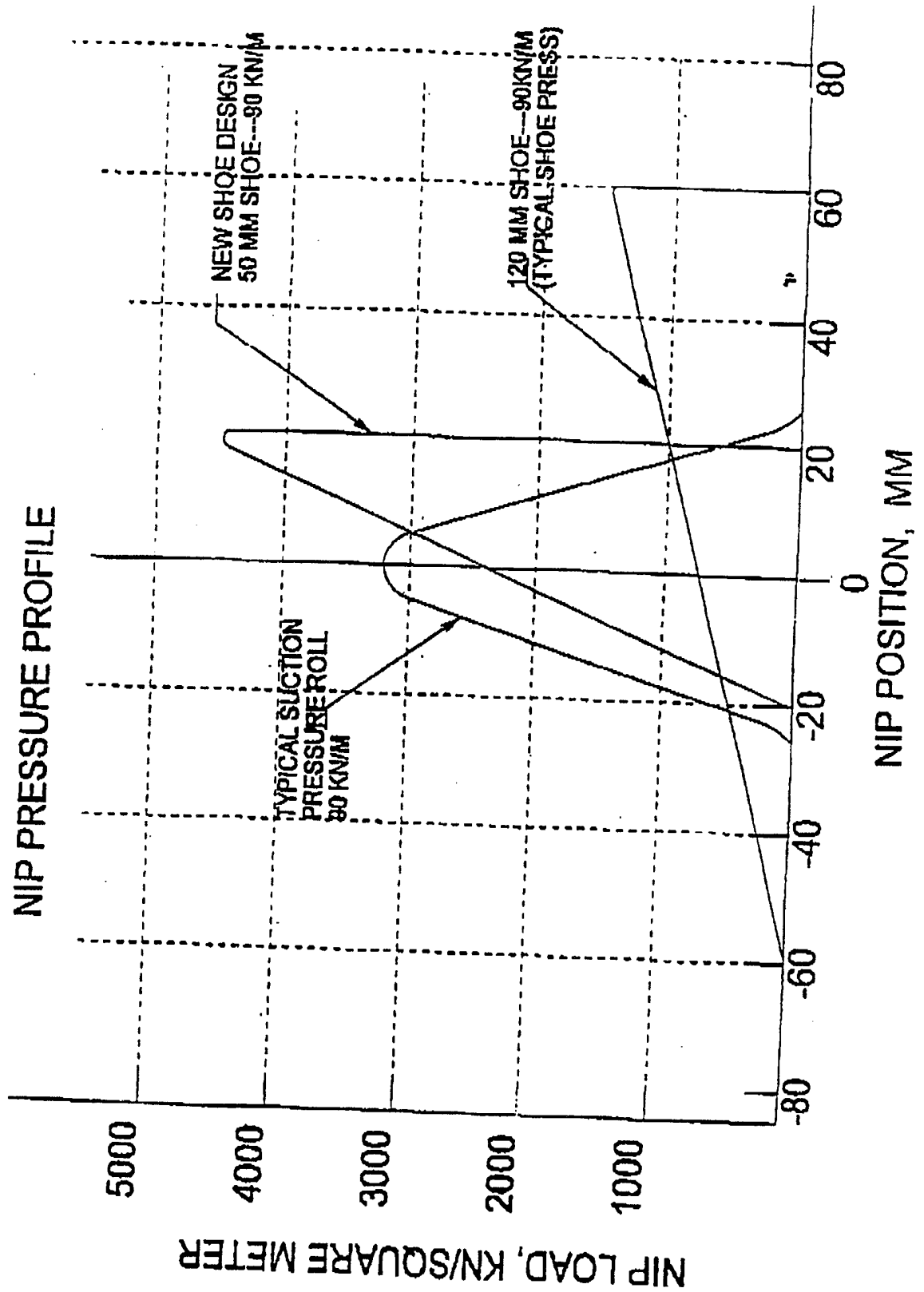
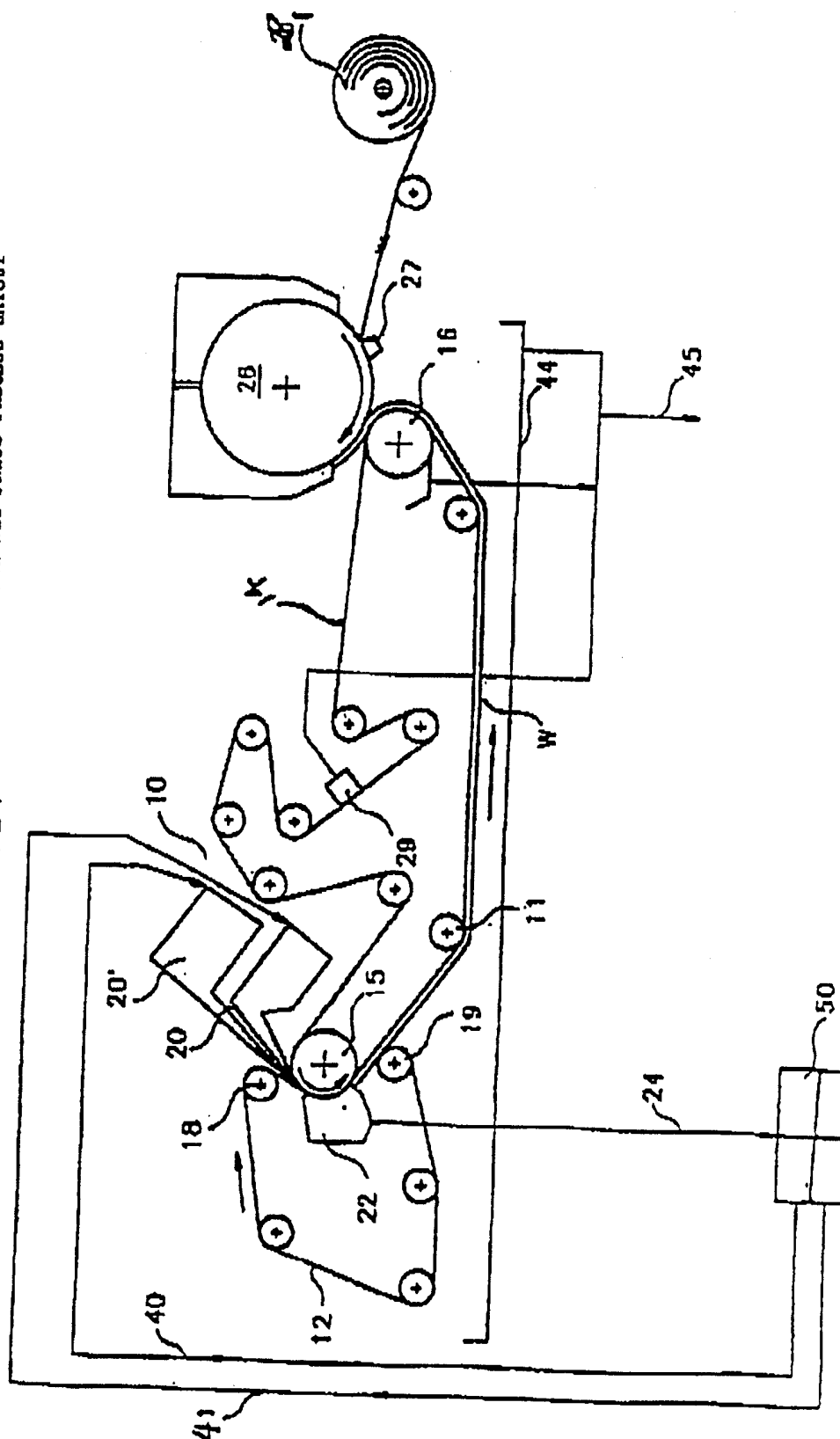


