(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
31 January 2013 (31.01.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/016261 A1

(51) International Patent Classification:
D21H 21/18 (2006.01) *D21H 27/30* (2006.01)
D21H 21/20 (2006.01) *D21H 27/00* (2006.01)

(21) International Application Number:
PCT/US2012/047802

(22) International Filing Date:
23 July 2012 (23.07.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/457,991 28 July 2011 (28.07.2011) US
13/548,600 13 July 2012 (13.07.2012) US

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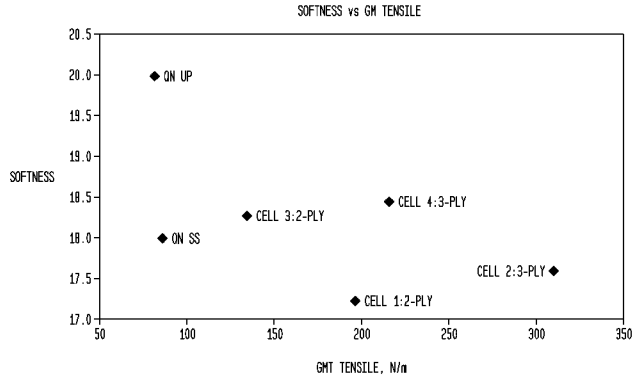
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ,

[Continued on next page]

(54) Title: HIGH SOFTNESS, HIGH DURABILITY BATH TISSUE WITH TEMPORARY WET STRENGTH

FIG. 7



(57) Abstract: A multi-ply bath tissue having no more than three plies and no fewer than two plies. The multi-ply tissue has a basis weight of from about 32.6 to about 57.0 g/m^2 and includes from about 3% to about 50% cellulosic microfiber, from about 50% to about 97% wood pulp fibers, has a geometric mean (GM) dry tensile of from about 1.37 to 6.33 N/m per g/m^2 of basis weight, a cross-machine direction (CD) dry tensile of between about 2.37 to about 4.74 N/m per g/m^2 of basis weight, and sufficient temporary wet strength resin to provide an initial Finch Cup CD wet tensile of from about 0.20 to about 1.58 N/m per g/m^2 of basis weight. The initial Finch Cup CD wet tensile decays to less than 65% of the initial value in less than fifteen minutes after immersion in water. The product has a caliper of at least 0.078 mm per 8 sheets per g/m^2 of basis weight.

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UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

HIGH SOFTNESS, HIGH DURABILITY BATH TISSUE

WITH

TEMPORARY WET STRENGTH

Technical Field

Bath tissue must reconcile several competing imperatives. It must be soft. It must be strong. Moreover, bath tissue must absolutely be flushable and protect the user's hands, while also being effective at cleaning. Bath tissue is primarily used for dry cleaning, although there have been several product entries that were advertised as being suitable for wet cleaning, being primarily, pre-moistened.

Requiring that bath tissue also have significant wet strength immensely complicates the problems that a tissue manufacturer faces, as not only are wet strength and flushability in direct conflict, but softness usually suffers as well when strength is increased, while use of wet tissue can result in linting -- conflicting with, if not entirely negating, a bath tissue's raison d'être of cleaning.

Background

Against this background, it is apparent that, while some products have reconciled these competing "must-haves" to some extent, there has been a longstanding un-met need for a bath tissue truly surmounting these inherent conflicts. There are also many patents that seem to assume that there is little more to making a viable bath tissue that is usable either dry or premoistened than providing a tissue weight product with significant initial wet strength that decays with time. We have discovered that we can provide a bath tissue that achieves a previously unmatched combination of wet and dry properties by incorporating a minor proportion of cellulosic microfibers into a furnish that is used for bath tissue, then forming a tissue web using a belt creping process, in which a nascent web at a consistency of between about 30 and about 60% is creped from an internally heated creping roll using a creping belt. We have found that, with belt-creping and cellulose microfiber (CMF) content, we can produce sheets that are particularly resistant to linting, even when used wet, while also retaining both sufficient wet strength to protect the user's hand and sufficient softness to be used dry by sensitive users. We have also found that we can substitute a controlled coarseness alkaline peroxide mechanical pulp (APMP) into these wet strength bath tissues as a replacement for eucalyptus kraft, and obtain excellent softness, wet strength, lint resistance and wet lint resistance, with very small amounts of CMF.

Others have attempted to address the need for a flushable bath tissue that can be used dry or premoistened, with a variety of wet wipe formulations, wherein fibers in the wet wipe are bonded together with a strength resin that is stabilized by a chemical species in the imbuement of the wet wipe, but is destabilized upon exposure to a large quantity of "normal" water. Thus, the wipe remains strong as long as the imbuement is in contact with the wipe in its package and for a period after removal, because the imbuement stabilizes the resin, but, when the imbuement is removed or, more properly, diluted with water, the strength agent is rendered less effective and the wipe, at least in theory, becomes dispersible. A major tissue producer is reported to have attempted to commercialize such a technology that was, however, not well accepted by the market. In another approach involving wet wipes, some circles maintain that flushability does not really require that the sheet disintegrate after flushing as long as the size of the sheet is kept under some fairly small maximum. Limited consumer research that has been conducted, however, indicates that most users will remove and use several sheets of bath tissue from the roll at a time, so that the sheet used has an area several times that of the so-called "flushable wet wipe" in which "flushability" is predicated upon the size of the sheet.

In contrast, the present invention is based upon a product that can be stored dry on a perforated roll and used like a conventional bath tissue employing a convenient number of unseparated sheets, as the user prefers. If, however, premoistened shortly before use, the tissue retains a sufficient wet strength to be used in the moist state without linting, pilling or shredding, but will disintegrate within a reasonable time after flushing, so that the effectiveness of plumbing is not unduly compromised. Significantly, these goals are achieved without requiring another product in the bathroom; although some users may prefer to use a small container, such as a spray bottle to hold aqueous liquid for moistening the sheet immediately before use. Such bottles can be conveniently disposed inside the roll core of packaged tissue, as promotional or introductory items, if desired.

As use of the present invention makes it possible to achieve quite a high wet/dry ratio, softness does not unduly suffer, as the actual dry tensile strength, which is strongly associated – negatively – with perceived softness, can be moderate, while the wet strength can remain quite high in the first minutes after moistening. Thus, the strength and softness of the tissue of the present invention can be comparable to that of premium bath tissue, while retaining a high temporary wet strength. Even though, when used with conventional papermaking furnishes, many wet strength resins make it possible to achieve wet strength levels necessary for the tissue to be employed premoistened, in many cases, the tactile properties of the dry sheet can be somewhat compromised thereby.

When employing substantial amounts of cellulosic microfibers in the furnish, in conjunction with temporary wet strength resin and belt-creped paper making technology, we have found that we can achieve a surprisingly good combination of softness, opacity, wet strength and resistance to pilling and shredding in a flushable bath tissue. In addition, the flushable bath tissue is capable of being stored on a roll, as is conventional bath tissue, and suitable for use either dry or premoistened. When alkaline peroxide mechanically pulped (APMP) eucalyptus fiber is included, we have found that we can obtain excellent results, even using far less of the cellulosic microfiber, even when using conventional wet press (CWP) technology. We have further discovered that the APMP eucalyptus fiber is an excellent substitute for conventional eucalyptus kraft fiber in conventional bath tissue, imparting increased opacity, bulk, softness, absorbency and reduced strength, even to tissue made with recycle furnishes.

One early pre-wettable tissue was disclosed in Bhat et al., "Prewettable High Softness Paper Product Having Temporary Wet Strength", U.S. Patent No. 5,958,187, September 28, 1999, relating to a paper product with a glabrous surface and adapted for use either dry or use in a manually pre-moistened condition. Bhat et al. disclose a paper product having a temporary wet strength and exhibiting an initial normalized cross machine direction (CD) wet tensile strength of at least about 0.98 g/m^2 strip, preferably, 31.38 g/mm strip as measured by the Finch Cup Test 5 seconds after immersion, and a subsequent CD wet tensile strength of less than about 2/3 the initial value as measured 30 minutes after immersion. Temporary wet strength was provided by addition to the furnish of a temporary wet strength agent comprising aldehydic units in the range of from about 0.5 kg per metric ton to about 7.5 kg per metric ton. The furnish also included a cationic nitrogenous softener/debonder in an amount of from about 0.25 kg per metric ton to about 1.5 kg per metric ton. The CD dry tensile strength of the paper product was from about 5.23 g/mm strip up to about 10.5 g/mm strip, and the tensile modulus was from about 10 to about 32 g/% strain, while the geometric mean friction deviation (GM MMD value) was from about 0.26 to about 0.10. The CD wet strength of the product decays to about 0.59 g/mm strip within 10 hours after immersion. When rubbed against a skin-like surface in a moistened condition, the paper product remains substantially free of pilling. Significantly, in Bhat et al., the wet abrasion resistance of a 5.1 cm by 11.4 cm sample of tissue was measured under a load of 135 grams against a wetted pigskin, and visual observation was made to determine whether the sample left pills, shreds or lint behind.

Another early pre-wettable tissue was disclosed in Van Luu et al. [sic, Luu et al.], "Prewettable High Softness Paper Product Having Temporary Wet Strength", U.S. Patent No. 6,059,928, May 9, 2000, in which a temporary wet strength agent comprising uncharged chemical moieties, such as aldehydes,

and aldehydes containing polymers, polyols and cyclic ureas, or mixtures thereof, in the range of from about 2 pounds per ton to about 30 pounds per ton are added to the web to provide the temporary wet strength. In this application, glyoxal was preferably sprayed on the sheet after it left the Yankee dryer.

"Belt-Creped, Variable Local Basis Weight Absorbent Sheet Prepared With Perforated Polymeric Belt" is disclosed in Super et al. U.S. Patent Application Publication No. 2010/0186913, which produces cellulosic tissue sheets exhibiting a surprising combination of bulk, roll firmness, absorbency and softness, from a sheet with a fiber-enriched higher basis weight, hollow domed regions joined by a network of lower local basis weight connecting regions forming a network in which upwardly and inwardly inflected consolidated fibrous regions exhibiting CD fiber orientation bias form transition areas between the connecting regions and the domed regions. The consolidated fibrous regions are, preferably, saddle shaped and exhibit a matted structure on both their outer and inner surfaces. Related technology is found in the following U.S. Patent Applications and U.S. Patents: U.S. Patent No. 7,494,563 entitled "Fabric Creped Absorbent Sheet with Variable Local Basis Weight", U.S. Patent No. 7,399,378 entitled "Fabric Crepe Process for Making Absorbent Sheet", U.S. Patent No. 7,789,995 entitled "Fabric Crepe/Draw Process for Producing Absorbent Sheet", the application of which was a continuation-in-part of the application of U.S. Patent No. 7,399,378 entitled "Fabric Crepe Process for Making Absorbent Sheet", U.S. Patent No. 7,442,278 entitled "Fabric Crepe and In Fabric Drying Process for Producing Absorbent Sheet", U.S. Patent No. 7,503,998 entitled "High Solids Fabric Crepe Process for Producing Absorbent Sheet With In-Fabric Drying", U.S. Patent No. 7,662,257 entitled "Multi-Ply Paper Towel With Absorbent Core", U.S. Patent No. 7,588,660 entitled "Wet-Pressed Tissue and Towel Products With Elevated CD Stretch and Low Tensile Ratios Made With a High Solids Fabric Crepe Process", and U.S. Patent No. 7,585,389 entitled "Method of Making Fabric-Creped Sheet for Dispensers", U.S. Patent No. 7,850,823 entitled "Method of Controlling Adhesive Build-Up on a Yankee Dryer", U.S. Patent No. 7,651,589 entitled "Process for Producing Absorbent Sheet", U.S. Patent No. 7,662,255 entitled "Absorbent Sheet", and U.S. Patent No. 7,670,457, which are each a division of the application of U.S. Patent No. 7,442,278; U.S. Patent No. 7,588,661 entitled "Fabric Crepe Process for Making Absorbent Sheet", and U.S. Patent No. 7,704,349 entitled "Fabric Crepe Process for Making Absorbent Sheet", which are both a division of the application of U.S. Patent No. 7,399,378, and U.S. Patent No. 7,670,457 entitled "Process for Producing Absorbent Sheet". The papermaking technology disclosed in the foregoing documents in this paragraph, makes it possible to form sheets with extremely high bulk stretch and absorbency.

Canadian Patent Application No. 2,095,554 in the name of William D. Lloyd, published August 6, 1994, discloses that hardwood bleached chemical thermomechanical pulp (BCTMP) fibers at amounts of about 5 weight percent or greater provide a soft tissue useful for use as facial or bath tissue, but fails to disclose the degree of bleaching and chemical refining applied to his fibers and is devoid of information concerning the brightness, lignin content or Kappa number of his fibers, other than to state that the fibers contain "substantial amounts of lignin" and the that pulping yield is "about 90% or greater". Lloyd also states that "it is not necessary to bury the BCTMP fibers in the middle of the tissue sheet by layering. Instead, the tissue sheets can be blended using a mixture of hardwood BCTMP fibers (for softness) and longer softwood fibers (for strength). If a layered tissue is preferred, the hardwood BCTMP fibers can be utilized in the outer layer(s)."

Summary of the Invention

We have found that we can achieve this desirable combination of properties in a two- or three-ply sheet formed from belt creped cellulosic basesheet, the multi-ply sheet having a basis weight of from about 32.6 to about 57.0 g/m^2 and comprising from about 10% to about 30% cellulosic microfiber, from about 70% to about 90% wood pulp fibers, with a geometric mean (GM) dry tensile of from about 2.7 to 6.3 N/m per g/m^2 of basis weight, a CD dry tensile of between about 2.4 to about 4.8 N/m per g/m^2 of basis weight, sufficient wet strength resin to provide a CD wet tensile of from about 0.67 to about 1.58 N/m per g/m^2 of basis weight, and a caliper of at least 0.078 mm per 8 sheets per g/m^2 of basis weight. Preferably, such a multi-ply tissue will have an opacity of at least about 1.5 MacBeth Opacity Units per g/m^2. More preferably, the basis weight will be between 35.8 and 52.1 g/m^2. Upon testing for Dry Lint, as referenced herein, sheets of the present invention will exhibit a ΔL^* of less than about 6. ("L*" as used in this connection relates to International Commission on Illumination (CIE) 1976, also known as CIELAB measurement of lightness and should not be confused with Hunter lightness, typically denominated "L". In this connection, the asterisk "*" is not a reference mark directing the reader to some other location in this document, but a portion of the commonly used symbol for CIE 1976 lightness "L*".) When tested for wet lint as set forth herein, sheets of the present invention will exhibit a Wet Abraded Lint Area of less than about 35 mm^2. Alternatively, when tested as set forth herein, resistance to wet linting will be represented by the number of fibers removed having a length of greater than 40 μm, with products of the invention suffering a loss of less than 2500 fibers having a length of greater than 40 μm.

We also have discovered that inclusion of eucalyptus pre-conditioning refiner chemical alkaline peroxide mechanical pulp (APMP) into tissue formulations intended to be used pre-wetted makes it possible to dramatically improve the performance of these tissues, even with concentrations of

cellulosic microfiber below the 10% by weight level in conventional wet press technology (i.e., CWP) tissues. U.S. Provisional Patent Application No. 61/574,200, entitled "High Softness, High Durability Bath Tissue Incorporating High Lignin Eucalyptus Fiber", filed on July 28, 2011, naming Jeffrey A. Lee and Daniel W. Sumnicht as inventors, illustrates the suitability of eucalyptus pre-conditioning refiner chemical alkaline peroxide mechanical pulp referred to herein as eucalyptus (APMP). We have found that we can get surprisingly good softness, bulk and wet properties using eucalyptus APMP, in conjunction with relatively low contents of CMF, even in CWP products. Accordingly, it is evident that eucalyptus APMP can be substituted into the formulations described elsewhere in this application to significant benefit, particularly, in cases when the amount of CMF is below 20% by weight.

Brief Description of the Drawings

The invention is described with reference to the drawings, wherein:

Figure 1 is a schematic illustration of a shaker for use in the "Dispersibility Test" described herein.

Figure 2 is a schematic illustration of a fixture used for holding the test bottle used in the "Dispersibility Test" upright, while the contents are being drained therefrom.

Figure 3 is photomicrograph of a perforated polymeric belt suitable for the practice of the present invention.

Figures 4 and **5** are schematic illustrations of papermachine configurations suitable for the practice of the present invention, **Figure 4** being a so-called crescent former and **Figure 5** being a twin wire.

Figures 6A to **6D** are photographs of black felts used in the "Dry Lint Test" described herein.

Figure 7 is a graphical representation of results of softness and tensile testing described in Example 1 hereof, wherein QN UP represents Quilted Northern® Ultra Plush and QN SS represents Quilted Northern® Soft & Strong.

Figures 8A to **8D** are graphical comparisons of properties of tissues of the present invention, particularly, softness, as compared to commercially available tissue products illustrating that Applicants have succeeded in manufacturing dispersible (flushable) temporary wet strength bath

tissues that not only can achieve at least parity softness with conventional ultra premium bath tissue, but have sufficient temporary wet strength to be usable pre-wetted without leaving excessive lint behind in use, whether used pre-wetted or dry.

Figures 9A to **9E** are photographs of black felts used in the "Wet Abrasion Lint Test" described herein, of tissues described in Example 3 hereof.

Figure 10 is photomicrograph of a perforated polymeric belt suitable for the practice of the present invention, while **Figure 11** is a schematic scale drawing of the perforated polymeric belt shown in **Figure 10**.

Figures 12 and **13** compare the Dry and Wet Lint properties of tissues of the present invention to commercially available tissues.

Figure 14 illustrates a schematic sectional view of a three-ply tissue with two stratified outer plies and a homogeneous inner ply, wherein eucalyptus alkaline peroxide mechanical pulp (APMP) is incorporated in all three plies.

Figure 15 is a bubble graph illustrating the inter-relationship among the softness, CD wet strength and wet linting resistance of several prototype products.

Figure 16 is a bubble graph illustrating the inter-relationship among dispersibility, CD wet strength and resistance to wet linting of several prototype products.

Figure 17 illustrates the dry tensile strength and softness of several prototype tissue products.

Figure 18 illustrates the caliper and basis weight of CWP prototype tissue products in comparison with those of Fabric Reorienting Belt Creping ("FRBC") prototypes.

Figure 19 illustrates the softness and wet lint resistance of CWP prototype tissue products in comparison with those of FRBC prototypes with bubble size representing basis weight.

Figure 20 is a schematic illustration of a glass microscope slide marked for use in the "Wet Abrasion Lint Test" test described herein.

Figures 21 to **23** are sectional scanning electron micrographs (SEM's) illustrating domed structures having consolidated regions formed therein.

Figure 24 is a schematic of the process of preparing eucalyptus APMP.

Figures 25 and **26** illustrate a fixture used for measuring roll compression of towel and tissue products. (**Figure 26** is a sectional view taken along line 28-28 of **Figure 25**.)

Figures 27, **27A** to **27F**, **27T** and **27H** illustrate details of the emboss pattern U 19 referred to herein.

Figures 28, **28A** to **28H**, **28J**, **28-1** and **28-2** illustrate details of the emboss pattern HVS 9 referred to herein.

Figure 29 illustrates the decay of CD wet tensile of various products evaluated herein.

Detailed Description

The invention is described below with reference to numerous embodiments. Such a discussion is for purposes of illustration only. Modifications to particular examples within the spirit and scope of the present invention, set forth in the appended claims, will be readily apparent to one of skill in the art.

Terminology used herein is given its ordinary meaning consistent with the exemplary definitions set forth immediately below: mg refers to milligrams and m^2 refers to square meters, mm^2 refers to square millimeters, and so forth.

The creping adhesive "add-on" rate is calculated by dividing the rate of application of adhesive (mg/min) by surface area of the drying cylinder passing under a spray applicator boom (m^2/min). The resinous adhesive composition most preferably consists essentially of a polyvinyl alcohol resin and a polyamide-epichlorohydrin resin, wherein the weight ratio of polyvinyl alcohol resin to polyamide-epichlorohydrin resin is from about 2 to about 4. The creping adhesive may also include modifier sufficient to maintain good transfer between the creping belt and the Yankee cylinder, generally, less than 5% by weight modifier, and, more preferably, less than about 2% by weight modifier, for peeled products. For blade creped products, from about 5% to about 25% modifier or more may be used.

Throughout this specification and claims, when we refer to a nascent web having an apparently random distribution of fiber orientation (or use like terminology), we are referring to the distribution

of fiber orientation that results when known forming techniques are used for depositing a furnish on the forming fabric. When examined microscopically, the fibers give the appearance of being randomly oriented, even though, depending on the jet to wire speed ratio, there may be a significant bias toward machine direction orientation making the machine direction tensile strength of the web exceed the cross-direction tensile strength.

In many applications related to U.S. Patent No. 7,399,378, entitled "Fabric Crepe Process for Making Absorbent Sheet", the importance of the distinction between creping using a woven fabric and a creping belt formed by perforating a solid belt was of minor importance, so the term “belt” could apply to either creping medium. In this application, however, as well as in U.S. Patent Application No. 12/694,650, filed on January 27, 2010, entitled “Belt-Creped, Variable Local Basis Weight Absorbent Sheet Prepared With Perforated Polymeric Belt” and published as U.S. Patent Application Publication No. 2010/0186913, the distinction between the use of a creping fabric and a perforated polymeric belt is of considerable importance, as it has been found that use of a perforated polymeric belt makes it possible to obtain consolidated regions, particularly, consolidated saddle shaped regions, in the web, giving it improved physical properties over the webs previously formed using the technique of creping from a transfer drum. For convenience, we refer to this method of forming a sheet as Fiber Reorienting Belt Creping or FRBC. Further, in this application, it is demonstrated that CMF containing wipers made using a perforated polymeric belt have substantial performance advantages over wipers made using a woven creping fabric, which we term Fiber Reorienting Fabric Creping or FRFC. Throughout this application, we have endeavored to make this distinction explicit. In this application, belts and creping fabrics should not be considered to be synonymous.

Basis weight is expressed in g/m^2 or gsm. Local basis weights and differences therebetween are calculated by measuring the local basis weight at two or more representative low basis weight areas within the low basis weight regions and comparing the average basis weight to the average basis weight at two or more representative areas within the relatively high local basis weight regions. For example, if the representative areas within the low basis weight regions have an average basis weight of 24.5 g/m^2 and the average measured local basis weight for the representative areas within the relatively high local basis regions is 32.6 g/m^2, the representative areas within high local basis weight regions have a characteristic basis weight of ((32.6-24.5)/24.5) × 100% or 33% higher than the representative areas within low basis weight regions. Preferably, the local basis weight is measured using a beta particle attenuation technique as referenced herein. In some cases, X-ray techniques can be suitably provided that the X-rays are sufficiently “soft” - that the energy of the photons is

sufficiently low and the basis weight differences between the various regions of the sheet are sufficiently high, so that significant differences in attenuation are attained.

"Belt crepe ratio" is an expression of the speed differential between the creping belt and the forming wire, and is typically calculated as the ratio of the web speed immediately before belt creping and the web speed immediately following belt creping, the forming wire and transfer surface being typically, but not necessarily, operated at the same speed:

Belt crepe ratio = transfer cylinder speed ÷ creping belt speed.

Belt crepe can also be expressed as a percentage calculated as:

Belt crepe = [Belt crepe ratio - 1] x 100.

A web creped from a transfer cylinder with a surface speed of 3.81 m/s to a belt with a velocity of 2.54 m/s has a belt crepe ratio of 1.5 and a belt crepe of 50%.

For reel crepe, the reel crepe ratio is typically calculated as the Yankee speed divided by reel speed. To express reel crepe as a percentage, one (1) is subtracted from the reel crepe ratio and the result multiplied by 100.

The belt crepe/reel crepe ratio is calculated by dividing the belt crepe by the reel crepe.

The line or overall crepe ratio is calculated as the ratio of the forming wire speed to the reel speed and a % total crepe is:

Line Crepe - [Line Crepe Ratio -1]/100.

A process with a forming wire speed of 10.2 m/s and a reel speed of 5.08 m/s has a line or total crepe ratio of 2 and a total crepe of 100%.

"Belt side" and like terminology refers to the side of the web that is in contact with the creping belt. "Dryer-side" or "Yankee-side" is the side of the web in contact with the drying cylinder, typically, opposite to the belt-side of the web in many papermaking configurations. In these configurations, the belt side could also be referred to as the air side. The air side, however, is always opposite to the Yankee side. In this application, "belt side" is determined when the sheet is in contact with the transfer cylinder from which it is creped by the creping belt.

Calipers and/or bulk reported herein may be measured at 8 or 16 sheet calipers as specified. The sheets are stacked and the caliper measurement taken about the central portion of the stack. Preferably, the test samples are conditioned in an atmosphere of 23° ± 1.0°C at 50% relative humidity for at least about 2 hours and then measured with a Thwing-Albert Model 89-II-JR or Progage Electronic Thickness Tester with 50.8 mm diameter anvils, 539 ± 10 grams dead weight load, and 5.87 mm/sec descent rate. For finished product testing, each sheet of product to be tested must have the same number of plies as the product as sold. For testing in general, eight sheets are selected and stacked together. For napkin testing, napkins are unfolded prior to stacking. For base sheet testing off of winders, each sheet to be tested must have the same number of plies as produced off of the winder. For base sheet testing off of the papermachine reel, single plies must be used. Sheets are stacked together aligned in the machine direction (MD). Bulk may also be expressed in units of volume/weight by dividing caliper by basis weight.

The term "cellulosic", "cellulosic sheet", and the like, is meant to include any wet-laid product incorporating papermaking fiber having cellulose as a major constituent. "Papermaking fibers" include virgin pulps or recycle (secondary) cellulosic fibers or fiber mixes comprising cellulosic fibers. Fibers suitable for making the webs of this invention include nonwood fibers, such as cotton fibers or cotton derivatives, abaca, kenaf, sabai grass, flax, esparto grass, straw, jute hemp, bagasse, milkweed floss fibers, and pineapple leaf fibers, and wood fibers, such as those obtained from deciduous and coniferous trees, including softwood fibers, such as northern and southern softwood kraft fibers, hardwood fibers, such as eucalyptus, maple, birch, aspen, or the like. Papermaking fibers can be liberated from their source material by any one of a 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, alkaline peroxide, and so forth. The products of the present invention may comprise a blend of conventional fibers (whether derived from virgin pulp or recycle sources) and high coarseness lignin-rich tubular fibers, mechanical pulps, such as bleached chemical thermomechanical pulp (BCTMP). "Furnishes" and like terminology refers to aqueous compositions including papermaking fibers, optionally, wet strength resins, debonders, and the like, for making paper products. Recycle fiber is typically more than 50% by weight hardwood fiber and may be 75% to 80% or more hardwood fiber.

As used herein, the term "compactively dewatering the web" (or furnish) refers to mechanical dewatering by overall wet pressing, such as on a dewatering felt, for example, in some embodiments, by use of mechanical pressure applied continuously over the web surface as in a nip between a press

roll and a press shoe, wherein the web is in contact with a papermaking felt. The terminology "compactively dewatering" is used to distinguish from processes wherein the initial dewatering of the web is carried out largely by thermal means, as is the case, for example, in U.S. Patent No. 4,529,480 to Trokhan and U.S. Patent No. 5,607,551 to Farrington et al. Compactively dewatering a web thus refers, for example, to removing water from a nascent web having a consistency of less than 30% or so by application of pressure thereto and/or increasing the consistency of the web by about 15% or more by application of pressure thereto, that is, increasing the consistency, for example, from 30% to 45%.

Consistency refers to % solids of a nascent web, for example, calculated on a bone dry basis. "Air dry" means including residual moisture, by convention, up to about 10% moisture for pulp and up to about 6% for paper. A nascent web having 50% water and 50% bone dry pulp has a consistency of 50%.

Consolidated fibrous structures are those that have been so highly densified that the fibers therein have been compressed to ribbon-like structures and the void volume is reduced to levels approaching or perhaps even less than those found in flat papers, such as are used for communication purposes. In preferred structures, the fibers are so densely packed and closely matted that the distance between adjacent fibers is typically less than the fiber width, often less than half or even less than a quarter of the fiber width. In the most preferred structures, the fibers are largely collinear and strongly biased in the machine direction (MD). The presence of consolidated fiber or consolidated fibrous structures can be confirmed by examining thin sections that have been imbedded in resin, then, microtomed in accordance with known techniques. Alternatively, if scanning electron microscope images (SEM's) of both faces of a region are so heavily matted as to resemble flat paper, then that region can be considered to be consolidated. Sections prepared by focused ion beam cross section polishers, such as those offered by JEOL® USA, Inc., 11 Dearborn Road, Peabody, Massachusetts, 01960, are especially suitable for observing densification throughout the thickness of the sheet, to determine whether regions in the tissue products of the present invention have been so highly densified as to become consolidated.

Creping belt and like terminology refers to a belt that bears a perforated pattern suitable for practicing the process of the present invention. In addition to perforations, the belt may have features, such as raised portions and/or recesses between perforations, if so desired. Preferably, the perforations are tapered, which appears to facilitate transfer of the web, especially, from the creping belt to a dryer, for example. Typically, the face of the sheet contacting the web during the fabric creping step will have a

greater open area than the face away from the web. In some embodiments, the creping belt may include decorative features, such as geometric designs, floral designs, and so forth, formed by rearrangement, deletion, and/or combination of perforations having varying sizes and shapes.

"Domed", "dome-like", and so forth, as used in the description and claims, generally refer to hollow, arched protuberances in the sheet of the class seen in the various **Figures** and is not limited to a specific type of dome structure. The terminology refers to vaulted configurations, generally, whether symmetric or asymmetric about a plane bisecting the domed area. Thus, "domed" generally refers to spherical domes, spheroidal domes, elliptical domes, ellipsoidal domes, oval domes, domes with polygonal bases and related structures, generally including a cap and sidewalls, preferably, inwardly and upwardly inclined, that is, the sidewalls being inclined toward the cap along at least a portion of their length. Cross-sectional photomicrographs are shown of such domed structures in **Figures 21** to **23**.

M/min refers to meters per minute.

MD means machine direction and CD means cross-machine direction.

When applicable, MD bending length (cm) of a product is determined in accordance with American Society for Testing and Materials (ASTM) test method D 1388-96, cantilever option. Reported bending lengths refer to MD bending lengths, unless a CD bending length is expressly specified. The MD bending length test was performed with a Cantilever Bending Tester available from Research Dimensions, 1720 Oakridge Road, Neenah, Wisconsin, 54956, which is substantially the apparatus shown in the ASTM test method, item 6. The instrument is placed on a level, stable surface, horizontal position being confirmed by a built in leveling bubble. The bend angle indicator is set at 41.5° below the level of the sample table. This is accomplished by setting the knife edge appropriately. The sample is cut with a one inch strip cutter available from Thwing-Albert Instrument Company, 14 Collins Avenue, W. Berlin, NJ 08091. Six (6) samples are cut: 25.4 mm × 203 mm machine direction specimens. Samples are conditioned at 23°C ± 1°C at 50% relative humidity for at least two hours. For machine direction specimens, the longer dimension is parallel to the machine direction. The specimens should be flat, free of wrinkles, bends or tears. The Yankee-side of the specimens is also labeled. The specimen is placed on the horizontal platform of the tester, aligning the edge of the specimen with the right hand edge. The movable slide is placed on the specimen, being careful not to change its initial position. The right edge of the sample and the movable slide should be set at the right edge of the horizontal platform. The movable slide is displaced to the right

in a smooth, slow manner, at approximately 127 mm/minute until the specimen touches the knife edge. The overhang length is recorded to the nearest 0.1 cm. This is done by reading the left edge of the movable slide. Three specimens are preferably run with the Yankee-side up and three specimens are preferably run with the Yankee-side down, on the horizontal platform. The MD bending length is reported as the average overhang length in centimeters, divided by two to account for bending axis location.

Nip parameters include, without limitation, nip pressure, nip width, backing roll hardness, creping roll hardness, belt approach angle, belt takeaway angle, uniformity, nip penetration and velocity delta between surfaces of the nip.

Nip width (or length as the context indicates) means the MD length over which the nip surfaces are in contact.

PLI or pli means pounds force per linear inch or N/m. The process employed is distinguished from other processes, in part, because belt creping is carried out under pressure in a creping nip. Typically, rush transfers are carried out using suction to assist in detaching the web from the donor fabric and, thereafter, attaching it to the receiving or receptor fabric. In contrast, suction is not required in a belt creping step, so, accordingly, when we refer to belt creping as being "under pressure," we are referring to loading of the receptor belt against the transfer surface, although suction assist can be employed at the expense of further complication of the system, as long as the amount of suction is not sufficient to undesirably interfere with rearrangement or redistribution of the fiber.

Pusey and Jones (P&J) hardness (indentation) is measured in accordance with ASTM D 531, and refers to the indentation number (standard specimen and conditions).

"Predominantly" means more than 50% of the specified component, by weight, unless otherwise indicated.

Roll compression is measured by compressing the roll 285 under a 1500 g flat platen 281 of a test apparatus 283 similar to that shown in **Figures 25** and **26**. Sample rolls 285 are conditioned and tested in an atmosphere of 23.0° ± 1.0°C. A suitable test apparatus 283 with a movable 1500 g platen 281 (referred to as a height gauge) is available from:

Research Dimensions
1720 Oakridge Road
Neenah, WI 54956
920-722-2289
920-725-6874 (FAX)

The test procedure is generally as follows:

(a) Raise the platen 281 and position the roll 285 to be tested on its side, centered under the platen, with the tail seal 287 to the front of the gauge 291 and the core 289 parallel to the back of the gauge 291.

(b) Slowly lower the platen 281 until it rests on the roll 285.

(c) Read the compressed roll diameter or sleeve height from the gauge pointer 293 to the nearest 0.254 mm.

(d) Raise the platen 281 and remove the roll 285.

(e) Repeat for each roll or sleeve to be tested.

To calculate roll compression (RC) in percent, the following formula is used:

$$RC(\%) = 100 \times \frac{\text{(initial roll diameter - compressed roll diameter)}}{\text{initial roll diameter}}$$

Dry tensile strengths (MD and CD), stretch, ratios thereof, modulus, break modulus, stress and strain are measured with a standard Instron test device or other suitable elongation tensile tester, which may be configured in various ways, typically, using 76.2 mm or 25.4 mm wide strips of tissue or towel, conditioned in an atmosphere of 23° ± 1°C at 50% relative humidity for 2 hours. The tensile test is run at a crosshead speed of 50.8 mm/min. Break modulus is expressed in g/mm/% strain. % strain is dimensionless and need not be specified. Unless otherwise indicated, values are break values. GM refers to the square root of the product of the MD and CD values for a particular product. Tensile energy absorption (TEA), which is defined as the area under the load/elongation (stress/strain) curve, is also measured during the procedure for measuring tensile strength. Tensile energy absorption is related to the perceived strength of the product in use. Products having a higher TEA may be perceived by users as being stronger than similar products that have lower TEA values, even if the

actual tensile strength of the two products are the same. In fact, having a higher tensile energy absorption may allow a product to be perceived as being stronger than one with a lower TEA, even if the tensile strength of the high-TEA product is less than that of the product having the lower TEA. When the term "normalized" is used in connection with a tensile strength, it simply refers to the appropriate tensile strength from which the affect of basis weight has been removed by dividing that tensile strength by the basis weight. In many cases, similar information is provided by the term "breaking length".

Tensile ratios are simply ratios of an MD value determined by way of the foregoing methods divided by the corresponding CD value. Unless otherwise specified, a tensile property is a dry sheet property.

"Upper", "upwardly" and like terminology is used purely for convenience and refers to a position or direction toward the caps of the dome structures, that is, the belt side of the web, which is generally opposite to the Yankee side, unless the context clearly indicates otherwise.

The wet tensile of the tissue of the present invention is measured generally following Technical Association of the Pulp and Paper Industry (TAPPI) Method T 576 pm 7, using a 76.2 mm wide strip of tissue that is folded into a loop, clamped in a special fixture termed a Finch Cup, then immersed in water. A suitable Finch cup, 76.2 mm, with base to fit a 76.2 mm grip, is available from:

High-Tech Manufacturing Services, Inc.
3105-B NE 65th Street
Vancouver, WA 98663
360-696-1611
360-696-9887 (FAX).

For fresh basesheet and finished product (aged 30 days or less for towel product, aged 24 hours or less for tissue product) containing wet strength additive, the test specimens are placed in a forced air oven heated to 105°C for five minutes. No oven aging is needed for other samples. The Finch cup is mounted onto a tensile tester equipped with a 8.9 Newton load cell with the flange of the Finch cup clamped by the tester's lower jaw and the ends of tissue loop clamped into the upper jaw of the tensile tester. The sample is immersed in water that has been adjusted to a pH of 7.0 ± 0.1 and the tensile is tested after a 5 second immersion time using a crosshead speed of 50.8 mm/minute. The results are expressed in g/mm or N/m, dividing the readout by two to account for the loop as appropriate.

A translating transfer surface refers to the surface from which the web is creped onto the creping belt. The translating transfer surface may be the surface of a rotating drum as described hereafter, or may

be the surface of a continuous smooth moving belt or another moving fabric that may have surface texture, and so forth. The translating transfer surface needs to support the web and to facilitate the high solids creping, as will be appreciated from the discussion that follows.

Velocity delta means a difference in linear speed.

The void volume and/or void volume ratio, as referred to hereafter, are determined by saturating a sheet with a nonpolar POROFIL™ liquid, available from Coulter Electronics Ltd., Beckman Coulter, Inc., 250 S. Kraemer Boulevard, P.O. Box 8000, Brea, CA 92822-8000 USA, and measuring the amount of liquid absorbed. The volume of liquid absorbed is equivalent to the void volume within the sheet structure. The % weight increase (PWI) is expressed as grams of liquid absorbed per gram of fiber in the sheet structure, times one hundred (100), as noted hereafter. More specifically, for each single-ply sheet sample to be tested, select 8 sheets and cut out a 25.4 mm by 25.4 mm square in the machine direction and 25.4 mm in the cross machine direction. For multi-ply product samples, each ply is measured as a separate entity. Multiple samples should be separated into individual single plies and 8 sheets from each ply position used for testing. Weigh and record the dry weight of each test specimen to the nearest 0.0001 gram. Place the specimen in a dish containing POROFIL™ liquid having a specific gravity of about 1.93 grams per cubic centimeter, also available from Coulter Electronics Ltd., Beckman Coulter, Inc., Part No. 9902458. After 10 seconds, grasp the specimen at the very edge (1-2 millimeters in) of one corner with tweezers and remove from the liquid. Hold the specimen with that corner uppermost and allow excess liquid to drip for 30 seconds. Lightly dab (less than ½ second contact) the lower corner of the specimen on #4 filter paper (Whatman Ltd., Maidstone, England) in order to remove any excess of the last partial drop. Immediately weigh the specimen, within 10 seconds, recording the weight to the nearest 0.0001 gram. The PWI for each specimen, expressed as grams of POROFIL™ liquid per gram of fiber, is calculated as follows:

$$PWI = \frac{(W_2 - W_1)}{W_1} \times 100$$

wherein

"W_1" is the dry weight of the specimen, in grams; and

"W_2" is the wet weight of the specimen, in grams.

The PWI for all eight individual specimens is determined as described above and the average of the eight specimens is the PWI for the sample.

The void volume ratio is calculated by dividing the PWI by 1.9 (density of fluid) to express the ratio as a percentage, whereas the void volume (gms/gm or g/g) is simply the weight increase ratio; that is, PWI divided by 100.

Water absorbency rate, or WAR, is measured in seconds and is the time that it takes for a sample to absorb a 0.1 gram droplet of water disposed on its surface by way of an automated syringe. The test specimens are preferably conditioned at 23° C± 1° C at 50 % relative humidity for 2 hours. For each sample, 4 test specimens 76.2 mm × 76.2 mm are prepared. Each specimen is placed in a sample holder such that a high intensity lamp is directed toward the specimen. 0.1 ml of water is deposited on the specimen surface and a stop watch is started. When the water is absorbed, as indicated by a lack of further reflection of light from the drop, the stopwatch is stopped and the time recorded to the nearest 0.1 seconds. The procedure is repeated for each specimen and the results averaged for the sample. WAR is measured in accordance with TAPPI method T 432 cm-99.

Dry Lint Test

To quantify the amount of lint removed from towel, tissue and related products when used dry, a Sutherland Rub Tester with 1816 g rub block is used. This apparatus is available from Danilee Company, 27223 Starry Mountain Street, San Antonio, Texas 78260, 830-438-7737; 800-438-7738 (FAX). The 1816 g rub block for the Rub Tester has dimensions of 5.1 cm by 10.2 cm so that the pressure exerted during testing is 3.45 kPa.

After the samples to be evaluated are preconditioned at 10 to 35% RH at 22° to 40°C for 24 hours, then conditioned at 50.0% ± 2.0% RH and 23.0 ± 1.0°C for 2 hours, all of the subsequent procedures are performed within the confines of a room maintained at between 48 to 53% RH and a temperature of between 22°C and 24°C.

Two stacks of four 5.72 cm × 11.43 cm test strips with 11.43 cm length in the machine direction are cut from the sample with the top (exterior of roll) side up.

Two 6.35 cm × 15.24 cm strips of black felt are cut with the 15.24 cm length in the machine direction, and the top side labeled with sample ID numbers.

A baseline reading for the felt is determined by taking one L* lightness color reading on the labeled side of each black felt strip used for testing in the middle of what will be the rubbed area using a GretagMacbeth® Ci5 spectrophotometer using the following settings on the spectrophotometer:

Large area view; Specular component excluded; UV Source C; 2 degree observer; and Illuminant C. The GretagMacbeth® spectrophotometer Model Ci5 is available from: GretagMacbeth; 617 Little Britain Road, New Windsor, NY 12553; 914-565-7660; 914-565-0390 (FAX); www.gretagmacbeth.com. The "before testing" reading is later compared to the "after testing" reading in the same area of the black felt strip on the same side, so particular care is taken to be sure that comparisons are made only between the same felt strips. "L*" as used in this connection relates to CIE 1976, also known as CIELAB measurement of lightness and should not be confused with Hunter lightness, typically denominated "L". In this connection, the asterisk "*" is not a reference mark directing the reader to some other location in this document, but a portion of the commonly used symbol for CIE 1976 lightness "L*".

To evaluate a specimen, the specimen is taped to the galvanized plate on the Sutherland Rub Tester with the top side up, so that rubbing will be in the machine direction with care being observed to ensure that each specimen is taped in the same rub area each time the test is performed. The first black felt specimen is taped, labeled side out, to the bottom of the 1816 g rub block of the Sutherland Rub Tester, the number of strokes on the rub tester is set to four, and the slow speed selected (#2 setting for 4 speed model or #1 setting for 2 speed model), the rub block is placed on the Sutherland Rub Tester carriage arm and the "Start" button pressed to start testing. After the four strokes are completed, the rub block is removed from the tester and the black felt is removed from the bottom of the rub block with the black felt being preserved for L* "after testing" color reading. The specimen is removed from the galvanized plate and discarded.

One L* color reading is taken on the labeled side of each black felt strip, reading the same spot used to obtain the "before testing" value, in the middle of the rubbed area. The "after testing" reading is paired up with the appropriate "before testing" reading to calculate a difference between the readings – "ΔL*".

For each sample, the average, standard deviation, minimum and maximum test results are recorded as measured to the nearest 0.01 L* unit for both the before testing and after testing values. The difference value of the after reading minus the before reading is indicative of the lint removal by the standardized dry rubbing procedure.

Wet Abrasion Lint Test

To evaluate a tissue sample for lint removal by wet abrasion, the sample is first subjected to simulated wet use against a sample of standard black felt with a Crockmeter Rub Tester, modified as described

herein. Then, the area in mm^2 of the lint left on the felt is measured with an Epson, Perfection 4490 flat bed Scanner and Apogee, SpecScan Software, version 2.3.36.

The Crockmeter Rub available from SDL Atlas, LLC, 3934 Airway Drive, Rock Hill, SC 29732; (803) 329-2110. To be used to measure wet lint as described herein, the Crockmeter is modified to accept a 360 gram arm and a 2.54 cm x 5.08 cm that exerts a pressure on the specimen of 3.0 kPa. The weight of the rub block is 355 g for the weighted arm supported on one end, and 36 g for the rub foot. These weights are exerted on a 2.54 cm × 5.08 cm area, for a pressure of 391 g/12.9 cm^2 = 30.3 g/cm^2 = 3.0 kPa. In contrast, the method of evaluating wet abrasion in the Bhat et al. and Luu patents referenced herein used a 135 g sled placed on a 5.08 cm × 7.62 cm sample for a pressure of 135 g/38.7 cm^2 = 3.5 g/cm^2 = 0.34 kPa.