FIG. 4 — CONVENTIONAL WET PRESS PROCESS LAYOUT



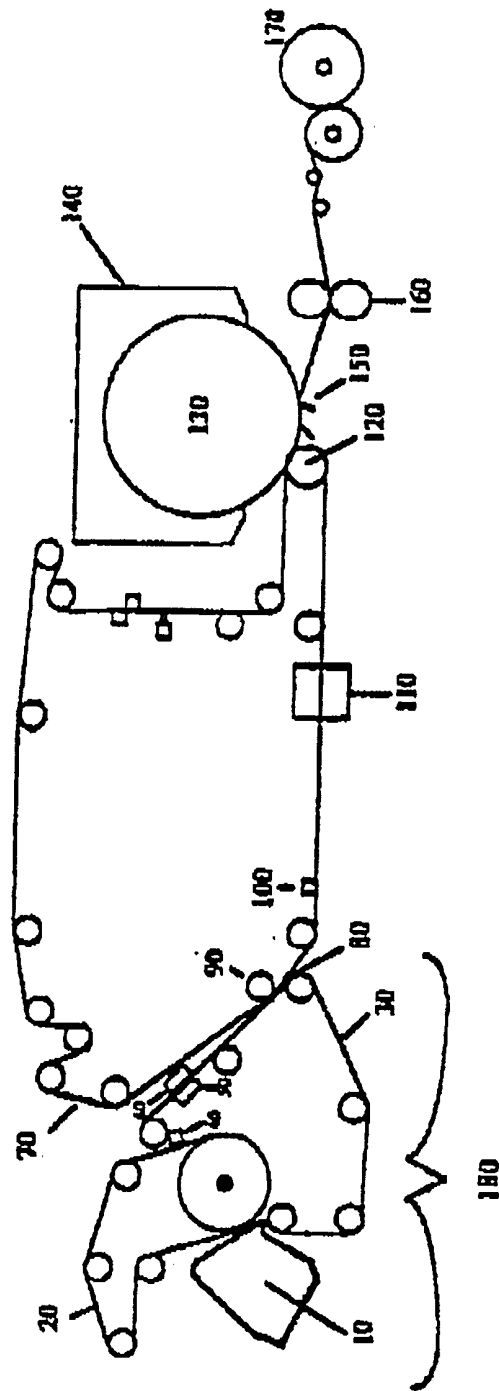


FIG. 5 --CONVENTIONAL THROUGH-AIR-DRYING PROCESS LAYOUT

FIGURE 6