Research Dimensions at 1720 Oakridge Road, Neenah, WI 54956, 920-722-2289, will modify Crockmeter Rub Testers to conform hereto.

Suitable black felt is 4.8 mm thick, part #113308F-24 available from Aetna Felt Corporation, 2401 W. Emaus Avenue, Allentown, PA 18103; 800-526-4451.

To test a sample, the outer three layers of tissue are removed from the roll. Three sheets of tissue are cut at the perforations and placed in a stack using a paper cutter ensuring that the tissue sheets are placed in the same orientation relative to the direction and the side of the roll. From the stack, samples that are 5.08 cm by 6.35 cm are cut with the long dimension being the machine direction. Enough samples are cut for 4 replicates. The short (5.08 cm) side of the tissue is marked with a small dot to indicate the surface of the tissue that was outwardly facing when on the roll. The foot is mounted to the arm of the Crockmeter with the short dimension parallel to the stroke of the Crockmeter and the stroke distance set at 10.2 cm ± 0.3 cm, and the stroke speed is set to strokes per minute. The black felt is cut into 7.62 cm by 15.24 cm pieces with the inside surface being marked along the short edge. In this test, the tissue sample to be tested will be rubbed against the inside of the felt starting at the mark. A 30.48 cm by 30.48 cm sheet of black acrylic, a 5.08 cm by 7.62 cm glass slide marked as shown in **Figure 20**, tape, a pipette and a beaker of distilled water are located on any nearby convenient flat surface. The Crockmeter is turned on, then turned off, to position the arm at its furthest back position. The spacer is placed under the arm to hold it above the rubbing surface. A clean piece of black felt is taped to the base of the Crockmeter over the rubbing surface with the marked surface oriented upward, with the marked end up adjacent to the beginning point of the stroke of the foot. A sample is taped along one shorter edge to the foot with the top side of the tissue facing

up, and the length of the tissue is wrapped around the foot and attached to the arm of the Crockmeter with the taped side and the marked location on the tissue sample facing the operator at the forward portion of the Crockmeter. The type of tape used is not critical. Office tape commonly referred to as cellophane tape or sold under the trademark "Scotch® Tape" is suitable. The spacer is removed from under the arm, and the arm with the attached foot is set down on the black felt with the long dimension of the foot perpendicular to the rub direction, and the foot is fixed in place. The glass microscope slide is placed on the felt forward of the foot and 3 volumes of 200 μL of distilled water each are dispensed from the pipette onto the cross-marks on the glass slide. The sample, foot and arm are gently lifted, the glass slide is placed under the sample and the sample is lowered to allow the water to wet the sample for 5 seconds, after which time the arm is lifted, the glass slide removed and the Crockmeter activated to allow the sample to make three forward strokes on the felt with the arm being lifted manually at the beginning of each return stroke to prevent the sample from contacting the felt during the return strokes. After three forward strokes, the Crockmeter is inactivated and the spacer placed under the arm so that the black felt can be removed without disturbing the abraded lint thereupon. Three minutes after the felt is removed from the rubbing surface, it is scanned in a flat bed scanner using Apogee SpecScan Software with the software being set for "lint" in the "Scanner Settings" window, with "5" being set in the "Process Groups of:" window on the "Defaults panel", the "Resolution" being set at "236 dots/cm", the "Scanner Mode" being set to "256-Grayscale", the "Area Setting" being set to "Special", the "Scan Image" being set to "Reverse Image", the "Upper Limit" window on the "Dirt Histogram" panel being set to ">= 5.000" the "Lower Limit" window of that panel being set to "0.013—0.020" and the "X Scale:" window being set to "25"; and the "PPM" window of the "Bad Handsheet" panel set to "2500.0". On the "Printout Settings:" panel, the "Gray-Summary", "Sheet Summary" and "Gray Histogram" boxes are checked, the "Copies" window is set to "1", while the "Dirt Histogram", "Categories" and "XY Location boxes on that panel are unchecked. Both the "Enable Display" and "Enable Zoom" boxes are checked on the Display Mode panel. On the "Scanner Setup" panel, the "White" box is set for "255" while the "Black" box is set for "0", the "Contrast Filter" box is set for "0.000", the upper "Threshold =" box is set for 80.0 [% percent of background plus] while the lower "Threshold =" box is set for "0.0" [grayscale value]. The "Percent of Background, plus offset" box on the "Scanner Setup" panel is checked while the "Manual Threshold Setting" and "Function of StdDev of Background" boxes are unchecked. If desired the "Grade Identification:" and "Reel/Load Number:" boxes may be used to record indicia related to the identification of the samples being tested. On the "Special Area Definition" panel, "Inches" is checked in the "Dimensions:" region while "Rectangular" is checked in the "Shape:" region. In the "Border at top and left:" region, "0.15" [in.] is entered in the "At the left side: (X)" box and "0.625" [in.] is entered in the "At the top: (Y)" box. In the "Area to scan:" regions "2.7" [in.] is entered in the

"Width (X)" box and "5.2" [in.] is entered in the "Height (Y)" box. After scanning, the area in mm^2 of the abraded lint left on the black felt is output in the "SHEETS" Table in the "Total Area" column under the "Sample Sheet(s)" heading on the "Sheet & Category Summary" screen. This result is sometimes referred to herein as "WALA" for Wet Abraded Lint Area, which is reported in mm^2.

In other cases, the fiber removed will be washed off and the solution subjected to testing in an Optest Fiber Quality Analyzer to determine the number of fibers that are removed having a length in excess of 40 μm. The Optest Fiber Quality Analyzer has become a standard in the paper industry for determining fiber length distributions and fiber counts above a certain minimal length, (currently, at about 40 μm), which keeps decreasing as Optest continually upgrades their technique. The Optest Fiber Quality Analyzer is available from:

OpTest Equipment Inc.
900 Tupper SI. - Hawkesbury - ON - K6A 3S3 - Canada
Phone: 613-632-5169; Fax: 613-632-3744.

Dispersibility Test

To determine how well bathroom tissue disintegrates in water under controlled agitation using a standard water solution, a sample of tissue is placed in a bottle of specified dimensions in a standardized water solution and subjected to controlled agitation using a standardized shaker that shakes the bottle for a preset number of shakes at 180±5 strokes per minute. One stroke is a complete cycle of back and forth. The bottle is then drained in a fixture adapted to hold the bottle with its centerline perpendicular. See **Figures 1** and **2**. More specifically, the test is conducted as follows.

The standardized bottle shaker 50 and bottle guide fixture 52 are available from Research Dimensions, 1720 Oakridge Road, Neenah, WI 54956, (920) 722-2289; FAX (920) 725-6874. A small mouth (1.75 cm diameter orifice) plastic bottle 54 with cap, 250 ml, is catalog number 02-924-6D, available from Fisher Scientific Company. The Standard Water Solution, catalog number NC9664362, is available from Fisher Scientific Company, 800-766-7000.

Remove and discard the first three layers of tissue from a roll of tissue. (The tissue sample to be tested may be taken from anywhere in the roll except for the three outer wraps and the last 20 sheets from the core.) If the tissue samples and/or base sheet samples are less than 24 hours old, they are to be oven cured for 5 minutes at 105°C.

For testing of a finished product: six 3-sheet strips are cut from the roll. If the product being tested is a multi-ply product, the plies are not separated from each other, but are tested still plied together.

For testing of a base sheet, specimens are to be cut equivalent to the length and width of the finished product for which they are intended. Three specimens are cut for one-ply product, six specimens are cut for two-ply product, and nine specimens are cut for three-ply product.

180±5 ml of standard water at 23°C is transferred to the bottle 54.

Shaker 50 is set for an appropriate number of strokes. In the case of finished product testing, the three-sheet strip of tissue is folded in half, rolled up and inserted into the plastic bottle 54, which is then capped. In the case of a base sheet, the specimen is folded in half and one strip of tissue is rolled up when the intended finished product is 1-ply, two strips of tissue for 2-ply finished product, and 3 strips of tissue for 3-ply finished product. The roll is inserted into the plastic bottle 54, which is then capped.

Bottle 54 is placed in shaker 50 (**Figure 1**) with bottom 51 toward the drive arm 58, and motor 60 started.

After shaker 50 has shaken bottle 54 for the set number of strokes, the contents are immediately checked for disintegration by inverting bottle 54 and placing it into bottle guide fixture 52 (**Figure 2**) in one quick motion to see if the contents will pour out into a beaker. In order for the specimen to pass the test for that number of shakes, the entire contents of bottle 54 must empty within eight seconds without shaking or squeezing bottle 54. The test is replicated and a "pass" is recorded only if both specimens pass.

Regenerated Cellulose Microfiber

In accordance with the invention, regenerated cellulose fiber is prepared from a cellulosic dope comprising cellulose dissolved in a solvent comprising tertiary amine N-oxides or ionic liquids. The solvent composition for dissolving cellulose and preparing underivatized cellulose dopes suitably includes tertiary amine oxides such as N-methylmorpholine-N-oxide (NMMO) and similar compounds enumerated in U.S. Patent No. 4,246,221 to *McCorsley*. Cellulose dopes may contain non-solvents for cellulose, such as water, alkanols or other solvents, as will be appreciated from the discussion that follows.

Suitable cellulosic dopes are enumerated in Table 1, below.

Table 1		
EXAMPLES OF TERTIARY AMINE N-OXIDE SOLVENTS		
Tertiary Amine N-oxide	% water	% cellulose
N-methylmorpholine N-oxide	up to 22	up to 38
N,N-dimethyl-ethanol-amine N-oxide	up to 12.5	up to 31
N,N-dimethylcyclohexylamine N-oxide	up to 21	up to 44
N-methylhomopiperidine N-oxide	5.5-20	1-22
N,N,N-triethylamine N-oxide	7-29	5-15
2(2-hydroxypropoxy)-N-ethyl-N,N,-dimethyl-amide N-oxide	5-10	2-7.5
N-methylpiperidine N-oxide	up to 17.5	5-17.5
N,N-dimethylbenzylamine N-oxide	5.5-17	1-20

See, also U.S. Patent No. 3,508,941 to *Johnson*.

Details with respect to preparation of cellulosic dopes including cellulose dissolved in suitable ionic liquids and cellulose regeneration therefrom are found in U.S. Patent Application No. 10/256,521, U.S. Patent Application Publication No. 2003/0157351 of *Swatloski et al.*, entitled "Dissolution and Processing of Cellulose Using Ionic Liquids." Here, again, suitable levels of non-solvents for cellulose may be included. There is generally described in this patent application a process for dissolving cellulose in an ionic liquid without derivatization and regenerating the cellulose in a range of structural forms. It is reported that the cellulose solubility and the solution properties can be controlled by the selection of ionic liquid constituents with small cations and halide or pseudohalide anions favoring solution. Preferred ionic liquids for dissolving cellulose include those with cyclic cations, such as the following cations: imidazolium, pyridinum, pyridazinium, pyrimidinium, pyrazinium, pyrazolium, oxazolium, 1,2,3-triazolium, 1,2,4-triazolium, thiazolium, piperidinium, pyrrolidinium, quinolinium, and isoquinolinium.

Processing techniques for ionic liquids/cellulose dopes are also discussed in U.S. Patent No. 6,808,557 to *Holbrey et al.*, entitled "Cellulose Matrix Encapsulation and Method." *Note also*, U.S. Patent Application Publication No. 2005/0288484, of *Holbrey et al.*, entitled "Polymer Dissolution and Blend Formation in Ionic Liquids", as well as U.S. Patent Application Publication No. 2004/0038031, also of *Holbrey et al.,* entitled "Cellulose Matrix Encapsulation and Method." With respect to ionic fluids, in general, the following documents provide further detail: U.S. Patent

Application Publication No. 2006/0241287 of *Hecht et al.*, entitled "Extracting Biopolymers From a Biomass Using Ionic Liquids"; U.S. Patent Application Publication No. 2006/0240727, of *Price et al.*, entitled "Ionic Liquid Based Products and Method of Using The Same"; U.S. Patent Application Publication No. 2006/0240728, of *Price et al.*, entitled "Ionic Liquid Based Products and Method of Using the Same"; U.S. Patent Application Publication No. 2006/0090271, of *Price et al.*, entitled "Processes For Modifying Textiles Using Ionic Liquids"; and Patent Application Publication No. 2006/0207722 of *Amano et al.*, entitled "Pressure Sensitive Adhesive Compositions, Pressure Sensitive Adhesive Sheets and Surface Protecting Films." Some ionic liquids and quasi-ionic liquids that may be suitable are disclosed by *Konig et al.*, Chem. Commun. 2005, 1170-1172.

"Ionic liquid" refers to a molten composition that includes an ionic compound that is preferably a stable liquid at temperatures of less than 100°C at ambient pressure. Typically, such liquids have a very low vapor pressure at 100°C, less than 75 mBar or so and, preferably, less than 50 mBar or less than 25 mBar at 100°C. Most suitable liquids will have a vapor pressure of less than 10 mBar at 100°C and often, the vapor pressure is so low that it is negligible and is not easily measurable, since it is less than 1 mBar at 100°C.

Suitable commercially available ionic liquids are Basionic™ ionic liquid products available from BASF (Florham Park, NJ).

Cellulose dopes including ionic liquids having dissolved therein about 5% by weight underivatized cellulose are commercially available from Sigma-Aldrich Corp., St. Louis, Missouri (Aldrich). These compositions utilize alkyl-methylimidazolium acetate as the solvent. It has been found that chorine-based ionic liquids are not particularly suitable for dissolving cellulose.

After the cellulosic dope is prepared, it is spun into fiber, fibrillated and incorporated into absorbent sheet as described later.

A synthetic cellulose, such as lyocell, is split into micro- and nano-fibers and added to conventional wood pulp. The fiber may be fibrillated in an unloaded disk refiner, for example, or any other suitable technique including using a Pulmac-Fiber (PFI) mill. Preferably, relatively short fiber is used and the consistency kept low during fibrillation. The beneficial features of fibrillated lyocell include, for example, biodegradability, hydrogen bonding, dispersibility, repulpability, and smaller microfibers than obtainable with meltspun fibers.

Fibrillated lyocell or its equivalent has advantages over splittable meltspun fibers. Synthetic microdenier fibers come in a variety of forms. For example, a 3 denier nylon/PET fiber in a so-called pie wedge configuration can be split into 16 or 32 segments, typically, in a hydroentangling process. Each segment of a 16-segment fiber would have a coarseness of about 2 mg/100 m versus eucalyptus pulp at about 7 mg/100 m. Unfortunately, a number of deficiencies have been identified with this approach for conventional wet laid applications. Dispersibility is less than optimal. Melt spun fibers must be split before sheet formation, and an efficient method is lacking. Most available polymers for these fibers are not biodegradable. The coarseness is lower than that of wood pulp, but still high enough that they must be used in substantial amounts and form a costly part of the furnish. Finally, the lack of hydrogen bonding requires other methods of retaining the fibers in the sheet.

Fibrillated lyocell has fibrils that can be as small as 0.1 to 0.25 microns (μm) in diameter, translating to a coarseness of 0.0013 to 0.0079 mg/100 m. Assuming these fibrils are available as individual strands – separate from the parent fiber – the furnish fiber population can be dramatically increased at various addition rates. Even fibrils not separated from the parent fiber may provide benefit. It is greatly preferred, however, that the fibrils be independent of the parent fiber from which they are split off. Dispersibility, repulpability, hydrogen bonding, and biodegradability remain product attributes, since the fibrils are cellulose.

Fibrils from lyocell fiber have important distinctions from wood pulp fibrils. The most important distinction is the length of the lyocell fibrils. Wood pulp fibrils are only perhaps microns long, and, therefore, act in the immediate area of a fiber-fiber bond. Wood pulp fibrillation from refining leads to stronger, denser sheets. Lyocell fibrils, however, are potentially as long as the parent fibers. These fibrils can act as independent fibers and improve the bulk while maintaining or improving strength. Southern pine and mixed southern hardwood (MSHW) are two examples of fibers that are disadvantaged relative to premium pulps with respect to softness. The term “premium pulps” used herein refers to northern softwoods and eucalyptus pulps commonly used in the tissue industry for producing the softest bath, facial, and towel grades. Southern pine is coarser than northern softwood kraft, and mixed southern hardwood is both coarser and higher in fines than market eucalyptus. The lower coarseness and lower fines content of premium market pulp leads to a higher fiber population, expressed as fibers per gram (N or $N_{i>0.2}$) in Table 3. The coarseness and length values in Table 2 were obtained with an OpTest Fiber Quality Analyzer. Definitions are as follows:

$$L_n = \frac{\sum_{\text{all fibers}} n_i L_i}{\sum_{\text{all fibers}} n_i} \qquad L_{n,i>0.2} = \frac{\sum_{i>0.2} n_i L_i}{\sum_{i>0.2} n_i} \qquad C = 10^5 \times \frac{sampleweight}{\sum_{\text{all fibers}} n_i L_i}$$

$$N = \frac{100}{CL} [=] \; millionfibers / gram$$

Northern bleached softwood kraft (NBSK) and eucalyptus have more fibers per gram than do southern pine and hardwood. Lower coarseness leads to higher fiber populations and smoother sheets.

Table 2– Fiber Properties

Sample	Type	C, mg/100 m	Fines, %	L_n, mm.	N, MM/g	$L_{n,i>0.2mm}$	$N_{i>0.2\,mm}$ MM/g
Southern HW	Pulp	10.1	21	0.28	35	0.91	11
Southern HW - low	Pulp	10.1	7	0.54	18	0.94	11
Aracruz Eucalyptus	Pulp	6.9	5	0.50	29	0.72	20
Southern SW	Pulp	18.7	9	0.60	9	1.57	3
Northern SW	Pulp	14.2	3	1.24	6	1.74	4
Southern (30 SW/70	Base	11.0	18	0.31	29	0.93	10
30 Southern SW/70	Base	8.3	7	0.47	26	0.77	16

For comparison, the "parent" or "stock" fibers of unfibrillated lyocell have a coarseness of 16.6 mg/100 m before fibrillation and a diameter of about 11 to about 12 μm.

The fibrils of fibrillated lyocell have a coarseness on the order of 0.001 to 0.008 mg/100 m. Thus, the fiber population can be dramatically increased at relatively low addition rates. Fiber length of the parent fiber is selectable, and fiber length of the fibrils can depend on the starting length and the degree of cutting during the fibrillation process.

The dimensions of the fibers passing the 200 mesh screen are on the order of 0.2 micron by 100 micron long. Using these dimensions, one calculates a fiber population of 200 billion fibers per gram. For perspective, southern pine might be three million fibers per gram and eucalyptus might be

twenty million fibers per gram. (*See* Table 2.) It appears that these fibers are the fibrils that are broken away from the original unrefined fibers. Different fiber shapes with lyocell intended to readily fibrillate could result in 0.2 micron diameter fibers that are perhaps 1000 microns or more long instead of 100. As noted above, fibrillated fibers of regenerated cellulose may be made by producing "stock" fibers having a diameter of 10-12 microns or so followed by fibrillating the parent fibers. Alternatively, fibrillated lyocell microfibers have recently become available from Engineered Fibers Technology (Shelton, Connecticut) having suitable properties. Particularly preferred materials are more than 40% fiber that is finer than 14 mesh and exhibit a very low coarseness (low freeness). For ready reference, mesh sizes appear in Table 3, below. The current limitations on minimum length detectable by the OpTest make it difficult to precisely ascertain the fiber length distribution of the very short fibrils. It does appear, however, that these are quite important in providing the improved sheet properties of the tissues of the present invention.

Table 3 – Mesh Size

Sieve Mesh #	Inches	Microns
14	.0555	1400
28	.028	700
60	.0098	250
100	.0059	150
200	.0029	74

Details as to fractionation using the Bauer-McNett Classifier appear in *Gooding et al.*, "Fractionation in a Bauer-McNett Classifier", *Journal of Pulp and Paper Science*; Vol. 27, No. 12, December 2001.

In connection with the present invention, an absorbent paper web is made by dispersing papermaking fibers into an aqueous furnish (slurry) and depositing the aqueous furnish onto the forming wire of a papermaking machine. Any suitable forming scheme might be used. For example, an extensive, but non-exhaustive, list in addition to Fourdrinier formers, includes a crescent former, a C-wrap twin wire former, an S-wrap twin wire former, or a suction breast roll former. The forming fabric can be any suitable foraminous member including single layer fabrics, double layer fabrics, triple layer fabrics, photopolymer fabrics, and the like. Non-exhaustive background art in the forming fabric area includes 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; 5,199,261; 5,199,467; 5,211,815; 5,219,004;

5,245,025; 5,277,761; 5,328,565; and 5,379,808. One forming fabric particularly useful with the present invention is Voith Fabrics Forming Fabric 2164 made by Voith Fabrics Corporation, Shreveport, LA.

Foam-forming of the aqueous furnish on a forming wire or fabric may be employed as a means to form sheets comprising fibers that are somewhat difficult to disperse in conventional aqueous furnishes. Foam forming may be especially advantageous if formation issues are encountered. Foam-forming techniques are disclosed in U.S. Patent Nos. 6,500,302; 6,413,368; 4,543,156 and Canadian Patent No. 2,053,505. The foamed fiber furnish is made up from an aqueous slurry of fibers mixed with a foamed liquid carrier just prior to its introduction to the headbox. The pulp slurry supplied to the system has a consistency in the range of from about 0.5 to about 7 weight % fibers, preferably, in the range of from about 2.5 to about 4.5 weight %. The pulp slurry is added to a foamed liquid comprising water, air and surfactant containing 50 to 80% air by volume, forming a foamed fiber furnish having a consistency in the range of from about 0.1 to about 3 weight % fiber by simple mixing from natural turbulence and mixing inherent in the process elements. The addition of the pulp as a low consistency slurry results in excess foamed liquid recovered from the forming wires. The excess foamed liquid is discharged from the system and may be used elsewhere or treated for recovery of surfactant therefrom.

The furnish will almost always 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. Such additives may be surface modifiers, softeners, debonders, strength aids, latexes, opacifiers, optical brighteners, dyes, pigments, sizing agents, barrier chemicals, retention aids, insolubilizers, organic or inorganic crosslinkers, or combinations thereof, the chemicals optionally comprising polyols, starches, PPG esters, PEG esters, phospholipids, surfactants, polyamines, HMCP (Hydrophobically Modified Cationic Polymers), HMAP (Hydrophobically Modified Anionic Polymers), or the like.

The pulp can be mixed with strength adjusting agents such as wet strength agents, dry strength agents, debonders/softeners, and so forth. Suitable wet strength agents are known to the skilled artisan. A comprehensive, but non-exhaustive, list of useful strength aids includes urea-formaldehyde resins, melamine formaldehyde resins, glyoxylated polyacrylamide resins, polyamide-epichlorohydrin resins, and the like. Thermosetting polyacrylamides are produced by reacting acrylamide with diallyl dimethyl ammonium chloride (DADMAC) to produce a cationic polyacrylamide copolymer that is ultimately reacted with glyoxal to produce a cationic cross-linking wet strength resin, glyoxylated

polyacrylamide. These materials are generally described in U.S. Patent No. 3,556,932 to *Coscia et al.* and No. 3,556,933 to *Williams et al.* Resins of this type are commercially available under the trade name of PAREZ 631NC by Bayer Corporation (Pittsburgh, PA). 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-epichlorohydrin wet strength resins, an example of which is sold under the trade names Kymene 557LX and Kymene 557H by Hercules Incorporated of Wilmington, Delaware, and Amres® from Georgia-Pacific Resins, 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. 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). A reasonably comprehensive list of wet strength resins is described by Westfelt in *Cellulose Chemistry and Technology*, volume 13, page 813, 1979.

Suitable temporary wet strength agents for use in the practice of the present invention include aliphatic and aromatic aldehydes, including glyoxal, malonic dialdehyde, succinic dialdehyde, glutaraldehyde and dialdehyde starches, as well as substituted or reacted starches, disaccharides, polysaccharides, chitosan, or other reacted polymeric reaction products of monomers or polymers having aldehyde groups, and optionally, nitrogen groups. Representative nitrogen containing polymers, which can suitably be reacted with the aldehyde containing monomers or polymers, includes vinyl-amides, acrylamides and related nitrogen containing polymers. These polymers impart a positive charge to the aldehyde containing reaction product. In addition, other commercially available temporary wet strength agents, such as, PAREZ FJ98, a low molecular weight slightly cationic glyoxalated polyacrylamide manufactured by Kemira (Atlanta, GA), can be used, along with those disclosed, for example, in U.S. Patent No. 4,605,702.

The temporary wet strength resin may be any one of a variety of water-soluble organic polymers comprising aldehydic units and cationic units used to increase dry and wet tensile strength of a paper product. Such resins are described in U.S. Patent Nos. 4,675,394; 5,240,562; 5,138,002; 5,085,736; 4,981,557; 5,008,344; 4,603,176; 4,983,748; 4,866,151; 4,804,769 and 5,217,576. Modified starches sold under the trademarks CO-BOND® 1000 and CO-BOND® 1000 Plus, by National Starch and Chemical Company of Bridgewater, N.J., may be used. Prior to use, the cationic aldehydic water soluble polymer can be prepared by preheating an aqueous slurry of approximately 5% solids, maintained at a temperature of approximately 240°F and a pH of about 2.7 for approximately 3.5

minutes. Finally, the slurry can be quenched and diluted by adding water to produce a mixture of approximately 1.0% solids at less than about 130°F.

Other temporary wet strength agents, also available from National Starch and Chemical Company are sold under the trademarks CO-BOND® 1600 and CO-BOND® 2300. These starches are supplied as aqueous colloidal dispersions and do not require preheating prior to use.

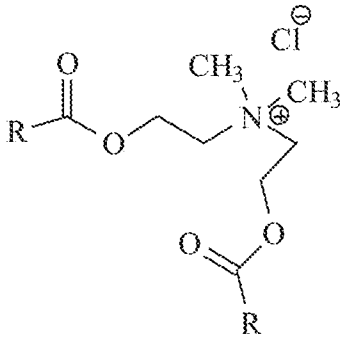
To the extent that dry strength agents are added, suitable dry strength agents include starch, guar gum, polyacrylamides, carboxymethyl cellulose, and the like. Of particular utility is carboxymethyl cellulose, an example of which is sold under the trade name Hercules® CMC, by Hercules Incorporated of Wilmington, Delaware.

Suitable debonders are likewise known to the skilled artisan. Debonders or softeners may also be incorporated into the pulp or sprayed upon the web after its formation. The present invention may also be used with softener materials including, but not limited to, the class of amido amine salts derived from partially neutralized amines. Such materials are disclosed in U.S. Patent No. 4,720,383. Evans, *Chemistry and Industry*, 5 July 1969, pages 893-903; Egan, *J.Am. Oil Chemist's Soc.*, Vol. 55 (1978), pages 118-121; and Trivedi et al., *J.Am.Oil Chemist's Soc.*, June 1981, pages 754-756, indicate that softeners are often available commercially only as complex mixtures rather 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.

Hercules® TQ 218 or equivalent is a suitable softener material, which may be derived by alkylating a condensation product of oleic acid and diethylenetriamine. 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 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 materials 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 head box should be approximately 6 to 8, more preferably, from about 6 to about 7 and, most preferably, from about 6.5 to about 7.

Quaternary ammonium compounds, such as dialkyl dimethyl quaternary ammonium salts, are also suitable, particularly, when the alkyl groups contain from about 10 to 24 carbon atoms. These compounds have 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. Biodegradable ester quats are suitable. These softeners are biodegradable by virtue of hydrolyzable ester linkages and are usually made by esterifying ethanol amines (i.e., di- and tri-ethanolamines) with a fatty acid followed by quaternization with dimethyl sulfate, or, more popularly, because of safety, diethylsulfate. A methylated example of such an ester quat has the following structural formula:



wherein R can conveniently be either an oleyl group, $CH_2(CH_2)_6CH=CH(CH_2)_7CH_3$, or an erucyl group, $CH_2(CH_2)_{10}CH=CH(CH_2)_7CH_3$, as these can be derived from oleic and erucic acids. In some embodiments, a particularly preferred debonder composition includes a quaternary amine component as well as a nonionic surfactant.

The nascent web may be compactively dewatered on a papermaking felt. Any suitable felt may be used. For example, felts can have double-layer base weaves, triple-layer base weaves, or laminated base weaves. Preferred felts are those having a laminated base weave design. A wet-press-felt that may be particularly useful with the present invention is Vector 3 made by Voith Fabric (Appleton, WI). Background art in the press felt area includes U.S. Patent Nos. 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. A differential pressing felt as is disclosed in U.S. Patent No. 4,533,437 to *Curran et al.* may likewise be utilized.

Preferred Embodiments

The products of this invention are advantageously produced in accordance with the teachings of U.S. Patent Application Publication No. 2010/0186913, "Belt-Creped, Variable Local Basis Weight Absorbent Sheet Prepared With Perforated Polymeric Belt", wherein, after dewatering, a wet-laid, compactively dewatered web is belt creped at a consistency of from 30 – 60% as described therein. For purposes of this invention, the creping belt employed is a perforated polymer belt of the class shown in **Figures 3, 10** and **11.** Other suitable belts are described in U.S. Patent Application

Publication No. 2010/0186913. Belts having a staggered interpenetrating array of perforations as shown in Figs. 29G and 41 of U.S. Patent Application Publication No. 2010/0186913 are particularly preferred.

Figure 3 is a plan view photograph of a portion of a first polymer belt **150** having an upper surface **152** that is generally planar and a plurality of tapered perforations **154**, **156** and **158**. The belt has a thickness of about 0.2 mm to 1.5 mm. Perforations **154**, **156** and **158** may be surrounded by lips as shown in U.S. Patent Application Publication No. 2010/0186913, **Figures 4** through **9**, but this is not required. The perforations on the upper surface are separated by a plurality of flat portions or lands **166**, **168** and **170** therebetween that separate the perforations. In the embodiment shown in **Figure 3**, each of the upper portions of the perforations **154**, **156** and **158** (sheet contacting side) has an open area of about 1500 square mils or so, and are oval in shape with a length of about 50 mils mm along a longer axis **172** and a width of about 36 mils or so along a shorter axis **174** of the perforations **154**, **156** and **158**, while those on the lower surface (roll contacting side) have an open area of approximately 300 square mils with a length of about 22 mils and a width of about 15 mils. It is greatly preferred that the perforations form a staggered interpenetrating array to provide flexibility to belt **150**, to accommodate the varying lengths of the fabric that run across the width of the paper machine. The belt shown in **Figure 3** has about 321 perforations per square inch and an open area of approximately 50% on the sheet contact side and about 10% on the roll contact side of the belt. It is not necessary that the perforations be oval shaped.

Figure 4 shows a papermachine **220** for use in connection with the present invention. Papermachine **220** is a three fabric loop machine having a forming section **222** generally referred to in the art as a crescent former. Forming section **222** includes headbox **250** depositing a furnish on forming wire **232** supported by a plurality of rolls, such as rolls **242**, **245**. The forming section also includes a forming roll **248** that supports papermaking felt **252**, such that web **254** is formed directly on felt **252**. Press section **226** includes felt **252**, suction roll **256**, press shoe **260** and backing roll **262**. Felt run **224** extends to shoe press section **226**, wherein the moist web is deposited on backing roll **262** and wet-pressed concurrently with the transfer. Thereafter, web **254** is creped onto belt **350** (top side large openings) in belt crepe nip **274** at roll **272** before being optionally vacuum drawn by suction box **276** and then deposited on Yankee dryer **230** in another press nip **292** using a creping adhesive as noted above. Transfer to a Yankee from the creping belt differs from conventional transfers in a CWP from a felt to a Yankee. In a CWP process, pressures in the transfer nip may be 87.6 kN/m or so, and the pressured contact area between the Yankee surface and the web is close to or at 100%. The press roll may be a suction roll, which may have a P&J hardness of 25 to 30. On the other hand, a belt crepe

process of the present invention typically involves transfer to a Yankee with a 4 to 40% pressured contact area between the web and the Yankee surface at a pressure of 43.8 to 61.3 kN/m. No suction is applied in the transfer nip and a softer pressure roll is used, P&J hardness of 35 to 45. The system includes a suction roll **256**, in some embodiments. The three loop system, however, may be configured in a variety of ways in which a turning roll is not necessary. This feature is particularly important in connection with the rebuild of a papermachine, inasmuch as the expense of relocating associated equipment, i.e., the headbox, pulping or fiber processing equipment, and/or the large and expensive drying equipment, such as the Yankee dryer or plurality of can dryers would make a rebuild prohibitively expensive, unless the improvements could be configured to be compatible with the existing facility.

Figure 5 is a schematic diagram of a papermachine **410** having a conventional twin wire forming section **412**, a felt run **414**, a shoe press section **416**, a creping belt **450** and a Yankee dryer **420** suitable for practicing the present invention. Forming section **412** includes a pair of forming fabrics **422, 424** supported by a plurality of rolls **426, 428, 430, 432, 434, 436** and a forming roll **438**. A headbox **440** provides papermaking furnish issuing therefrom as a jet in the machine direction to a nip **442** between forming roll **438** and roll **426** and the fabrics. The furnish forms a nascent web **444** that is dewatered on the fabrics with the assistance of suction, for example, by way of suction box **446**.

The nascent web is advanced to a papermaking felt **452**, which is supported by a plurality of rolls **451, 453, 454, 455**, and the felt is in contact with a shoe press roll **456**. The web is of a low consistency as it is transferred to the felt. Transfer may be assisted by suction, for example, roll **451** may be a suction roll, if so desired, or a pickup or suction shoe, as is known in the art. As the web reaches the shoe press roll, it may have a consistency of 10 to 25%, preferably, 20 to 25% or so as it enters nip **458** between shoe press roll **456** and backing roll **462**. Backing roll **462** may be a heated roll if so desired. It has been found that increasing steam pressure to backing roll **462** helps to lengthen the time between required stripping of excess adhesive from the cylinder of Yankee dryer **420**. Suitable steam pressure may be about 95 psig or so, bearing in mind that backing roll **462** is a crowned roll and creping roll **472** has a negative crown to match, such that the contact area between the rolls is influenced by the pressure in backing roll **462**. Thus, care must be exercised to maintain matching contact between rolls **462, 472** when elevated pressure is employed.

Instead of a shoe press roll, roll **456** could be a conventional suction pressure roll. If a shoe press roll is employed, it is desirable and preferred that roll **454** be a suction roll effective to remove water from the felt prior to the felt entering the shoe press nip, since water from the furnish will be pressed into

the felt in the shoe press nip. In any case, using a suction roll at **454** is typically desirable to ensure that the web remains in contact with the felt during the direction change as one of skill in the art will appreciate from the diagram.

Web **444** is wet-pressed on the felt in nip **458** with the assistance of press shoe **460**. The web is thus compactively dewatered at nip **458**, typically, by increasing the consistency by fifteen or more points at this stage of the process. The configuration shown at nip **458** is generally termed a shoe press, in connection with the present invention, backing roll **462** is operative as a transfer cylinder that operates to convey web **444** at a high speed, typically, 1000 fpm to 6000 fpm, to the creping belt. Nip **458** may be configured as a wide or an extended nip shoe press, as is detailed, for example, in U.S. Patent No. 6,036,820 to *Schiel, et al.*

The use of particular adhesives cooperates with a moderately moist web (25 to 70% consistency) to adhere it to the Yankee sufficiently, to allow for high velocity operation of the system and high jet velocity impingement air drying, and subsequent peeling of the web from the Yankee. In this connection, a poly(vinyl alcohol)/polyamide adhesive composition, as noted above, is applied at any convenient location between cleaning doctor **D** and nip **482**, such as at location **486**, as needed, preferably, at a rate of less than about 40 mg/m^2 of sheet.

The web is dried on Yankee cylinder **480**, which is a heated cylinder, and by high jet velocity impingement air in Yankee hood **488**. Hood **488** is capable of variable temperatures. During operation, the web temperature may be monitored at wet-end **A** of the hood **488** and dry end **B** of the hood **488** using an infra-red detector, or any other suitable means if so desired. As the cylinder rotates, web **444** is peeled from the cylinder at **489** and wound on a take-up reel **490**. Reel **490** may be operated at 5 to 30 fpm (preferably, 10 to 20 fpm) faster than the Yankee cylinder at steady-state when the line speed is 2100 fpm, for example. Instead of peeling the sheet, a creping doctor **C** may be used to conventionally dry-crepe the sheet. In any event, a cleaning doctor **D** mounted for intermittent engagement is used to control build up. When adhesive build-up is being stripped from Yankee cylinder **480,** the web is typically segregated from the product on reel **490**, preferably, being fed to a broke chute at **495** for recycle to the production process.

Backing roll **462** has a smooth transfer surface **464** that may be provided with adhesive (the same as the creping adhesive used on the Yankee cylinder) and/or release agents, if needed. Web **444** is adhered to transfer surface **464** of backing roll **462** that is rotating at a high angular velocity as the

web continues to advance in the machine-direction indicated by arrows **466**. On the cylinder, web **444** has a generally random apparent distribution of fiber orientation.

Direction **466** is referred to as the machine direction (MD) of the web as well as that of papermachine **410**. Whereas, the cross machine direction (CD) is the direction in the plane of the web perpendicular to the MD.

Web **444** enters nip **458**, typically, at consistencies of 10-25% or so, and is dewatered and dried to consistencies of from about 25 to about 70 by the time it is transferred to the top side of the creping belt **450**, as shown in the diagram.

Creping belt **450** is supported on a plurality of rolls **468, 472, 473** and a press nip roll **478** and forms a belt crepe nip **474** with backing roll **462**, as shown.

The creping belt defines a creping nip over the distance in which creping belt **450** is adapted to contact backing roll **462**. That is, a significant pressure is applied to the web against the transfer cylinder. To this end, creping roll **472** may be provided with a soft deformable surface that will increase the width of the creping nip and increase the belt creping angle between the belt and the sheet at the point of contact, or a shoe press roll could be used as creping roll **472** to increase effective contact with the web in high impact belt creping nip **474** when web **444** is transferred to creping belt **450** and advanced in the machine-direction.

The nip pressure in crepe nip **474**, that is, the loading between creping roll **472** and backing roll **462** is suitably 3.5 to 35 kN/m, preferably, 7 to 12.25 kN/m. A substantial pressure in the nip of about 1.7 kN/m or 3.5 kN/m or more is preferable. One of skill in the art, however, will appreciate that, in a commercial machine, the maximum pressure may be as high as possible, limited only by the particular machinery employed. Thus, pressures in excess of 17.5 kN/m, 87.5 kN/m, 175 kN/m or more may be used, if practical and provided a sufficient velocity delta can be maintained between the transfer roll and creping belt.

After belt creping, the web **444** continues to advance along MD **466** where it is wet-pressed onto Yankee cylinder **480** in transfer nip **482**. Optionally, suction is applied to the web by way of a suction box **476**, to draw out minute folds, as well as to expand the dome structure discussed hereafter.

Transfer at nip **482** occurs at a web consistency of generally from about 25 to about 70%. At these consistencies, it is difficult to adhere the web to surface **484** of Yankee cylinder **480** firmly enough to remove the web from the belt thoroughly. This aspect of the process is important, particularly when it is desired to use a high velocity drying hood.

The products of the invention are produced with or without application of a vacuum to draw out minute folds to restructure the web and with or without calendering. In many cases, however, it is desirable to use both to promote a more absorbent and uniform product.

Bath tissue of the present invention preferably comprises cellulosic fibers chosen from the group consisting of chemically pulped fibers and mechanically pulped fibers, and from about 5 to about 50% by weight of eucalyptus fibers having a lignin content of at least about 15% by weight, more preferably, from about 10 to about 50% by weight of eucalyptus fibers having a lignin content of at least about 20% by weight, and from about 3 to about 10% by weight of regenerated cellulosic microfiber having a fiber count of greater than 100 million fibers per gram. Typically, paper making fibers useful in the present invention include cellulosic fibers commonly known as wood pulp fibers. Applicable wood pulps include chemical pulps, such as kraft, sulfite and sulfate pulps, as well as mechanical pulps including groundwood, thermomechanical pulp, chemically modified, and the like. Chemical pulps may be used in tissue embodiments since they are known to those of skill in the art to impart a superior tactile sense of softness to tissue sheets made therefrom. Pulps derived from deciduous trees (hardwood) and/or coniferous trees (softwood) can be utilized herein. Such hardwood and softwood fibers can be blended or deposited in layers to provide a stratified web. Additionally, fibers derived from wood pulp, such as cotton linters, bagasse, and the like, can be used. Additionally, fibers derived from recycled paper, which may contain any or all of the categories, as well as other non-fibrous materials, such as fillers and adhesives used to manufacture the original paper product, may be used in the present web.

In one embodiment, particularly, if a two-ply structure is being formed, the plies of the multi-ply fibrous structure may be of the same basesheet formulation or the plies may comprise differing basesheets combined to create desired consumer benefits. In one embodiment, the fibrous structures comprise two plies of substantially identical tissue basesheet. In a preferred embodiment, the fibrous structure comprises a first ply, a second ply, and at least one inner ply, as shown in **Figure 14**. A particularly preferred construction is that shown in U.S. Patent Application Publication No. 2009/0297781, in the name of *Richard D. Huss et al.*, entitled "Ultra Premium Bath Tissue", published December 3, 2009. In many embodiments of the present invention, the web has a plurality

of embossments formed therein. In one embodiment, the embossment pattern is applied only to two plies that are bonded either by knurling or glue lamination to a third ply that is either unembossed or far more lightly embossed than the other two. In such structures, the points of the embossed structure of the two embossed sheets are usually in contact with the unembossed or lightly embossed backing sheet, as shown in *Dwiggins*, U.S. Patent No. 6,896,768, discussed below. Often, such structures are referred to as having "points to the inside". In another embodiment, the fibrous structure product is a two-ply product wherein both plies comprise a plurality of embossments, either in a nested structure or a point to point structure. Nested products are disclosed in U.S. Patent No. 6,413,614 to *Giesler et al.*, "High Softness Embossed Tissue" issued July 2, 2002. Variations or combinations of the rigid-to-resilient and/or rigid-to-rigid embossing processes are well understood by the skilled artisan and could be appropriately used in conjunction with the present invention. For example, nested embossing, point-to-point embossing, and multi-nip embossing processes are also within those configurations appropriate for use with the present invention. See, for example, U.S. Patent Nos. 5,093,068, 5,091,032, 5,269,983 and 5,030,081 to *Galyn A. Schulz.*

In one embodiment, the fibrous structure product comprises two or more plies of fibrous structure, wherein at least one of the plies has a plurality of embossments thereon comprising an embossment height from about 600 μm to about 1,200 μm. In another embodiment, the embodiment height is from about 700 μm to about 1,100 μm, and the backing roll is either lightly embossed on unembossed, as disclosed in U.S. Patent No. 6,896,768 to *Dwiggins et al.*, entitled "Soft Bulky Multi-Ply Product and Method of Making Same", issued May 24, 2005. The multi-ply fibrous structure product may be in roll form. When in roll form, the multi-ply fibrous structure product may be wound about a core or may be wound without a core.

Example 1

Base sheets having the composition set out in Table 4 were manufactured on a low speed pilot machine using conventional wet press (*i.e.*, CWP) technology, then converted into multi-ply products having the constructions set forth in Table 5.