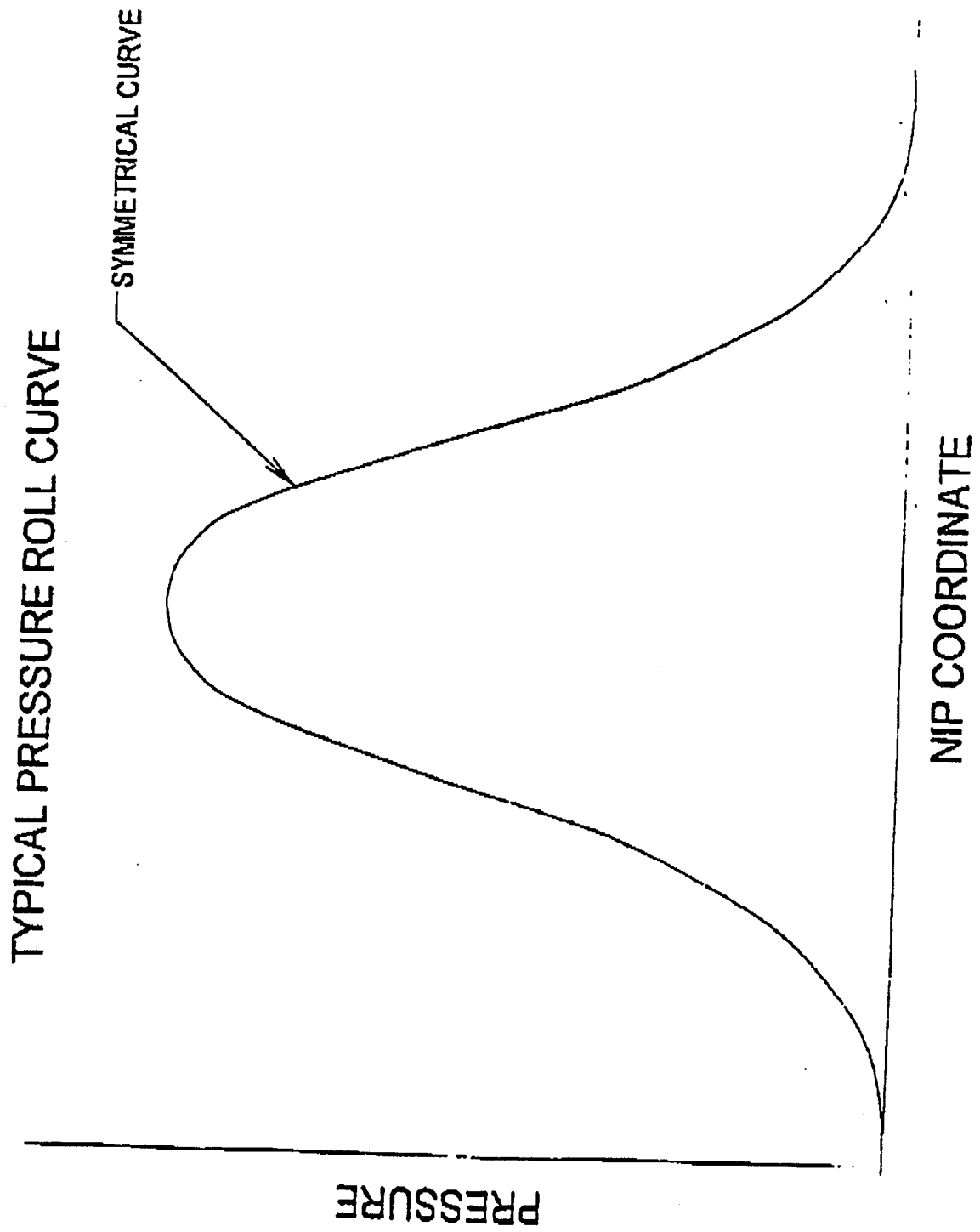


FIGURE 7

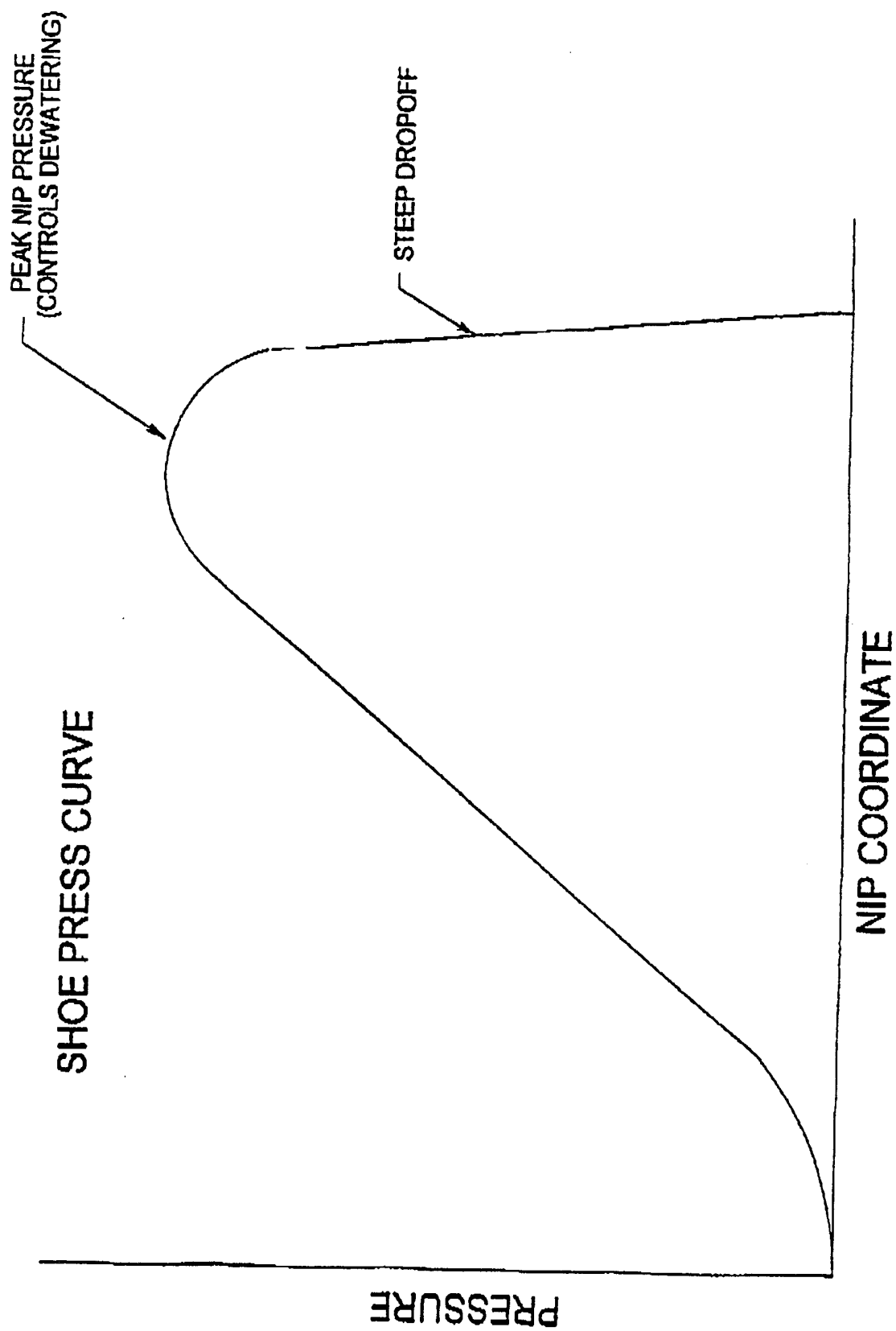


FIGURE 8

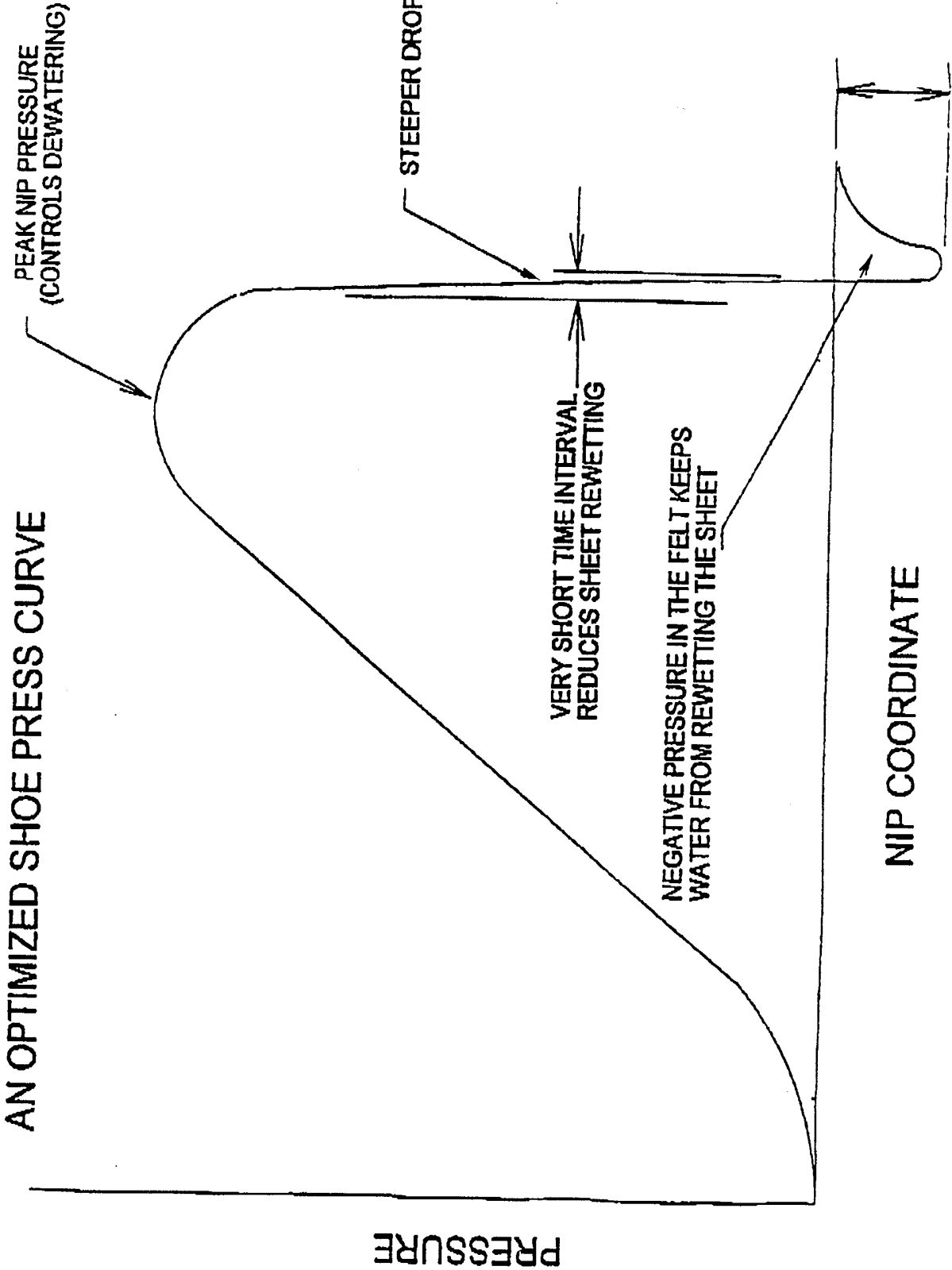


FIGURE 9