Table 4 basesheet																			
Sample	Desc.	Marathon	CMF	FJ98, g/kg	Varisott GP-C debonder, g/kg	Caliper 8 Sheet mm/ 8 sht	Basis Weight g/m^2	Tensile MD N/m	Stretch MD %	Tensile CD N/m	Stretch CD %	Tensile GM N/m	CD Wet Tens Finch Cured-N/m	Break Modulus GM g/%	TEA CD mm-g/ mm^2	TEA MD mm-g/ mm^2	Break Mod. CD g/%	Break Mod. MD g/%	Wet/Dry
30.1	4882-28 754	50	50	10	0	0.75	14.8	260	28.5	107	7.7	167	21	91	0.503	2.772	111	74	0.20
31-1	4882-29 814	50	50	10	1.5	0.67	15.1	263	27.6	96	7.1	159	23	88	0.420	2,305	104	74	0.24
32-1	4882-30 833	50	50	10	1.5	0.70	15.9	294	29.5	110	6.8	179	28	100	0.442	2.669	127	79	0.25
33-1	4882-31 850	50	50	10	1.5	0.74	16.4	289	28.3	119	7.9	186	30	97	0.568	2.591	118	80	0.25
34-1 base	4882 - 32 915	50	50	10	3	0.68	13.2	191	27.1	74	7.4	119	20	67	0.327	1.803	BO	56	0.27
35-1 base	4882-33 941	50	50	10	3	0.67	14.5	214	28.9	78	8.0	129	23	68	0.379	1.876	BO	59	0.29
36-1 base	4882 - 34 1000	50	50	10	3	0.69	15.5	230	27.2	91	8.2	144	20	73	0.472	2.062	82	65	0.22
37.1 base	4882 - 35 1018	50	50	11.5	3.5	0.58	11.4	114	25.7	59	8.1	84	16	44	0.314	1.215	58	34	0.26
38-1 base	4882 - 36 1035	50	50	11.5	3.5	0.59	11.4	133	27.2	57	7.5	87	15	48	0.250	1.329	59	39	0.26
39.1 base	4882-37 1057	50	50	11.5	3.5	0.63	11.4	127	27.8	57	8.8	85	14	42	0.315	1.265	51	35	0.24

Table 5 Converted Product Construction											
	Description	Caliper 8 Sheet mm/ 8 sht	Basis Weight g/m^2	Tensile MD N/m	Stretch MD %	Tensile CD N/m	Stretch CD %	Tensile GM N/m	Wet Tens N/m	Break Modulus GM N/%	FQA Fiber Count Number
Condition 1 Average	4882 - 32	0.68	13.2	191	27.1	74	7.4	118	27	0.7	435
	4882 - 33	0.67	14.5	214	28.9	48	8.0	129	21	0.7	494
	4882 - 34	0.70	15.4	230	27.2	91	8.2	144	26	0.7	468
		0.68	**14.4**	**212**	**27.72**	**81**	**7.86**	**130**	**25**	**0.7**	**466**
Condition 2 Average	4882 - 35	0.58	11.4	113	25.7	62	8.1	83	18	0.4	383
	4882 - 36	0.59	11.4	133	27.2	57	7.5	87	16	0.5	363
	4882 - 37	0.63	11.4	127	27.8	57	8.8	85	17	0.4	305
		0.60	**11.4**	**125**	**26.89**	**59**	**8.15**	**85**	**17**	**0.4**	**350**

When tested for physical properties, Dry Linting and Wet Abrasion Resistance, as set forth above, the results set forth in Table 6 were obtained:

Table 6

Description	Base Sheet Condition 1		Base Sheet Condition 2	
	Cell 1 2-Ply	Cell 2 3-Ply	Cell 3 2-Ply	Cell 4 3-Ply
Basis Weight (g/m^2)	27.9	42.5	22.7	33.3
Caliper (mm/8 sheets)	1.53	2.74	1.41	2.25
MD Dry Tensile (N/m)	283	454	178	323
CD Dry Tensile (N/m)	138	214	102	146
Geometric Mean Tensile (N/m)	197	311	135	217
MD Stretch (%)	16.7	19.1	16.7	18.9
CD Stretch (%)	7.4	7.5	7.6	8.4
Perforation Tensile (N/m)	112	178	84	125
Wet Tensile (N/m)	40	61	27	43
GM Break Modulus (N/% strain)	0.45	0.66	0.31	0.44
MB 3100 Brightness (%)	92.1	92.2	92.1	91.7
MB 3100 b*	2.3	2.4	2.1	2.3
Opacity	74.0	82.4	67.1	76.1
Wet Abrasion FQA Lint Count	500	495	346	444
Dry Lint L * Difference	-0.26	-0.37	-0.43	-0.43
TMI Fric GMMMD 4 Scan-W (Unitless)	0.47	0.49	0.38	0.49
Sensory Softness	17.22	17.61	18.29	18.47

Dry Lint: No data is shown in Table 4 for dry linting of the base sheets as the finished product. Dry-lint metrics as shown in Table 6 are all negative, indicating that the lint on the black felt was under the non-detect limit of the scanner. If it is taken that no dry lint was observed for the finished product, then it is extremely likely that the lint from the base sheets would similarly be under the detection limit.

Wet Abrasion Lint: At the time this data was collected, we were still in the process of developing a quantitative wet lint test, and so we used a qualitative wet abrasion test based on digital pictures taken to show the lint left behind prior to washing the sample for quantitative – FQA –testing that we were considering at that time. Accordingly, no statistical analysis was conducted to compare the linting of the CMF prototypes to the commercial products. From a comparison of **Figures 6A-6D**, however, it can be appreciated that Quilted Northern® Ultra Plush (**Figure 6A**) and Quilted Northern® Soft & Strong (**Figure 6C**) left behind large amounts of lint as compared to the two sheets containing 50% CMF which were, however, deemed not sufficiently dispersible, as it was determined that in excess of 2000 shakes would be required to disperse these sheets – if they could be dispersed at all.

Softness: The softness scores of the four prototypes are set forth in **Figure 7**. It is apparent that cells 3 and 4 made from condition 2 base sheet are softer than cells 1 and 2. These two are also softer than

Quilted Northern® Soft & Strong, Assignee's premium two-ply product, but not as soft as Quilted Northern® Ultra Plush, Assignee's Ultra Premium three-ply product, but are far stronger than either.

Example 2

Based upon the results from Example 1, it was determined to evaluate whether product designs satisfying the criteria of low lint, high softness, and dispersibility could be achieved using 20 to 50% CMF, 1.5 to 3.5 g/kg FJ98, and 11.4 to 13.8 g/m^2 basis weight.

It was further determined that three-ply glue lamination was an unexpectedly desirable converting configuration for CMF sheets, as unexpectedly high caliper was obtained out of low basis weight sheets. Accordingly, basesheets were made having the properties set forth in Table 7 using CWP technology. When converted into finished three-ply glue laminated rolls, as set forth in Table 8, the products had the physical properties set forth in Table 9. While these products achieve significantly improved levels of softness, strength and resistance to linting whether wet or dry, it can be appreciated that none of those presented so far has met the ultimate goal of producing a tissue that is as soft as the softest available commercial tissues, but has sufficient resistance to wet linting to be usable pre-moistened.

Table 7 Basesheet Properties																
Cell	Roll	Cell	CMF	FJ98 g/kg	BW Target, gsm	SW %	8 Sheet Caliper mm/ 8 sht	Basis Weight g/m^2	MD Tensile N/m	MD Stretch %	CD Tensile N/m	CD Stretch %	Wet Tens Finch Cured-CD N/m	Dispersibility # of Shakes	GM Tensile N/m	GM Break Modulus N/%
3	4885-12	4	25	2	14.6	50	0.76	15.0	100	26.5	49	5.3	13	800	70	47
	4885-13	4	25	2	14.6	50	0.80	15.3	107	23.2	49	4.9	13	800	72	53
	4885-14	4	25	2	14.6	50	0.73	14.1	92	24.8	44	5.8	12	800	63	41
	Average						0.76	14.8	100	**24.8**	**48**	**5.3**	**13**	**800**	**69**	**47**
4	4885-33	7	50	2	14.6	50	0.71	13.1	85	25.3	45	6.8	10		62	37
	4885-34	7	50	2	14.6	50	0.76	14.2	117	27.8	50	6.8	11	500	76	42
	4885-35	7	50	2	14.6	50	0.83	15.9	138	27.6	54	6.1	12	600	87	51
	Average						**0.76**	**14.4**	**113**	**26.9**	**50**	**6.6**	**11**	**550**	**75**	**43**

Table 8 Converted Product Construction			
cell	Front Roll	Middle Roll	Back Roll
3	4885-12	4885-13	4885-14
4	4885-34	4885-33	4885-35

Table 9, part 1, Converted Product Physical Properties											
Description	Softness Panel	Dispersibility # of Shakes	Lint Black Felt Unitless	Basis Weight gsm	Caliper 8 Sheet mm/8 sht	MD Tensile N/m	CD Tensile N/m	MD Stretch %	CD Stretch %	CD Wet Tens Finch N/m	Break Modulus GM g/%
Cell 3, 3-ply	18.7	713	1.92	40.6	4.17	130	86	11.8	7.0	18	92
Cell 3, 3-ply	18.7	663	1.73	40.8	4.01	137	84	13.0	6.5	19	90
Cell 4, 3-ply	18.6	788	0.35	39.7	4.07	212	109	15.2	9.3	20	100
Cell 4, 3-ply	18.6	800	0.12	38.0	3.91	190	109	15.6	9.1	20	97
Cell 3 Average	18.7	688	1.83	40.7	4.09	133	85	12.4	6.8	18	91
Cell 4 Average	18.6	794	0.24	38.9	3.99	201	109	15.4	9.2	20	98

Table 9, part 2, Converted Product Physical Properties											
	Opacity MacBeth Opacity Units	TMI Ply Bond. g	Void Volume Wt Inc %	Break Modulus MD g/%	Break Modulus CD g/%	Void Volume Ratio	TEA MD mm-gm/ mm^2	TEA CD mm-gm mm^2	FQA Fiber Count Number	FQA Fiber Len L_w mm	FQA Fine Len L_w %
Cell 3, 3-ply	79	10.9	1,353	88	97	7.2	0.76	0.37	2408	0.80	9.0
Cell 3, 3-ply	80	6.5	1,399	82	99	7.4	0.94	0.33	2011	0.79	9.1
Cell 4, 3-ply	82	7.6	1,399	108	93	6.9	1.65	0.61	1563	0.64	17.7
Cell 4, 3-ply	82	9.5	1,373	98	95	7.3	1.21	0.60	2985	0.78	10.4
Cell 3 Average	79	8.7	1376	85	98	7.3	0.85	0.35	2209	0.80	9.0
Cell 4 Average	82	8.5	1386	103	94	7.1	1.43	0.60	2274	0.71	14.0

Table 10 shows a comparison of converted low-lint CWP, CMF containing products with an ultra-premium retail tissue, Assignee's Quilted Northern® Ultra Plush and a competitive product which, judging from its name, is apparently promoted at least partially on the basis of its strength, Charmin® Ultra Strong. Three-ply CWP products with CMF were able to at least slightly surpass the performance of Charmin® Ultra Strong in several ways: higher bulk, higher wet strength, higher opacity, and much lower lint, achieving these advantages at equal weight and softness. The softness difference, however, is not sufficiently large, so that it is entirely certain that the difference could be replicated in subsequent panels testing the same products. It is clear, however, that the softness of the CMF containing protocepts was significantly inferior to that of Quilted Northern® Ultra Plush even though their bulk, wet and dry strength, opacity and linting resistance were improved.

Table 10 Comparison of Converted Product					
	Quilted Northern® Ultra Plush	Charmin® Ultra Strong	Previous low-lint protocept Comparative Example 1	Current 25%CMF Protocept	Current 50%CMF Protocept
CMF, %			50	25	50
SW, %			50	37.5	25
Euc, %			0	37.5	25
FJ98, g/kg			10	2	2
Basesheet BW, gsm	19.5 – 20.3		11.4	14.6	14.6
Emboss			HVS-9 knurl	HVS-9 glue	HVS-9 glue
Caliper mm/8 sheet	3.66	3.55	2.24	4.09	3.99
Caliper, cm^3/g	7.8	11.4	8.4	12.6	12.9
Void Volume, % increase		1,301		1,376	1,386
Basis Weight, gsm	22.1	14.7	12.5	15.4	14.7
MDDT, N/m	154	177	323	133	201
MD str, %		16.6	18.9	12.4	15.4
CDDT, N/m	58	90	146	85	109
CD Str, %		11.1	8.4	6.8	9.2
CDWT, N/m	5	10	43	19	20
GMT, N/m	95	126	217	107	148
GM Break Modulus, N/m/%/3	7.6	9.4	17.2	11.7	12.6
Opacity	77	67		79	82
Softness	20.0	18.6	18.5	18.7	18.6
Dispersibility, # of Shakes	<700		2000+	688	794
Dry Lint (Delta L*)	10.2	3.0	-0.4	1.8	0.24
Wet Lint (Fiber Count)	15000	8,480	444	2209	2274

It can be appreciated that the protocept (trial product produced in the laboratory that may not necessarily be commercially or economically practical to manufacture in commercial equipment) with 25% CMF exhibited quite good levels of softness, linting, opacity, dispersibility and strength. The softest products, however, were somewhat deficient in softness compared to Quilted Northern® Ultra Plush.

Example 3

As the protocepts of Examples 1 and 2 were unable to match the softness performance of Assignee's ultra premium product, Quilted Northern® Ultra Plush, exploratory work was done using the paper-making technology disclosed in U.S. Patent Application Publication No. 2010/0186913, in conjunction with lower CMF content furnishes, to determine the possible interaction of this new belt-creping technology with CMF containing furnishes and to determine whether the two technologies were compatible, and, if so, whether the use of the two together had advantages in the formation of a pre-wettable bath tissue. It had been hoped that, if this effort were successful, it might be possible to develop a pre-wettable bath tissue that, even though it might not match Quilted Northern® Ultra Plush in absolute level of softness, might be close enough that any deficiency would not be easily perceptible. So, rather improved softness was desired to exceed the 18.7 panel softness achieved in Comparative Example 2 and more closely approach the Panel softness value of 20 achieved by Quilted Northern® Ultra Plush.

Accordingly, basesheet samples were prepared using a belt similar to that illustrated in **Figure 3** on a pilot scale paper machine using a furnish comprising 65% northern bleached softwood kraft, 15% eucalyptus, and 20% CMF with temporary wet strength with process parameters set as described in Table 11. The properties of those basesheets are set forth in Table 12. Using the scheme set forth in Table 13, the basesheets were converted into finished product, as set forth in Table 14, the properties of which, as determined by physical properties testing and sensory panels, are set forth in Table 15.

Table 16 sets forth the dispersibility, wet tensile strength and basis weight of several commercial products along with those of many products produced in this Example. *See* **Figure 29** as well.

Table 11 Process Data

Roll#	64551 g/kg	64601 g/kg	PVOH g/kg	GPB100 g/kg	GP C g/kg	FJ98 g/kg	Jet Spd m/s	Form Roll Speed, m/s	Yankee Speed, m/s	Reel Speed, fm/s	Jet/Wire Ratio	Slice Opening mm	Total HB Flow, l/s	Refiner kW	WE Yankee Hood Temp., C.	DE Yankee Hood Temp., C.	Suction roll vacuum, mm Hg.	Molding Box Vacuum, mm Hg.	ViscoNip Load, kN/m
22910	0.5	0.3	3.7	3.0	0.0	1.2	13.4	9.8	8.1	7.7	1.36	19.8	109	10.9	221	194	279	271	98
22911	0.5	0.3	3.6	2.9	0.0	1.5	13.4	9.8	8.1	7.7	1.36	19.8	109	10.9	200	172	280	271	105
22912	0.5	0.3	3.6	2.9	0.0	1.5	13.4	9.8	8.1	7.7	1.36	19.8	109	10.9	200	170	280	272	105
22918	0.6	0.3	4.5	3.6	0.0	1.8	13.4	9.8	8.1	7.7	1.36	19.8	110	25.8	162	96	274	294	105
22919	0.6	0.3	4.3	3.3	0.0	1.8	13.4	9.8	8.1	7.7	1.36	19.8	109	25.9	163	95	274	297	105
22920	0.6	0.3	4.2	3.3	0.0	1.9	13.4	9.8	8.1	7.7	1.36	19.8	109	25.9	164	94	276	298	105
22921	0.6	0.3	4.2	3.3	0.0	4.5	13.4	9.8	8.1	7.7	1.36	19.8	109	25.9	163	94	276	299	105
22922	0.6	0.3	4.2	3.4	0.0	4.5	13.4	9.8	8.1	7.7	1.36	19.8	109	26.0	163	94	277	299	105
22923	0.6	0.3	4.2	3.3	0.0	4.5	13.4	9.8	8.1	7.7	1.36	19.8	109	25.1	163	93	279	302	105
22928	0.6	0.3	3.9	2.4	0.0	7.2	13.4	9.9	8.1	7.7	1.36	19.5	107	26.3	175	89	285	297	105
22929	0.6	0.3	3.9	2.6	0.0	7.2	13.4	9.9	8.1	7.7	1.36	19.5	107	26.4	178	89	286	297	105
22931	0.6	0.3	3.9	2.4	0.0	7.3	13.4	9.9	8.1	7.7	1.36	19.7	107	26.5	178	90	288	296	105
22932	0.6	0.3	3.9	2.5	0.0	7.2	13.4	9.9	8.1	7.7	1.36	19.7	107	26.5	174	90	288	530	105
22933	0.6	0.3	4.0	2.5	0.0	7.2	13.4	9.9	8.1	7.7	1.36	19.7	107	26.4	177	90	289	565	105
22948	0.7	0.4	4.7	0.5	0.0	2.0	12.3	8.6	7.1	6.8	1.43	19.1	82	7.7	215	192	289	477	66
22949	0.7	0.4	4.8	0.5	0.0	2.0	12.4	8.6	7.1	6.8	1.44	19.1	83	7.7	200	170	286	591	66
22950	0.7	0.2	4.9	0.5	0.0	2.0	12.6	8.6	7.1	6.8	1.46	19.1	84	7.7	204	175	285	593	66
22960	0.5	0.2	3.2	1.1	0.0	1.4	13.0	9.9	8.1	7.7	1.32	22.3	146	7.5	315	292	286	576	105
22961	0.5	0.4	3.2	1.3	0.0	1.3	13.0	9.9	8.1	7.7	1.32	22.3	146	7.5	317	286	288	579	105
22966	0.8	0.4	5.0	1.4	0.0	1.1	12.8	9.9	8.1	7.7	1.30	22.3	142	23.3	203	173	273	554	105
22968	0.8	0.4	5.0	1.4	0.0	1.1	12.8	9.9	8.1	7.7	1.30	22.3	141	25.5	203	178	259	555	105
22969	0.8	0.4	5.0	1.4	0.0	1.1	12.8	9.9	8.1	7.7	1.30	22.3	141	26.3	202	173	259	555	105
22973	0.7	0.4	4.8	1.4	0.3	1.0	12.8	9.9	8.1	7.7	1.30	23.1	141	16.8	205	172	263	561	105
22974	0.7	0.4	4.8	1.7	0.3	1.0	12.8	9.9	8.1	7.7	1.30	23.1	141	16.8	204	181	264	564	105
22975	0.7	0.4	4.7	1.4	0.4	1.0	12.8	9.9	8.1	7.7	1.30	23.1	141	16.7	204	174	265	564	105
22981	0.5	0.2	3.1	0.9	2.0	1.1	13.3	9.9	8.1	7.7	1.35	19.1	99	7.5	316	287	285	583	61
22982	0.6	0.3	1.9	1.4	3.1	1.3	13.3	9.9	8.1	6.4	1.35	19.1	99	7.5	317	288	290	506	61

Table 12 Basesheet Data															
TL2009-2041 Parent Roll	Basesheet CMF %	FJ98, g/kg	8 Sheet Caliper mm/8 sht	Basis Weight lb/3000 g/m^2	Tensile MD N/m	Stretch MD %	Tensile CD N/m	Stretch CD %	Tensile GM N/m	Wet Tens Finch Cured-CD N/m	Break Modulus GM N/m/%	TEA GM mm-gm/ mm^2	W/D	Void Volume Wt Inc. %	Lint Black Felt Unitless
22910	20	1.2	1.38	14.6	46	30.4	34	8.2	39	3.8	2.5	0.289	0.11	999	2.94
22911	20	1.5	1.36	14.9	51	31.3	34	7.9	42	4.4	2.7	0.308	0.13	1,093	2.68
22912	20	1.5	1.33	13.9	44	29.1	37	8.1	40	5.3	2.5	0.293	0.14	1,013	2.51
22918	20	1.8	1.01	11.6	46	27.2	37	7.6	41	5.2	2.8	0.285	0.14	1,084	1.00
22919	20	1.8	1.08	11.7	50	26.8	40	8.0	45	5.3	3.0	0.295	0.13	1,103	0.58
22920	20	1.9	1.02	11.5	53	28.0	40	7.1	46	5.4	3.3	0.309	0.14	1,075	0.71
22921	20	4.5	1.06	11.8	66	27.2	52	7.0	58	11.5	4.3	0.390	0.22	1,010	0.51
22922	20	4.5	1.02	11.9	63	26.0	53	7.9	58	11.8	4.0	0.409	0.22	971	0.20
22923	20	4.5	1.03	11.9	68	26.2	49	7.1	58	10.7	4.2	0.380	0.22	1,020	0.33
22928	20	7.2	1.06	12.1	81	28.5	67	7.4	74	18.5	5.1	0.531	0.28	938	0.02
22929	20	7.2	1.05	11.7	76	27.7	65	8.1	70	20.6	4.8	0.533	0.32	922	-0.17
22931	20	7.3	1.10	11.9	83	28.8	62	7.9	72	17.9	4.8	0.541	0.29	908	0.12
22932	20	7.2	1.21	11.7	74	27.1	55	7.4	64	17.5	4.5	0.443	0.32		
22933	20	7.2	1.20	11.7	70	26.6	60	8.0	65	18.5	4.5	0.476	0.31		
22948	20	2.0	1.77	19.6	85	35.0	45	11.0	62	9.1	3.2	0.542	0.20		
22949	20	2.0	1.88	19.6	85	32.6	48	10.1	64	7.3	3.5	0.529	0.15		
22950	20	2.0	1.82	19.4	85	33.5	53	9.9	67	10.6	3.7	0.554	0.20		
22960	0	1.4	2.11	24.0	64	22.8	51	5.2	57	5.8	5.3	0.251	0.11		
22961	0	1.3	2.14	23.9	68	24.1	59	6.1	64	8.1	5.1	0.395	0.14		
22966	0	1.1	1.46	14.5	41	22.7	33	7.1	37	3.2	3.0	0.239	0.10		
22968	0	1.1	1.41	14.6	45	20.5	37	6.2	41	3.8	3.7	0.237	0.10		
22969	0	1.1	1.47	14.9	42	19.6	38	6.4	40	3.3	3.5	0.230	0.09		
22973	10	1.0	1.42	15.0	53	22.9	35	4.8	43	3.1	4.1	0.229	0.09		
22974	10	1.0	1.45	15.8	64	24.1	51	6.4	57	4.2	4.7	0.357	0.08		
22975	10	1.0	1.43	15.7	56	23.6	45	6.3	50	4.2	4.1	0.310	0.10		
22981	10	1.1	2.10	23.8	58	27.6	35	5.7	45	5.8	3.7	0.010	0.17		
22982	10	1.3	2.00	23.9	68	30.3	38	5.5	51	6.2	3.9	0.005	0.16		

Table 13 Basesheet Configuration					
Cell	Marathon/Euc/CMF	Basis wt.	FJ98	Notes	Parent rolls
1	65/15/20	14.6	Low	Softest	22910, 22911, 22912
2	65/15/20	11.4	Low	Some durability	22918, 22919, 22920
3	65/15/20	11.4	Med.	More durable	22921, 22922, 22923
4	65/15/20	11.4	High	Most durable	22928, 22929, 22931
5	65/15/20	11.4	High	Aperture	22932, 22933
6	65/15/20	24.4	Low	Ultra	22948, 22949, 22950
7	35/65/zero	24.4	Low	Ultra 2-ply Control	22960, 22961
8	35/65/zero	14.6	Low	Ultra 3-ply Control	22966, 22968, 22969
9	35/65/10	14.6	Low	Ultra 3-ply	22973, 22974, 22975
10	35/65/10	24.4	Low	Ultra 2-ply	22981, 22982

Table 14 Converting Configuration					
Cell No.	#1 Unwind Base Sheet	#2 Unwind Base Sheet	#3 Unwind Base Sheet	Product Description	Converting Process
P3403	22910	22911	22912	Wet durable	"K" = 3-Ply Unembossed, knurled; "G" = 3-ply HVS U19, glued
P3404	22918	22919	22920	Wet durable	"K" = 3-Ply Unembossed, knurled; "G" = 3-ply HVS U19, glued
P3405	22921	22922	22923	Wet durable	"K" = 3-Ply Unembossed, knurled; "G" = 3-ply HVS U19, glued
P3406	22928	22929	22931	Wet durable	"K" = 3-Ply Unembossed, knurled; "G" = 3-ply HVS U19, glued
P3407	22932	22949	22933	Wet durable, aperture*	"K" = 3-Ply Unembossed, knurled
P3408	22948	22949	22950	Ultra	"K" = 3-Ply Unembossed, knurled; "G" = 3-ply HVS U19, glued
P3409	22948	22949		Ultra	"K" = 2-Ply Unembossed, knurled; "G" = 2-ply HVS U19, glued
P3410	22932	22911	22933	Wet durable, aperture*	"K" = 3-Ply Unembossed, knurled
P3411	22960	22961		Ultra	"K" = 2-Ply Unembossed, knurled; "G" = 2-ply HVS U19, glued
P3412	22966	22968	22969	Ultra	"K" = 3-Ply Unembossed, knurled; "G" = 3-ply HVS U19, glued
P3413	22973	22974	22975	Ultra	"K" = 3-Ply Unembossed, knurled; "G" = 3-ply HVS U19, glued
P3415	22981		22982	Ultra	"K" = 2-Ply Unembossed, knurled; "G" = 2-ply HVS U19, glued
P3416	22981	22960	22982	Ultra	"K" = 3-Ply Unembossed, knurled; "G" = 3-ply HVS U19, glued

* aperture basesheet -- a very open, porous construction similar to that shown in **Figure 1** of US 2004/0238135, but heavier.

Table 15 Finished Product Data														
Description	Basis Weight g/m^2		Caliper 8 Sheet mm/8 sheet		Softness Panel		Tensile GM N/m		Wet Tens Finch CD (N/m)		Dry Lint BlackFelt (ΔL^*)		Dispersibility #shakes	
	Knurled	Glued	Knurled	Glued	Knurled	Glued	Knurled	Glued	Knurled	Glued	Knurled	Glued	Knurled	Glued
Wet Durable														
P3403 (20%CMF)	43.4	42.8	3.85	3.67	20.1	19.3	108	120	13	15	4.0	5.4	600	600
P3404 (20%CMF)	35.7	35.3	2.97	2.92	19.5	18.6	136	149	18	20	0.8	1.1	575	550
P3405 (20%CMF)	36.4	35.2	3.07	2.90	19.2	18.2	181	179	35	36	0.4	0.8	1,600	2,000
P3406 (20%CMF)	37.6	36.2	3.19	3.01	18.7	17.9	221	215	57	56	-0.1	0.5	3,700	3,600
P3407 (20%CMF)	44.7		4.09		18.9		181		41		0.2		2,800	
P3410 (20%CMF)	39.3		3.59		19.2		169		37		0.2		1,800	
3-Ply Ultra, I.C. and Parity														
P3412 (no CMF)	45.8	44.8	4.22	3.93	19.2	18.7	116	122	11	11	2.3	2.4		
P3413 (10%CMF)	47.9	46.9	4.28	3.99	19.5	18.3	145	150	14	13	1.9	2.3		
3-Ply Ultra, Superior														
P3416 (13%CMF)	73.6	71.5	5.99	5.19	19.7	18.9	150	157	21	18	7.4	7.6		
2-ply Ultra														
P3411 (no CMF)	49.9	50.5	3.83	3.91	19.2	18.5	118	117	15	13	4.5	6.2		
P3415 (10%CMF)	48.3	47.5	3.85	3.81	19.7	19.3	91	90	12	12	7.2	5.8		
Other														
3-ply P3408 (20%CMF)	60.3	57.1	5.23	4.56	19.6	18.0	185	221	29	35	4.4	5.2		
2-ply P3409 (20%CMF)	40.0	39.0	3.41	4.36	19.3	18.7	125	125	20	20	4.6	4.2		

Knurled product is Unembossed. Glued product is embossed with U19

Table 16			
Description	Dispersibility # of Shakes	CD Wet Tensile Finch (N/m)	Basis weight, g/m^2
P3403K	600	13.4	43.5
P3404K	575	17.9	35.6
P3405K	1600	34.5	36.5
P3406K	3700	56.5	37.6
P3407K	2800	41.3	44.6
P3410K	1800	36.9	39.4
P3403G	600	14.5	42.8
P3404G	550	19.6	35.3
P3405G	2000	36.2	35.2
P3406G	3600	55.6	36.3
Charmin® Ultra Soft	400	9.1	47.2
Quilted Northern® Ultra Plush	850	5.1	58.6
Cottonelle® Ultra Ave	56	3.0	45.1
Charmin® Ultra Soft Ave	349	7.9	47.0
Charmin® Ultra Strong Ave	297	8.9	39.7
QUILTED NORTHERN® ULTRA	997	5.4	59.9
Charmin® Basic Ave	250	6.8	29.3
Cottonelle® Fresh	20000+	91.4	78.1

The results, as set forth in Table 15, were considered unexpectedly good - especially in terms of softness. It was surprisingly found that not only was it possible to achieve close parity to Quilted Northern® Ultra Plush, but that, in one case, at least numerical superiority was achieved even though the margin of superiority was slight. Table 10, above, shows properties of an ultra-premium retail tissue, Assignee's Quilted Northern® Ultra Plush, and a competitive product that is apparently promoted at least partially on the basis of its strength, Charmin® Ultra Strong. Several knurled three-ply CWP products with CMF of this example were able to surpass the performance of Charmin® Ultra Strong in several ways: softness, higher bulk, higher wet strength, higher opacity, and much lower lint achieving these advantages at equal weights. The softness difference for P3406K, however, is not sufficiently large that it is entirely certain that the difference could be replicated in subsequent panels testing the same products. (Typically, we find that an improvement of 0.5 points of softness on the scales reported by our sensory panels will consistently be considered distinctly and noticeably softer.) The softness of the glued products was lower than what we would normally expect in comparison to the knurled. The reason for this deficiency is not known, but could easily lie more in the embossing and gluing techniques used rather than in the basesheets themselves. Even more surprisingly, it was found that the strength of P3403K was actually significantly higher than that of

Quilted Northern® Ultra Plush, even though the basis weight of the softer, but stronger sheet, was less than 75% of Quilted Northern® Ultra Plush. Further, the sheet was dispersible, but exhibited sufficient wet strength to be usable pre-wetted. In terms of dry lint, this product also surpassed Quilted Northern® Ultra Plush, exhibiting a ΔL^* of 4.0 as compared to 10.2 for Quilted Northern® Ultra Plush.

Figures 8A to **8D** provide graphic comparisons of the most significant properties of the tissues to Quilted Northern® Ultra Plush, Quilted Northern® Soft & Strong, Charmin® Ultra Soft and Charmin® Ultrastrong.

Figure 8A demonstrates that P3403K, the wet linting of which is shown in **Figure 9A**, is comparable in softness to Quilted Northern® Ultra Plush and Charmin® Ultra Soft, both of which currently are generally perceived as having very high softness by Assignee's sensory softness testing panels, while a comparison of **Figures 9A** and **9C** demonstrates that Charmin® Ultra Soft is quite susceptible to wet linting, indicating that it would not generally be considered to be satisfactory for use pre-moistened, while P3405K leaves behind far less lint and so might be deemed to be acceptable for that use. **Figure 8A** also illustrates that the dry linting of P3403K is somewhat less than that of either Charmin® Ultra Soft or Quilted Northern® Ultra Plush, which are not perceived as having significant quality issues in this regard. The comparison shown in **Figures 9A** to **9E** visually portrays the qualitative results that considerable lint is left on the felt with the two Charmin® products, a much smaller, but detectable amount of lint is left behind with P3403K, while it is quite difficult to detect lint left behind with either P3405K or the Kimberly-Clark Cottonelle® Fresh. It is considered quite significant that P3405K achieves softness clearly exceeding that of Charmin® Ultra Strong, while leaving almost no lint behind on either of the wet linting test or the dry. See **Figure 9B**. Quilted Northern® Ultra Plush and Quilted Northern® Soft & Strong are roughly comparable in wet linting to the two Charmin® products. **Figure 8B** illustrates that P3403K achieves Total Energy Absorption, (TEA, a measure of toughness), equivalent to Charmin® Ultra Soft while P3405K, in addition to its remarkable resistance to linting, clearly surpasses Charmin® Ultra Strong both in toughness and softness. **Figure 8C** illustrates the same advantages in term of tensile strength rather than toughness. **Figure 8D** compares the fiber required for a statistical case among the various tissues examined, although it should be noted that this does not translate into savings due to the increased cost of the CMF as compared to wood pulp. Preliminary testing, done before the procedures for measuring dispersibility and wet lint were developed, indicated that high linting products, such as the two Charmin® tissues, were quite easily dispersed, as were the very soft products P3403G and P3403K,

which exhibited moderate linting. The very low lint CMF containing products of this Example could be dispersed without undue difficulty, while the non-wovens, Cottonelle® Fresh and Always were far more difficult to disperse, if dispersible at all.

Example 4

In an attempt to improve upon earlier wet-durable tissue made with the belt of **Figure 3**, bath tissue was made with cellulose microfiber (CMF) and temporary wet strength using the belt shown in **Figures 10** and **11.** Table 17 below sets forth important parameters of the belt construction.

Table 17 Belt Geometry

Parameters	Units	Dimensions
Sheet Side Hole CD Diameter	mm	0.9652
Sheet Side Hole MD Diameter	mm	0.9652
Sheet Side Hole CD/MD	CD/MD (unitless)	1.0
Sheet Side Hole Unit Area	mm^2	0.732
Top Hole Rim Thickness	mm	
Sheet Side Hole % Open Area	%	52.7
Air Side Hole CD Diameter	mm	0.5461
Air Side Hole MD Diameter	mm	0.5461
Air Side Hole CD/MD	CD/MD (unitless)	1.00
Air Side Hole Unit Area	mm^2	0.234
Air Side Hole % Open Area	%	16.9
Sheet Side/Air Side Area Ratio	Top/Bottom	3.1
Side Wall Angle CD 1	° (Degrees)	67.3
Side Wall Angle CD 2	° (Degrees)	67.3
Side Wall Angle MD 1	° (Degrees)	67.3
Side Wall Angle MD 2	° (Degrees)	67.3
Unit Volume	mil^3	15863
Unit Volume	mm^3	0.260
% Material Volume Removed	%	37.5%
MD Land Distance	mm	1.3016
MD Land / MD Dia. Ratio	%	134.9%
CD Land Distance	mm	0.2589
CD Land / CD Dia. Ratio	%	26.82%
1./width	Columns/cm	8.17
1/height	Rows/cm	8.82
Holes per cm^2	$\#/cm^2$	72

Basesheets were made using generally those procedures used in Example 3. Basesheet properties are set forth in Table 18.

Table 18 Basesheet										
Description	8 Sheet Caliper mm/8 sht	Basis Weight g/m^2	MD Tensile N/m	MD Stretch %	CD Tensile N/m	CD Stretch %	CD Wet Tens Finch Cured N/m	GM Tensile N/m	GM Break Modulus N/m/%	CD Tensile Wet/Dry Unitless
24482	1.24	13.1	60	31.8	48	9.5	13	54	3.1	0.28
24483	1.28	12.9	65	31.2	50	9.1	13	57	3.4	0.25
24484	1.19	13.0	65	30.7	50	9.5	13	57	3.4	0.25
24496*	2.24	22.2	62	33.9	46	6.0	11	54	3.8	0.24
24499	1.87	21.9	77	29.8	57	5.4	15	66	5.2	0.25
24500	1.82	22.6	63	29.0	52	6.5	11	57	4.2	0.22
24501	1.80	22.1	68	28.3	59	6.4	14	63	4.6	0.23

*uncalendered

These products were converted into three-ply tissue product using the converting scheme set forth in Table 19, the finished tissue having the properties set forth in Table 20.

Table 19 (U19 Glue Laminated)					
Front Roll #	Middle Roll #	Back Roll #	Marry Roll Nip Open/ Closed	Caliper mm/8 sheet	Roll Diameter, mm
24482	24483	24484	open	3.40	12
24500	24483	24484	open	3.89	12
24500	24496	24483	open	4.57	
24499	24501		open	3.35	
24499	24501		open		
24482	24483	24484			
24496	24483	24484			

Table 20 Finished Product Properties													
Cell	Basis Weight g/m^2	8 Sheet Caliper mm/ 8 sht	Tensile GM N/m	Lint Black Felt Unitless	CD Wet Tens Finch Cured- N/m	Softness Panel	Dispers. # of Shakes	MD Tensile N/m	CD Tensile N/m	GM Break Modulus N/m/%	Opacity MacBeth Opacity Units	Sheet Length mm	Sheet Width mm
1	39.9	3.61	182	1.1	44	18.4	2,500	207	161	12	75.4	10	10
2	48.0	4.01	158	1.2	35	18.6	2,100	190	132	12	79.1	10	10
3	56.8	4.67	162	1.5	35	18.0	3,200	194	136	13	81.6	10	10
4	43.3	3.43	124	2.3	29	17.7	2,000	145	105	10	76.3	10	10
5	39.1	3.45	182	0.6	41	18.5	1,500	205	162	12	75.1	18	12
6	47.4	4.09	169	1.3	38	18.6	1,500	194	147	13	78.5	18	12
8	43.1	3.48	117	2.2	27	17.6	1,500	137	101	10	75.9	18	12

Even though the bath tissue of Example 3 made using the belt described and illustrated in **Figure 3** had a desirable combination of softness, wet durability, and low lint, achieving both premium softness as a dry tissue and sufficient wet tensile to be used for wet cleansing without pilling, the amount of temporary wet strength resin in the sheets was quite high, ranging up to 7 g/kg resulting in a finished product with a wet tensile up to 56.5 N/m. Accordingly, we wished to investigate whether we could achieve satisfactory properties with a more moderate level of temporary wet strength resin.

Several adjustments were made relative to the preceding trial. Basis weight was increased slightly, eucalyptus was increased in the Yankee layer, stretch was increased, and bulky fiber was added to the air layer (for stratified conditions). Basesheets at 11.4 g/m^2 using the belt of **Figure 3** had caliper around 1 mm/8 sheets, and three-ply product had caliper around 3 mm/8 sheets. Increasing basis weight to 13.0 g/m^2 was intended to get basesheet caliper over 1 mm and finished product around 3.7 mm/8 sheets. The previous low-lint furnish comprising 60% NBSK, 15% eucalyptus, and 20% CMF yielded very low lint when combined with higher levels of temporary wet strength. In this Example 4, eucalyptus content was increased to 40%, to impart an even smoother surface, while maintaining low lint. Higher crepe was used to lower modulus. Hardwood BCTMP was used in the air layer in one cell for additional bulk. A glue-laminated three-ply prototype was made with a very desirable combination of softness, wet strength, and low pilling tendency: 18.4 softness panel rating, 44 N/m CD wet tensile, 1.1 ΔL^* dry lint. **Figures 12** and **13** present the results of cell 5 of this Example 4 along with data from the previous Examples. It can be appreciated that the CD wet tensile is still quite high – ranging from 26.8 to 44, so even though these sheets had excellent softness, there is still the possibility of achieving higher softness by going to lower CD wet tensile as for most of these

sheets. That works out to between 0.8 and 1.03 N/m per gsm of basis weight and we have discovered that about 0.67 per gsm of basis weight is sufficient to render these CMF containing sheets usable pre-wetted.

Figures 21 to **23** illustrate domed structures having consolidated regions formed therein. **Figure 21** is an SEM section (75×) along the machine direction (MD) of perforated polymeric belt creped basesheet **600**, showing a domed area corresponding to a belt perforation as well as the densified pileated structure of the sheet. It is seen in **Figure 21** that the domed regions, such as region **640**, have a "hollow" or domed structure with inclined and at least partially densified sidewall areas, while surrounding areas **618, 620** are densified, but less so than transition areas. Sidewall areas **658, 660** are inflected upwardly and inwardly and are so highly densified as to become consolidated, especially, about the base of the dome. It is believed that these regions contribute to the very high caliper and roll firmness observed. The consolidated sidewall areas form transition areas from the densified fibrous, planar network between the domes to the domed features of the sheet and form distinct regions that may extend completely around and circumscribe the domes at their bases, or may be densified in a horseshoe or bowed shape only around a portion of the bases of the domes. At least portions of the transition areas are consolidated and also inflected upwardly and inwardly.

Figure 22 is another SEM (120×) along the MD of basesheet **600** showing hollow **640**, as well as consolidated sidewall areas **658** and **660**. It is seen in this SEM that the cap **662** is fiber-enriched, of a relatively high basis weight as compared with areas **618, 620, 658, 660**. CD fiber orientation bias is also apparent in the sidewalls and dome.

Figure 23 is an SEM section (120×) along the machine direction (MD) of basesheet **700**, in which consolidated sidewall areas **758, 760** are densified and are inflected inwardly and upwardly.

As illustrated in **Figure 24**, the process for producing high lignin eucalyptus by pre-conditioning refiner chemical alkaline peroxide mechanical pulping consists of five main process steps:

1. Impregnation: Wood chips (or plant fibers) are compressed in a large screw press and discharged into an inclined (atmospheric) impregnation vessel. The vessel contains a mixture of chelant, hydrogen peroxide and caustic. The chemicals soften the chips and begin the bleaching process.

2. High Consistency Pressurized Refining: The impregnated chips drain as they are lifted out of the impregnation vessel and are fed through a high consistency refiner. The refiner separates the chips into individual fibers and provides heat to drive the bleaching reactions. Hydrogen peroxide is injected into the refiner discharge to boost the brightness. The hot pulp is discharged into an atmospheric tank and achieves full brightness after 30 to 90 minutes of retention.

3. Low consistency secondary refining: A final refining pass is done at low consistency to develop the desired fiber properties and to complete fiberization of any shives.

4. Shive Screening: The pulp is screened to separate shives from the fully individualized fibers. The rejects are fed back into the low consistency refiner to complete separation into individual fibers.

5. Washing: A tissue grade system would use three stages of presses to separate residual bleaching chemicals and anionic trash formed in the process.

For further information concerning pre-conditioning refiner chemical alkaline peroxide mechanical pulping, *see*:

Xu, U.S. Patent Application Publication No. 2010/0263815 A1, "Multi-Stage AP Mechanical Pulping With Refiner Blow Line Treatment", October 21, 2010; *Herkel et al.*, U.S. Patent Application Publication No. 2010/0186910 A1, "Four Stage Alkaline Peroxide Mechanical Pulpings", July 29, 2010; *Sabourin*, U.S. Patent Application Publication No. 2008/0066877 A1, "High Defiberization Pretreatment Process For Mechanical Refining", March 20, 2008; *Herkel*, U.S. Patent Application Publication No. 2004/0200586 Al, "Four Stage Alkaline Peroxide Mechanical Pulping", October 14, 2004; *Sabourin*, U.S. Patent No. 7,892,400 B2, "High Defiberization Chip Pretreatment Apparatus", February 22, 2011; *Sabourin,* U.S. Patent No. 7,758,721 B2, "Pulping Process With High Defiberization Chip Pretreatment", July 20, 2010; *Sabourin*, U.S. Patent No. 7,300,541 B2, "High Defiberization Chip Pretreatment", November 27, 2007; *Sabourin*, U.S. Patent No. 6,899,791 B2, "Method Of Pretreating Lignocellulose Fiber-Containing Material In A Pulp Refining Process", May 31, 2005; *Xu*, U.S. Patent Application Publication No. 2004/0069427 A1., "Multi-Stage AP Mechanical Pulping With Refiner Blow Line Treatment", April 15, 2004; and *Xu et al.,* International Publication No. WO 03/008703 A1; "Four Stage Alkaline Peroxide Mechanical Pulping", January 30, 2003.

Table 21 sets forth suitable process details for preparation of eucalyptus APMP for use in the present invention.

Table 21 Processing Conditions for eucalyptus APMP											
SAMPLE FURNISH		A1 I1	A2 A1	A3 A1	A4 A1	A5 A1	A6 I1	A7 A6	A8 A6	A9 A6	A10 A6
kWh/ODMT APPLIED	PASS Total	584 655	87 742	181 836	301 1137	322 1158	576 647	78 725	140 787	187 974	226 1013
Total Alkalinity % Impregnation		1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Refiner Total Applied Residual Net		5.6 6.7 0.47 6.23	5.6 6.7 0.47 6.23	5.6 6.7 0.47 6.23	5.6 6.7 0.47 6.23	5.6 6.7 0.51 6.19	10 11.1 2.01 9.09	10 11.1 2.01 9.09	10 11.1 2.01 9.09	10 11.1 2.01 9.09	10 11.1 2.94 8.16
Hydrogen Peroxide % Impregnation		1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Refiner Total Applied Residual Net		9.6 10.7 4.57 6.13	9.6 10.7 4.57 6.13	9.6 10.7 4.57 6.13	9.6 10.7 4.57 6.13	9.6 10.7 3.33 7.37	11.9 13 0.92 12.08	11.9 13 0.92 12.08	11.9 13 0.92 12.08	11.9 13 0.92 12.08	11.9 13 0.74 12.26
FREENESS (CSF)		577	474	427	344	335	541	448	396	317	307
DENSITY		0.27	0.3	0.27	0.34	0.36	0.36	0.38	0.41	0.46	0.47
BULK (cm^3/g)		3.69	3.28	3.68	2.92	2.81	2.78	2.62	2.43	2.15	2.11
BURST INDEX ($kPa.m^2/g$)		0.59	0.84	1.07	1.47	1.44	1.1	1.6	1.99	2.38	2.73
TEAR INDEX ($mN.m^2/g$)		3.7	4.5	4.7	4.8	4.9	5.9	6.6	6.1	6.1	6
TENSILE INDEX (N.m/g)		16	23.7	28.3	34.6	38	28.7	36.7	42.2	52.6	55
Breaking Length km		1.6	2.4	2.9	3.5	3.9	2.9	3.7	4.3	5.4	5.6
%STRETCH		0.86	1.13	1.33	1.52	1.65	1.21	1.49	1.7	2.07	2.34
TEA (J/m^2)		4.81	9.33	13.38	19.04	22.92	12.56	19.47	25.92	39.63	49.01
ABSORPTION COEFF. (m)		0.21	0.2	0.2	0.21	0.22	0.28	0.27	0.23	0.25	0.25
% OPACITY		80.7	81.1	82.5	82.9	83.5	79.7	79.9	80.6	80.2	80.8
SCATT. COEFF. (m^2/kg)		47	48.2	52	52.8	54	42.7	45.3	46.7	45.8	46.2
ISO BRIGHTNESS		85.6	85.9	85.8	86	85.4	84.9	85.4	85.2	84.8	84.7
% SHIVES (PULMAC-0.10 mm)		12.34	6.98	4	0.78	0.68	11.84	5.54	2.68	1.08	0.78
LENGTH WEIGHTED AVG LNG (mm)		0.893	0.845	0.831	0.782	0.762	0.806	0.813	0.84	0.784	0.772
ARITHMETIC AVG.LENGTH (mm)		0.455	0.446	0.446	0.451	0.447	0.455	0.448	0.447	0.453	0.452
WGT WEIGHTED AVG LNG(mm)		1.87	1.57	1.54	1.22	1.12	1.3	1.37	1.65	1.19	1.2
AVERAGE WIDTH(pm)		32.7	31.91	31.23	29.46	29.15		31.07	32.15	29.52	29.05
SURFACE AREA (m^2)		1155	1060	1305	1371	1592	1467	1277	1045	1629	1465
FIBER CLASS	% ON 14 MESH	10.1	5.9	3.2	1.1	0.9	9.2	4.7	**3.1**	**0.8**	**0.6**
	%ON 28 MESH	15.1	14.4	11.5	5.3	4.7	16	13	11.4	6.4	4.7
	%ON 48 MESH	26.4	29.8	31.3	34.7	33.4	27.1	29.6	34	35.2	35.6
	% ON 100 MESH	20.8	20.8	22	25.4	24.2	21.1	22	23.7	24.3	25
	% ON 200 MESH	14	13.8	14.4	16.6	15.9	13.1	14.1	14.6	16.2	16.2
	% THRU 200 MESH	13.6	15.3	17.6	16.9	20.9	13.5	16.6	13.2	17.1	17.9
	+28 MESH	25.2	20.3	14.7	6.4	5.6	25.2	17.7	14.5	7.2	5.3

Example 5

This example is taken from U.S. Provisional Patent Application No. 61/574,200, entitled "High Softness, High Durability Bath Tissue Incorporating High Lignin Eucalyptus Fiber", filed on July 28, 2011, naming *Jeffrey A. Lee* and *Daniel W. Sumnicht* as inventors, illustrating the suitability of eucalyptus pre-conditioning refiner chemical alkaline peroxide mechanical pulp referred to herein as eucalyptus APMP for short. We have found that we can get surprisingly good softness, bulk and wet properties using eucalyptus APMP, in conjunction with relatively low contents of CMF, even in CWP products. Accordingly, it is evident that eucalyptus APMP can be substituted into the formulations described elsewhere in this application to significant benefit, particularly, in cases where the amount of CMF is below 20% by weight.

Experimental Procedure

Pulps were distributed from Tanks according to Table 22. The strategy for the outer plies was to make a Yankee layer with kraft pulp and good durability with a layer of high-bulk APMP or other integrated furnish. The middle ply was homogeneously formed with a high (65%) percentage of APMP to maximize bulk or 100% southern kraft. P6 high bulk APMP was used for outer plies, and P3 APMP was used for the middle ply. Marathon NBSK was unrefined. The source of eucalyptus was Votorantim Celulose e Papel (VCP), aka Fibria, Sao Paulo, Brazil.

Table 22						
Cell	Tank 1, Air layer		Tank 3, Yankee layer		Total BW	Purpose
	B.W.	Pulp	B.W	Pulp		
Stratified						
1	6.3	P6 APMP	11.6	50/50 Mar./Euc.	17.9	Outer plies
2	7.2	P6 APMP	13.3	50/50 Mar./Euc.	20.5	Outer plies
3	7.3	P6 APMP	10.6	18/41/41 CMF/Mar./Euc.	17.9	Outer plies
7	6.3	40/60 P3 APMP/Fibria	11.6	15/42/43 CMF/Mar./Euc.	17.9	Outer plies
8	9.0	50/50SSWK/SHWK	11.6	15/42/43 CMF/Mar./Euc.	20.5	Outer plies
9	10.1	50/50 SSWK/SHWK	10.1	20%CMF/80% Euc. Kraft	20.2	Outer plies
Homogeneous						
Cell	B.W.	Pulp				Purpose
4	20.5	65/35 P3 APMP/Mar.				Middle ply
5	17.9	65/35 P3 APMP/Mar.				Middle ply
6	20.5	50/50 SSWK/SHWK				Middle ply
10		50/50 SSWK/SHWK				Middle ply, No FJ 98

Mar. = Marathon NBSK

Nalkat® 2020 was added as an "anionic trash killer" at 2.5 g/kg APMP. This was done to prevent trash from poorly washed pilot APMP from interfering with retention of temporary wet strength. GP-C, an imidazolinum type softener, was added to the static mixer at 1.5 g/kg APMP. T1 and T3 pH were adjusted to 5.0 to 5.5 with sulfuric acid to optimize retention of temporary wet strength. FJ98 (low molecular weight slightly cationic glyoxalated polyacrylamide temporary wet strength agent) was added into the pump suction at 3 g/kg kraft pulp. GP-C was added at 1.5 g/kg Yankee layer just before the fan pump.

All sheets for outer plies were calendered and had a geometric mean tensile (GMT) target of 45 N/m and cross machine direction wet tensile (CDWT) target of 5 N/m. Sheets for middle plies were uncalendered and creped with a 10 degree bevel blade. Tensile control was achieved by increasing FJ98 or increasing debonder as necessary. A reel crepe of 25% was used for all basesheets. A 15° crepe blade was used for outer plies. In some cases, use of creping adhesive could be dispensed with, so water alone could be applied through the Yankee spray, as sufficient adhesion for satisfactory creping was provided by FJ98 and the hemicellulose remaining in the eucalyptus APMP. In other cases, when debonder in the sheet interfered with adhesion, it was desirable to apply about 0.125 to 0.25 g/kg PAE coating to the Yankee. A sheet temperature of 110°C was targeted. Only Yankee steam (no hood) was necessary for drying.

Method of Analysis

Results set forth in Table 23 were obtained when converted into finished product and evaluated for basis weight, caliper, wet and dry tensiles, softness, wet and dry lint and dispersibility. **Figure 14** sets forth a desirable design for a three-ply bath tissue **4-10** product utilizing eucalyptus APMP, in which upper ply **4-12** comprising two strata **4-14 and 4-16**, in which upper stratum **4-14** comprising 50% northern bleached softwood kraft fiber and 50% by weight of eucalyptus kraft has a basis weight of about 11.6 g/m^2; lower stratum **4-16** comprising 100% P6 eucalyptus APMP has basis weight of 6.3 g/m^2; while interior ply **4-18** comprising 65% P3 APMP and 35% by weight of northern bleached softwood kraft has a basis weight of 7.9 g/m^2 while lower ply **4-20** comprising two strata **4-22** and **4-24**, in which lower stratum **4-24** comprising 50% northern bleached softwood kraft fiber and 50% by weight of eucalyptus kraft has a basis weight of about 11.6 g/m^2; and upper stratum **4-22** comprising 100% P6 eucalyptus APMP has a basis weight of 17.9 g/m^2. It can be observed that upper ply **4-12** and interior ply **4-18** have been embossed together while lower ply **4-20** is relatively planar and is preferably unembossed. While the configuration shown in **Figure 14** is somewhat more convenient for manufacturing, in many instances, lower ply **4-20** will be inverted so that stratum **4-22** is on an exterior surface of the sheet to take advantage of its usually superior tactile properties.

Table 23 summarizes the properties of CWP prototypes wherein the three-ply prototypes therein are made having a structure like that illustrated in **Figure 14.** Where "knurl" is indicated in the converting column, interior ply **4-18** was joined to lower ply **4-20** by knurling in a meandering path. Where "glue" is indicated in the converting column, the plies were joined to each other by glue lamination. Note that the last two rows provide a comparison to Quilted Northern® Ultra Plush bath tissue and prototypes made using a newer technology, in which a nascent web is creped off of a transfer cylinder at between 30% and 60% consistency. Table 24 sets forth details concerning the structure of each glue laminated product; while Tables 24A-24G set forth further details on the physical properties of the finished products and basesheets, the finished product composition, and the converting parameters used for of each of the finished glue laminated products. Tables 25A-25D do the same for the knurled products. Tables 26 to 28 delineate the properties and construction of CWP sheets made using a high bulk birch pulp manufactured by a high yield pulping process.

Table 23 Summary of CWP prototypes.										
Item	Description	Basis weight, g/m²	Caliper, mm/8 sht	GMT, N/m	Softness	CD Wet, N/m	Dry Lint, ΔL*	Wet lint, mm²	Dispersibility, #shakes	Converting
1	High-bulk mechanical HW w/CMF	43.9	3.33	114	19.7	25	0.4			2-ply, HVS9 knurl
2	High-bulk mechanical HW w/CMF	61.4	4.42	116	20.0	25	-0.1			2-ply, HVS9 knurl
3	High durable no cmf	43.9	2.57	310	17.5	44	0.2	1		3-ply, U19 lines, glue
4	Med durable no cmf	45.7	2.41	267	18.1	34	0.9	7		3-ply, U19 lines, glue
5	Less durable no cmf	46.2	2.67	192	18.5	25	1.9	12		3-ply, U19 lines, glue
6	Less durable 20% cmf	43.5	2.41	262	17.8	29	0.8	3		3-ply, U19 lines, glue
7	High durable 20% cmf	44.3	2.44	339	17.2	49	0.2	1		3-ply, U19 lines, glue
8	Euc APMP 33%	62.7	3.58	116	19.1	11	6.0	19		3-ply, U19 lines, glue
9	Euc APMP 50%	49.6	2.84	94	18.9	8	5.6	28		2-ply, U19 lines, glue
10	Euc APMP 60%	63.1	3.68	109	18.2	8	5.9	24		2-ply, U19 lines, glue
11	Euc APMP 44%	54.8	3.86	126	19.3	12	2.1	11	688	3-ply, U19 , glue
12	Euc APMP 44%	59.1	4.06	131	19.4	15	4.3	15	1450	3-ply, U19 , glue
13	Euc APMP 49%, 7% CMF	53.2	3.76	107	19.3	12	2.6	4	575	3-ply, U19 , glue
14	Euc APMP 49%, 7% CMF	52.9	3.71	133	19.1	17	0.6	2	838	3-ply, U19, glue
15	Euc APMP 31%, 6% CMF	52.7	3.53	129	19.1	14	1.7	6	975	3-ply, U19, glue
16	Southern 62%, 6% CMF	59.7	3.73	150	19.3	13	1.5	6	2000	3-ply, U19, glue
17	Integrated 57%	55.8	3.91	95	20.0	9	2.4	66	875	3-ply, HVS9 knurl
18	Integrated 57%	57.1	4.06	80	20.4	9	5.0	22	1000	3-ply, HVS9 knurl
19	Euc APMP 49%, 7% CMF	50.3	3.71	98	19.8	13	1.1	18	850	3-ply, HVS9 knurl
20	Euc APMP 49%, 7% CMF	52.2	3.76	123	19.8	16	0.7	3	1450	3-ply, HVS9 knurl
21	Euc APMP 33%, 6% CMF	53.2	3.63	114	19.6	13	2.0	10	1025	3-ply, HVS9 knurl
22	Southern 63%, 6% CMF	59.7	3.76	123	19.8	13	1.9	8	2000	3-ply, HVS9 knurl
23	Southern 65%, 7% Pilot CMF	58.3	3.81	101	20.1	9	3.8	13	2000	3-ply, HVS9 knurl
24	Southern 65%, 7% Pilot CMF	57.0	3.81	106	20.1	11	2.7	11	2000	3-ply, HVS9 knurl
Comparatives										
FRBC P3403G		42.8	3.68	120	19.3	15	5.4	30	600	
Quilted Northern® UltraPlush		60.2	3.76	99	20.0	5				3-ply, HVS9 knurl

Table 24 Basesheet data for Three-Ply U19/glue lamination prototypes														
TL 2011-0039 Sample	Conv. Cell	PM cell	Basesheet Description	Caliper 8 Sheet mm/ 8 sht	Basis Weight g/m^2	Tensile MD N/m	Stretch MD %	Tensile CD N/m	Stretch CD %	Tensile GM N/m	Wet Tens Finch Cured-CD N/m	Break Modulus GM N/m/%	Break Modulus CD N/m/%	Break Modulus MD N/m/%
4-1	1	1	0110-4	1.25	18.5	50	28.5	37	4.7	43	3.0	3.7	7.7	1.8
32-1	1	5	0110-31	1.64	18.8	61	31.1	33	4.3	45	6.9	3.8	7.1	2.0
5-1	1	1	0110-5	1.20	18.6	45	26.9	36	4.4	40	3.4	3.6	8.3	1.6
				4.09	55.9	156	28.8	106	4.45	128	13.3	3.7	7.7	1.8
10-1	2	2	0110-9	1.27	20.4	53	29.6	42	4.4	47	5.4	4.1	9.3	1.8
27-1	2	4	0110-26	1.67	20.7	81	29.7	48	4.2	62	7.9	6.2	14.0	2.8
11-1	2	2	0110-10	1.35	20.5	43	28.7	33	4.7	37	4.5	3.2	6.9	1.5
				4.30	61.5	176	29.3	122	4.45	146	17.9	4.5	10.0	2.1
15-1	3	3A	0110-14	1.17	18.3	62	32.2	41	5.1	50	5.7	4.1	8.9	1.9
31-1	3	5	0110-30	1.58	18.9	71	30.2	40	3.9	53	6.2	4.9	10.3	2.4
16-1	3	3A	0110-15	1.23	17.8	49	30.9	34	4.7	41	4.4	3.5	7.8	1.6
				3.98	55.0	182	31.1	115	4.54	145	16.3	4.2	9.0	1.9
19-1	4	3B	0110-18	1.16	17.7	61	29.8	47	4.9	53	8.4	4.4	9.5	2.0
26-1	4	4	0110-25	1.66	21.3	97	29.3	56	3.8	74	9.5	7.2	15.4	3.3
20-1	4	3B	0110-19	1.17	17.8	63	30.8	46	5.0	54	8.1	4.3	9.4	2.0
				3.99	56.8	221	29.9	149	4.59	181	26.1	5.3	11.4	2.5
39-1	5	7	0110-38	1.11	19.0	59	29.8	40	5.8	49	6.1	3.5	6.4	2.0
30-1	5	5	0110-29	1.57	18.5	78	28.1	42	4.1	57	4.3	5.2	9.3	3.0
40-1	5	7	0110-39	1.04	17.6	49	29.3	37	5.1	43	5.4	3.4	7.2	1.6
				3.73	55.2	186	29.1	119	4.99	148	15.8	4.1	7.6	2.2
46-1	6	8	0110-45	1.14	20.3	69	28.9	41	5.6	53	5.0	4.1	7.3	2.3
35-1	6	6	0110-34	1.60	20.8	41	35.9	34	5.5	38	4.0	2.7	6.1	1.2
47-1	6	8	0110-46	1.14	21.0	74	28.7	46	5.7	58	5.4	4.5	7.9	2.5
				3.88	62.1	185	31.1	121	5.58	149	14.4	3.7	7.1	2.0

Table 24A, Ply data for low-weight CWP products. Basesheet data for each Ply												
Cell	X-Ref to Table 23	Roll ID		8 Sheet Caliper mm/ 8 sht	Basis Weight g/m^2	MD Tensile N/m	MD Stretch %	CD Tensile N/m	CD Stretch %	GM Tensile N/m	CD Wet Tensile Cured N/m	GM Break Modulus N/m/%
1	3	1130-4	Hi durable No CMF	0.686	15.0	162.0	31.3	112.0	4.7	**134.5**	**22.0**	11.2
		1130-5		0.693	15.0	143.1	31.9	91.6	4.4	**114.3**	**19.2**	9.7
		1130-6		0.706	14.3	171.2	33.2	110.6	4.4	**137.3**	**16.3**	11.2
2	4	1130-7	Med durable No CMF	0.749	15.6	140.5	33.0	72.3	4.0	**100.6**	**11.6**	8.6
		1130-8		0.739	15.8	127.4	32.4	85.6	4.6	**104.4**	**11.8**	9.1
		1130-9		0.686	14.5	140.4	34.8	74.0	4.7	**101.8**	**12.7**	7.9
3	5	1130-16	Less durable No CMF	0.850	14.8	59.3	31.1	48.9	5.2	**53.8**	**6.3**	4.1
		1130-17		0.831	16.1	81.3	34.3	63.6	5.2	**71.9**	**8.2**	5.5
		1130-18		0.782	15.0	73.6	31.6	50.4	4.9	**60.6**	**8.2**	4.9
4	6	1130-20	Less durable 20% CMF	0.765	15.0	125.1	33.3	65.5	6.1	**90.5**	**9.0**	6.0
		1130-21		0.782	15.5	132.4	33.5	65.1	6.6	**92.8**	**9.1**	5.8
		1130-22		0.749	14.8	109.6	33.1	64.5	6.4	**84.0**	**7.5**	6.2
5	7	1130-24	Hi durable 20% CMF	0.752	15.6	154.6	34.9	90.7	5.6	118.4	15.2	9.3
		1130-25		0.724	15.1	154.2	32.3	80.4	6.4	111.3	14.8	7.5
		1130-26		0.663	13.7	114.4	30.3	70.8	6.1	90.0	16.2	6.6
6	8	4905-57	High bulk 33% APMP	1.323	21.3	48.8	27.6	38.7	5.1	43.4	4.6	3.7
		4905-58		1.232	20.5	52.6	25.9	38.4	4.8	44.8	4.0	4.1
		4905-59		1.250	21.0	50.3	27.7	39.4	5.7	44.4	4.0	3.5
7	9	4905-60	High bulk 50%APMP	1.560	26.2	59.2	28.5	49.0	5.3	53.7	4.6	4.5
		4905-61		1.562	25.9	63.3	28.0	43.6	5.1	52.5	5.0	4.2
8	10	4905-62	High bulk 60% APMP	2.075	33.0	65.4	26.6	55.9	5.0	60.4	4.9	5.3
		4905-63		2.035	33.5	81.4	28.0	59.1	5.3	69.4	5.1	5.8

Table 24B Finished product composition.						
	Euc APMP	SBHK	SBSK	NBSK	Euc Kraft	CMF
1	44.4	0.0	0.0	33.7	21.9	0.0
2	44.4	0.0	0.0	33.7	21.9	0.0
3	48.6	0.0	0.0	28.1	16.1	7.2
4	49.4	0.0	0.0	28.4	15.3	6.9
5	31.3	0.0	0.0	29.8	32.6	6.4
6A	0.0	31.2	31.2	15.8	16.1	5.6
6B	0.0	31.2	31.2	15.8	16.1	5.6

Table 24C Converting Parameters (U19/Glue)							
Emboss Sleeves: U19 300-0436.2 HVS				Sheet Length: 104 mm			
Plybond Adhesive: TT 3005, 5% solids				Sheet Count: 200			
Perf Blades: 1866 X 0.040							
Cell ID	Emboss Pen. µm	Front Roll #	Middle Roll # Embossed	Back Roll # Embossed	Marry Roll Nip Open/ Closed	# of logs/Rolls	Notes
1	1321	Cell 1-4	Cell 5-31	Cell 1-5	16 mm	12/24	
2	1321	Cell 2-9	Cell 4-26	Cell 2-10	16 mm	6/12	
3	1397	Cell 3A-14	Cell 5 – 30	Cell 3A-15	16 mm	13/26	
4	1397	Cell 3B-18	Cell 4 – 25	Cell 3B-19		16/32	Decreased marry roll nip width
5	1321	Cell 7-38	Cell 5 – 29	Cell 7 – 39		16/32	
6A	1321	Cell 8-45	Cell 6 – 34	Cell 8 - 46		6/12	
6B	1143	Cell 8-45	Cell 6 - 34	Cell 8 - 46		10/20	

Table 24D
Glue Laminated Finish Product - Physical Properties (pt. 1)

	Table 23 ref	Description	Softness Panel	Wet Abrasion mm^2	Lint Black Felt Unitless	Basis Weight g/m^2	Caliper 8 Sheet mm/8sht	MD Tensile N/m	CD Tensile N/m	GM Tensile N/m	MD Stretch %	CD Stretch %	CD Wet Tens Finch N/m
1	3	High durable no cmf	17.5	1	0.2	43.9	2.57	417	230	310	28.0	5.1	44
2	4	med durable no cmf	18.1	7	0.9	45.7	2.41	346	206	267	27.7	5.6	34
3	5	less durable no cmf	18.5	12	1.9	46.2	2.67	243	153	192	26.1	5.2	25
4	6	less durable 20& cmf	17.8	3	0.8	43.5	2.41	373	184	262	28.1	6.3	29
5	7	High durable 20% cmf	17.2	1	0.2	44.3	2.44	480	240	339	28.9	6.2	49
6	8	33% APMP (P6)	19.1	19	6.0	62.7	3.68	142	95	116	19.8	4.7	11
7	9	5-% APMP (P6)	18.9	28	5.6	49.6	2.84	113	79	94	20.5	5.2	7.6
8	10	60% APMP (P6)	18.2	24	5.9	63.1	3.68	134	90	109	19.0	4.7	7.7

Table 24E

	Table 23 ref	Description	GM Break Modulus N/m/%	Brtness MacBeth UV-C %	MacBeth Opacity Units	Roll Diameter mm	Roll Compress Value %	TMI Ply Bond g	MD Break Modulus N/m/%	CD Break Modulus N/m/%	MD T.E.A. $mm\text{-}g/mm^2$	CD T.E.A. $mm\text{-}g/mm^2$
1	3	High durable no cmf	26	89.7	72	122	29.29	4.65	15	46	4.20	0.59
2	4	med durable no cmf	21	89.8	72	110	19.10	5.14	12	37	3.66	0.59
3	5	less durable no cmf	17	89.8	73	116	19.33	20.69	9.4	30	2.61	0.40
4	6	less durable 20& cmf	19	91.6	80	108	17.84	8.63	13	28	3.44	0.60
5	7	High durable 20% cmf	25	91.3	79	111	17.93	3.98	16	39	4.27	0.80
6	8	33% APMP (P6)	12	87.8	82	125	21.40	9.54	7.2	20	1.46	0.23
7	9	5-% APMP (P6)	9.1	87.8	77	105	13.73	11.80	5.5	15	1.24	0.22
8	10	60% APMP (P6)	11	86.6	83	120	16.88	10.96	7.1	19	1.37	0.23

Table 24F Finished product composition for CWP sheets				
	NBSK	VCP Eucalyptus Kraft	Euc APMP P6	CMF
1	40	40	0	20
2	40	40	0	20
3	40	40	0	20
4	40	40	0	20
5	40	40	0	20
6	40	27	33	0
7	30	20	50	0
8	24	16	60	0

Table 24G
Glue Laminated Finished product – Physical Properties (pt. 1)

Description	Table 23 ref	Softness Panel	Dispersibility, #shakes	Wet Abrasion Tissue mm^2	Lint Black Felt Unitless	Basis Weight g/m^2	Caliper 8 Sheet mm/ 8 sht	Tensile MD N/m	Tensile CD N/m	Tensile GM N/m	Stretch MD %	Stretch CD %
1	11	19.33	688	11.0	2.1	54.8	3.86	165	97	126	22.2	5.1
2	12	19.35	1450	15.1	4.3	59.1	4.06	150	114	131	21.7	4.9
3	13	19.31	575	3.9	2.6	53.2	3.76	131	89	107	20.3	5.2
4	14	19.05	838	1.7	0.6	52.9	3.71	169	105	133	20.6	5.3
5	15	19.11	975	6.3	1.7	52.7	3.53	169	99	129	22.2	5.1
6A	16	19.29	2000	5.9	1.5	59.7	3.73	189	119	150	25.5	5.9
6B	--	19.31	2000	5.4	1.3	59.9	3.63	188	125	153	26.6	5.8

Table 24G
Glue Laminated Finished product – Physical Properties (pt. 2)

Description	Table 23 ref	Perf Tensile N/m	Finch CD N/m	Modulus GM N/m/%	Roll Diameter mm	Compress Value %	TMI Ply Bond g	Modulus MD N/m/%	Modulus CD N/m/%	mm-gm/ mm^2	mm-gm/ mm^2
1	11	48.5	11.6	12.1	129	21.9	9.0	7.5	19.7	1.65	0.28
2	12	53.0	14.9	12.9	130	21.2	7.5	7.1	23.4	1.60	0.32
3	13	43.2	11.8	10.4	130	26.5	8.8	6.4	16.7	1.27	0.25
4	14	57.7	16.7	12.9	126	22.6	8.0	8.2	20.1	1.55	0.31
5	15	51.1	13.9	12.1	126	27.8	11.1	7.7	19.3	1.62	0.29
6A	16	56.8	13.0	12.2	125	22.5	15. 3	7.3	20.3	1.96	0.40
6B	--	54.2	12.6	12.5	128	28.4	14.6	7.2	21.6	2.04	0.42

Table 25A Construction data for HVS9/knurl prototypes w/ Basesheet data.												
TL2011-0039 Sample	Converting Cell	PM cell	Description	8 Sheet Caliper mm/8 sht	Basis Weight g/m^2	MD Tensile N/m	MD Stretch %	Tensile CD N/m	Stretch CD %	Tensile GM N/m	CD Wet Tens Finch Cured N/m	GM Break Modulus N/m/%
6-1	1	1	0110-6	1.19	18.1	47.0	28.8	36.0	4.5	41.2	3.3	3.7
37-1	1	6	0110-36	1.47	19.7	52.4	35.0	46.5	5.3	49.3	6.3	3.7
7-1	1	1	0110-7	1.20	18.4	47.5	28.7	37.8	4.6	42.3	3.5	3.7
				3.86	56.1	146.8	30.8	120.3	4.8	**132.7**	13.1	3.7
12-1	2	2	0110-11	1.42	20.7	43.1	29.9	37.3	4.5	40.0	4.2	3.3
34-1	2	6	0110-33	1.61	21.2	45.9	38.7	35.3	5.4	40.2	3.9	3.0
13-1	2	2	0110-12	1.33	20.0	42.0	29.1	32.2	5.3	36.7	4.4	2.8
				4.36	61.7	131.0	32.6	104.9	5.1	**116.9**	12.4	3.1
17-1	3	3A	0110-16	1.19	17.7	53.7	30.3	43.9	5.0	48.4	6.3	4.0
29-1	3	5	0110-28	1.60	19.2	58.3	30.4	46.7	4.4	52.1	5.8	4.5
18-1	3	3A	0110-17	1.16	17.1	49.2	29.3	38.7	5.2	43.5	5.5	3.5
				3.95	54.0	161.1	30.0	129.2	4.9	**144.0**	17.6	4.0
21-1	4	3B	0110-20	1.16	17.9	61.1	31.3	44.3	5.0	52.0	7.6	4.1
25-1	4	4	0110-24	1.62	20.0	91.1	30.0	48.1	4.1	66.1	6.0	5.9
22-1	4	3B	0110-21	1.16	17.1	50.6	29.9	40.0	6.2	45.0	7.6	3.1
				3.94	54.8	202.8	30.4	132.4	5.1	**163.1**	21.2	4.4
41-1	5	7	0110-40	1.06	17.6	47.0	27.9	35.3	5.2	40.7	5.4	3.5
28-1	5	4	0110-27	1.67	21.2	94.5	29.3	53.9	4.2	71.3	9.3	6.3
42-1	5	7	0110-41	1.05	17.6	46.7	30.4	36.5	5.3	41.3	5.0	3.2
				3.77	56.3	188.2	29.2	125.7	4.9	**153.3**	19.0	4.4
				4.14	0.0	141.2		94.3		114.9	14.8	0.0
48-1	6	8	0110-47	1.17	20.7	78.0	31.3	45.9	5.2	59.8	5.8	4.8
36-1	6	6	0110-35	1.62	22.1	50.2	35.3	40.2	5.0	44.4	5.5	3.5
49-1	6	8	0110-48	1.16	20.3	62.3	28.1	37.7	5.6	48.4	4.9	4.0
				3.95	63.1	190.5	31.6	123.8	5.3	**152.6**	16.2	4.1
				4.33	0.0	142.9		92.8		114.5	12.1	0.0
56-1	7	9	0216-7	1.18	20.5	52.0	30.9	43.2	5.3	47.4	4.5	3.7
66-1	7	10	0216-16	1.69	20.7	41.6	36.9	30.6	5.8	35.6	0.8	2.4
57-1	7	9	0216-8	1.21	20.3	61.4	32.7	46.6	5.2	53.4	4.5	4.0
				4.08	61.7	154.8	33.5	120.5	5.4	**136.4**	9.7	3.3
58-1	8	9	0216-9	1.17	20.3	56.9	30.5	42.6	4.9	49.2	5.0	4.1
63-1	8	6	0216-13	1.65	20.3	50.2	35.8	42.7	5.8	46.2	5.8	3.1
59-1	8	9	0216-10	1.19	20.7	58.0	31.0	47.5	5.0	52.5	5.0	4.4
				4.00	61.4	165.2	32.4	132.8	5.2	**147.9**	16.0	3.9

Table 25B						
Finished product composition for HVS 9 Knurl Products.						
	APMP Euc.	SBHK	SBSK	NBSK	Kraft Euc.	CMF
1	22	17	17	21	21	0
2	22	17	17	22	22	0
3	49	0	0	28	16	7.1
4	49	0	0	28	16	7.0
5	33	0	0	30	31	6.0
6	0	32	32	15	16	5.5
7	0	32	32	0	28	7.0
8	0	32	32	0	28	7.1

Table 25C, HVS9/knurl finished product Physical Properties (pt. 1)											
			Dispersibility	Wet Abrasion Tissue	Lint Black felt	Basis Weight	Caliper 8 Sheet	Tensile MD	Tensile GM	Stretch MD	Stretch CD
Description	Table 23 desc.	Softness Panel	# of Shakes	mm^2	Unitless	g/m^2	mm/8 Sheet	N/m	N/m	%	%
5-1	17	20.02	875		2.4	55.8	3.91	117	77	18.1	4.8
5-2	18	20.36	1000		5.0	57.1	4.06	98	65	17.8	5.1
5-3	19	19.84	850		1.1	50.5	3.71	130	75	17.4	5.2
5-4	20	19.79	1450		0.7	52.2	3.76	158	95	18.4	5.0
5-5	21	19.56	1025		2.0	53.2	3.63	158	83	18.7	5.0
5-6	22	19.79	2000		1.9	59.7	3.76	166	91	21.5	5.6
5-7	23	20.10	2000		3.8	58.3	3.81	118	87	20.3	5.1
5-8	24	20.08	2000		2.7	57.0	3.81	122	92	18.9	5.0

Table 25C, HVS9/knurl finished product Physical Properties (pt. 2)											
		Perf-Tensile	Wet Tens Finch CD	Break Modulus GM	Roll Diameter	Roll Compress Value	TMI Ply Bond	Break Modulus MD	Break Modulus CD	TEA MD	TEA CD
Description	Table 23 desc.	N/m	N/m	N/m/%	mm	%	g	N/m/%	N/m/%	$mm\text{-}g/mm^2$	$mm\text{-}g/mm^2$
5-1	17	50	9.3	10.3	126	21	7.9	6.7	16	1.02	0.19
5-2	18	46	9.4	8.2	123	23	5.7	5.5	12	0.86	0.17
5-3	19	44	12.9	10.3	127	24	3.2	7.4	14	1.03	0.20
5-4	20	59	16.2	12.9	128	23	4.4	8.7	19	1.31	0.24
5-5	21	55	12.9	12.0	125	22	6.8	8.6	17	1.28	0.21
5-6	22	67	12.7	11.2	128	24	8.7	7.8	16	1.51	0.26
5-7	23	46	8.8	10.0	125	20	6.9	5.9	17	1.13	0.22
5-8	24	45	11.5	10.9	129	25	7.7	6.4	19	1.07	0.23

Table 25D																
Converting parameters Sheet Length 104 mm Sheet Width 103 mm																
Cell No.	**#1 Unwind Base Sheet**	**#2 Unwind Base Sheet**	**#3 Unwind Base Sheet**	**Lower Emboss Pattern #**	**Converting Process**	**Lower Emboss Depth, mm**	**Feedroll Calender**	**Mach. Speed m/s**	**Unwind Tension #1**	**Unwind Tension #2**	**Unwind Tension #3**	**Plybond Air Pressure, kPa**	**Draw Tension**	**Winding Tension**	**Sheet Count**	**Finished Roll Diameter, mm**
1	110-6	110-36	110-7	300-107.1	3 ply HVS	2.29	open	0.66	0.5	0.5	0.5	159	float	0.8	200	125
2	110-12	110-33	110-11	300-107.1	3 ply HVS	2.29	open	0.66	0.5	0.5	0.5	159	float	0.6	176	123
8	216-10	216-13	216-9	300-107.1	3 ply HVS	2.29	open	0.66	0.5	0.5	0.5	159	float	0.5	200	125
6	110-48	110-35	110-47	300-107.1	3 ply HVS	2.29	open	0.66	0.5	0.5	0.5	159	float	0.7	200	124
3	0110-17	0110-28	0110-16	300-107.1	3 ply HVS	2.29	open	0.66	0.5	0.5	0.5	159	float	0.8	200	124
4	0110-21	0110-24	0110-30	300-107.1	3 ply HVS	2.29	open	0.66	0.5	0.5	0.5	159	float	0.9	200	126
5	0110-41	0110-27	0110-40	300-107.1	3 ply HVS	2.29	open	0.66	0.5	0.5	0.5	159	float	0.8	200	124
7	216-8	216-16	216-7	300-107.1	3 ply HVS	2.29	open	0.66	0.5	0.5	0.5	159	float	0.7	200	125

Table 26, Physical Properties of two-ply, high-bulk tissue with Tembec birch APMP (pt. 1).								
Description	8 Sheet Caliper mm/ 8 sht	Basis Weight g/m^2	MD Tensile N/m	MD Stretch %	CD Tensile N/m	CD Stretch %	GM Tensile N/m	CD Wet Tens Finch Cured N/m
0302-2	1.57	22.9	113	28.1	77	5.1	93	22
0302-3	1.63	23.6	127	30.3	70	5.4	94	21
0302-4	2.24	32.4	112	28.1	76	5.0	92	20
0302-5	2.13	32.1	114	28.4	90	5.0	101	24

Table 26 Physical Properties of two-ply, high-bulk tissue with Tembec birch APMP (pt. 2).								
Description	GM Break Modulus N/m/%	SAT Capacity g/m^2	SAT Rate $g/s^{0.5}$	SAT Time s	CD T.E.A mm-gm/ mm^2	MD TEA mm-gm/ mm^2	CD Break Modulus N/m/%	MD Break Modulus N/m/%
0302-2	7.9	337	0.0613	124.9	0.21	0.96	15.1	4.1
0302-3	7.5	350	0.0667	112.6	0.21	1.12	13.1	4.2
0302-4	7.5	548	0.1047	141.4	0.20	1.01	14.0	4.0
0302-5	8.1	532	0.1043	146.6	0.25	1.03	17.6	3.7

Table 27, Overall Composition of 3 Ply prototypes* using Tembec Birch APMP for bulky inner layer.				
	Mar. NBSK	VCP Euc	CMF	Birch APMP
1	32%	7%	10%	51%
2	23%	5%	7%	65%

Table 28, Physical Properties of 3 Ply prototypes* using Tembec Birch APMP for bulky inner layer (pt. 1).										
Description	Softness Panel	Lint Black Felt Unitless	Basis Weight g/m^2	Caliper 8 Sheet mm/ 8 sht	Tensile MD N/m	Tensile CD N/m	Tensile GM N/m	Stretch MD %	Stretch CD %	Wet Tens Finch CD N/m
1	19.7	0.4	43.9	3.33	147	90	114	17.0	5.1	25
2	20.0	-0.1	61.4	4.42	147	92	116	18.7	4.7	25

Table 28, Physical Properties of 3 Ply prototypes using Tembec Birch APMP for bulky inner layer (pt. 2).										
Description	Break Modulus N/m/%	Brtness MacBeth UV-C %	Opacity MacBeth Opacity Units	Roll Diameter mm	Roll Compress Value %	TMI Ply Bond g	Break Modulus MD N/m/%	Break Modulus CD N/m/%	TEA MD mm-gm/ mm^2	TEA CD mm-gm/ mm^2
1	12.2	85.9	78.5	117	22.3	0.5	8.3	18.1	1.0	0.2
2	12.5	84.9	84.2	132	22.8	0.6	8.0	19.9	1.1	0.2

*Items 1 and 2 from Table 23

Summary of Results

Table 23 illustrates several rather surprising results in that three-ply bath tissue incorporating eucalyptus APMP exceeded Quilted Northern® Ultra Plush caliper without unduly degrading softness. This is considered quite surprising for a bath tissue comprising such large quantities of high yield pulp.

Even with products with excellent resistance to pilling, linting and shredding, it was possible to achieve softness panel ratings greater than nineteen while reducing wet lint up to 96% versus Charmin® Ultra Strong. It can also be observed that in those products comprising rather small amounts of CMF, even further reductions in wet lint values were obtained. This was especially true of sheets containing CMF at 6 to 7% of furnish, wherein the CMF was concentrated in the surface strata of the outer plies by stratification without CMF in the inner ply. This is considered to be especially significant as, currently, CMF is substantially more expensive than most papermaking fibers. Accordingly, it is particularly important both to reduce the amount needed and to obtain easily perceptible benefit for the CMF. Products without CMF, however, particularly, those made with glue lamination, exhibited reduced wet lint relative to products where the plies were joined by knurling, thus making it possible to achieve excellent results without the use of CMF.

It is clear that applicants have succeeded in manufacturing a bath tissue that is usable prewetted, yet fully achieves a softness that is not merely comparable to premium and super premium bath tissue, but is at full parity and is arguably even softer, although the improvement is most likely not significant enough to be noticed reliably by most users. This is a dramatic reversal of previous wet strength bath tissues, in which it was hoped that the deficit in softness was not large enough to be readily noticeable by most users. The softness panel rating of 20.1 achieved with furnish comprising 7% pilot CMF, 65% southern softwood kraft, and 28% eucalyptus kraft is considered to be a significant improvement in wet strength bath tissue.

High basis-weight CWP prototypes comprising less than 30% southern pine with large amounts of eucalyptus APMP were dispersible, passing the test described above in under 1500 shakes. Surprisingly, high basis-weight CWP product with an excess of 30% southern pine did not pass the dispersibility test after 2000 shakes as, despite appearing to be disintegrated, the slurry did not drain with the requisite speed. It appears that dispersibility may be helped significantly by the inclusion of short, eucalyptus APMP fibers relative to longer southern pine kraft fibers.

Between comparable prototypes, products having plies joined by knurling had a slight edge in softness over glue laminated prototypes.

As expected, however, CWP products were at a disadvantage to those products produced by creping a nascent web at a 30 to 60% consistency off of a transfer cylinder.

Two-ply bath tissue made with a furnish including Tembec Birch APMP achieved a softness rating of 20 at 4.5 mm/8 sheet caliper, exhibiting considerable dusting along with knurled ply bonding, which was poor, suggesting that mechanical hardwood APMP other than eucalyptus may achieve a similar bulk result as eucalyptus if used in the interior ply of a three-ply product, but likely might be rather weak for use in the exterior plies.

These results, however, also demonstrate that the current best practice for making soft tissue does not optimize the properties of tissues to be used wet. In particular, the current best practice for dry tissue uses about 1/3 northern softwood kraft and 2/3 eucalyptus kraft with the softwood providing network integrity while the eucalyptus provides smoothness and opacity. When a stratified headbox is available, in a refinement of this approach, the eucalyptus is stratified in the Yankee side of the sheet and spray softeners are applied up to about the limit at which they begin to interfere with creping. The stronger air layer with softwood provides strength while the eucalyptus layer becomes very smooth and velvety. As mentioned, however, not only can spray softeners act as release agents interfering with effective creping of the sheet, and thus interfering with realization of the full softness potential of the sheet, but surfaces comprised of 100% eucalyptus kraft often have increased tendency to shed lint. Thus, it can be appreciated that a premium softness wet or dry bath tissue product does not necessarily result from merely adding temporary wet strength agents to traditional premium bath tissue products intended for dry use.

A different strategy is needed for wet-durable tissue to reduce the linting tendency for both dry and wet use. CMF and northern softwood are incorporated in the Yankee layer, while a temporary wet strength agent is concentrated in the Yankee layer to provide durability. Thus, the Yankee layer provides wet tensile and surface strength to reduce pilling. The air layer contains an integrated furnish that is debonded as much as is tolerable, with little or no temporary wet strength, as shown in the representative tissue structure of **Figure 14**. In this approach to providing a premium softness wet or dry bath tissue, the outer plies are stratified with softness and integrity, providing premium fibers in the Yankee layer and lower cost furnish in the air layer to provide bulk and overall strength. The

middle ply is homogeneously formed APMP and softwood kraft. Alternatively, the middle ply can be made with integrated furnish such as southern kraft. The middle ply is creped with a relatively closed pocket to create bulk through coarser crepe and uncalendered to preserve the bulk added by the coarse creping. In this approach, stratification to provide a strong coherent Yankee layer of low weight with a debonded air layer combined to produce a finely creped, but coherent tissue on the surface. **Figure 14** sets forth a desirable design for a three-ply bath tissue **4-10** product utilizing eucalyptus APMP, in which upper ply **4-12** comprising two strata **4-14 and 4-16**, in which upper stratum **4-14** comprising primarily northern bleached softwood kraft fiber and eucalyptus kraft, has a basis weight of about 6.5 to 14.6 g/m^2; lower stratum **4-16** comprising primarily eucalyptus APMP has basis weight of 3.3 to 9.8 g/m^2; while interior ply **4-18** comprising primarily APMP and northern bleached softwood kraft has a basis weight of 11.4 to 24.4 g/m^2, while lower ply **4-20** comprising two strata **4-22** and **4-24**, in which lower stratum **4-24** comprising primarily northern bleached softwood kraft fiber and eucalyptus kraft has a basis weight of about 6.5 g/m^2; and upper stratum **4-22** comprising primarily eucalyptus APMP has basis weight of 3.3 to 9.8 g/m^2. In many cases, it will be preferable to substitute furnishes comprising about 20% CMF; 40% eucalyptus kraft and 40% northern bleached softwood kraft fiber for 50% northern bleached softwood kraft fiber and 50% by weight of eucalyptus kraft in the above. It can be observed that upper ply **4-12** and interior ply **4-18** have been embossed together, while lower ply **4-20** is relatively planar and is preferably unembossed.

Table 23 summarizes CWP prototype properties made using the general strategy shown in **Figure 14** in comparison to some other tissue structures. Product 18 is an example of using an integrated furnish to lower cost through cheaper and bulkier fiber, while maintaining softness. The 176 count roll has a 12.3 cm diameter and a 23% roll compression. Alternatively, basis weight can be taken out of the 4.06 mm caliper product to keep 200 sheets, as in, for example, the 50.3 g/m^2 product 19.