SHOE PRESS WITH LARGE DIAMETER TRANSFER CYLINDER AND WITH FELT PARTIALLY WRAPING CYLINDER

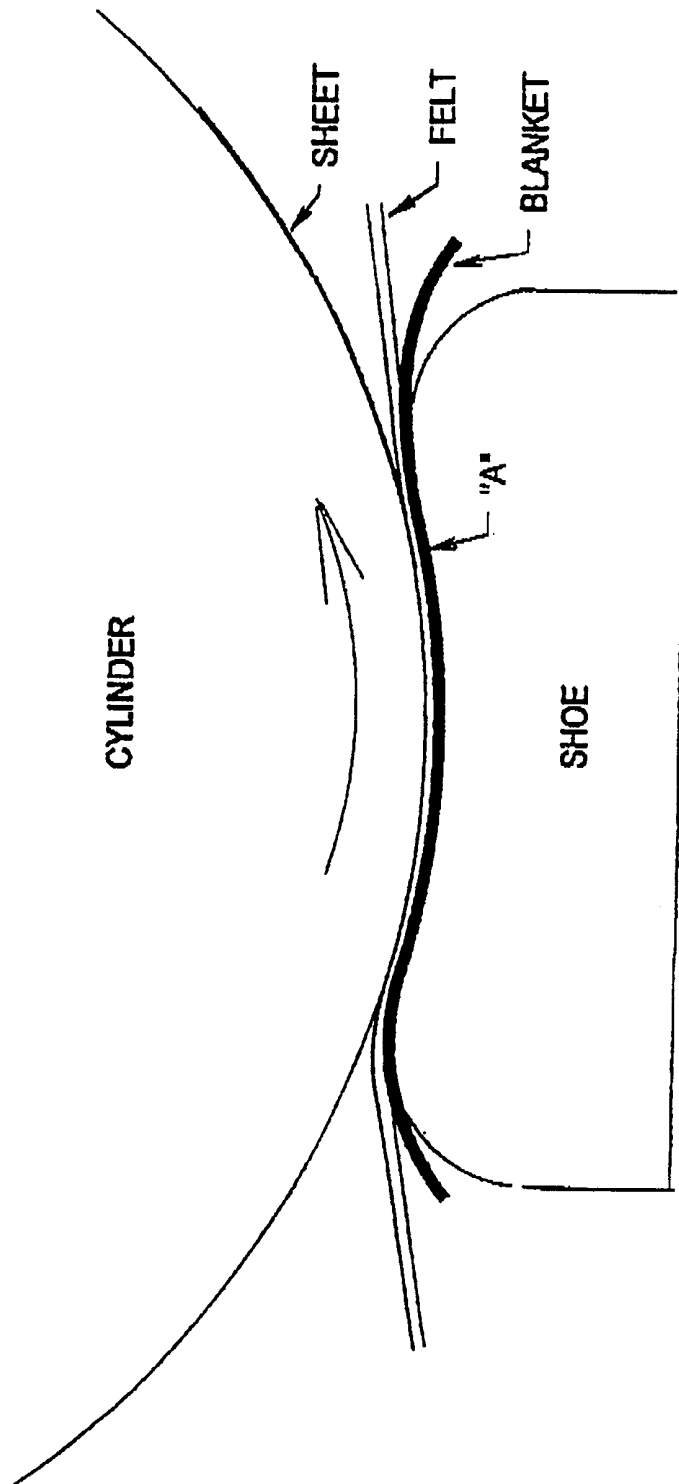


FIGURE 10

SHOE PRESS TAPERED ON THE EXIT SIDE SO THAT