Product 24 is a CMF containing prototype offsetting the high cost CMF in the Yankee stratum by low cost integrated furnish away from the surface to produce a tissue achieving an extremely high softness rating of 20 when tested by a trained softness panel. Product 24 is made with an outer ply comprising a 10.9 g/m^2 Yankee layer with 20% pilot CMF and 80% eucalyptus kraft with the remaining 9.8 g/m^2 air layer being made with 50% southern softwood kraft and 50% southern hardwood kraft. As the middle ply is an uncalendered sheet with 50% southern softwood and 50% southern hardwood kraft, the finished product content nets out to only 7% CMF, 28% eucalyptus kraft, and 65% southern kraft for a product that is potentially economically feasible in view of the benefits resulting from the use of the CMF.

Figures 13 and **15** show plots of softness versus wet lint with the bubble size representing CD wet tensile. Softness greater than 19 was achieved for most CWP prototypes whether they are glue laminated or knurled. Wet lint was very low and wet tensile was generally less than the Delve 358 product, but greater than Charmin® Ultra Strong (8.9 N/m CDWT). Many prototypes have a combination of softness, low lint, and durability.

It can also be appreciated that prototypes with CMF have less wet lint than comparable prototypes with only wood pulp. Prototypes with just wood pulp, however, have substantially reduced lint relative to other retail products, so they may provide the most economical way of delivering low lint.

Another comparison to highlight is the lower wet lint achieved with glue lamination relative to knurling, particularly, in products without CMF. The bubbles **90** and **116** in **Figure 15** (glue lamination) were made with outer plies similar to the product represented by bubble **315** (glue lamination). One of the knurled products had higher lint attributable to the surface ply failing, while other knurled products were both soft and durable. The difference between these two products was a higher basis weight and strength in the product that did not fail. While all glued products had low lint, most knurled prototypes performed nearly as well.

Figure 16 compares the dispersibility of previous FRBC prototypes with current CWP. Many CWP products have both dispersibility and low lint, while others fail dispersibility, despite being less durable than FRBC prototypes. This difference between FRBC and CWP can be explained mostly by basis weight, but the data also suggest a fiber composition contribution. CWP prototypes with a value of 2000 shakes were terminated without passing. The samples were observed to be largely disintegrated, but too floccy to pass the small bottle opening in 8 seconds per the procedure. Higher softwood contents will increase the flocciness of the disintegrated tissue, and this effect was often seen in a product that was made with a middle ply with 50% southern pine. On the other hand, sheets with more eucalyptus APMP passed the test. Minimizing softwood content, particularly, southern pine, can benefit dispersibility, particularly, in high basis weight tissue with more durability. Desirably, softwood content will be kept to less than about 40%, more preferably, to less than about 35%, still more preferably, between about 20% and about 35%, and most preferably, to between about 25% and about 35%.

Figure 17 shows that embossing with pattern HVS 9 (**Figure 28**), then ply bonding by knurling, resulted in a softer product on similar sheets than embossing with pattern U 19 (**Figure 27)** and joining by glue. The HVS 9 microemboss reduced basesheet tensile on the order of 25%, while there was almost no tensile breakdown with the emboss penetration used in U 19.

Figures 18 and 19 compare the attributes of bath tissue made using FRBC technology to tissue made using CWP. In particular, while FRBC clearly has a striking advantage in terms of bulk generation/caliper (**Figure 18**), the difference in softness is considerably less substantial (**Figure 19**).

Referring back to Table 23, Products 1 and 2 are early prototypes that used birch APMP for the bulky inner layer. It appears that other APMP hardwood pulps can be substituted for eucalyptus APMP in the interior plies of three-ply products to provide the bulk benefit of the eucalyptus APMP. The sheets are, however, weak and subject to considerable dusting, suggesting that they are not all that desirable for exterior plies.

In contrast, the preceding Examples demonstrate that low cost eucalyptus APMP furnish can be incorporated into premium three-ply bath tissue without sacrificing softness or the attributes of quality, while adding bulk. Three-ply CWP can be an acceptable format for a premium quality wet or dry bath tissue.

While the invention has been described in connection with numerous examples and embodiments, modifications to those examples and embodiments within the spirit and scope of the invention will be readily apparent to those of skill in the art. In view of the foregoing discussion, relevant knowledge in the art and references including copending applications discussed above, further description is deemed unnecessary.

WE CLAIM:

1. A multi-ply bath tissue having no more than three plies and no fewer than two plies, the multi-ply tissue having a basis weight of from about 32.6 to about 57.0 g/m^2 and comprising:

(a) from about 3% to about 50% cellulosic microfiber; and

(b) from about 50% to about 97% wood pulp fibers,

the multi-ply bath tissue having:

(i) a GM dry tensile of from about 1.34 to 6.33 N/m per g/m^2 basis weight;

(ii) a cross machine direction (CD) dry tensile of between about 2.37 to about 4.74 N/m per g/m^2 of basis weight;

(iii) sufficient temporary wet strength resin to provide an initial Finch Cup CD wet tensile of from about 0.20 to about 1.58 N/m per g/m^2 of basis weight, the initial Finch Cup CD wet tensile decaying to less than 65% of the initial value in less than 15 minutes after immersion in water; and

(iv) a caliper of at least 0.078 mm per 8 sheets per g/m^2 of basis weight.

2. The multi-ply bath tissue of claim 1, having an opacity of at least about 1.54 MacBeth Opacity Units per g/m^2 of basis weight.

3. The multi-ply bath tissue of claim 1, comprising from about 5% to about 25% cellulosic microfiber and from about 85% to about 75% wood pulp fibers.

4. The multi-ply bath tissue of claim 1, comprising two substantially unembossed plies and one embossed ply.

5. The multi-ply bath tissue of claim 1, comprising one substantially unembossed ply and two embossed plies.

6. The multi-ply bath tissue of claim 1, having a basis weight of from about 35.8 to 52.1 g/m^2.

7. The multi-ply bath tissue of claim 1, comprising overall from at least about 5% up to about 50% CMF by weight and from about 50% to about 95% wood pulp fibers, the multi-ply bath tissue comprising three plies, at least one of the plies comprising at least one stratum comprising from about 15% to about 50% cellulosic microfiber, the multi-ply tissue having a basis weight of between

32.6 to 57.0 g/m^2, an eight sheet caliper of at least about 0.082 mm per g/m^2 of basis weight, a breaking modulus of between 1.5 and 2.2 g/% stretch per g/m^2 of basis weight, a CD wet tensile of between 0.28 and 1.42 N/m per g/m^2 of basis weight, and a GM dry tensile (GMT) of between 2.37 and 4.74 N/m per g/m^2 of basis weight.

8. The multi-ply bath tissue of claim 7, wherein at least one of the three plies comprises a plurality of fiber-enriched hollow domed regions having a relatively high basis weight and connecting regions of a relatively lower basis weight forming a network interconnecting the relatively high local basis weight domed regions of the sheet, and transition regions with upwardly and inwardly inflected consolidated fibrous regions transitioning from the connecting regions into the domed regions.

9. The multi-ply bath tissue of claim 8, wherein:

(i) the ply comprising a plurality of fiber-enriched hollow domed regions having a relatively high basis weight and connecting regions of a relatively lower basis weight forming a network interconnecting the relatively high local basis weight domed regions of the sheet, and transition regions with upwardly and inwardly inflected consolidated fibrous regions transitioning from the connecting regions, into the domed regions is a ply other than an interior ply, and wherein

(ii) the at least one of the plies comprising at least one stratum comprising from about 15% to about 50% cellulosic microfiber is disposed such that the stratum defines an exterior surface of the multi-ply bath tissue.

10. The multi-ply bath tissue of claim 8, wherein the fiber-enriched hollow domed regions having a relatively high basis weight in the plurality of fiber-enriched hollow domed regions having a relatively high basis weight are provided in an interpenetrating staggered array.

11. The multi-ply bath tissue of claim 7, wherein at least two of the three plies comprise a plurality of fiber-enriched hollow domed regions having a relatively high basis weight and connecting regions of a relatively lower basis weight forming a network interconnecting the relatively high local basis weight domed regions of the sheet, and transition regions with upwardly and inwardly inflected consolidated fibrous regions transitioning from the connecting regions into the domed regions.

12. The multi-ply bath tissue of claim 7, wherein each of the three plies comprises a plurality of fiber-enriched hollow domed regions having a relatively high basis weight and connecting regions of a relatively lower basis weight forming a network interconnecting the relatively high local basis weight domed regions of the sheet, and transition regions with upwardly and inwardly inflected consolidated fibrous regions transitioning from the connecting regions into the domed regions.

13. The multi-ply bath tissue of claim 1, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 35 mm^2.

14. The multi-ply bath tissue of claim 1, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 30 mm^2.

15. The multi-ply bath tissue of claim 1, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 25 mm^2.

16. The multi-ply bath tissue of claim 1, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 20 mm^2.

17. The multi-ply bath tissue of claim 1, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 6.0.

18. The multi-ply bath tissue of claim 1, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 5.0.

19. The multi-ply bath tissue of claim 1, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 4.5.

20. The multi-ply bath tissue of claim 1, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 4.25.

21. The multi-ply bath tissue of claim 1, wherein the plies are joined to each other by knurling.

22. The multi-ply bath tissue of claim 1, wherein the plies are embossed with a pattern having primarily points to the inside and are joined by glue-lamination.

23. The multi-ply bath tissue of claim 1, comprising three plies of tissue, wherein two plies are embossed, one ply is unembossed, and the plies are joined by knurling, wherein the knurled regions are arranged in a meandering path.

24. The multi-ply bath tissue of claim 1, comprising three plies of tissue, wherein two plies are unembossed, one ply is embossed, and the plies are joined by knurling, wherein the knurled regions are arranged in a meandering path.

25. The multi-ply bath tissue of claim 1, comprising three plies of tissue, wherein two plies are embossed, one ply is unembossed, and the plies are joined by knurling, wherein the knurled regions are arranged in a meandering path and the exterior stratum of the lower ply has substantially the same composition as that of the outermost stratum of the upper ply.

26. A three-ply bath tissue sheet having a basis weight of from about 32.6 to 57.0 g/m^2, and comprising:

(A) from about 5% to about 25% cellulosic microfiber; and

(B) from about 75% to about 95% wood pulp fibers,

the three-ply sheet having:

(a) a GM dry tensile of from about 1.34 to 6.33 N/m per g/m^2 of basis weight;

(b) a GM breaking modulus of between 0.92 and 4.0 g/% stretch per g/m^2 of basis weight;

(c) a CD dry tensile of between about 0.16 to about 2.37 N/m per g/m^2 of basis weight;

(d) sufficient temporary wet strength resin to provide an initial Finch Cup CD wet tensile of from about 0.20 to about 1.58 N/m per g/m^2 of basis weight, the initial Finch Cup CD wet tensile decaying to less than 75% of the initial value in less than 1 hour after immersion in water; and

(e) an opacity of at least about 1.2 MacBeth Opacity Units per g/m^2 of basis weight,

wherein at least one of the plies, other than an interior ply, comprises:

(i) a plurality of fiber-enriched hollow domed regions having a relatively high basis weight;

(ii) a plurality of connecting regions of a relatively lower basis weight forming a network interconnecting the relatively high local basis weight domed regions of the sheet; and

(iii) a plurality of transition regions with upwardly and inwardly inflected consolidated fibrous saddle shaped regions transitioning from the connecting regions into the domed regions.

27. A multi-ply bath tissue sheet having no more than three-plies and no fewer than two-plies, the multi-ply sheet having a basis weight of from about 32.6 to 61.8 g/m^2, and comprising:

(a) up to about 30% cellulosic microfiber;

(b) from about 70% to about 90% wood pulp fibers; and

(c) from about 5% to about 50% by weight of the tissue comprising eucalyptus fibers having a lignin content of at least about 20%,

the multi-ply bath tissue having:

(i) a GM dry tensile of from about 2.77 to 6.33 N/m per g/m^2 of basis weight;

(ii) a CD dry tensile of between about 0.16 to about 2.4 N/m per g/m^2 of basis weight;

(iii) sufficient temporary wet strength resin to provide an initial Finch Cup CD wet tensile of from about 0.2 to about 1.58 N/m per g/m^2 of basis weight, the initial Finch Cup CD wet tensile decaying to less than 65% of the initial value in less than one half hour after immersion in water; and

(iv) a caliper of at least 0.062 mm per 8 sheets per g/m^2 of basis weight.

28. The multi-ply bath tissue of claim 27, having a caliper of at least 0.070 mm per 8 sheets per g/m^2 of basis weight.

29. The multi-ply bath tissue of claim 27, having a caliper of at least 0.078 mm per 8 sheets per g/m^2 of basis weight.

30. The multi-ply bath tissue of claim 27, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 35 mm^2.

31. The multi-ply bath tissue of claim 27, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 30 mm^2.

32. The multi-ply bath tissue of claim 27, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 25 mm^2.

33. The multi-ply bath tissue of claim 27, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 20 mm^2.

34. The multi-ply bath tissue of claim 27, having an opacity of at least about 1.54 MacBeth Opacity Units per g/m^2 of basis weight.

35. The multi-ply bath tissue of claim 27, comprising from about 3% to about 10% cellulosic microfiber and from about 85% to about 75% wood pulp fibers.

36. The multi-ply bath tissue of claim 27, comprising two substantially unembossed plies and one embossed ply.

37. The multi-ply bath tissue of claim 27, comprising one substantially unembossed ply and two embossed plies.

38. The multi-ply bath tissue of claim 27, having a basis weight of from about 35.8 to 52.1 g/m^2.

39. The multi-ply bath tissue of claim 27, comprising three plies, at least the first and second plies of which comprise from about 3% to about 25% cellulosic microfiber, up to about 50% APMP eucalyptus and from about 75% to about 97% wood pulp fibers, the multi-ply bath tissue having:

(a) an overall basis weight of between 35.8 to 58.6 g/m^2;

(b) an eight sheet caliper of at least about 0.082 mm per g/m^2 of basis weight;

(c) a breaking modulus of between 0.20 and 0.28 N/m/% stretch per g/m^2 of basis weight;

(d) a CD wet tensile of between 0.24 and 1.42 N/m per g/m^2 of basis weight; and

(e) a GMT of between 3.2 and 5.5 N/m per g/m^2 of basis weight, wherein the percentage of eucalyptus APMP in the third ply is:

(i) being greater than at least about 20%;

(ii) being greater than the percentage of eucalyptus APMP in the first ply; and

(iii) exceeding the percentage of eucalyptus APMP in the first ply by an amount which is at least 20% of the weight of eucalyptus APMP in the first ply, if any.

40. The multi-ply bath tissue of claim 39, wherein at least one of the plies comprises a web having a plurality of fiber-enriched hollow domed regions having a relatively high basis weight and connecting regions of a relatively lower basis weight forming a network interconnecting the relatively high local basis weight domed regions of the sheet, and transition regions with upwardly and inwardly inflected consolidated fibrous regions transitioning from the connecting regions into the domed regions.

41. The multi-ply bath tissue of claim 40, wherein the ply comprising a plurality of fiber-enriched hollow domed regions having a relatively high basis weight and connecting regions of a relatively lower basis weight forming a network interconnecting the relatively high local basis weight domed regions of the sheet, and transition regions with upwardly and inwardly inflected consolidated fibrous regions transitioning from the connecting regions into the domed regions, is a ply other than an interior ply.

42. The multi-ply bath tissue of claim 40, wherein the fiber-enriched hollow domed regions having a relatively high basis weight in the plurality of fiber-enriched hollow domed regions having a relatively high basis weight are provided in an interpenetrating staggered array.

43. The multi-ply bath tissue of claim 39, wherein at least two of the three plies comprise a plurality of fiber-enriched hollow domed regions having a relatively high basis weight and connecting regions of a relatively lower basis weight forming a network interconnecting the relatively high local basis weight domed regions of the sheet, and transition regions with upwardly and inwardly inflected consolidated fibrous regions transitioning from the connecting regions into the domed regions.

44. The multi-ply bath tissue of claim 39, wherein each of the three plies comprises a plurality of fiber-enriched hollow domed regions having a relatively high basis weight and connecting regions of a relatively lower basis weight forming a network interconnecting the relatively high local basis weight domed regions of the sheet, and transition regions with upwardly and inwardly inflected consolidated fibrous regions transitioning from the connecting regions into the domed regions.

45. The multi-ply bath tissue of claim 39, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 35 mm^2.

46. The multi-ply bath tissue of claim 39, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 30 mm^2.

47. The multi-ply bath tissue of claim 39, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 25 mm^2.

48. The multi-ply bath tissue of claim 39, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 20 mm^2.

49. The multi-ply bath tissue of claim 39, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 6.0.

50. The multi-ply bath tissue of claim 39, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 5.5.

51. The multi-ply bath tissue of claim 39, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 5.0.

52. The multi-ply bath tissue of claim 39, wherein the plies are joined to each other by knurling.

53. The multi-ply bath tissue of claim 39, wherein the plies are embossed in a pattern having primarily points to the inside and are joined by glue-lamination.

54. The multi-ply bath tissue of claim 39, comprising three plies of tissue, wherein two plies are embossed, one ply is unembossed, and the plies are joined by knurling, wherein the knurled regions are arranged in a meandering path.

55. The multi-ply bath tissue of claim 39, comprising three plies of tissue, wherein two plies are unembossed, one ply is embossed, and the plies are joined by knurling, wherein the knurled regions are arranged in a meandering path.

56. The multi-ply bath tissue of claim 39, comprising two plies of tissue, wherein one ply is embossed, one ply is unembossed, and the plies are joined by knurling, wherein the knurled regions are arranged in a meandering path.

57. A three-ply bath tissue sheet having a basis weight of from about 32.6 to 61.8 g/m^2, and comprising:

(A) from about 15% to about 25% cellulosic microfiber; and

(B) from about 78% to about 85% wood pulp fibers from about 10% to about 50% of the weight of the tissue comprising high lignin eucalyptus fibers having a lignin content of at least about 20%, an ISO brightness of at least about 84, a Canadian Standard Freeness (CSF) freeness of at least about 400 ml, a bulk of between 2.2 and 4.2 cm^3/g, and a breaking length of between about 1.2 and 4.7 km,

the three-ply sheet having:

(a) a GM dry tensile of from about 2.0 to 6.3 N/m per g/m^2 of basis weight;

(b) a breaking modulus of between 0.20 and 0.28 N/m/% stretch per g/m^2 of basis weight;

(c) a cross-machine (CD) dry tensile of between about 2.4 to about 4.7 N/m per g/m^2 of basis weight;

(d) sufficient temporary wet strength resin to provide an initial Finch Cup CD wet tensile of from about 0.20 N/m to about 1.58 N/m per g/m^2 of basis weight, the initial Finch Cup CD wet tensile decaying to less than 65% of the initial value in less than one hour after immersion in water; and

(e) an opacity of at least about 1.5 MacBeth Opacity Units per g/m^2 of basis weight,

wherein at least one of the plies, other than an interior ply, comprises:

(i) a plurality of fiber-enriched hollow domed regions having a relatively high basis weight;

(ii) a plurality of connecting regions of a relatively lower basis weight forming a network interconnecting the relatively high local basis weight domed regions of the sheet; and

(iii) a plurality of transition regions with upwardly and inwardly inflected consolidated fibrous saddle shaped regions transitioning from the connecting regions into the domed regions.

58. The three-ply bath tissue of claim 57, wherein at least 50% of the high lignin eucalyptus fibers having a lignin content of at least about 20% are never dried fibers.

59. A three-ply bath tissue product having:

(a) an upper stratified ply comprising two strata, an outer stratum and an inner stratum,

(i) the outer stratum comprising a blend of at least about 30% to about 70% kraft fiber and at least 30% to about 70% by weight of eucalyptus kraft and having a basis weight of at least about 8.1 to about 19.5 g/m^2;

(ii) the inner stratum comprising at least about 50% eucalyptus fibers having a lignin content of at least about 20% by weight and a basis weight of at least about 3.3 g/m^2;

(b) an interior ply having a basis weight of at least about 9.8 to about 24.4 g/m^2, comprising:

(i) at least about 30% to about 70% eucalyptus fibers having a lignin content of at least about 20% by weight; and

(ii) from at least about 30% to about 70% by weight of bleached softwood kraft fibers; and

(c) a lower stratified ply comprising two strata, a first stratum and a second stratum,

(i) the first stratum comprising from at least about 30% to about 70% kraft fiber and from about 30% to about 70% by weight of eucalyptus kraft and having a basis weight of about 8.1 to about 19.5 g/m^2; and

(ii) the second stratum comprising at least about 50% eucalyptus fibers having a lignin content of at least about 20% by weight and a basis weight of at least about 3.3 g/m^2,

wherein at least one of the plies comprises:

(i) a plurality of fiber-enriched hollow domed regions having a relatively high basis weight;

(ii) a plurality of connecting regions of a relatively lower basis weight forming a network interconnecting the relatively high local basis weight domed regions of the sheet; and

(iii) a plurality of transition regions with upwardly and inwardly inflected consolidated fibrous saddle shaped regions transitioning from the connecting regions into the domed regions.

60. The three-ply bath tissue product of claim 59, wherein at least 50% of the high lignin eucalyptus fibers having a lignin content of at least about 20% are never dried fibers.

61. The three-ply bath tissue product of claim 59, wherein the interior ply and the upper ply have been joined by being embossed together.

62. The three-ply bath tissue product of claim 61, wherein the fibrous composition of the upper stratified ply is substantially the same as the fibrous composition of the lower stratified ply.

63. The three-ply bath tissue product of claim 61, wherein the depth of emboss of the lower stratified ply is less than 80% of the depth of emboss of the upper stratified ply.

64. The three-ply bath tissue product of claim 61, wherein the depth of emboss of the lower stratified ply is less than 50% of the depth of emboss of the upper stratified ply.

65. The three-ply bath tissue product of claim 61, wherein the lower stratified ply is generally unembossed.

66. The three-ply bath tissue product of claim 59, wherein the fibrous composition of the upper stratified ply is substantially the same as the fibrous composition of the lower stratified ply.

67. The three-ply bath tissue product of claim 59, wherein the outer stratum of the upper ply further comprises at least about 5% by weight of individualized regenerated cellulosic microfiber having a diameter of no more than about 5 microns and passing a screen of about 14 mesh.

68. The three-ply bath tissue product of claim 59, wherein the outer stratum of the upper ply further comprises at least about 5% by weight of individualized regenerated cellulosic microfiber having a number average diameter of no more than about 4 microns and a number average length of between about 50 microns and 2000 microns.

69. The three-ply bath tissue product of claim 60, wherein the outer stratum of the upper ply comprises at least about 8% by weight of individualized regenerated cellulosic microfiber.

70. The three-ply bath tissue product of claim 60, wherein the outer stratum of the upper ply comprises at least about 8% by weight of individualized regenerated cellulosic microfiber having a number average diameter of at most about 2 microns.

71. The three-ply bath tissue product of claim 59, wherein the outer stratum of the upper ply further comprises at least about 10% by weight of individualized regenerated cellulosic microfiber having a number average diameter of at most about 4 microns and a number average length of between about 50 microns and 2000 microns.

72. The three-ply bath tissue product of claim 63, wherein the outer stratum of the upper ply comprises at least about 8% by weight of individualized regenerated cellulosic microfiber having a number average diameter of at most about 2 microns.

73. The three-ply bath tissue product of claim 59, wherein the outer stratum of the upper ply further comprises at least about 10% by weight of individualized regenerated cellulosic microfiber having a number average diameter of at most about 2 microns and a number average length of between about 50 microns and 2000 microns.

74. The three-ply bath tissue product of claim 65, wherein the outer stratum of the upper ply comprises at least about 5% by weight of individualized regenerated cellulosic microfiber having a number average diameter of at most about 1 micron.

75. The three-ply bath tissue product of claim 59, wherein the outer stratum of each of the upper ply and the lower ply further comprises at least about 5% by weight of individualized regenerated cellulosic microfiber having a number average diameter of at most about 4 microns and a number average length of between about 50 microns and 2000 microns.

76. The three-ply bath tissue product of claim 59, wherein each of the inner stratum of the upper ply and the second stratum of the lower ply comprises at least about 70% eucalyptus fibers having a lignin content of at least about 20% by weight.

77. The three-ply bath tissue product of claim 59, wherein each of the inner stratum of the upper ply and the second stratum of the lower ply comprises debonder.

78. The three-ply bath tissue product of claim 59, wherein the interior ply is creped, exhibiting a percent crepe at least 3% greater than that of the exterior plies.

79. A three-ply bath tissue product having:

(a) an upper stratified ply comprising two strata, an outer stratum and an inner stratum,

(i) the outer stratum comprising a blend of at least about 30% to about 70% kraft fiber and at least 30% to about 70% by weight of eucalyptus kraft and at least about 5% by weight of individualized regenerated cellulosic microfiber having a number average diameter of at most about 4 microns and a number average length of between about 50 microns and 2000 microns, the outer stratum having a basis weight of at least about 8.1 to about 19.5 g/m^2;

(ii) the inner stratum comprising at least about 70% eucalyptus fibers having a lignin content of at least about 20% by weight, and a basis weight of at least about 3.3 g/m^2;

(b) an interior ply having a basis weight of at least about 9.8 to about 24.4 g/m^2, comprising:

(i) at least about 40% to about 90% eucalyptus fibers having a lignin content of at least about 20% by weight; and

(ii) from at least about 10% to about 60% by weight of bleached kraft fiber; and

(c) a lower stratified ply comprising at least two strata, including a first stratum and a second stratum,

(i) the first stratum comprising from at least about 30% to about 70% kraft fiber and from about 30% to about 70% by weight of eucalyptus kraft and having a basis weight of about 8.1 to about 19.5 g/m^2; and

(ii) the second stratum comprising at least about 70% eucalyptus fibers having a lignin content of at least about 20% by weight and a basis weight of at least about 3.3 g/m^2,

wherein at least one of the plies, other than an interior ply, comprises:

(i) a plurality of fiber-enriched hollow domed regions having a relatively high basis weight;

(ii) a plurality of connecting regions of a relatively lower basis weight forming a network interconnecting the relatively high local basis weight domed regions of the sheet; and

(iii) a plurality of transition regions with upwardly and inwardly inflected consolidated fibrous saddle shaped regions transitioning from the connecting regions into the domed regions.

80. The three-ply bath tissue product of claim 79, wherein the upper stratified ply and the lower stratified have substantially identical fibrous compositions.

81. The three-ply bath tissue product of claim 79, exhibiting an ISO brightness of at least:

$0.82 \times (\%VCP) + .795 \times (\%RF)^{98} + 0.84 \times (\%APMP + CFM)$,

where %VCP is the percentage of virgin chemical pulp in the sheet in the outer ply; %RF, the percentage of recycle fiber in the outer ply and %APMP+CMF is the percentage of APMP eucalyptus and regenerated cellulosic microfiber in the outer ply.

82. The three-ply bath tissue product of claim 79, wherein a major portion of the eucalyptus fibers in the interior ply are never dried fibers having a lignin content of at least about 23%, and exhibit an ISO brightness of at least about 82.

83. The three-ply bath tissue product of claim 79, wherein the weight percentage of chemically pulped softwood fiber in the tissue is limited to at most 30% of the weight of the three-ply tissue product.

84. The three-ply bath tissue product of claim 79, wherein a major portion of the eucalyptus fibers in the interior ply have a lignin content of at least about 23%, and exhibit an ISO brightness of at least about 82.

85. A multi-ply bath tissue having a basis weight of from about 32.6 to 65.1 g/m^2, and comprising:

(a) from about 3% to about 50% cellulosic microfiber; and

(b) from about 50% to about 97% wood pulp fibers,

the multi-ply bath tissue having:

(i) a GM dry tensile of from about 1.34 to 6.33 N/m per g/m^2 of basis weight;

(ii) a CD dry tensile of between about 2.37 to about 4.74 N/m per g/m^2 of basis weight;

(iii) sufficient temporary wet strength resin to provide an initial Finch Cup CD wet tensile of from about 0.32 to 2.57 N/m per g/m^2 of basis weight, the initial Finch Cup CD wet tensile decaying to less than 65% of the initial value in less than 15 minutes after immersion in water; and

(iv) a caliper of at least 0.078 mm per 8 sheets per g/m^2 of basis weight.

86. The multi-ply bath tissue of claim 85, having an opacity of at least about 1.5 MacBeth Opacity Units per g/m^2 of basis weight.

87. The multi-ply bath tissue of claim 85, comprising from about 5% to about 25% cellulosic microfiber and from about 75% to about 85% wood pulp fibers.

88. The multi-ply bath tissue of claim 85, having a basis weight of from about 35.8 to 52.1 g/m^2.

89. The multi-ply bath tissue of claim 85, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 35 mm^2.

90. The multi-ply bath tissue of claim 85, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 30 mm^2.

91. The multi-ply bath tissue of claim 85, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 25 mm^2.

92. The multi-ply bath tissue of claim 85, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 20 mm^2.

93. The multi-ply bath tissue of claim 85, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 6.0.

94. The multi-ply bath tissue of claim 85, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 5.0.

95. The multi-ply bath tissue of claim 85, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 4.5.

96. The multi-ply bath tissue of claim 85, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 4.25.

97. The multi-ply bath tissue of claim 85, wherein the plies are joined to each other by knurling.

98. The multi-ply bath tissue of claim 85, wherein the plies are embossed with a pattern having primarily points to the inside and are joined by glue-lamination.

99. A bath tissue having a basis weight of from about 32.6 to 65.1 g/m^2, and comprising:

(a) from about 3% to about 50% cellulosic microfiber; and

(b) from about 50% to about 97% wood pulp fibers,

the bath tissue having:

(i) a GM dry tensile of from about 1.34 to 6.33 N/m per g/m^2 of basis weight;

(ii) a CD dry tensile of between about 2.37 to about 4.74 N/m per g/m^2 of basis weight;

(iii) sufficient temporary wet strength resin to provide an initial Finch Cup CD wet tensile of from about 0.20 to about 1.58 N/m per g/m^2 of basis weight, the initial Finch Cup CD wet tensile decaying to less than 65% of the initial value in less than 15 minutes after immersion in water; and

(iv) a caliper of at least 0.078 mm per 8 sheets per g/m^2 of basis weight.

100. The bath tissue of claim 99, having an opacity of at least about 1.5 MacBeth Opacity Units per g/m^2 of basis weight.

101. The bath tissue of claim 99, comprising from about 5% to about 25% cellulosic microfiber and from about 75% to about 85% wood pulp fibers.

102. The bath tissue of claim 99, having a basis weight of from about 35.8 to 52.1 g/m^2.

103. The bath tissue of claim 99, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 35 mm^2.

104. The bath tissue of claim 99, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 30 mm^2.

105. The bath tissue of claim 99, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 25 mm^2.

106 The bath tissue of claim 99, wherein, when tested according to the Wet Abrasion Lint Test, the Wet Abraded Lint Area is less than 20 mm^2.

107. The bath tissue of claim 99, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 6.0.

108. The bath tissue of claim 99, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 5.0.

109. The bath tissue of claim 99, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 4.5.

110. The bath tissue of claim 99, wherein, when tested according to the Dry Lint Test, the ΔL^* is less than 4.25.

FIG. 1

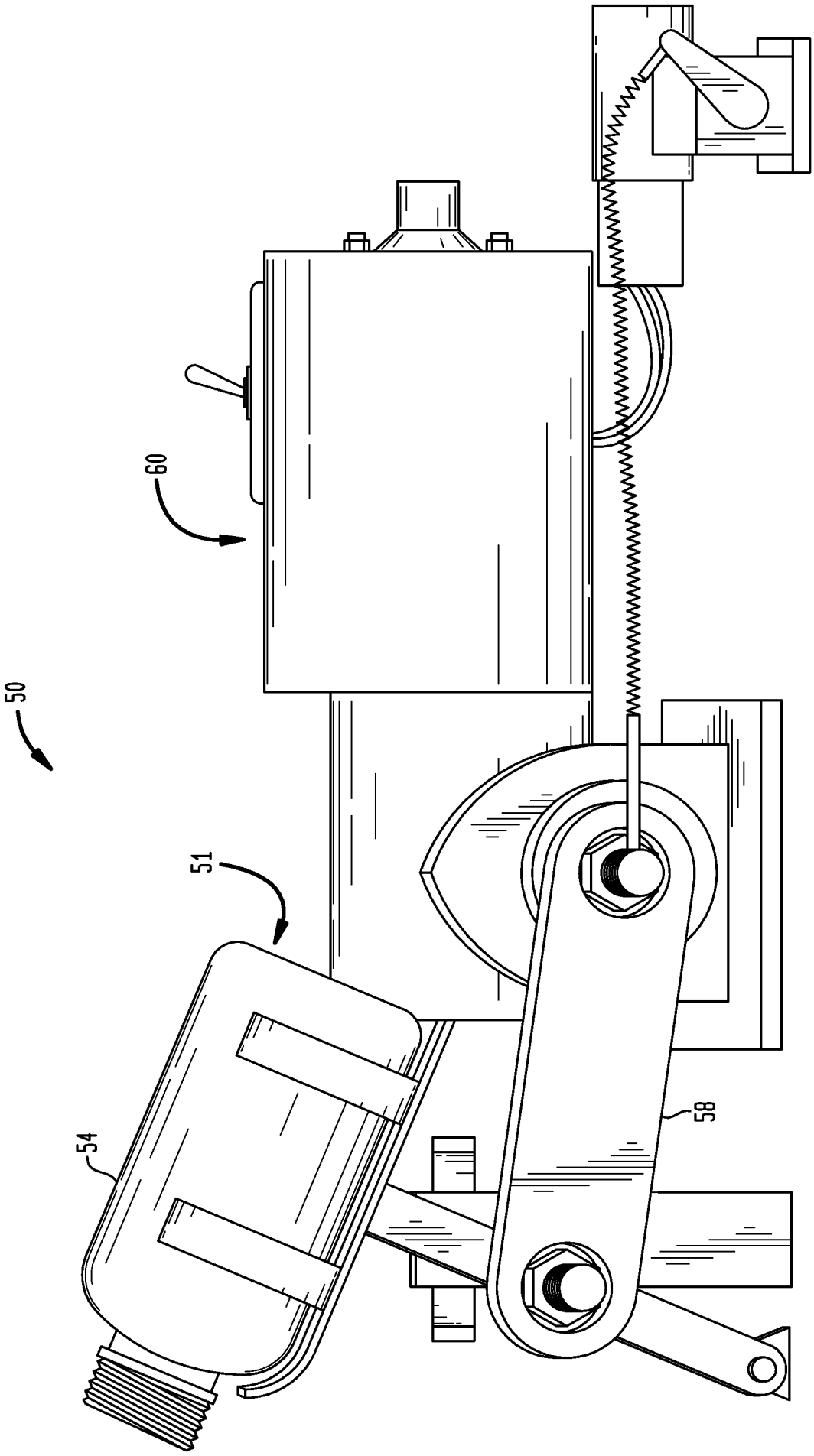


FIG. 2

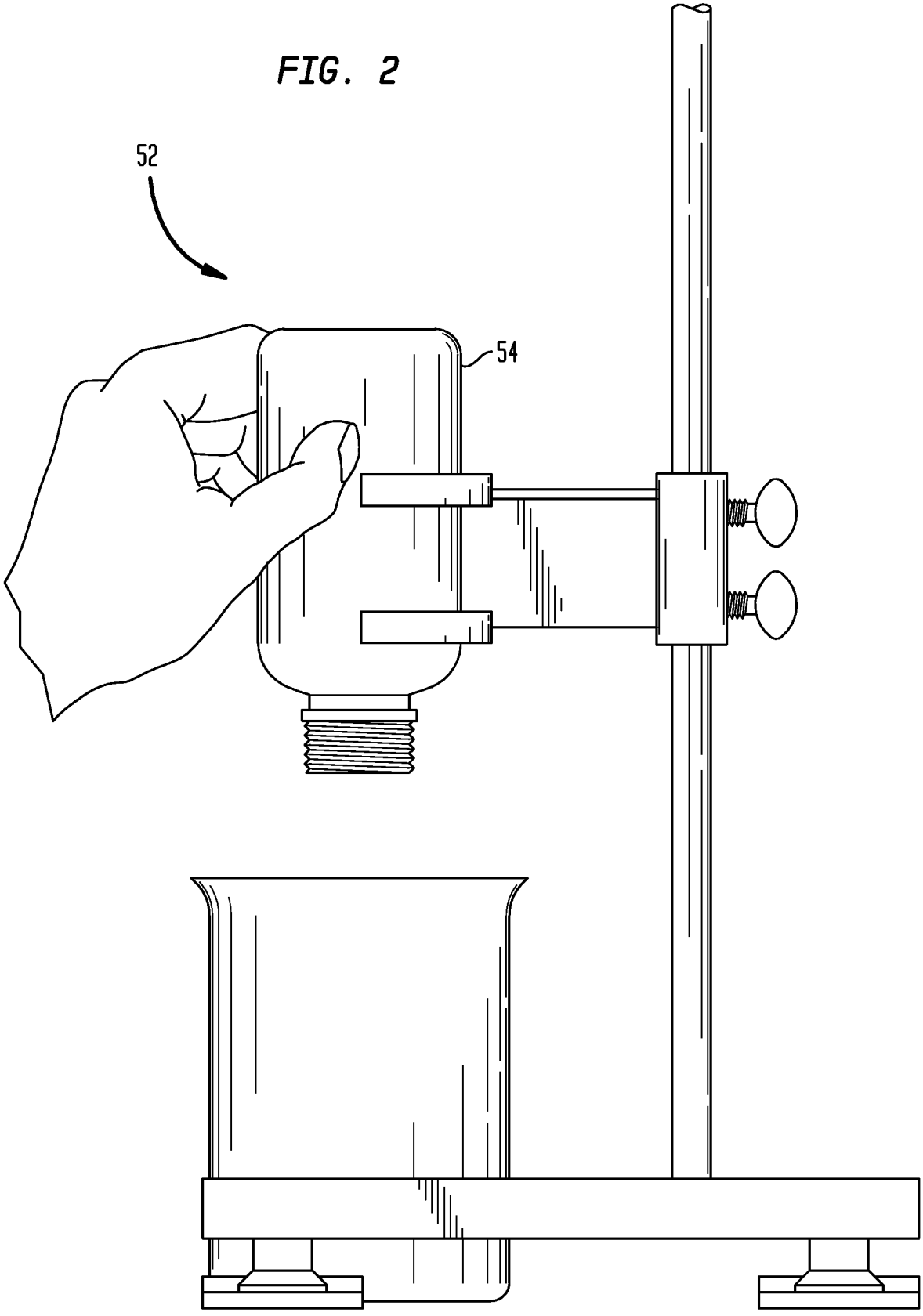
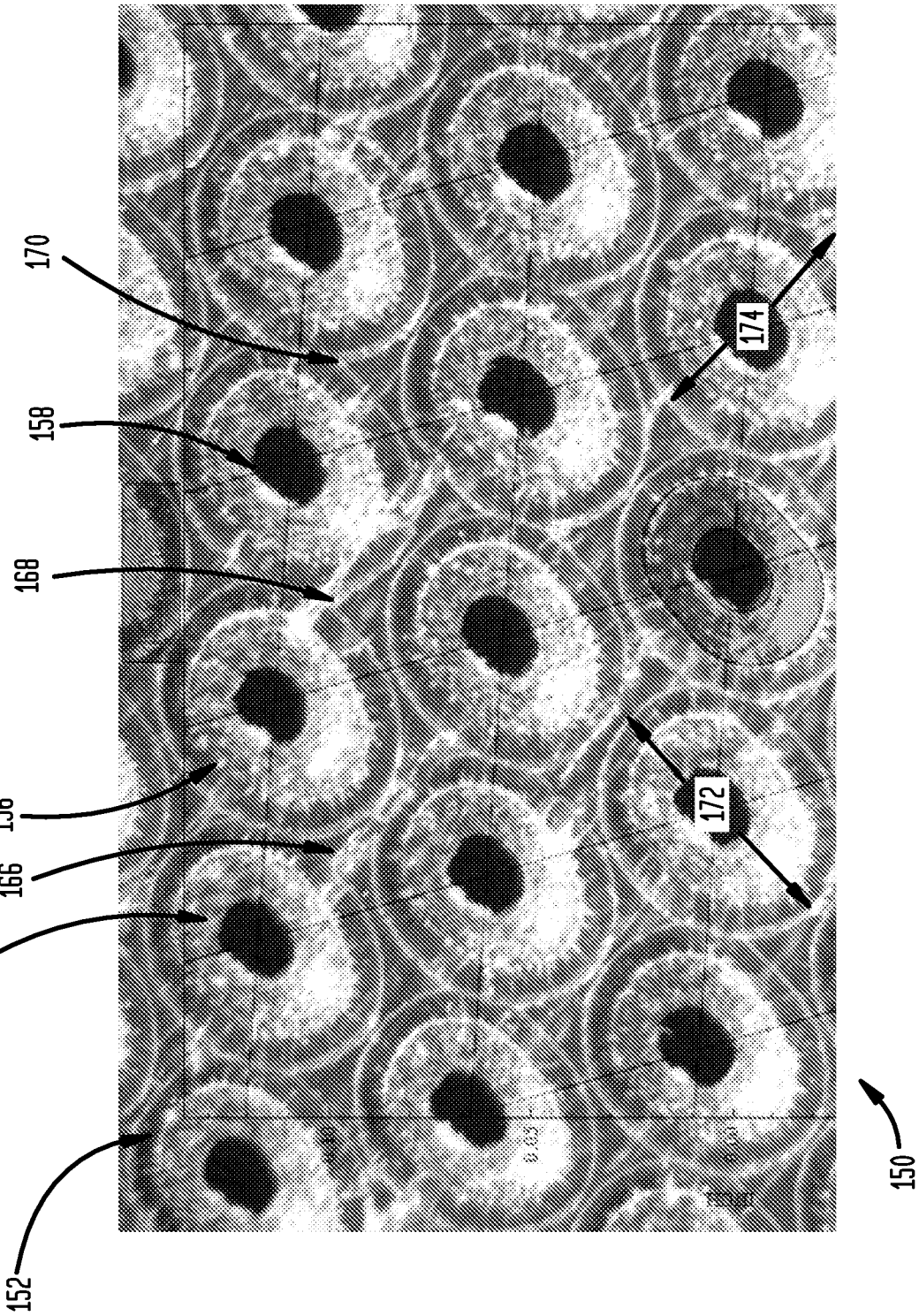


FIG. 3



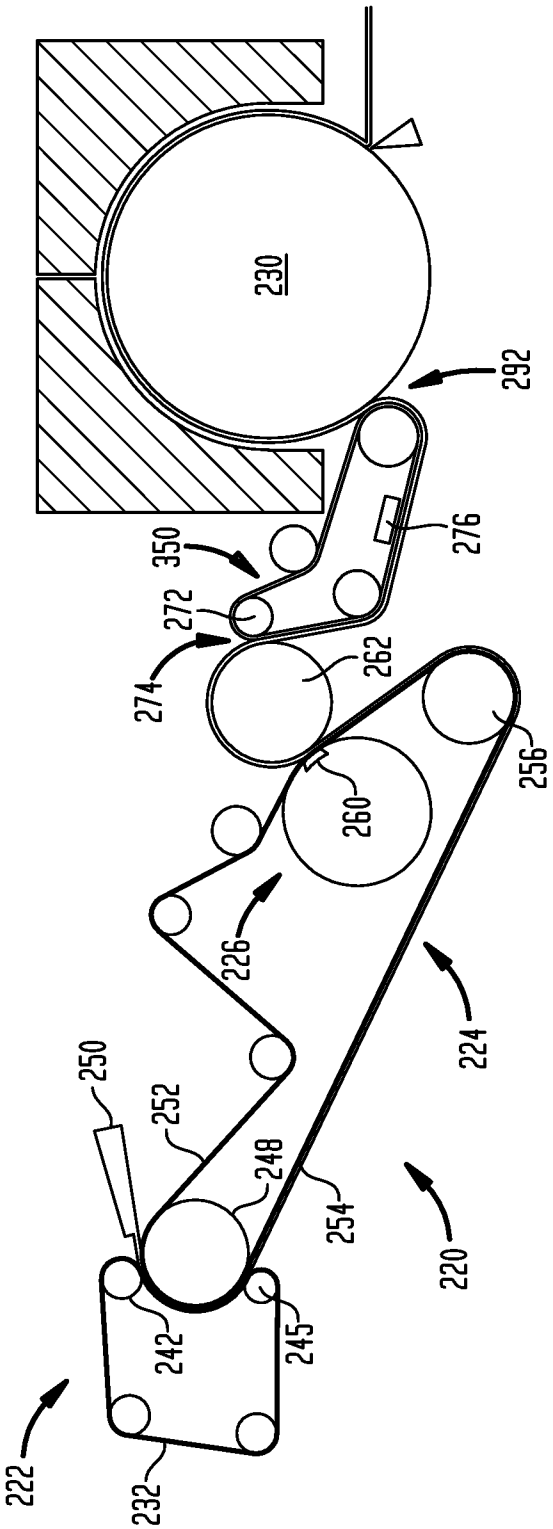

230
292
276
350
272
274
262
256
260
226
224
250
252
248
254
220
242
245
222
232

FIG. 4

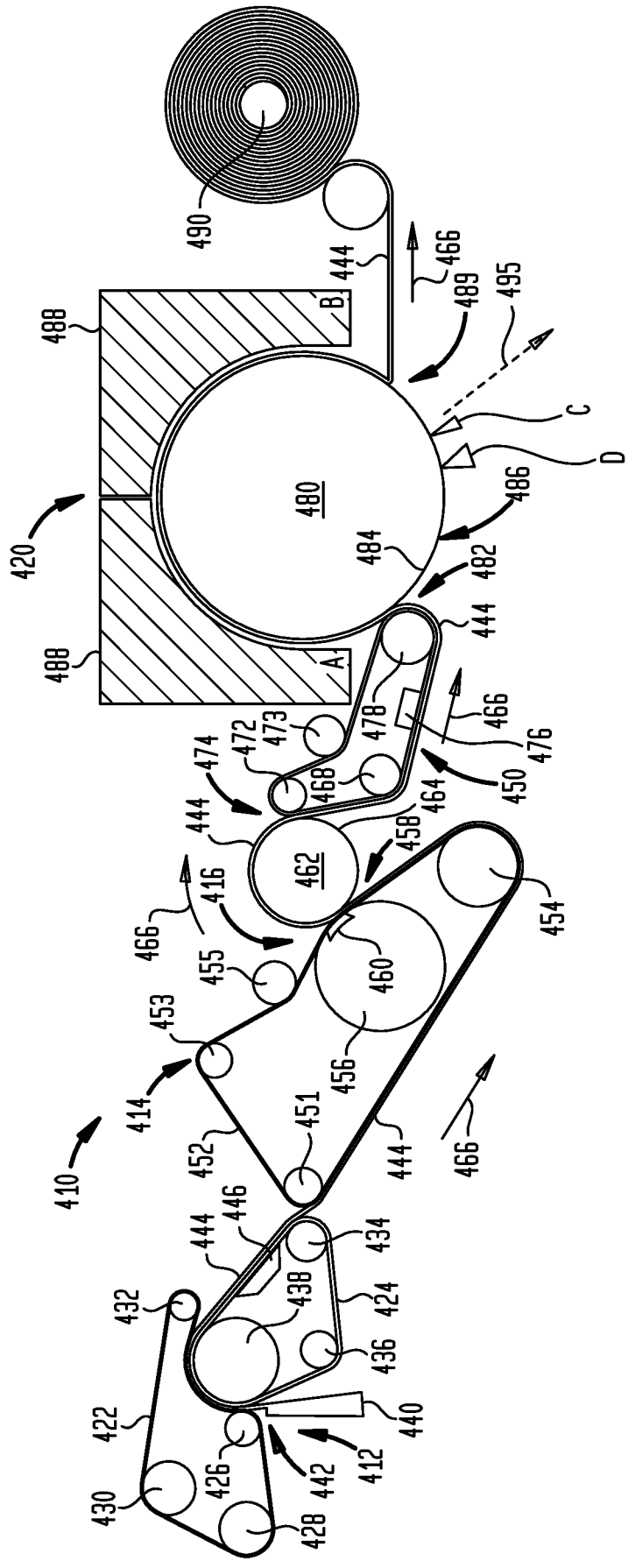

490
444
466
489
495
488
B
C
D
480
486
420
484
482
444
488
A
466
478
473
472
474
476
468
450
464
444
458
462
454
416
466
455
460
453
456
414
451
452
444
466
410
446
444
434
438
424
432
436
422
440
426
412
442
430
428

FIG. 5

FIG. 6A

QUILTED NORTHERN® ULTRA PLUSH

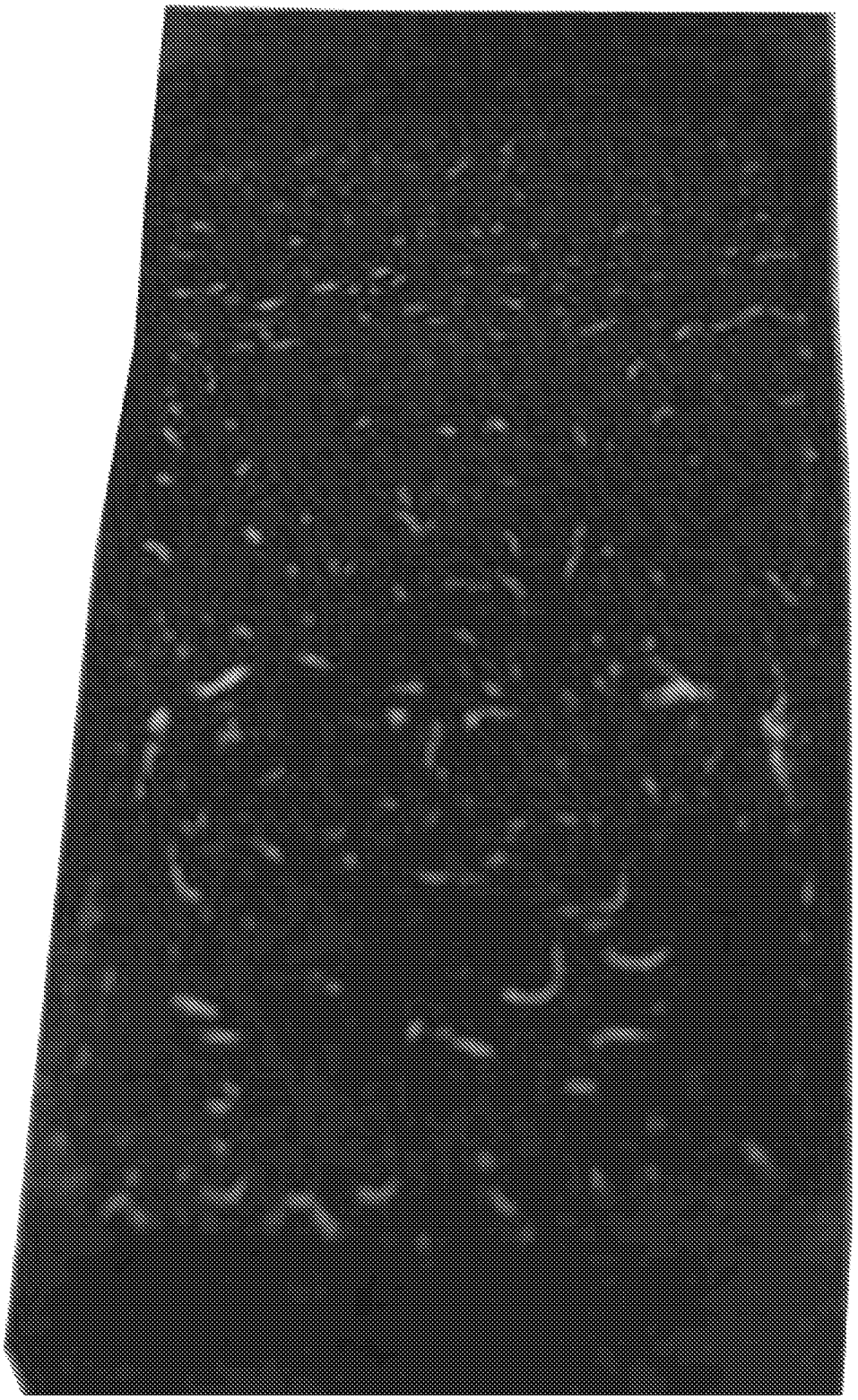


FIG. 6B

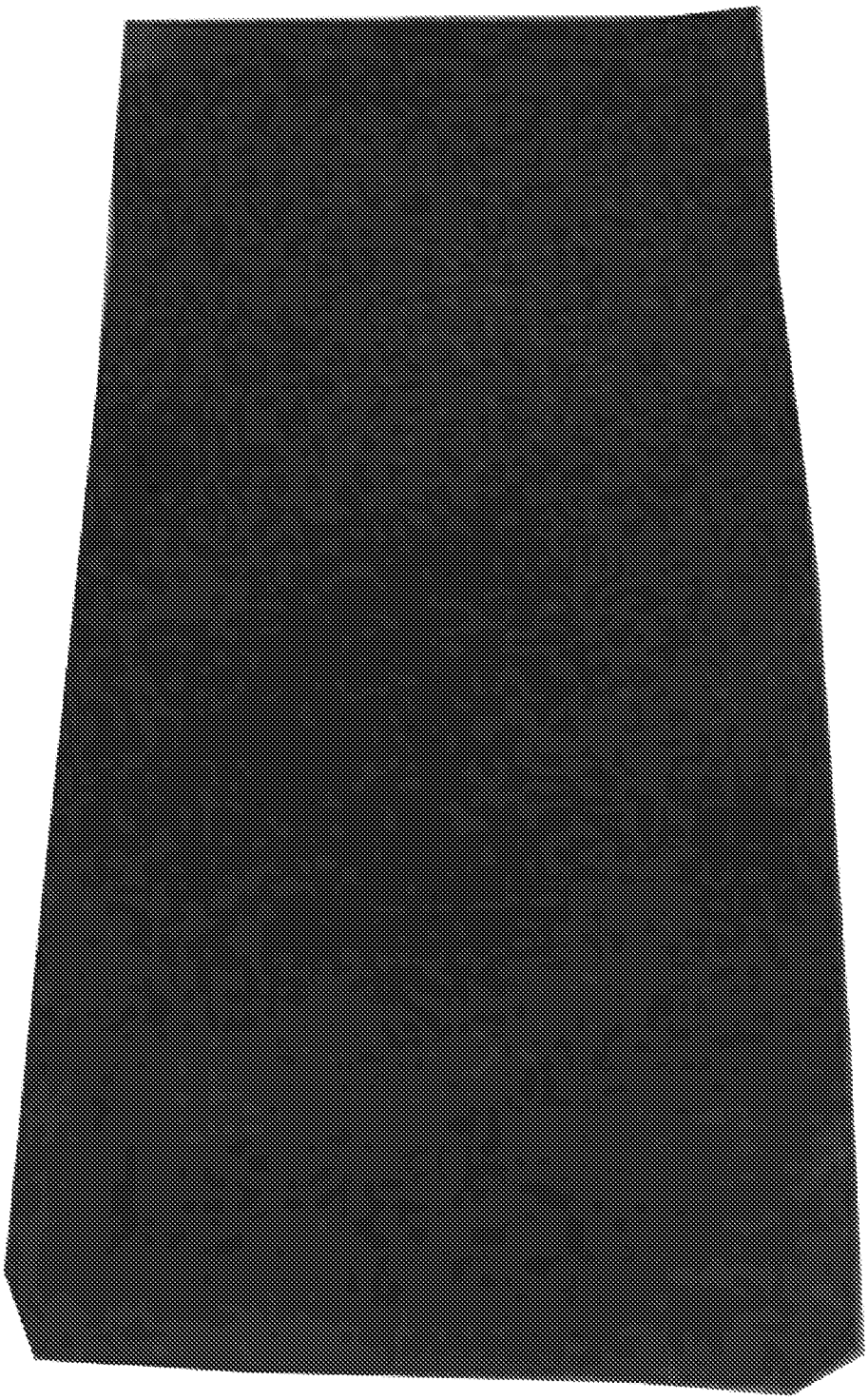


FIG. 6C

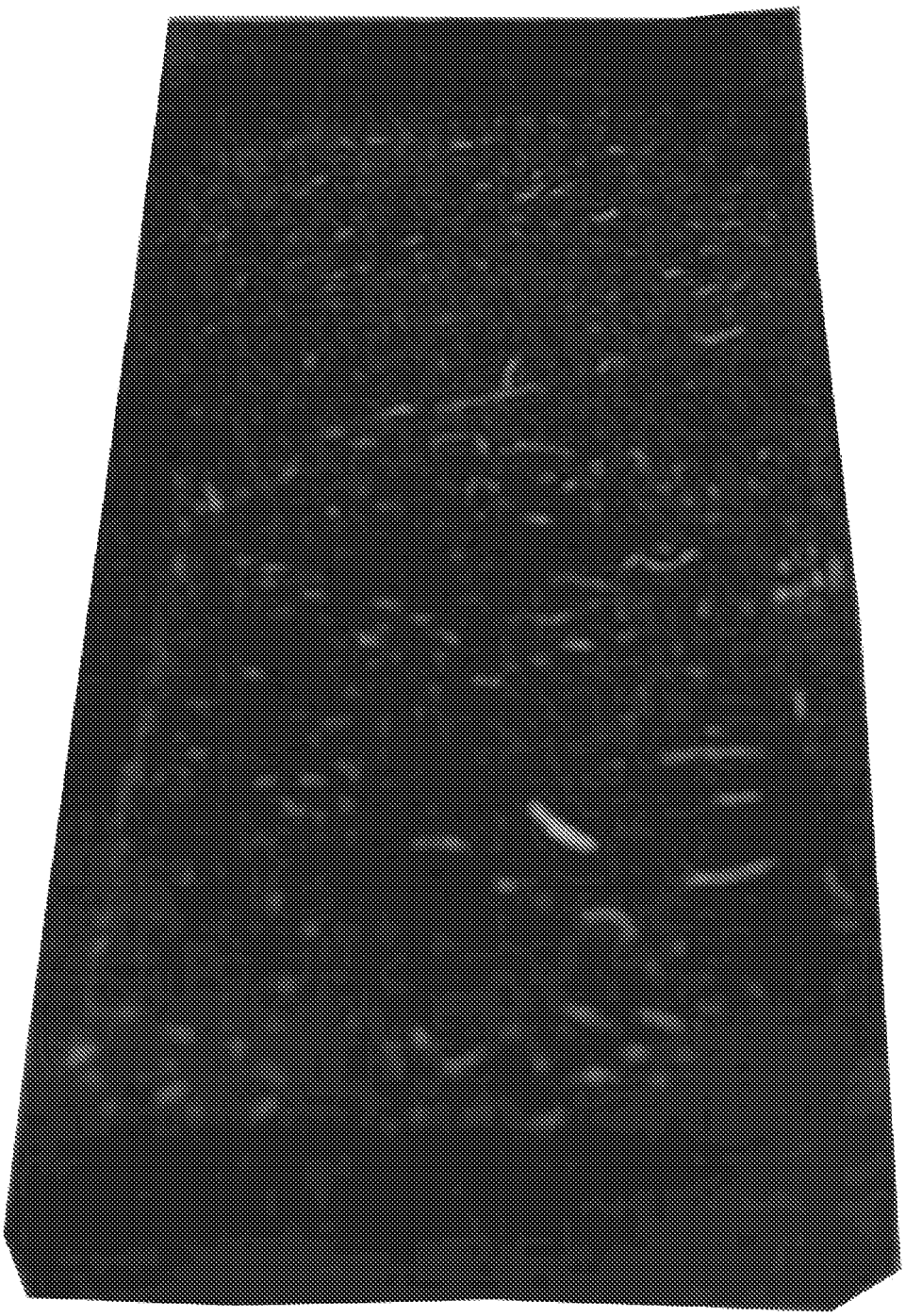


FIG. 6D

FIG. 7

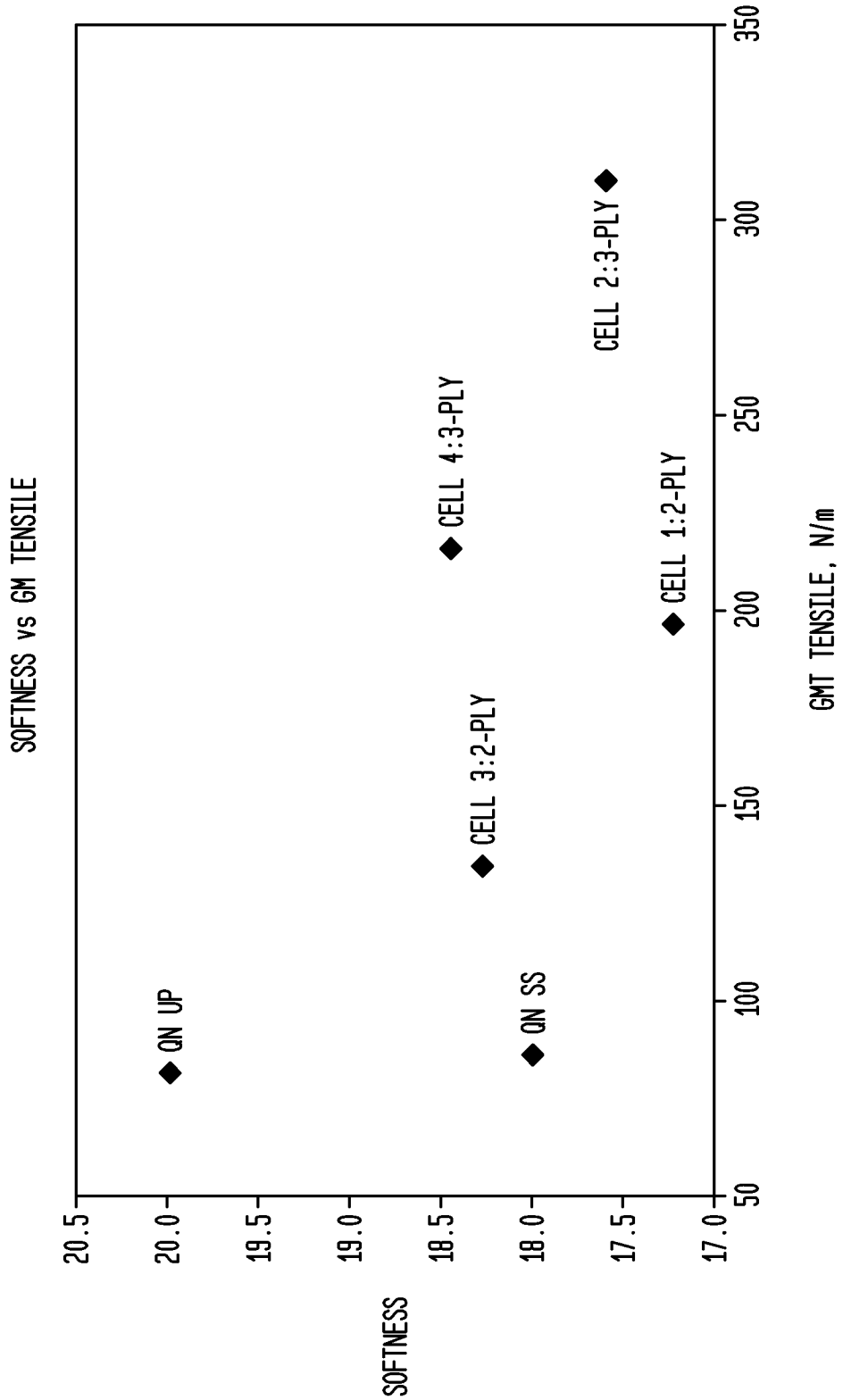

SOFTNESS vs GM TENSILE
SOFTNESS
GMT TENSILE, N/m
20.5
20.0
19.5
19.0
18.5
18.0
17.5
17.0
50
100
150
200
250
300
350
QN UP
QN SS
CELL 3:2-PLY
CELL 4:3-PLY
CELL 1:2-PLY
CELL 2:3-PLY

FIG. 8A

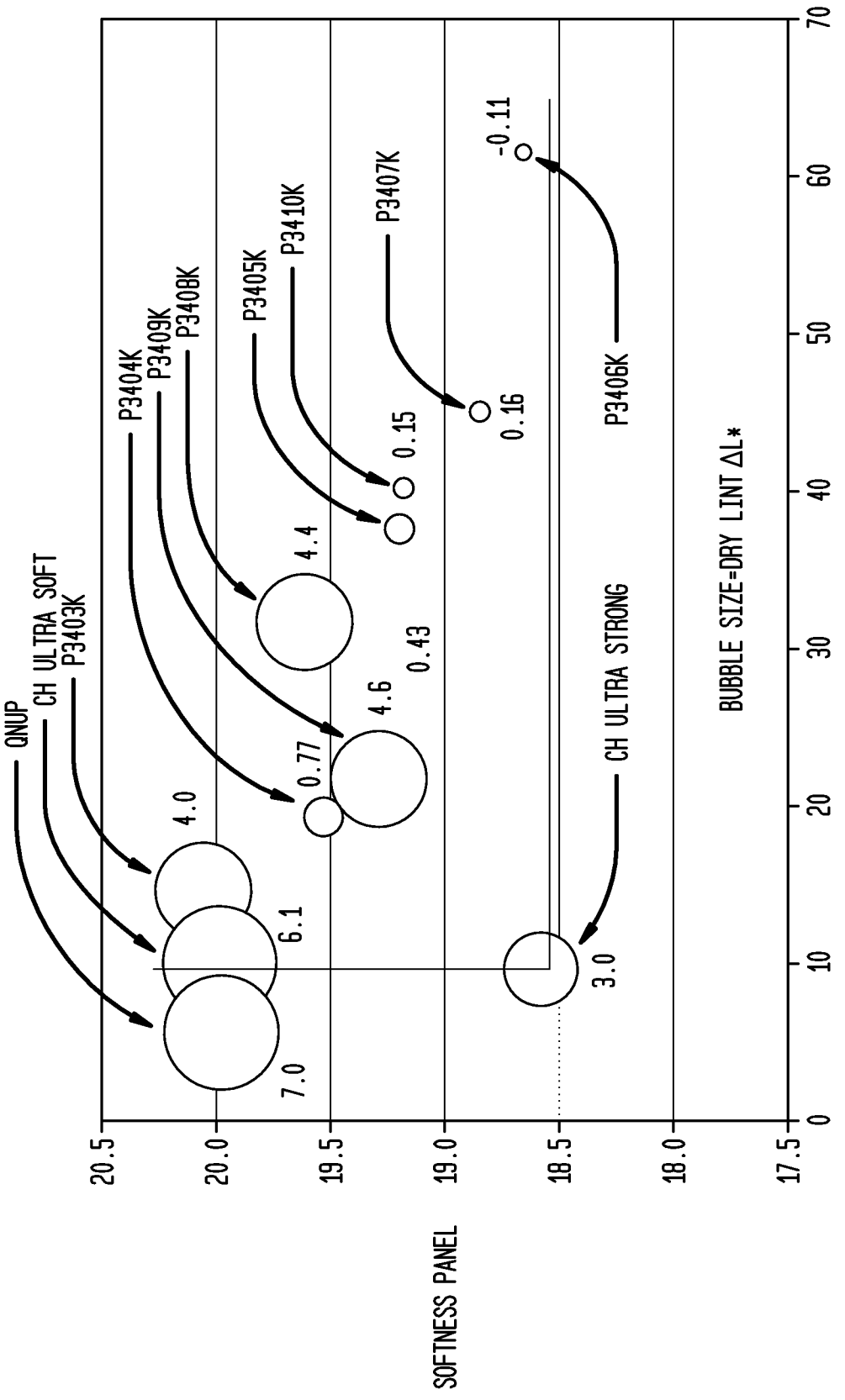

QNUP
CH ULTRA SOFT
P3403K
P3404K
P3409K
P3408K
P3405K
P3410K
P3407K
P3406K
CH ULTRA STRONG
7.0
6.1
4.0
0.77
4.6
0.43
4.4
0.15
0.16
-0.11
3.0
BUBBLE SIZE=DRY LINT ΔL*
SOFTNESS PANEL
CD WET TENSILE, N/m
20.5
20.0
19.5
19.0
18.5
18.0
17.5
0
10
20
30
40
50
60
70

FIG. 8B

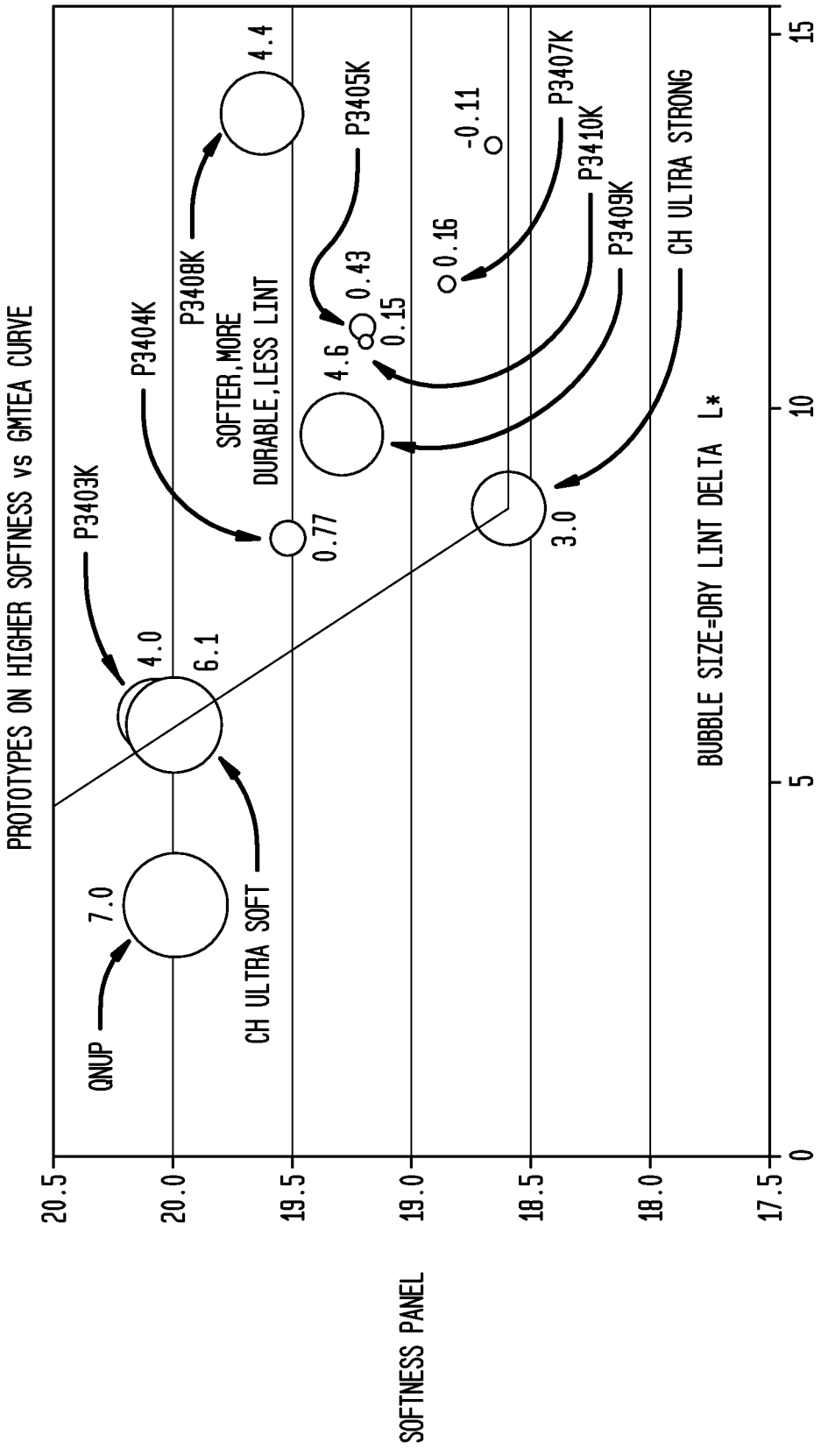

PROTOTYPES ON HIGHER SOFTNESS vs GMTEA CURVE
SOFTER, MORE DURABLE, LESS LINT
BUBBLE SIZE=DRY LINT DELTA L*
SOFTNESS PANEL
GM TEA, J/m2
20.5
20.0
19.5
19.0
18.5
18.0
17.5
0
5
10
15
QNUP
7.0
P3403K
4.0
CH ULTRA SOFT
6.1
P3404K
0.77
P3408K
4.4
4.6
P3405K
0.43
0.15
0.16
-0.11
P3407K
P3410K
P3409K
3.0
CH ULTRA STRONG

FIG. 8C

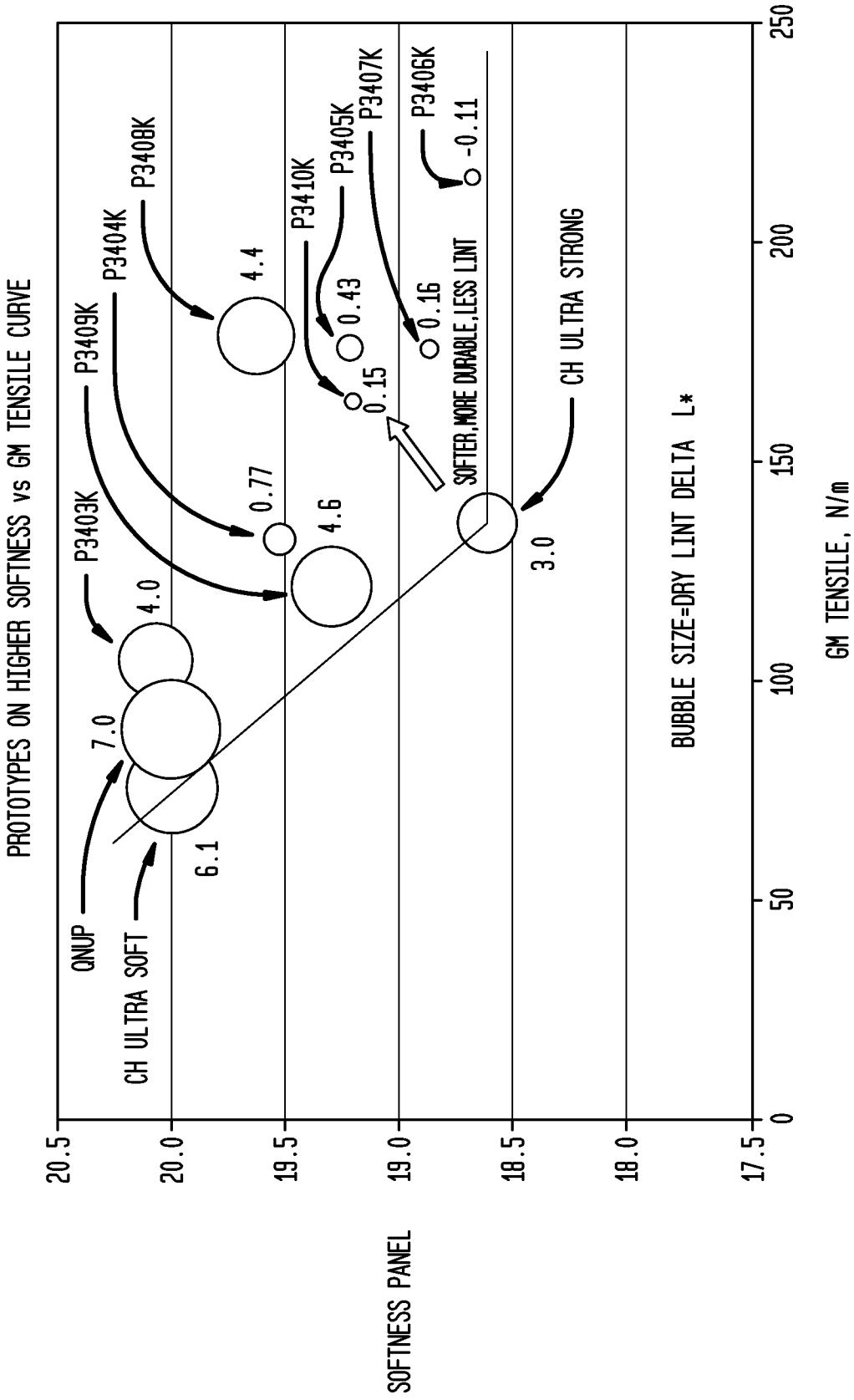

PROTOTYPES ON HIGHER SOFTNESS vs GM TENSILE CURVE
QNUP
CH ULTRA SOFT
P3403K
P3409K
P3404K
P3408K
P3410K
P3405K
P3407K
P3406K
7.0
4.0
6.1
0.77
4.6
4.4
0.43
0.15
0.16
-0.11
SOFTER, MORE DURABLE, LESS LINT
3.0
CH ULTRA STRONG
BUBBLE SIZE=DRY LINT DELTA L*
SOFTNESS PANEL
GM TENSILE, N/m
20.5
20.0
19.5
19.0
18.5
18.0
17.5
0
50
100
150
200
250

FIG. 8D

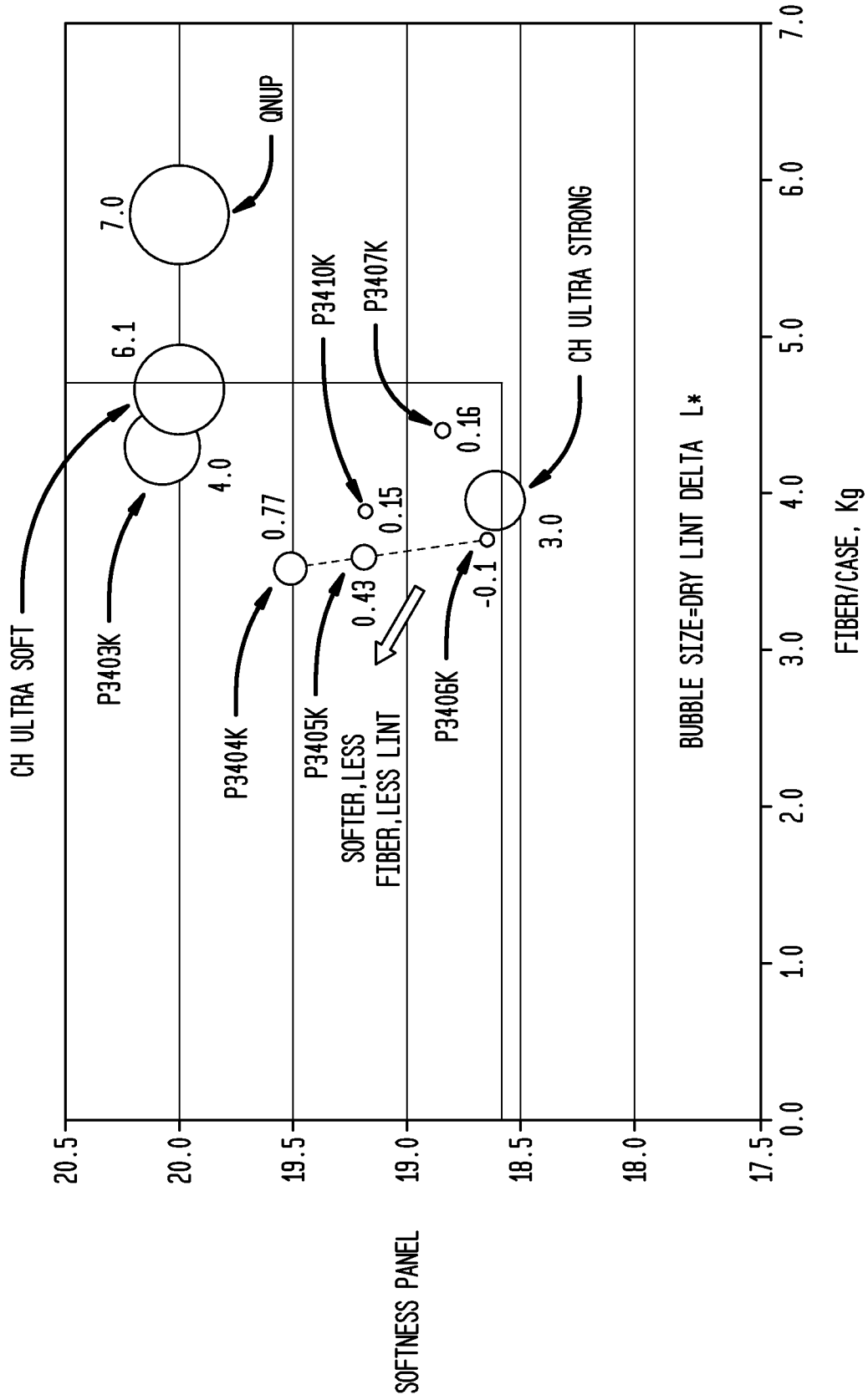

CH ULTRA SOFT
P3403K
P3404K
P3405K
SOFTER, LESS FIBER, LESS LINT
P3406K
P3410K
P3407K
CH ULTRA STRONG
QNUP
7.0
6.1
4.0
0.77
0.43
0.15
-0.1
0.16
3.0
BUBBLE SIZE=DRY LINT DELTA L*
SOFTNESS PANEL
FIBER/CASE, Kg
20.5
20.0
19.5
19.0
18.5
18.0
17.5
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0