BLANKET/FELT CAN BE RAPIDLY REMOVED FROM THE SHEET

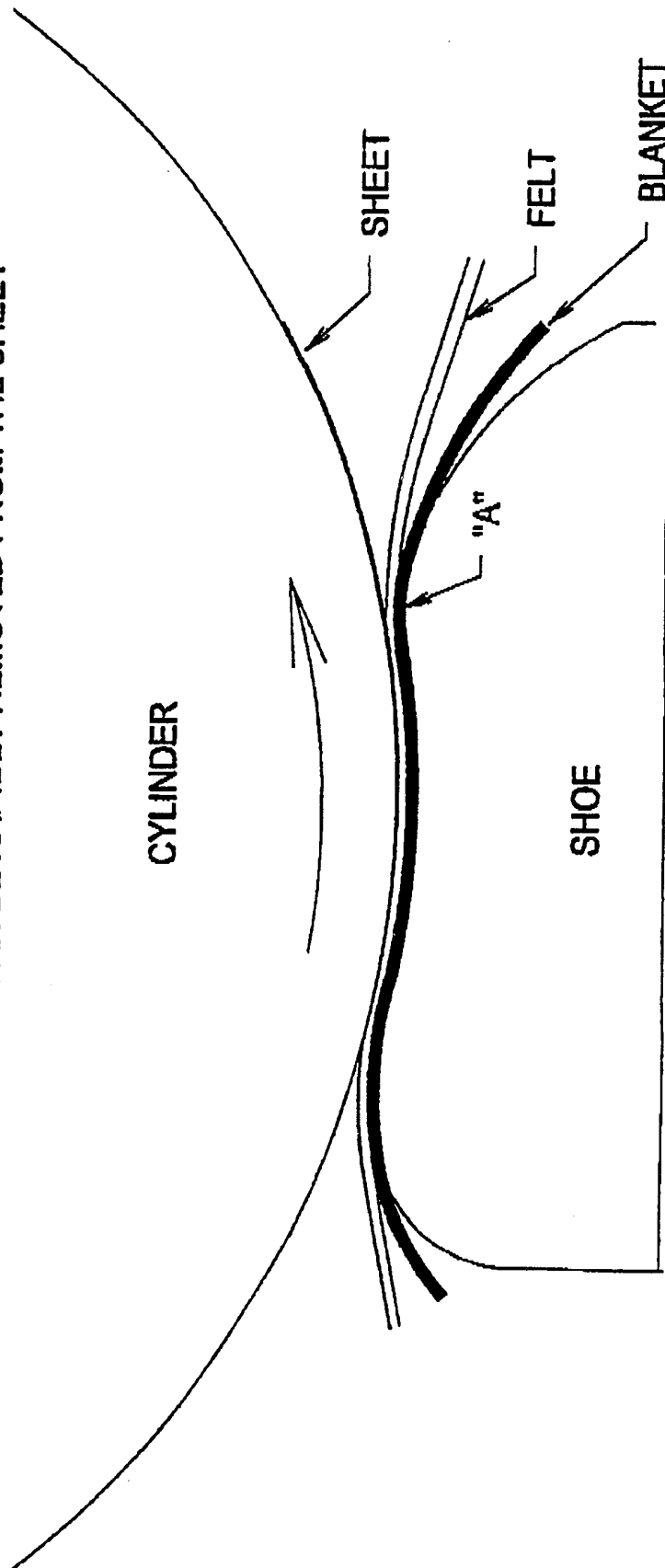
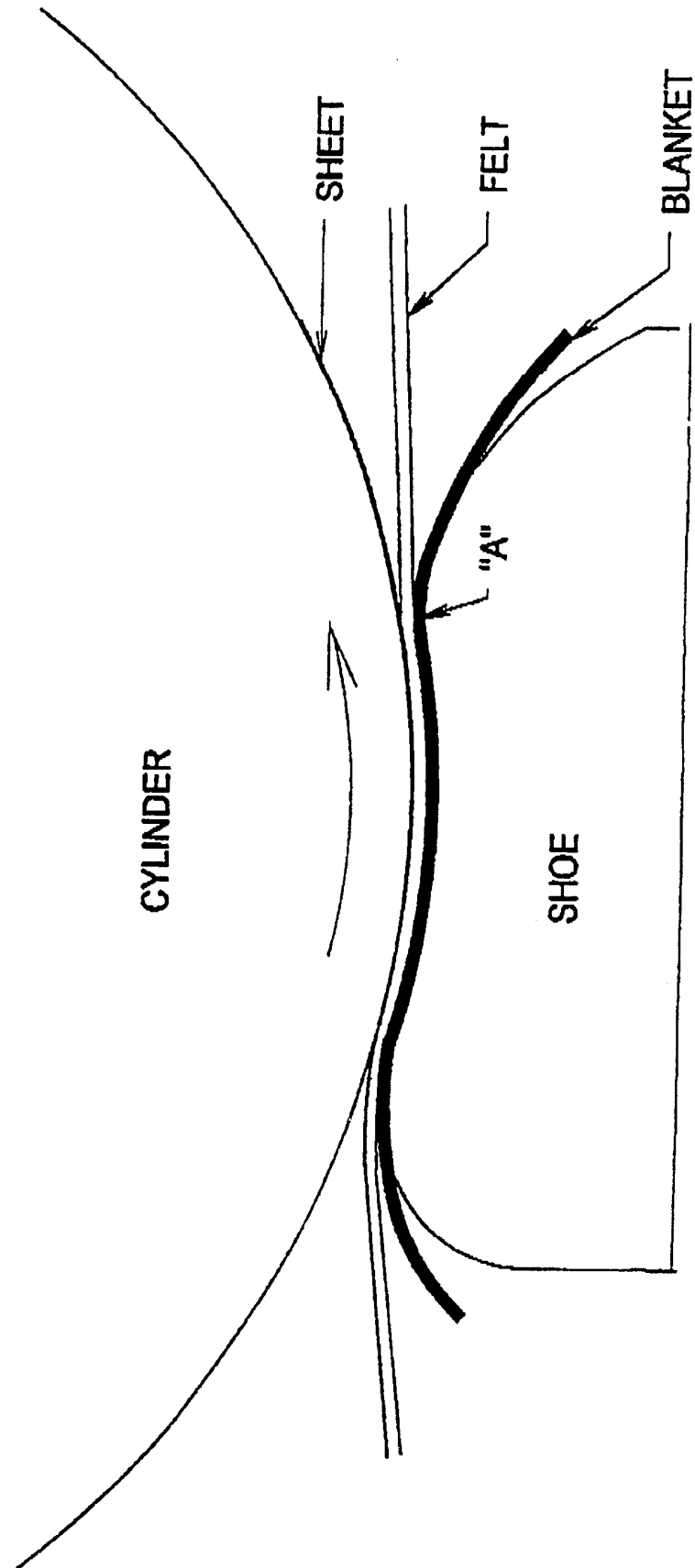


FIGURE 11

SHOE PRESS TAPERED ON THE EXIT SIDE SO THAT FELT CAN BE RAPIDLY REMOVED FROM THE SHEET WHILE THE BLANKET IS SIMULTANEOUSLY RAPIDLY REMOVED FROM THE FELT