FIG. 9A

P3403 K

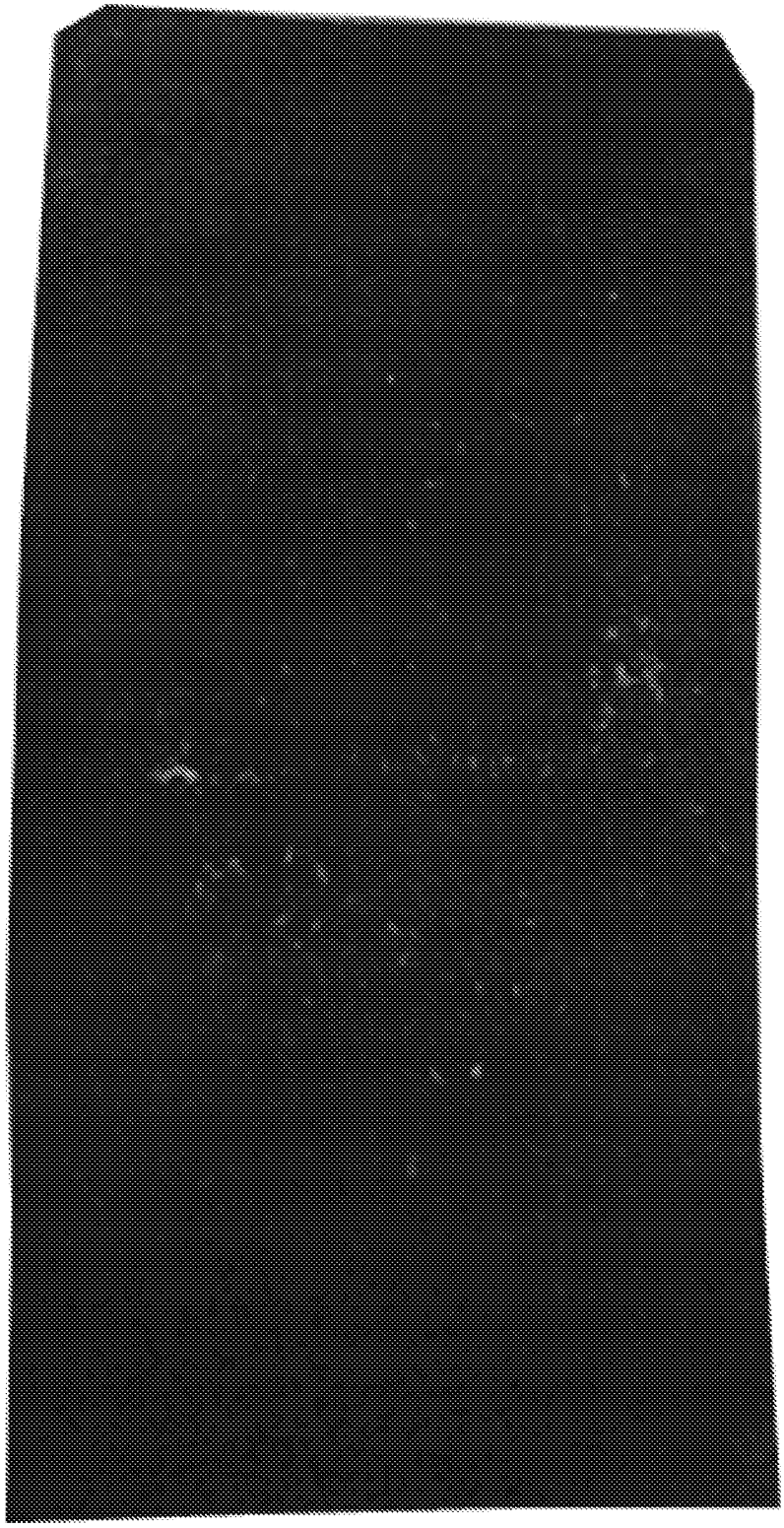


FIG. 9B

P3405 K

FIG. 9C

FIG. 9D

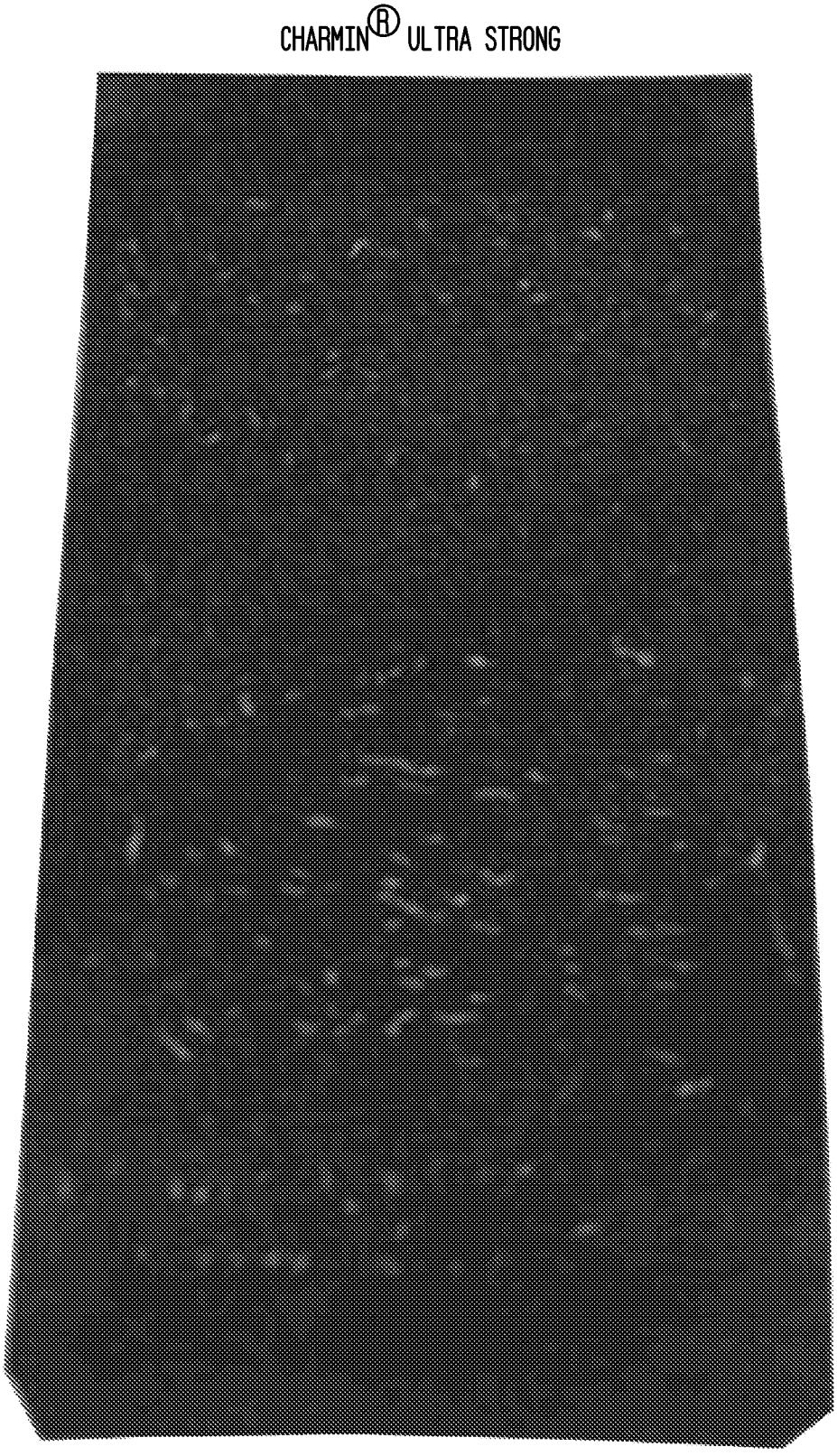


FIG. 9E

COTTONELLE® FRESH

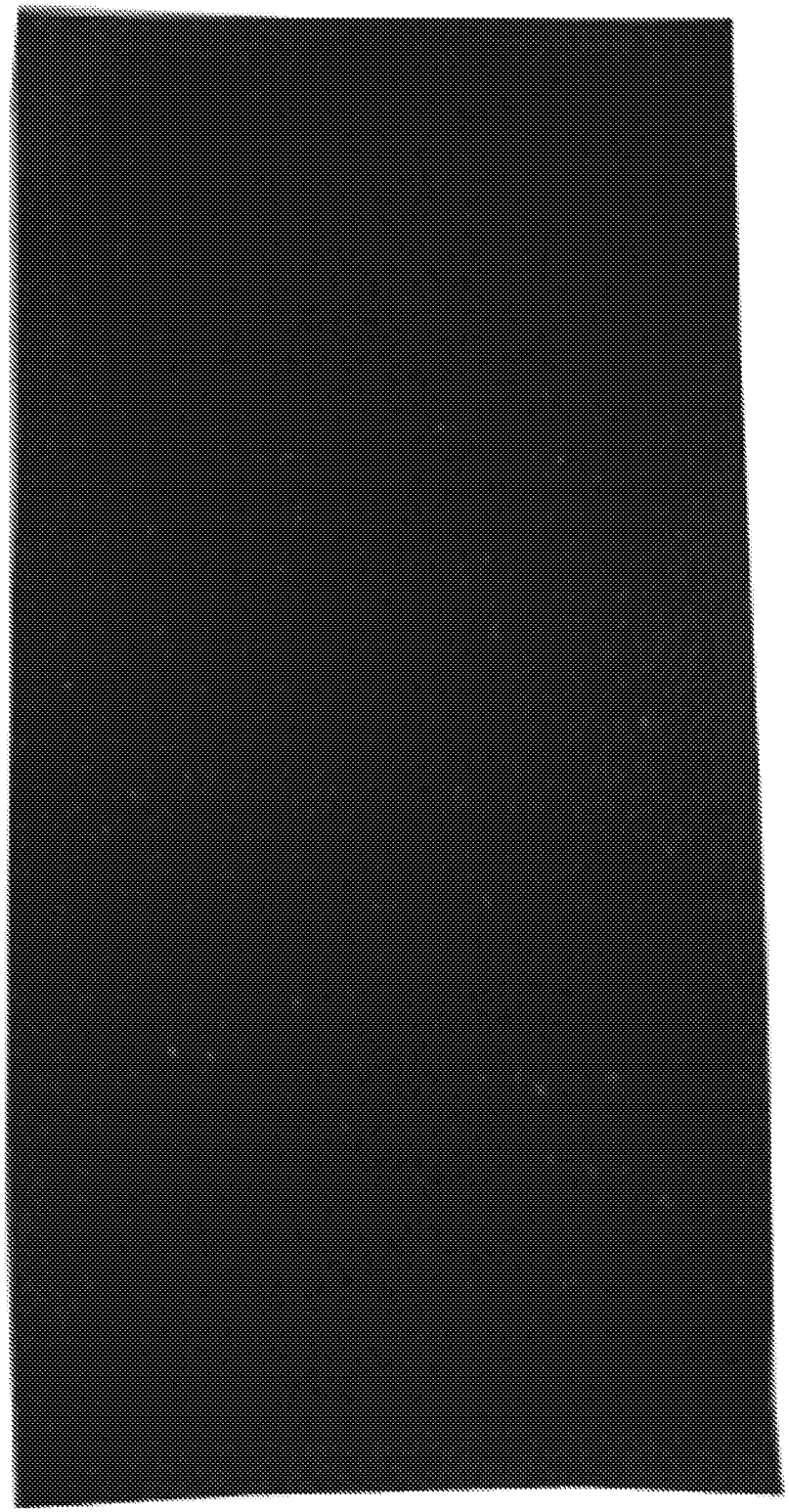


FIG. 11

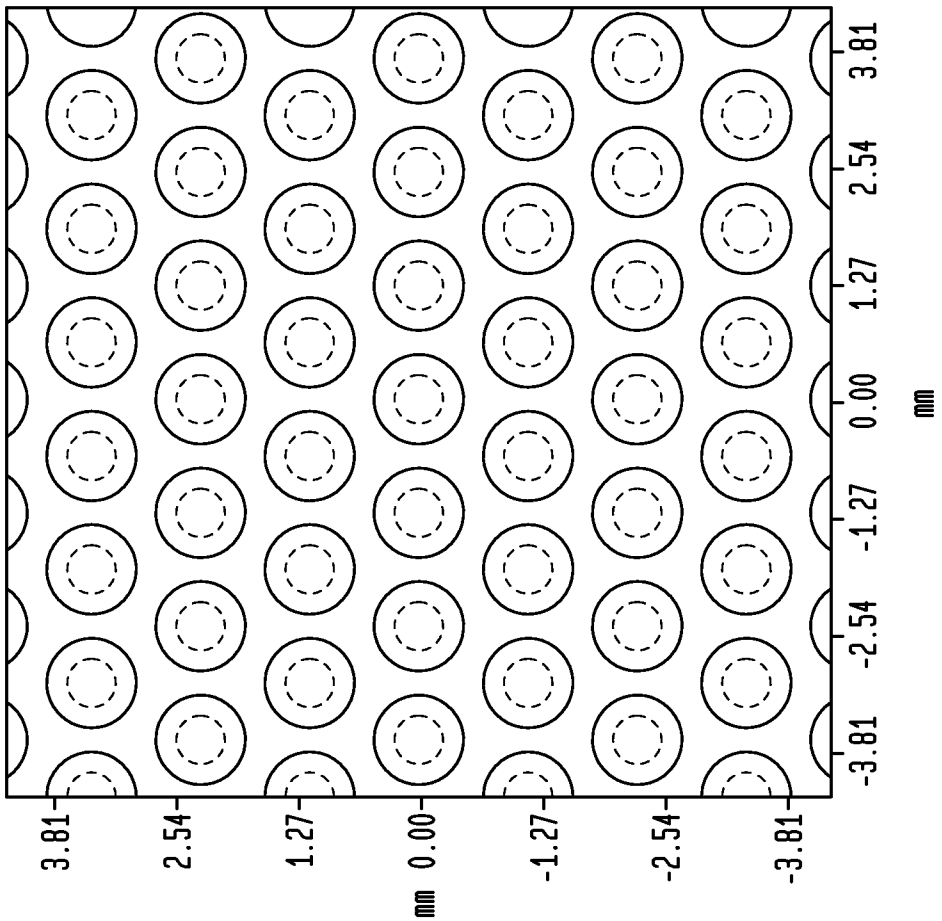


FIG. 10

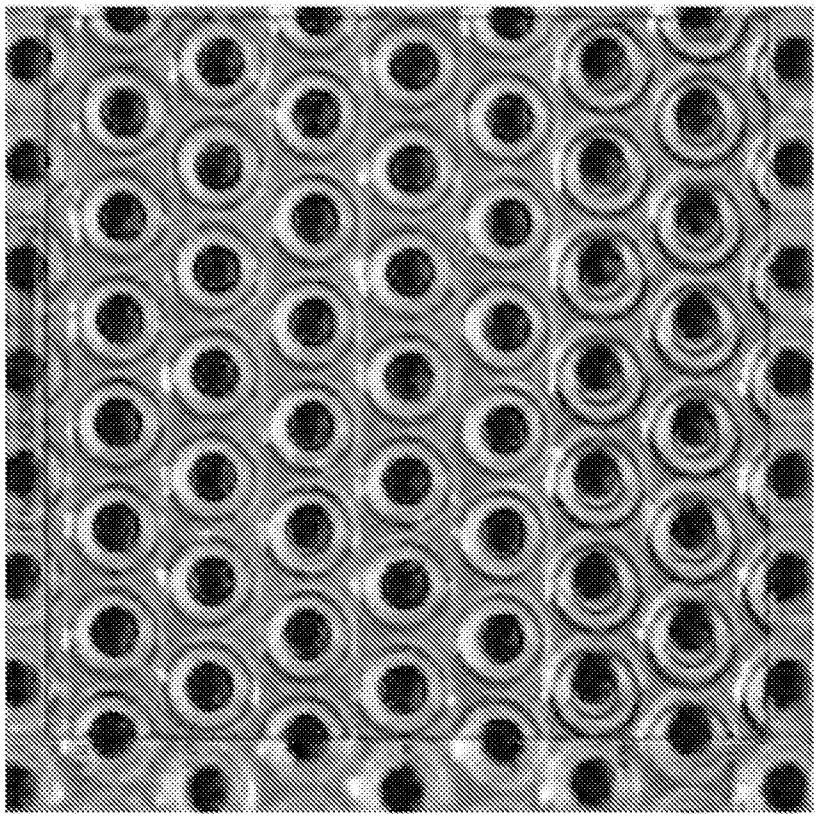


FIG. 12

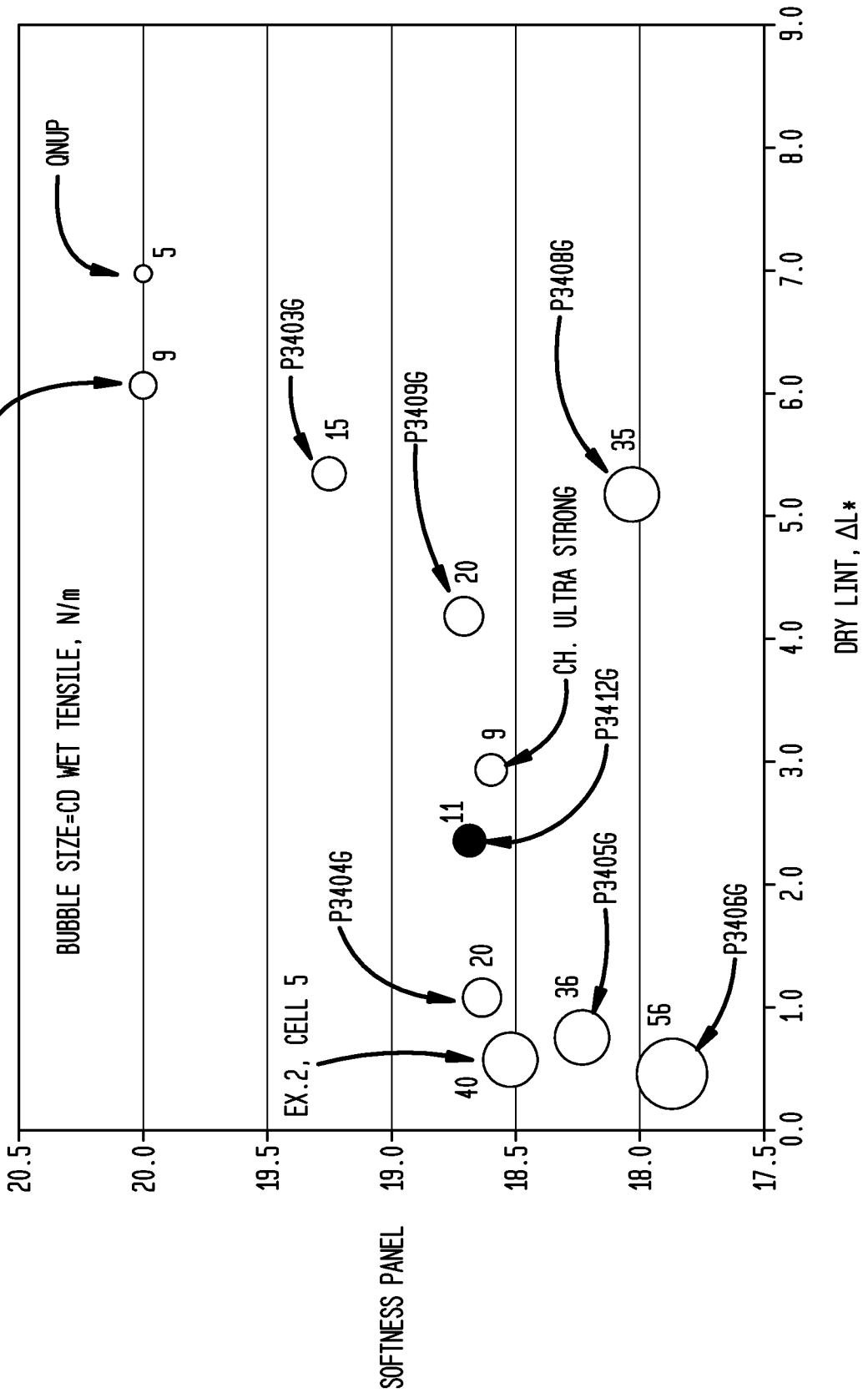

BUBBLE SIZE=CD WET TENSILE, N/m
SOFTNESS PANEL
DRY LINT, ΔL*
20.5
20.0
19.5
19.0
18.5
18.0
17.5
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
CH ULTRA SOFT
QNUP
5
9
P3403G
15
P3409G
20
P3408G
35
CH. ULTRA STRONG
9
P3412G
11
P3404G
20
EX.2, CELL 5
40
P3405G
36
P3406G
56

FIG. 13

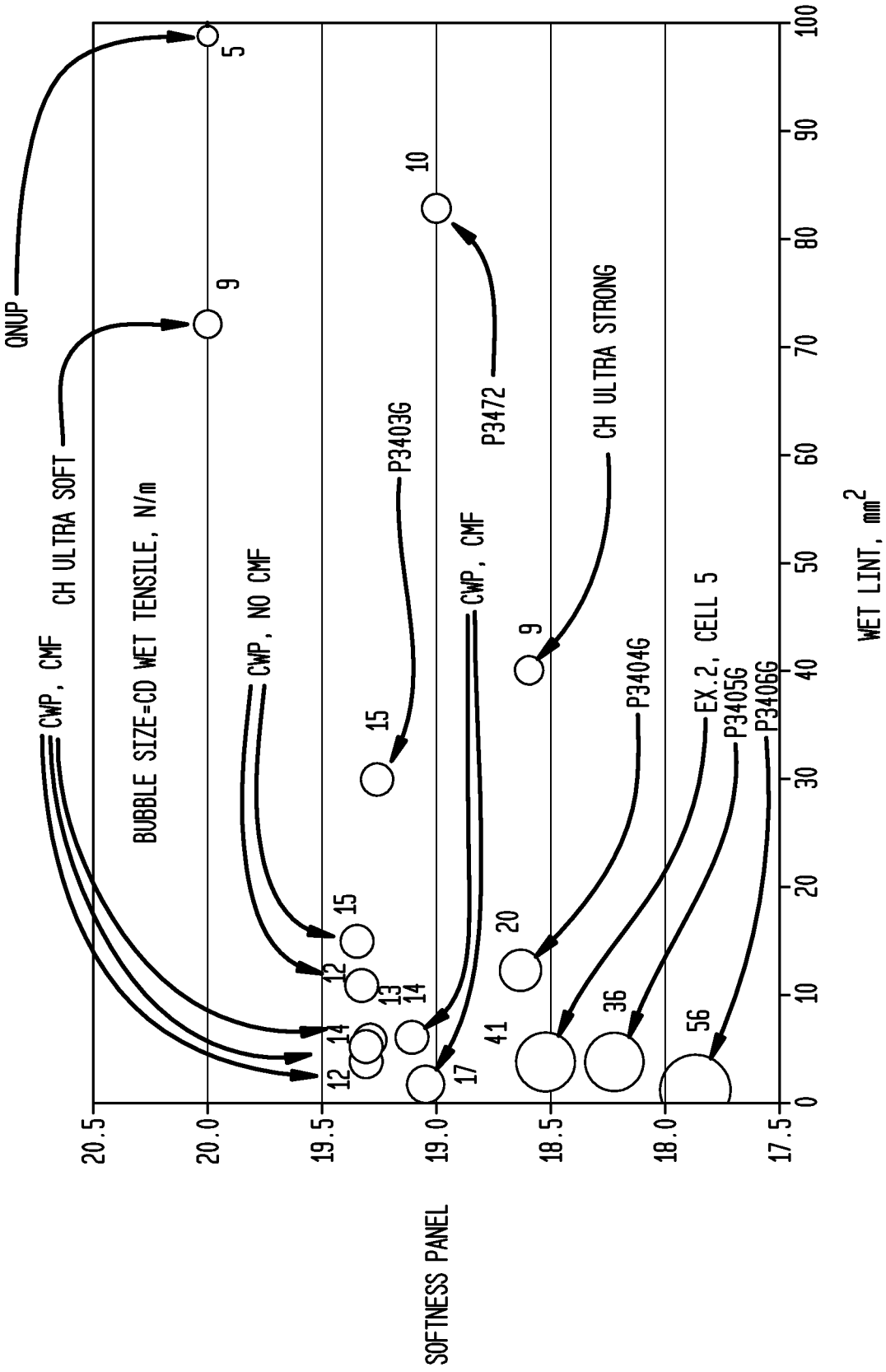

QNUP
CH ULTRA SOFT
CWP, CMF
BUBBLE SIZE=CD WET TENSILE, N/m
CWP, NO CMF
P3403G
P3472
CWP, CMF
CH ULTRA STRONG
P3404G
EX.2, CELL 5
P3405G
P3406G
5
9
10
15
12
13
14
12
14
15
20
41
17
9
36
56
20.5
20.0
19.5
19.0
18.5
18.0
17.5
SOFTNESS PANEL
0
10
20
30
40
50
60
70
80
90
100
WET LINT, mm2

FIG. 14

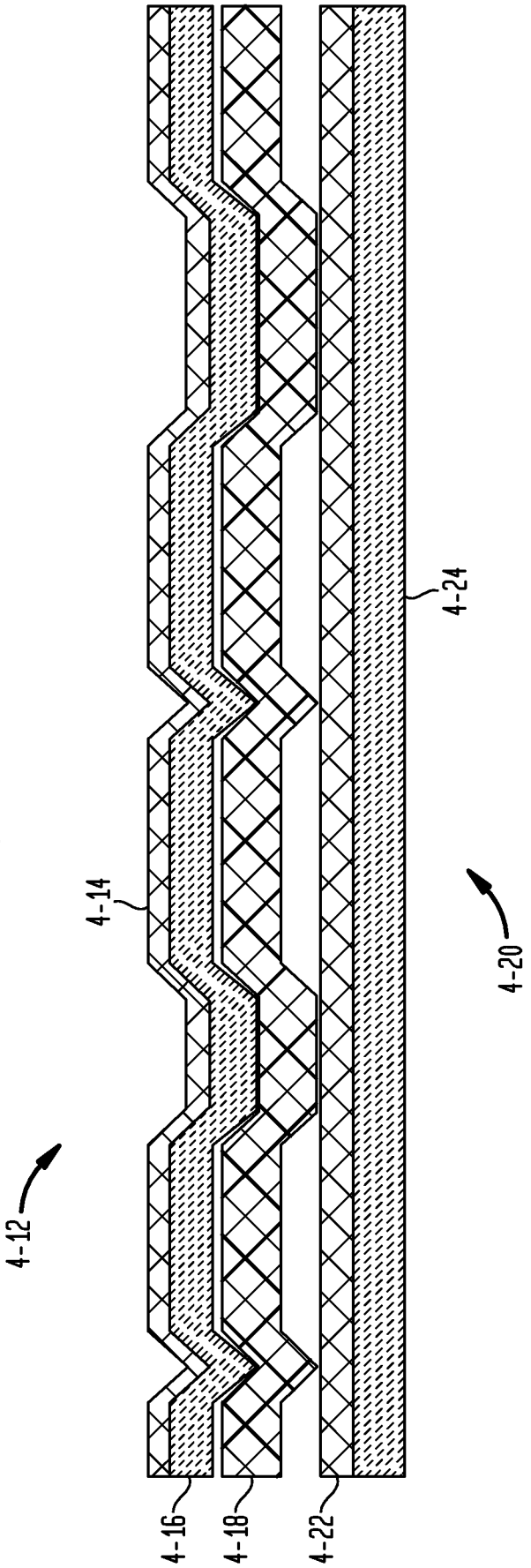


FIG. 15

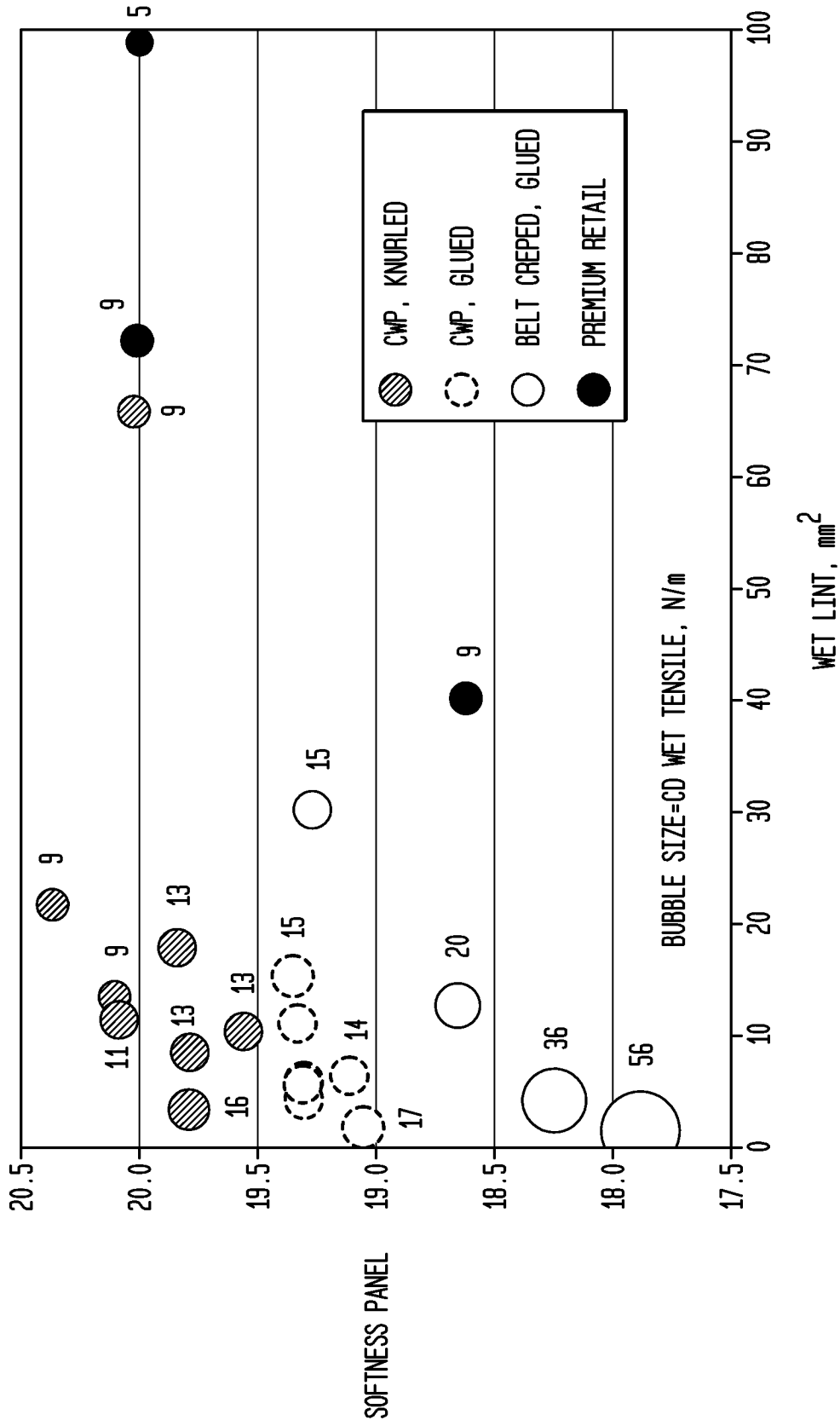

CWP, KNURLED
CWP, GLUED
BELT CREPED, GLUED
PREMIUM RETAIL
BUBBLE SIZE=CD WET TENSILE, N/m
SOFTNESS PANEL
WET LINT, mm2
20.5
20.0
19.5
19.0
18.5
18.0
17.5
0
10
20
30
40
50
60
70
80
90
100
5
9
9
9
11
13
13
16
13
15
14
17
15
9
20
36
56

FIG. 16

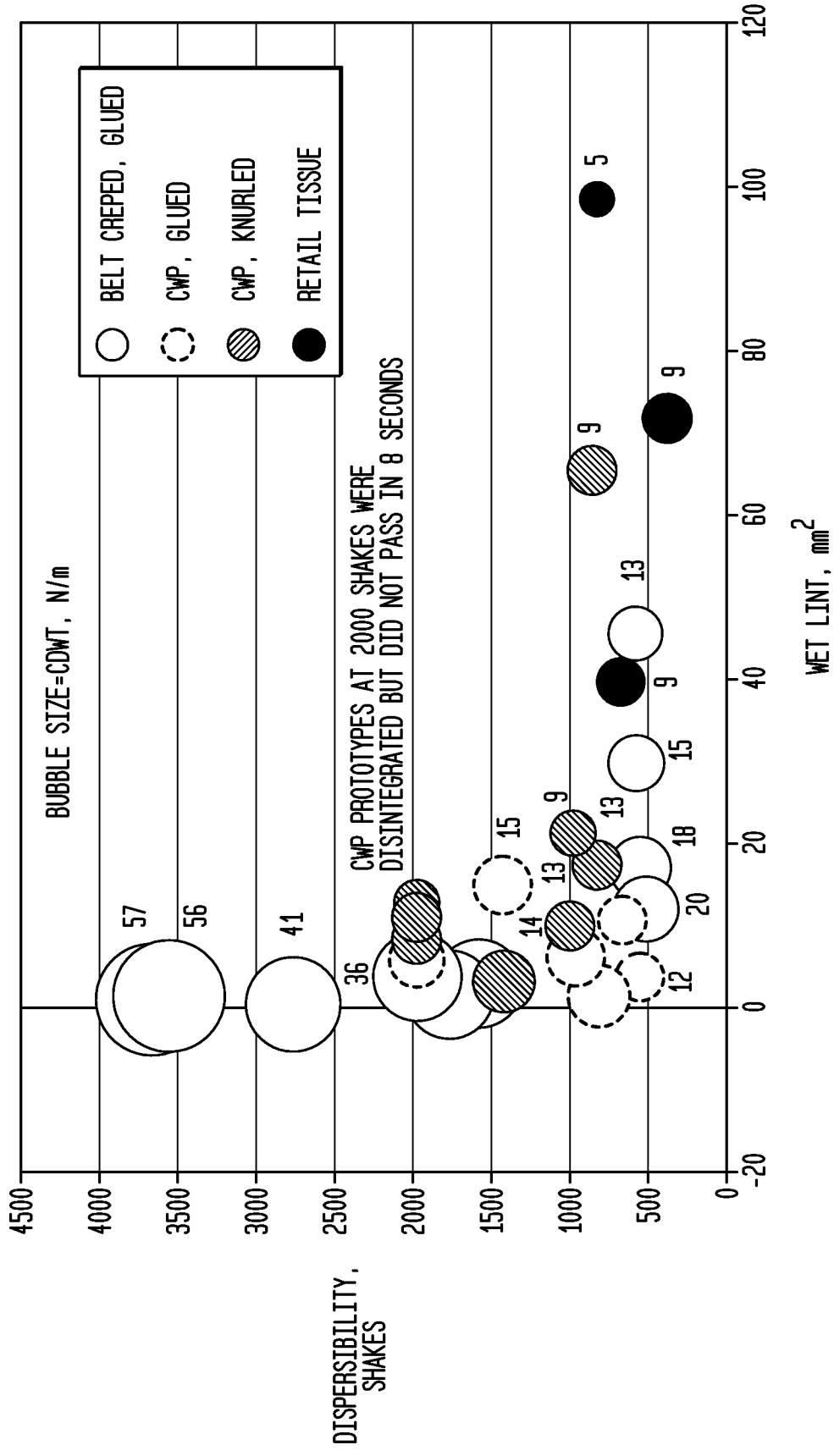

BELT CREPED, GLUED
CWP, GLUED
CWP, KNURLED
RETAIL TISSUE
BUBBLE SIZE=CDWT, N/m
CWP PROTOTYPES AT 2000 SHAKES WERE DISINTEGRATED BUT DID NOT PASS IN 8 SECONDS
DISPERSIBILITY, SHAKES
WET LINT, mm2
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-20
0
20
40
60
80
100
120
57
56
41
36
15
14
13
9
13
18
20
12
15
9
13
9
9
5

FIG. 17

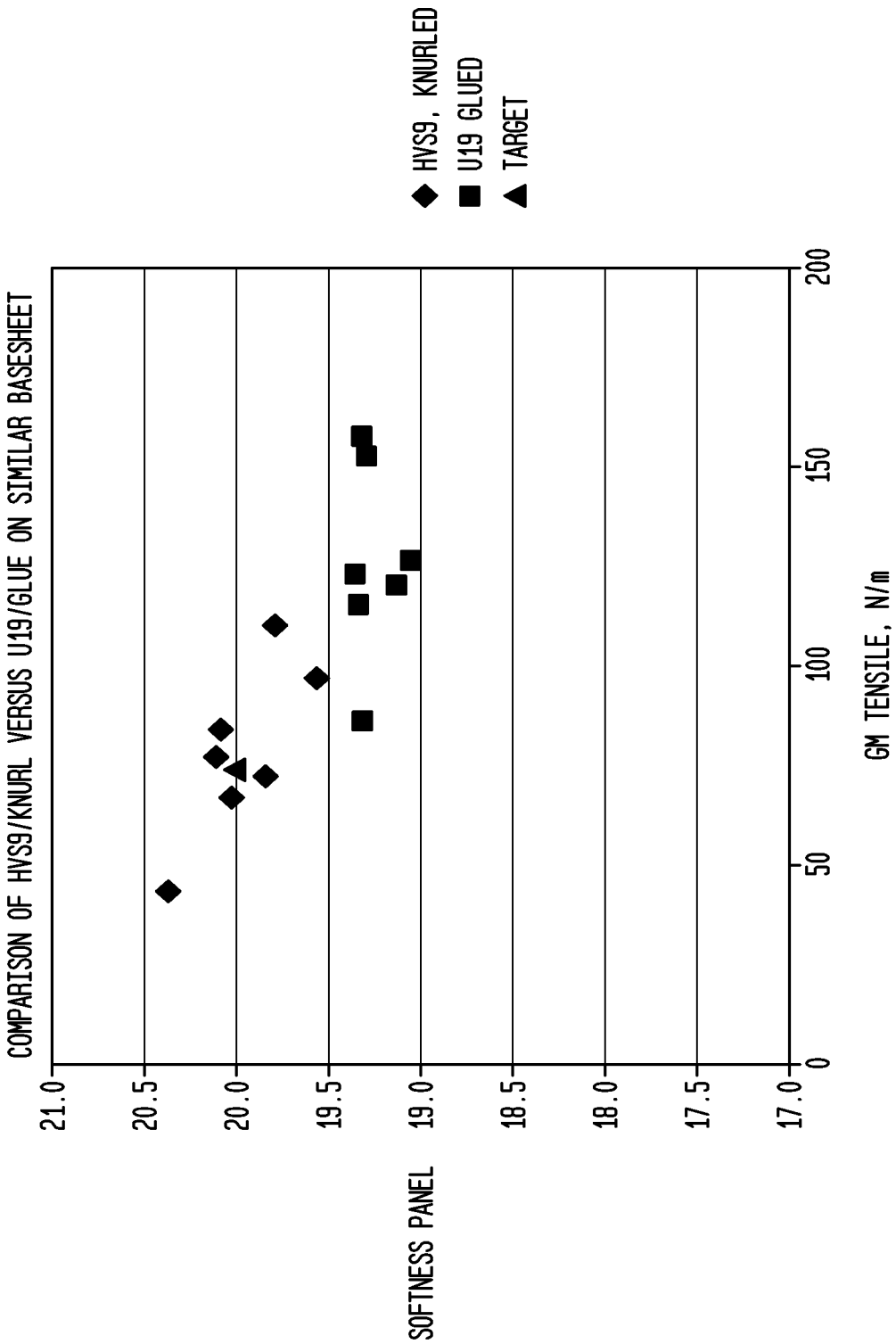

COMPARISON OF HVS9/KNURL VERSUS U19/GLUE ON SIMILAR BASESHEET
HVS9, KNURLED
U19 GLUED
TARGET
SOFTNESS PANEL
21.0
20.5
20.0
19.5
19.0
18.5
18.0
17.5
17.0
0
50
100
150
200
GM TENSILE, N/m

FIG. 18

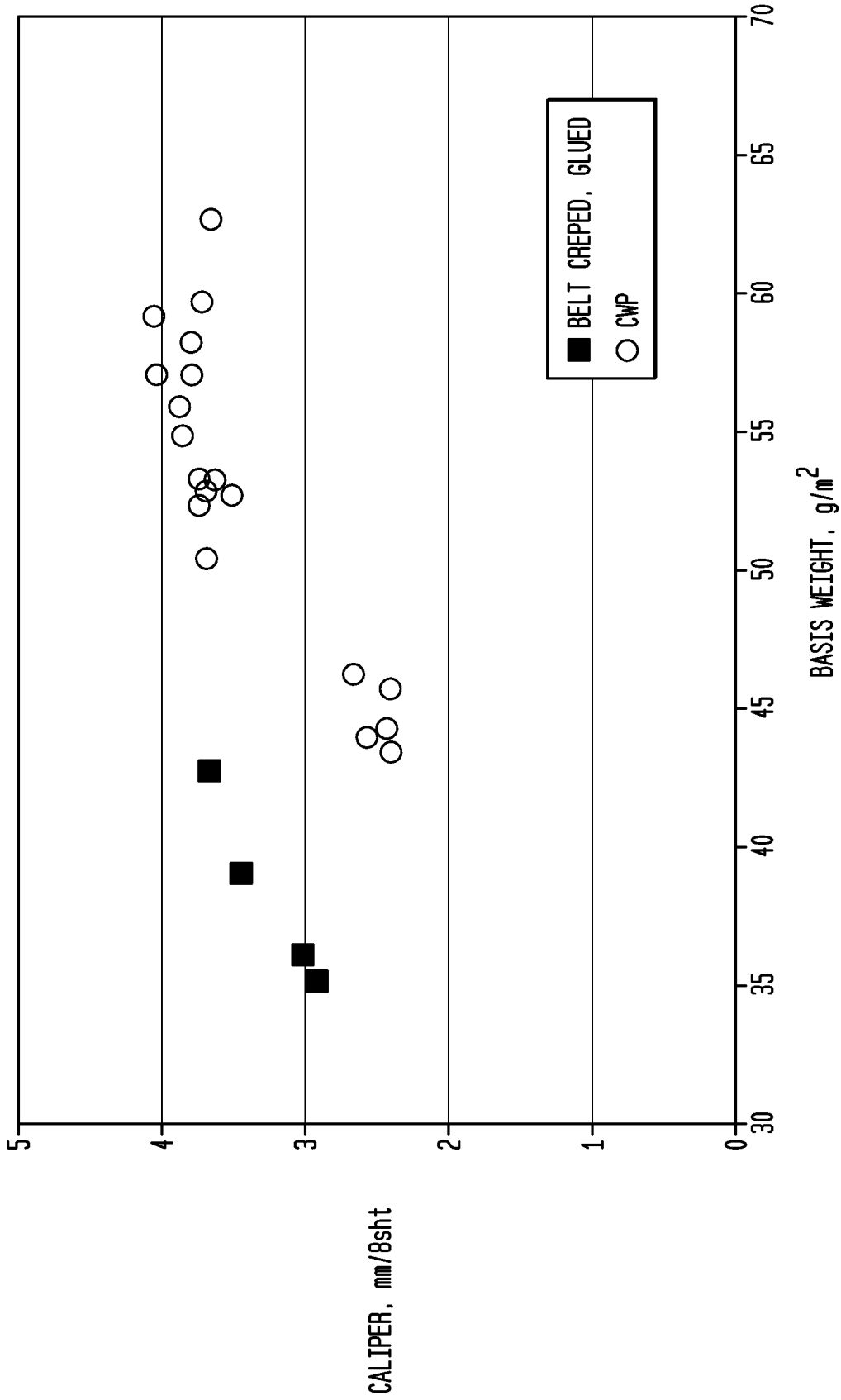
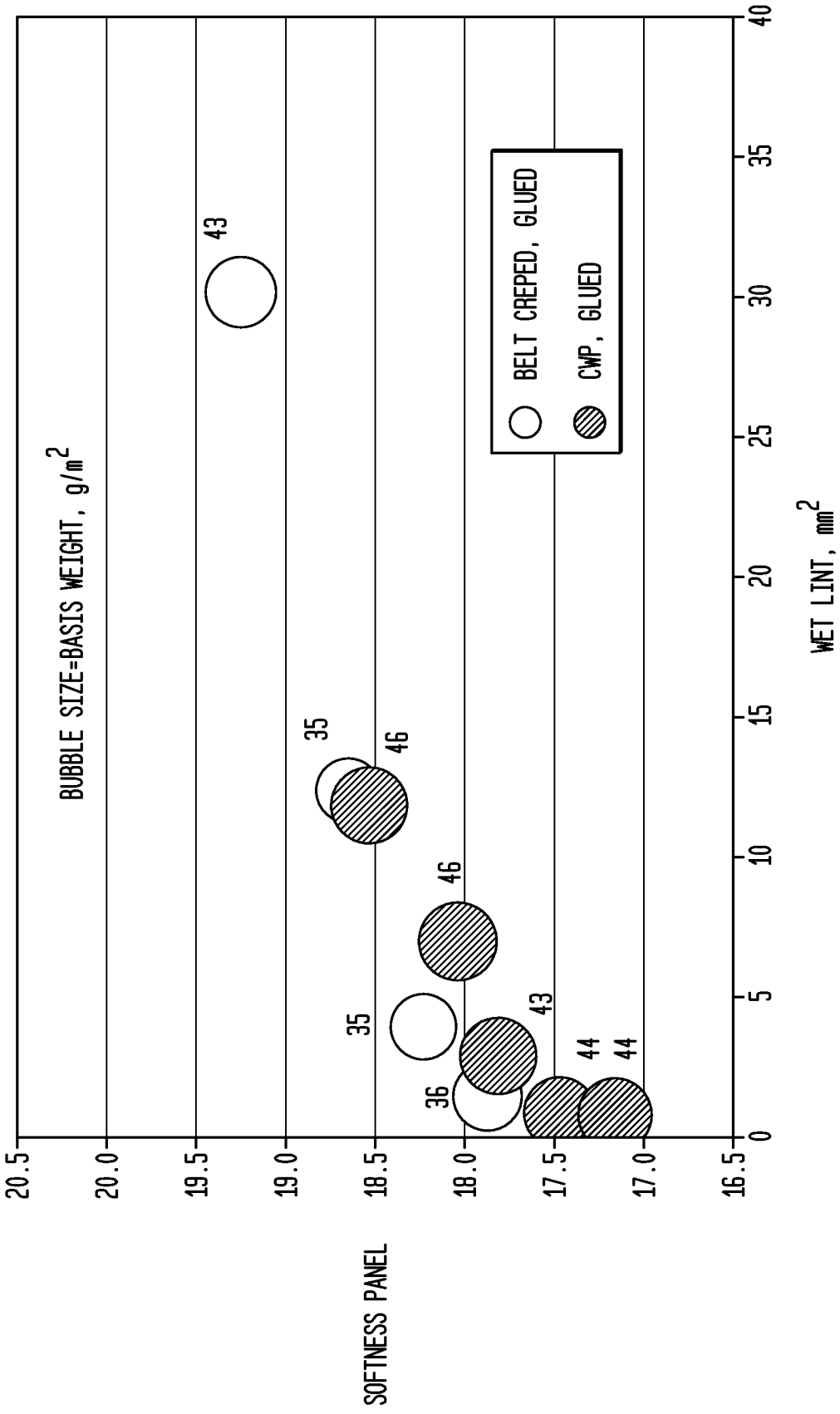

BELT CREPED, GLUED
CWP
CALIPER, mm/8sht
BASIS WEIGHT, g/m2
0
1
2
3
4
5
30
35
40
45
50
55
60
65
70

FIG. 19


BUBBLE SIZE=BASIS WEIGHT, g/m2
BELT CREPED, GLUED
CWP, GLUED
43
35
46
46
35
43
36
44
44
SOFTNESS PANEL
WET LINT, mm2
20.5
20.0
19.5
19.0
18.5
18.0
17.5
17.0
16.5
0
5
10
15
20
25
30
35
40