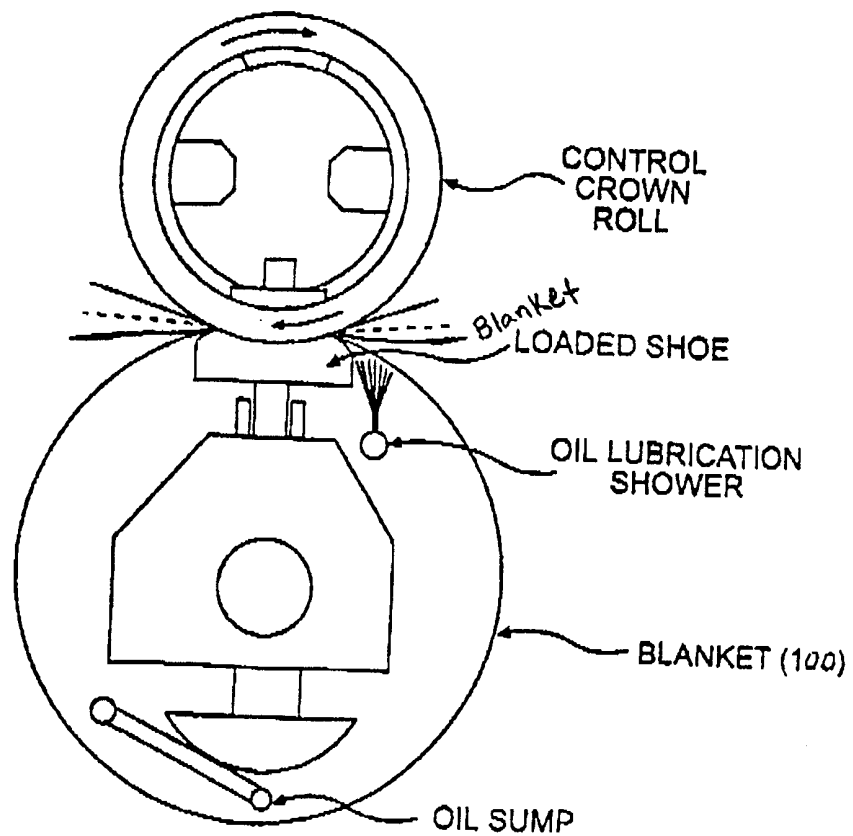


FIG. 13

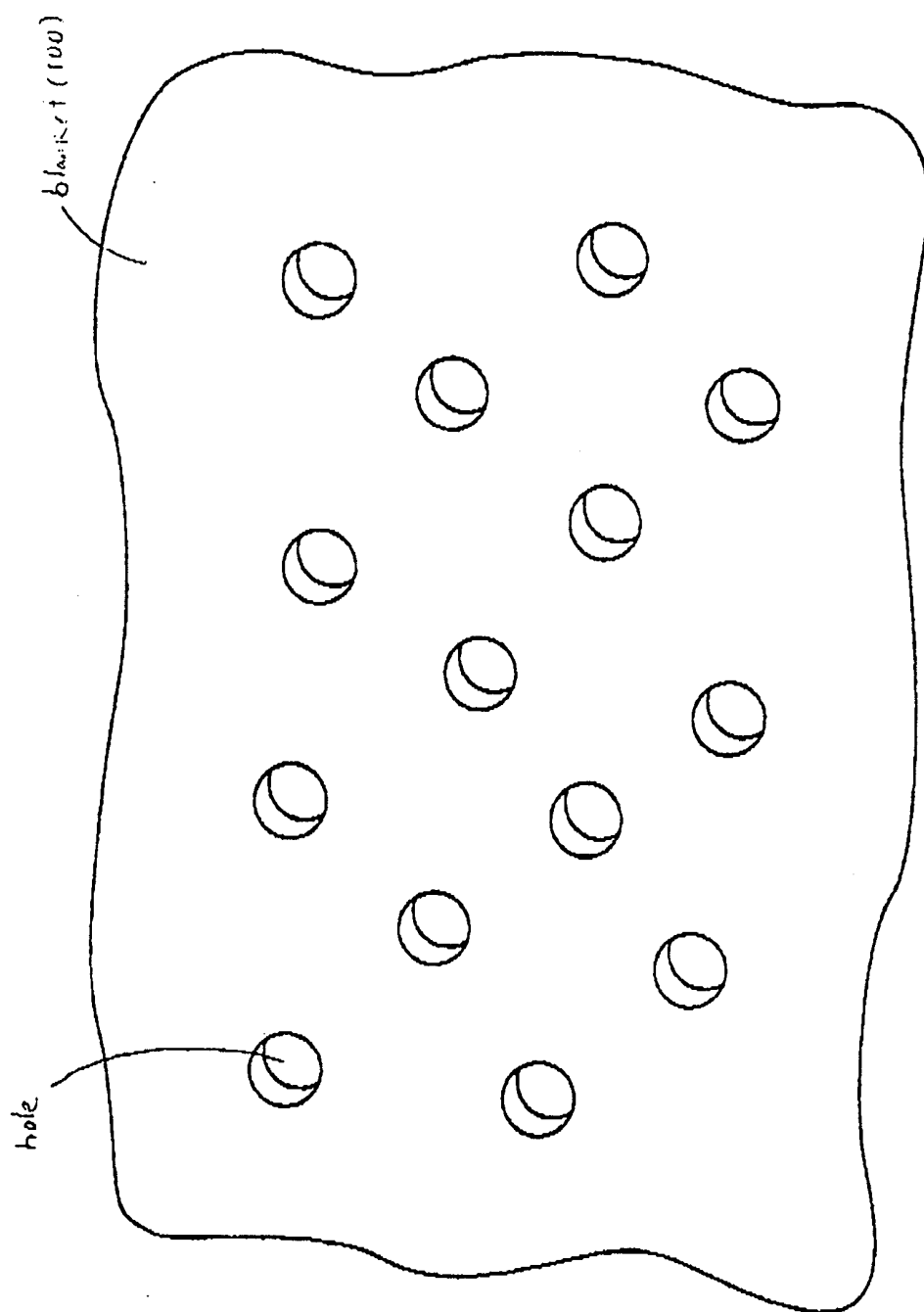


FIG. 14

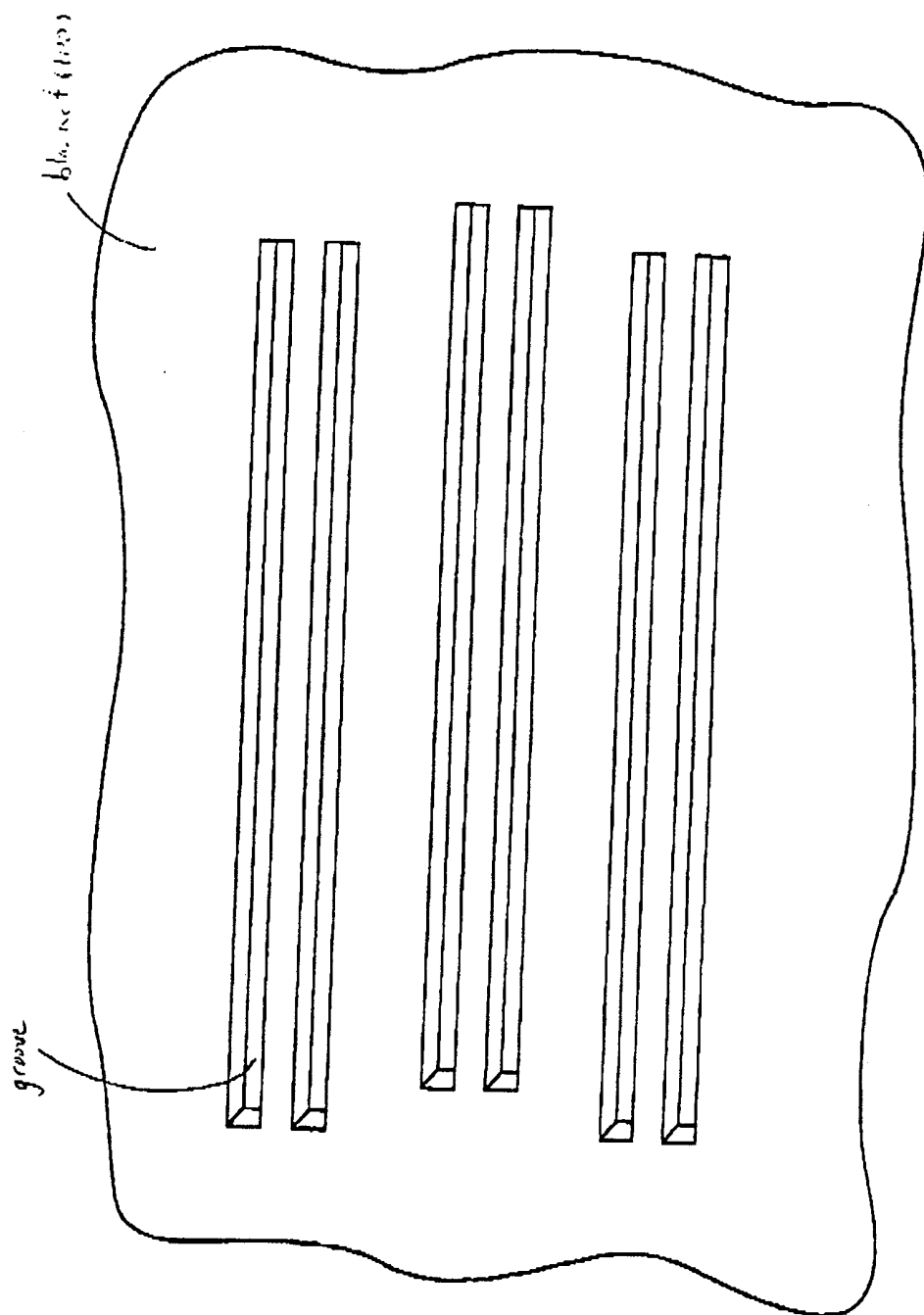


FIG. 15

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/27097

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 D21F3/02 D21F11/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 D21F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|----------|--|---------------------------------|
| A | DE 196 54 198 A (VOITH SULZER PAPIERMASCH GMBH) 25 June 1998 (1998-06-25) abstract; figures column 4, line 42 - line 62 --- | 1,67,89, 104,147, 194,199 |
| A | EP 0 289 477 A (VALMET PAPER MACHINERY INC) 2 November 1988 (1988-11-02) column 6, line 6 - line 42 column 7, line 59 - column 8, line 16; figures --- | 1,67,89, 104,147, 194,199 |
| A | EP 0 854 232 A (VOITH SULZER PAPIERMASCH GMBH) 22 July 1998 (1998-07-22) abstract; figures page 4, line 1 - line 35 ----- | 1,67,89, 104,147, 194,199 |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

17 March 2000

Date of mailing of the international search report

29/03/2000

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Helpiö, T.

INTERNATIONAL SEARCH REPORT

Information on patent family members

In ternational Application No

PCT/US 99/27097

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---------------------|----------------------------|---------------------|
| DE 19654198 A | 25-06-1998 | EP 0854229 A | 22-07-1998 |
| | | US 6004429 A | 21-12-1999 |
| EP 0289477 A | 02-11-1988 | FI 871870 A | 29-10-1988 |
| | | FI 880700 A | 16-08-1989 |
| | | CA 1325546 A | 28-12-1993 |
| | | JP 1052897 A | 28-02-1989 |
| | | US 4976820 A | 11-12-1990 |
| EP 0854232 A | 22-07-1998 | DE 19654197 A | 25-06-1998 |