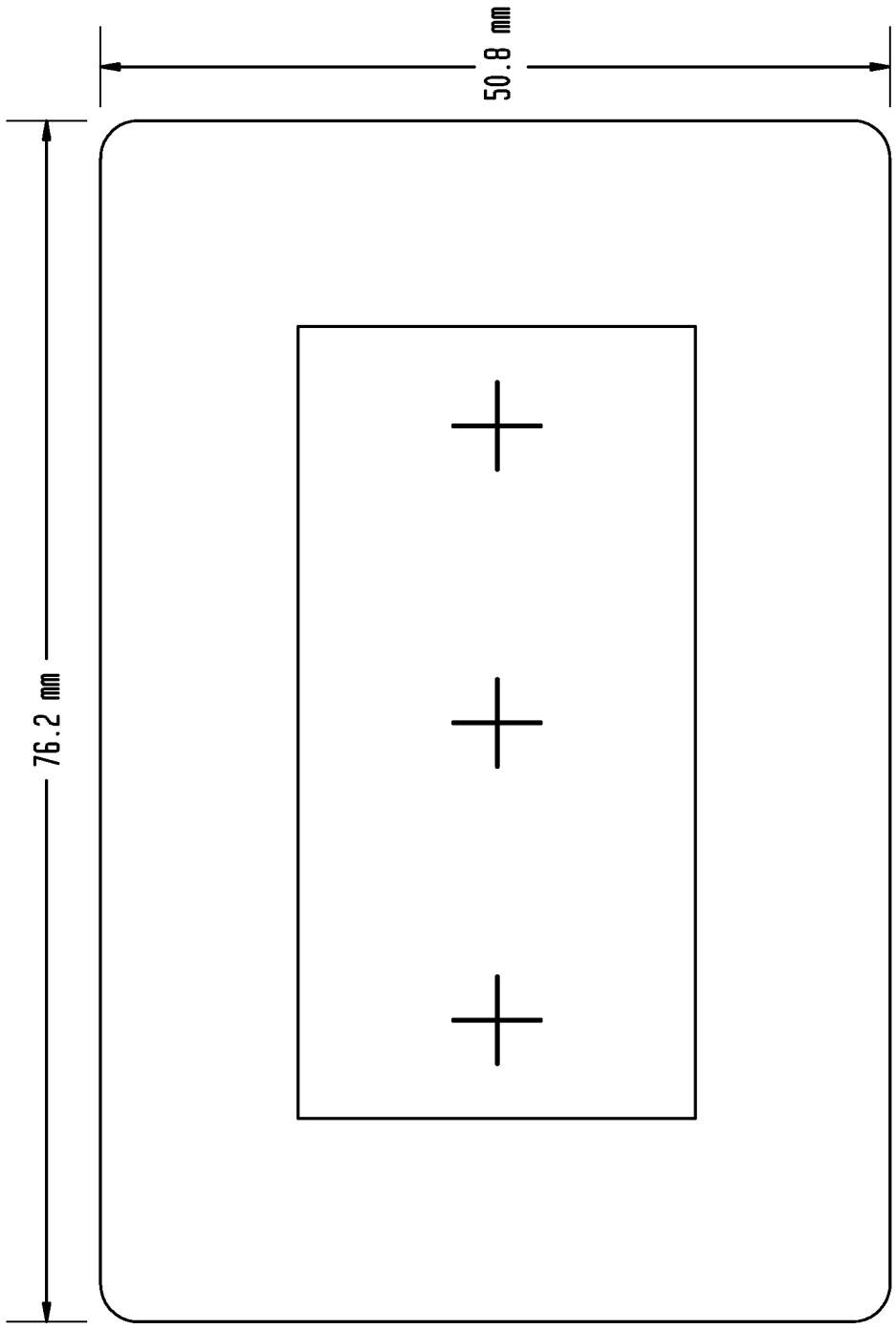


FIG. 20

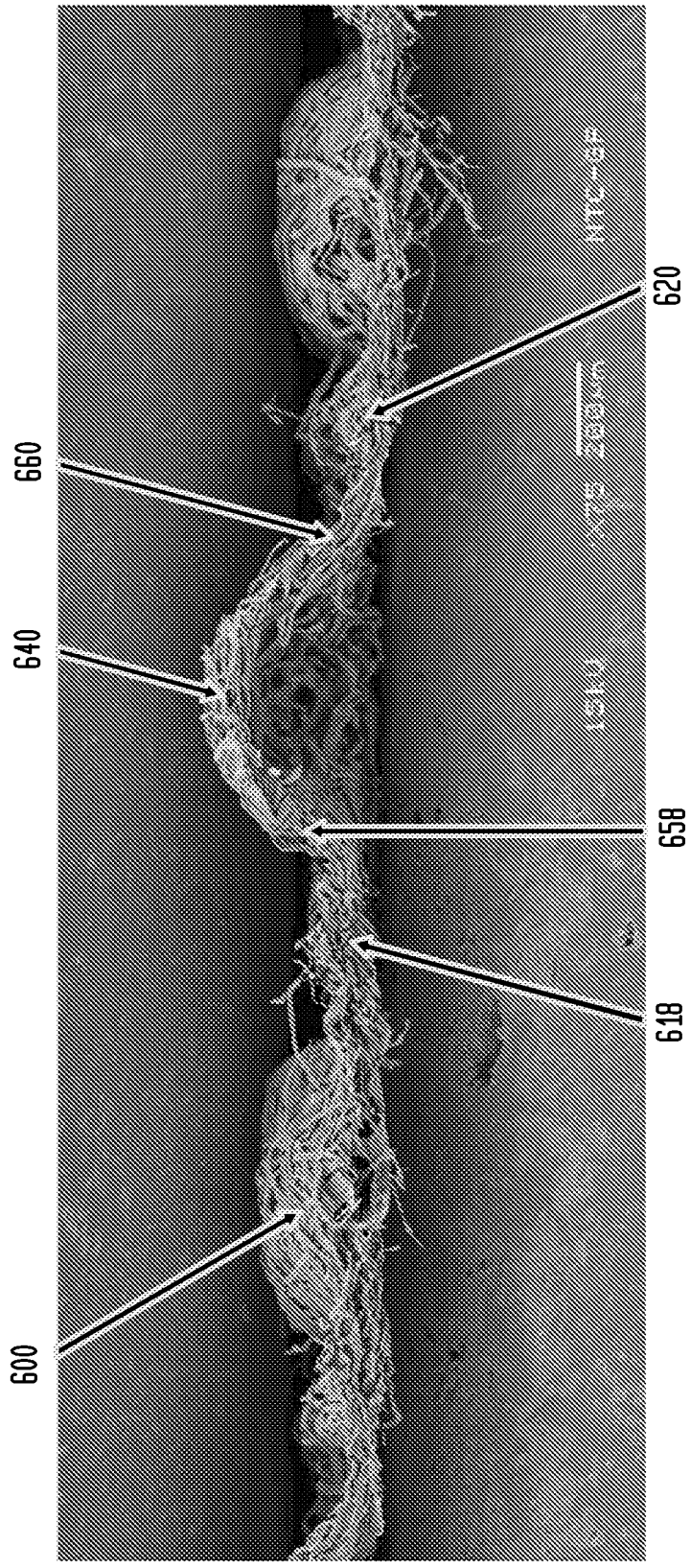


FIG. 21
18" Hg, VACUUM, UNCALENDERED, BELT 50, MD

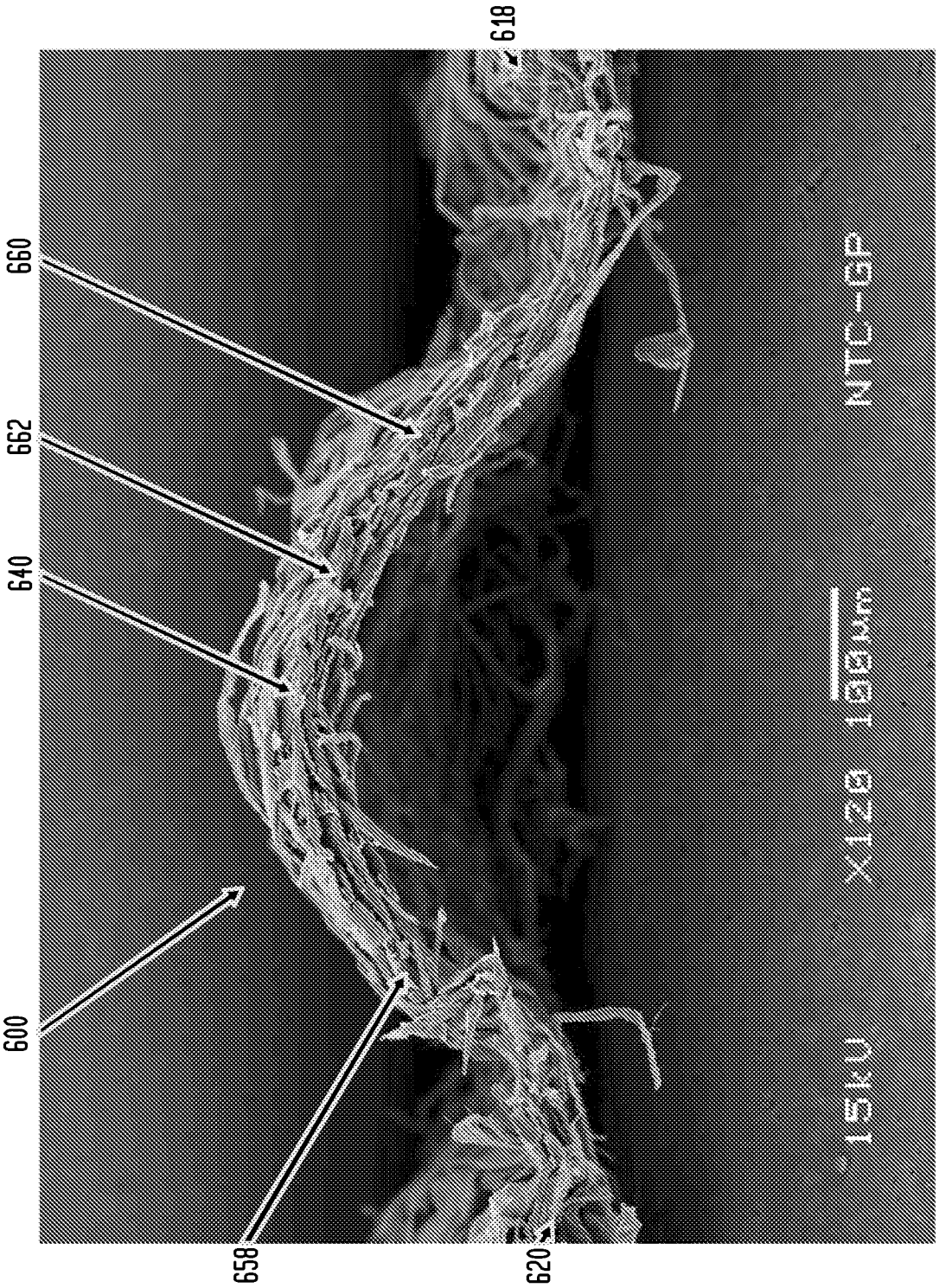


FIG. 22
18" Hg VACUUM, UNCALENDERED, BELT 50, MD

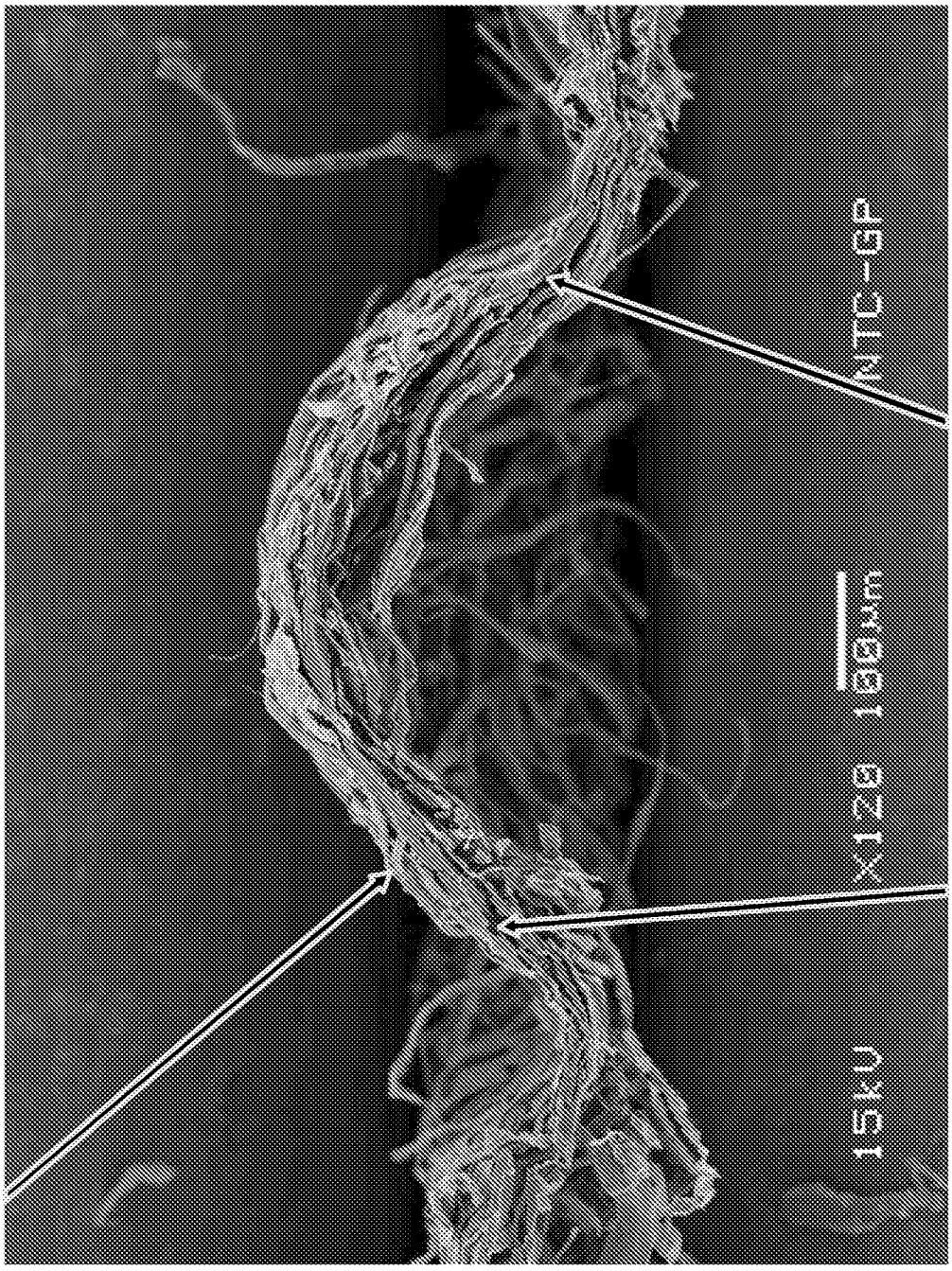


FIG. 23
18" Hg VACUUM, CALENDERED, BELT 50, MD

FIG. 24

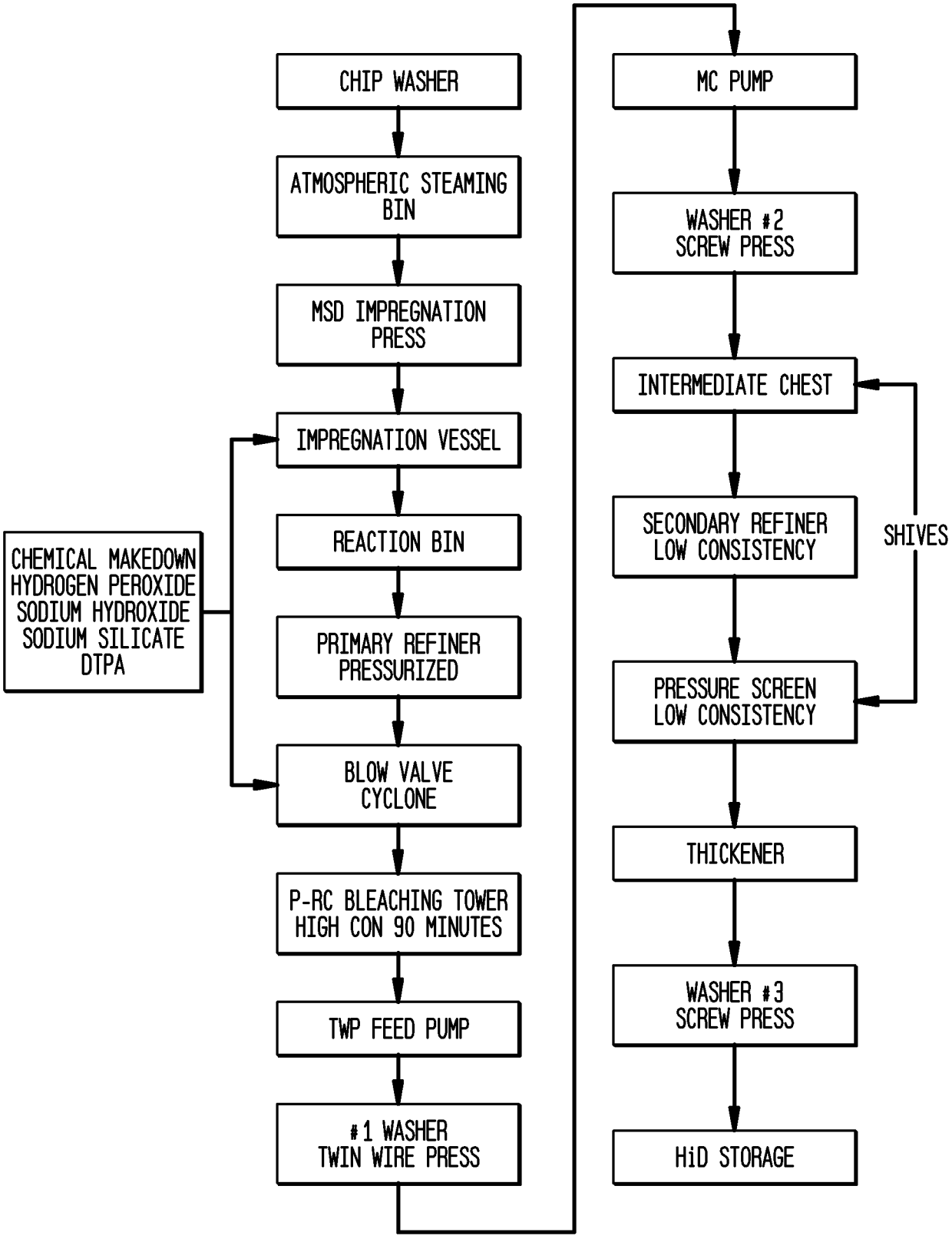

CHIP WASHER
ATMOSPHERIC STEAMING BIN
MSD IMPREGNATION PRESS
IMPREGNATION VESSEL
REACTION BIN
PRIMARY REFINER PRESSURIZED
BLOW VALVE CYCLONE
P-RC BLEACHING TOWER HIGH CON 90 MINUTES
TWP FEED PUMP
#1 WASHER TWIN WIRE PRESS
CHEMICAL MAKEDOWN HYDROGEN PEROXIDE SODIUM HYDROXIDE SODIUM SILICATE DTPA
MC PUMP
WASHER #2 SCREW PRESS
INTERMEDIATE CHEST
SECONDARY REFINER LOW CONSISTENCY
PRESSURE SCREEN LOW CONSISTENCY
THICKENER
WASHER #3 SCREW PRESS
HiD STORAGE
SHIVES

FIG. 25

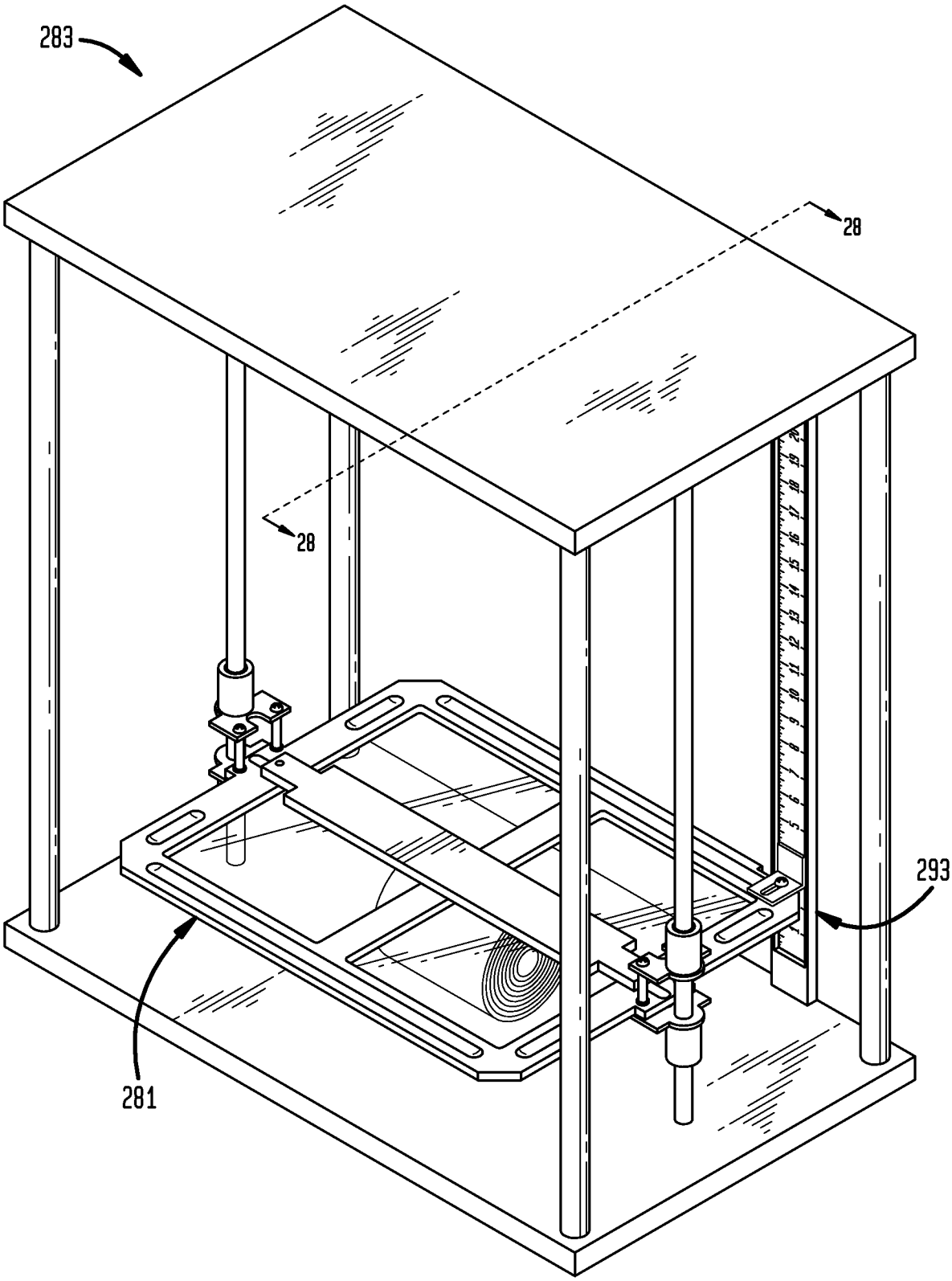


FIG. 26

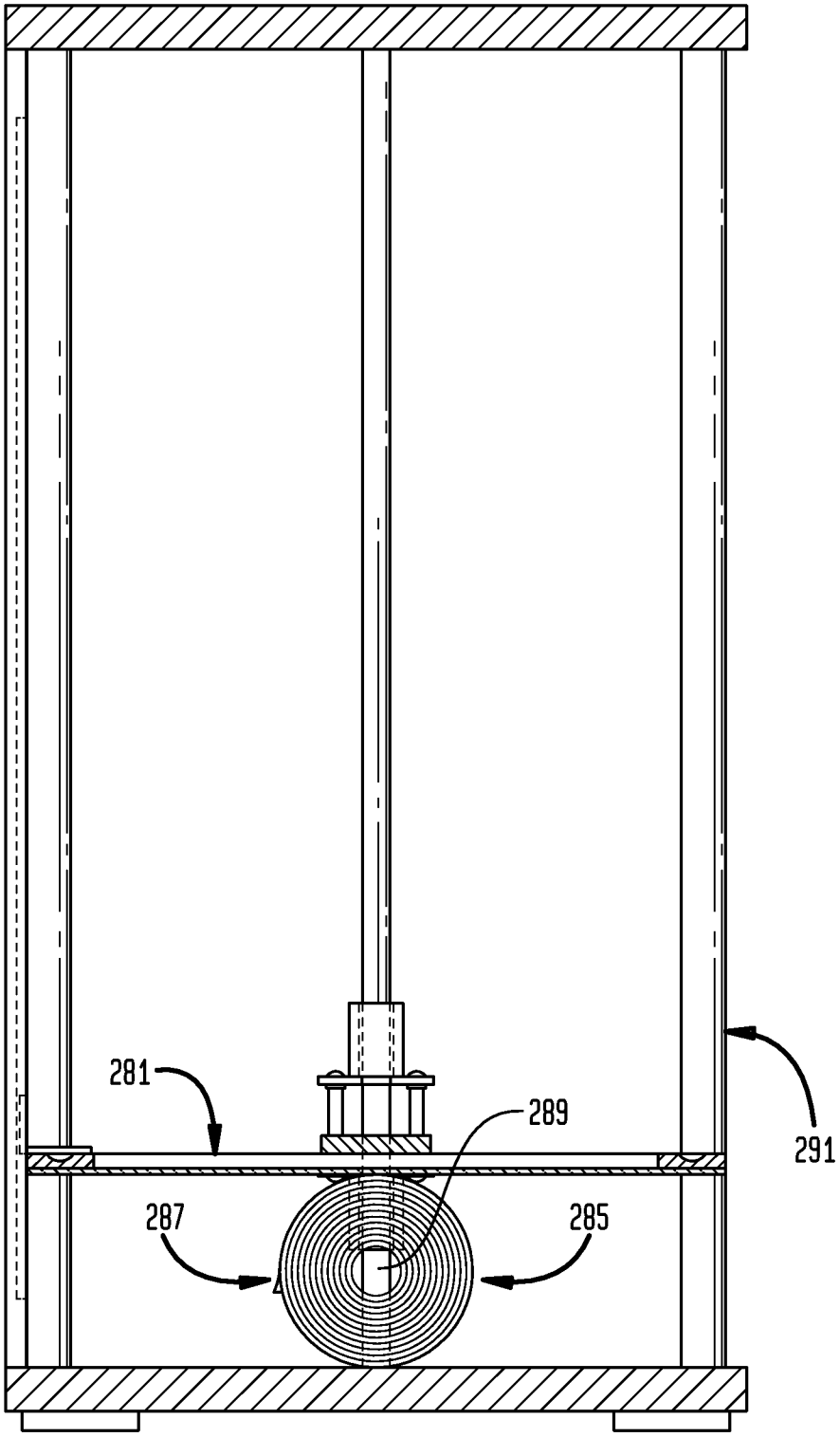


FIG. 27

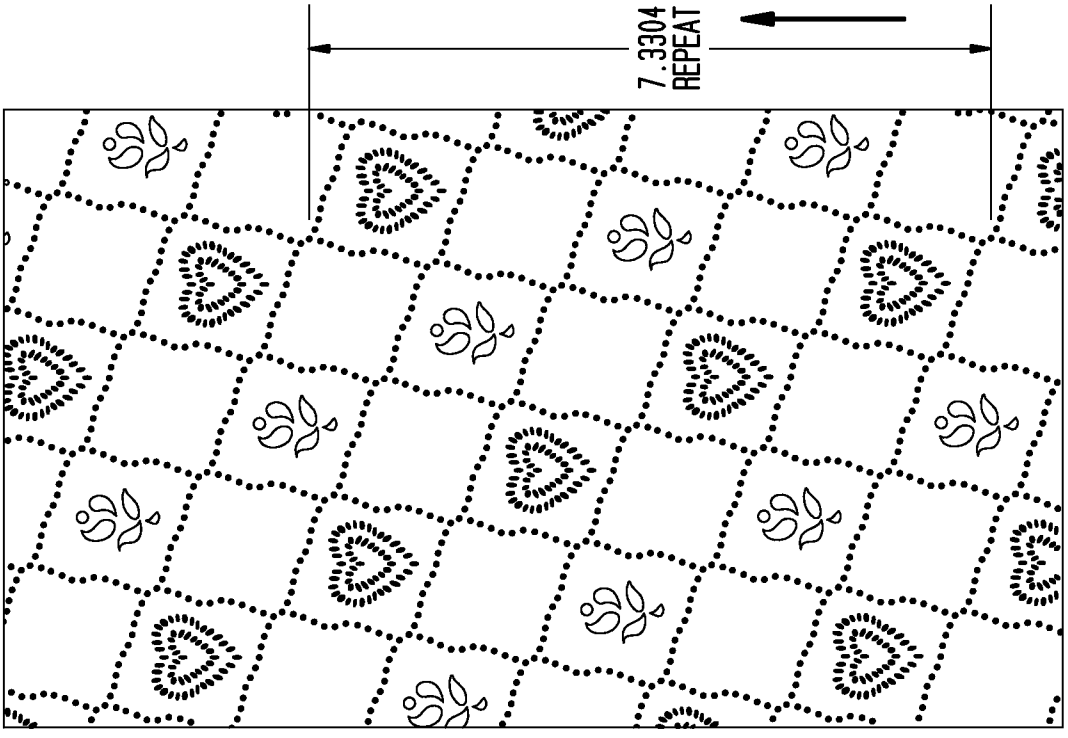


FIG. 27A

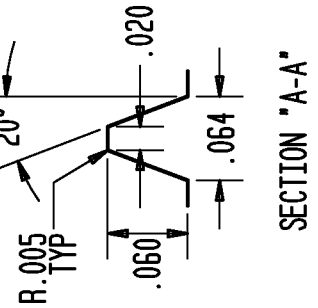


FIG. 27B

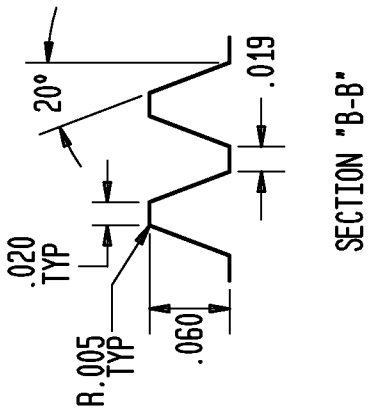


FIG. 27C

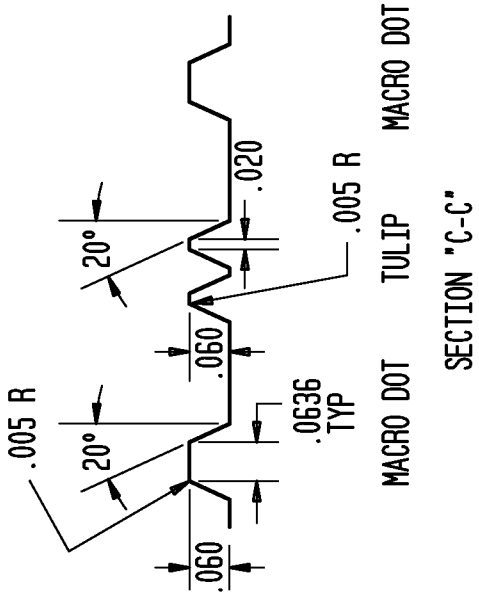
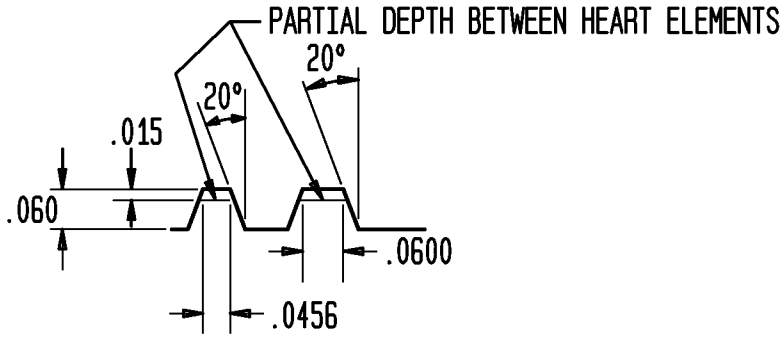
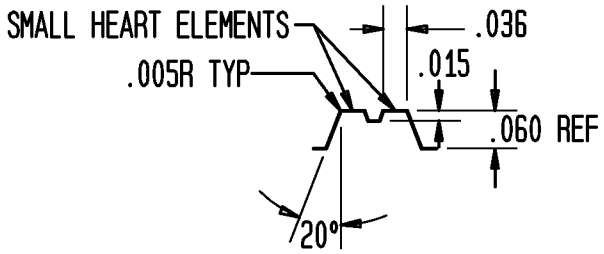


FIG. 27D



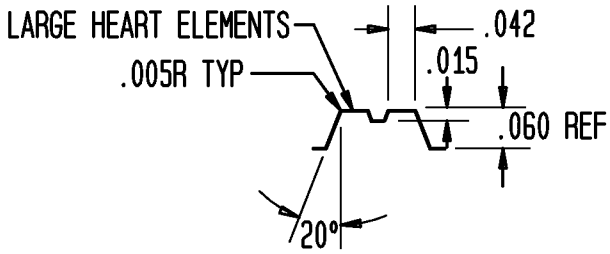
SECTION "D-D"

FIG. 27E



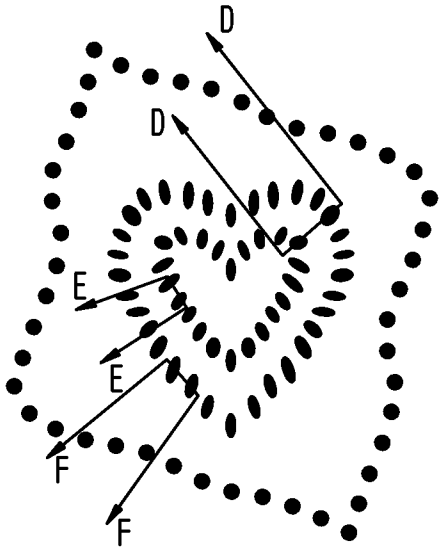
SECTION "E-E"

FIG. 27F



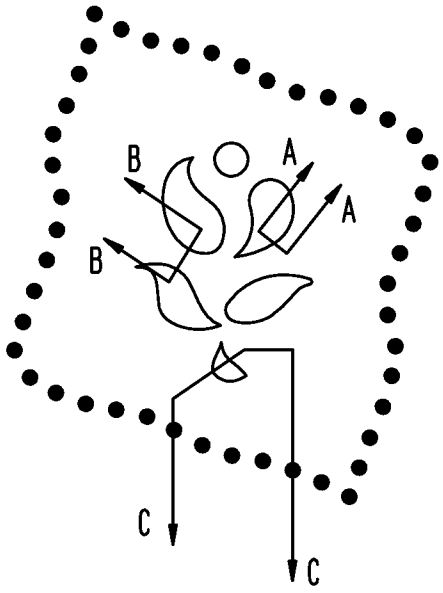
SECTION "F-F"

FIG. 27H



HEART DETAIL

FIG. 27T



TULIP DETAIL

FIG. 28

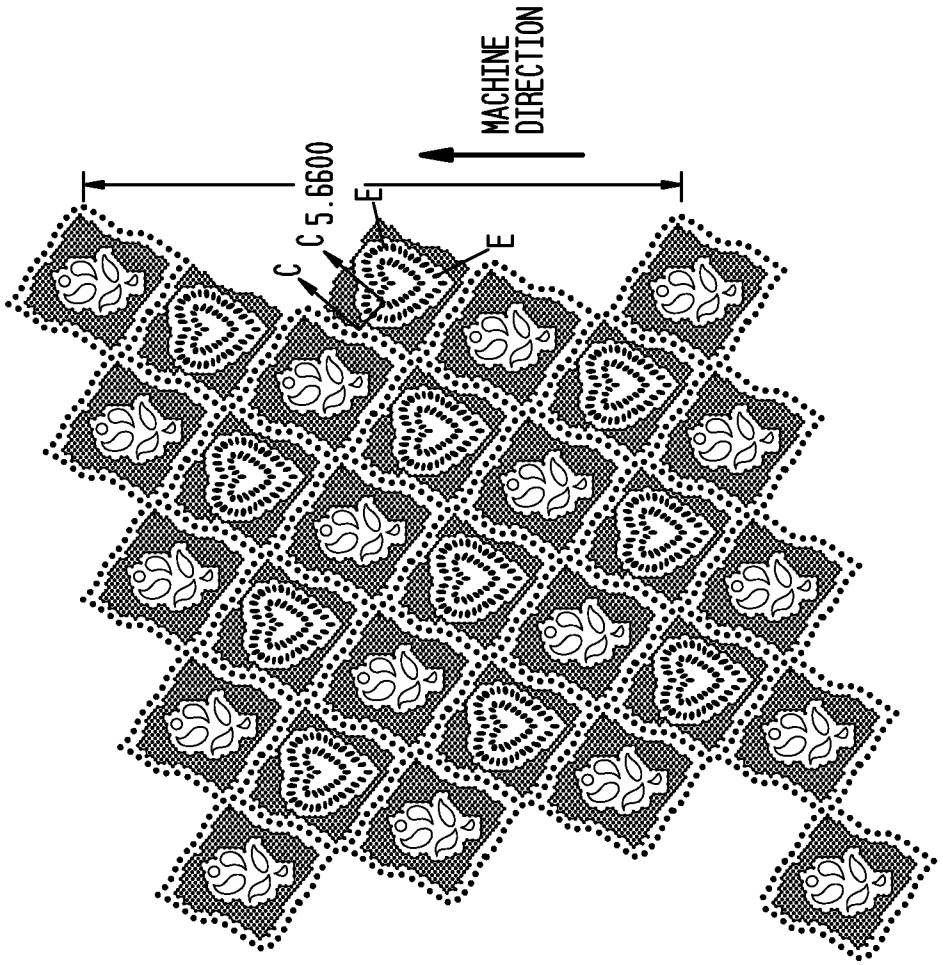


FIG. 28-1

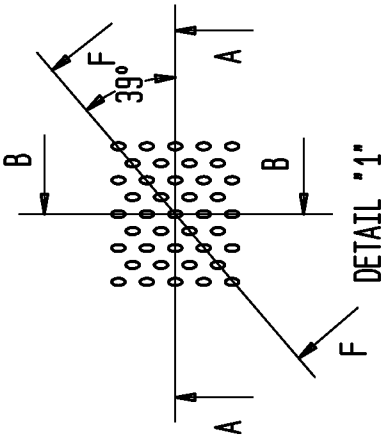


FIG. 28-2

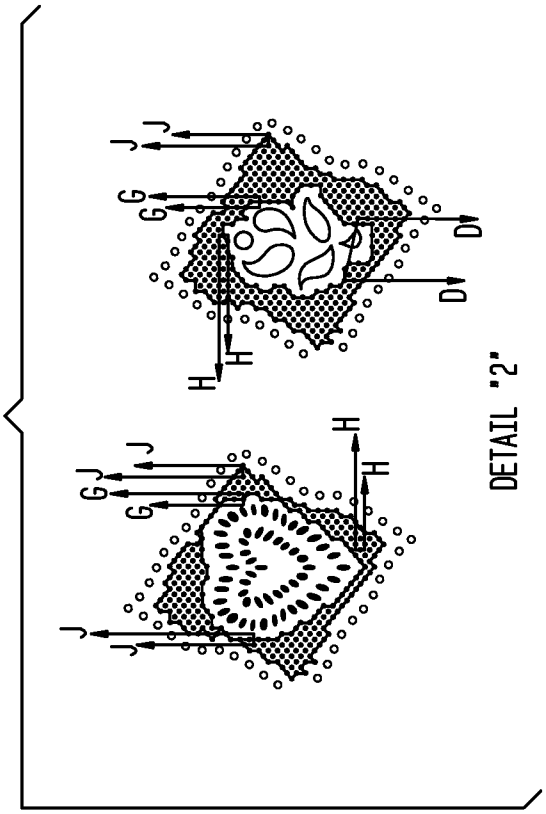
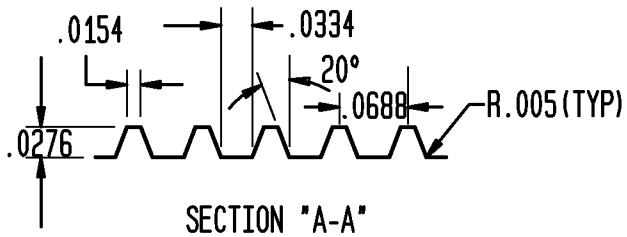
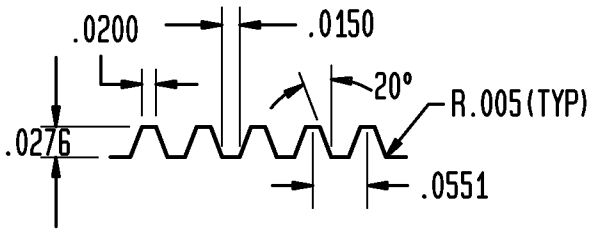


FIG. 28-A



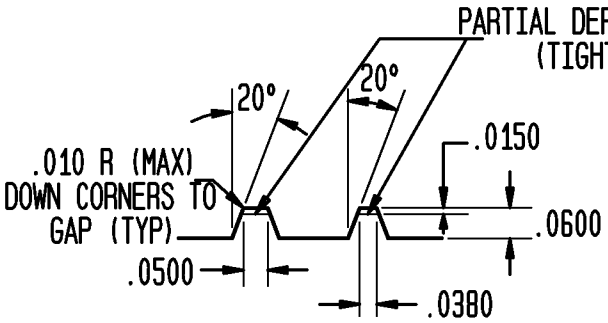
SECTION "A-A"

FIG. 28-B



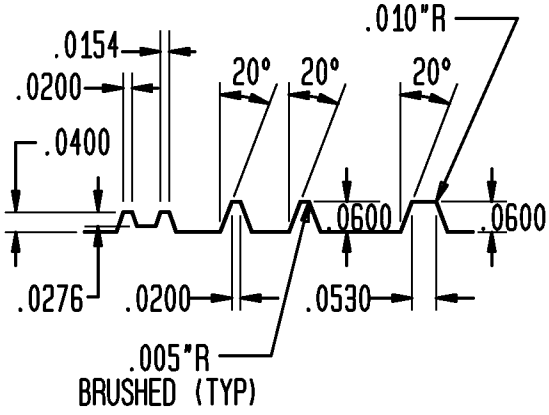
SECTION "B-B"

FIG. 28-C



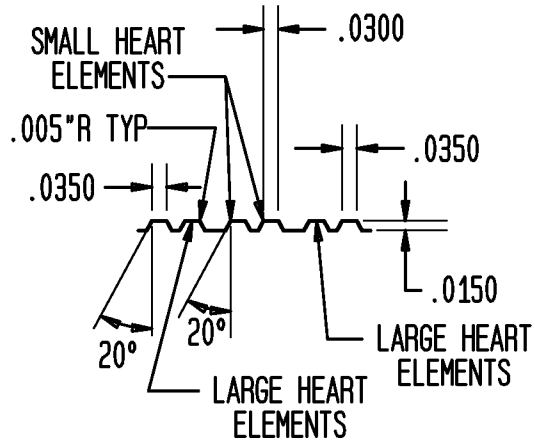
SECTION "C-C"

FIG. 28-D



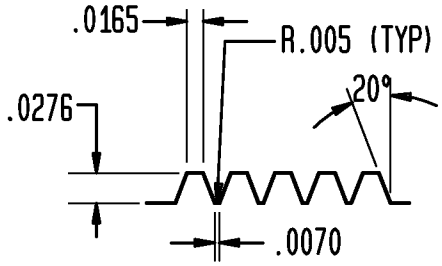
SECTION "D-D"

FIG. 28-E



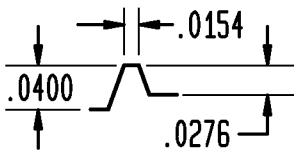
SECTION "E-E"

FIG. 28-F



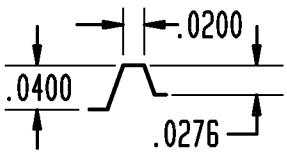
SECTION "F-F"

FIG. 28-G



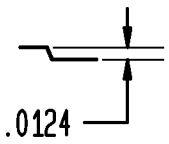
SECTION "G-G"

FIG. 28-H



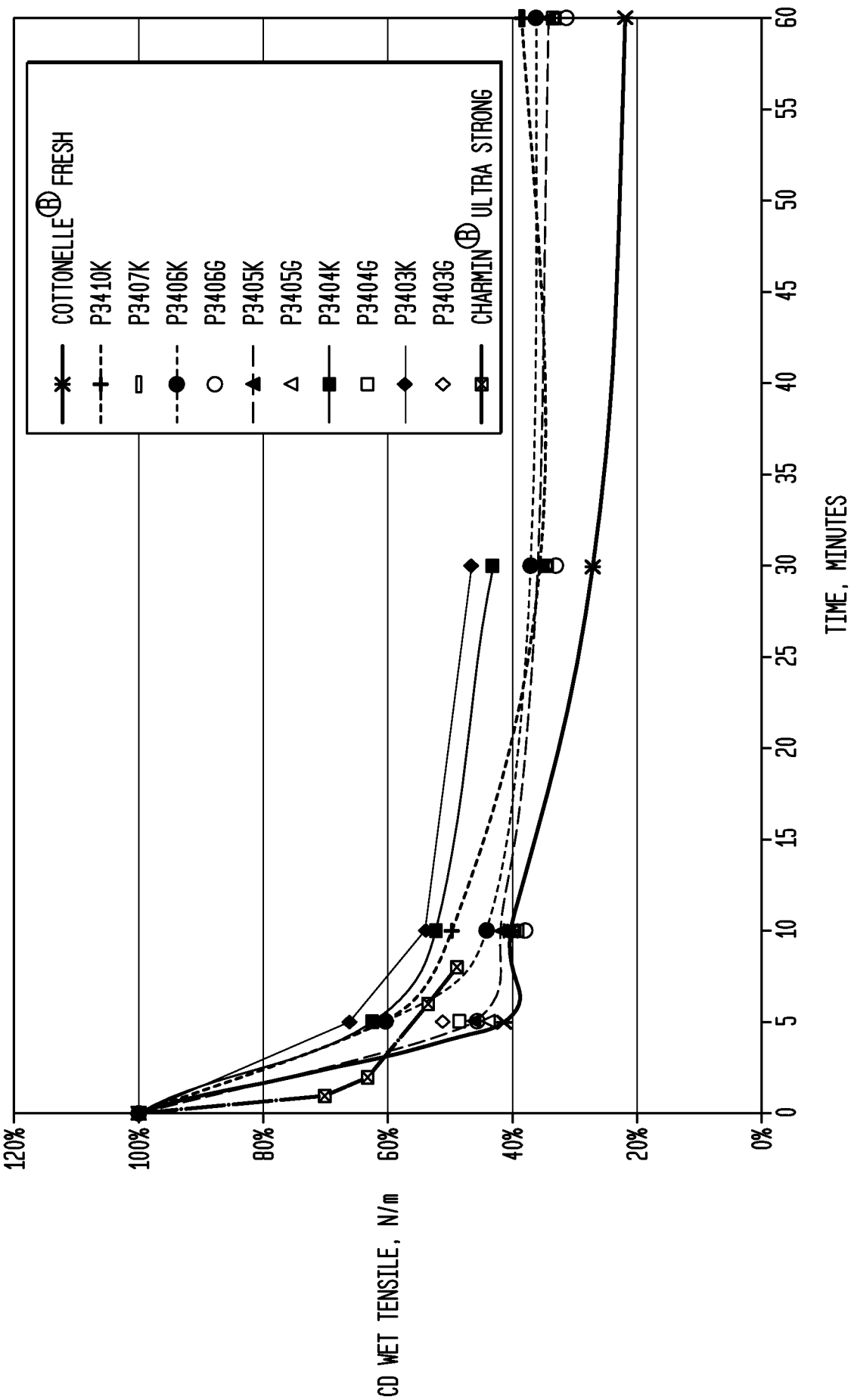
SECTION "H-H"

FIG. 28-J



SECTION "J-J"

FIG. 29


COTTONELLE® FRESH
P3410K
P3407K
P3406K
P3406G
P3405K
P3405G
P3404K
P3404G
P3403K
P3403G
CHARMIN® ULTRA STRONG
120%
100%
80%
60%
40%
20%
0%
CD WET TENSILE, N/m
0
5
10
15
20
25
30
35
40
45
50
55
60
TIME, MINUTES

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/047802

A. CLASSIFICATION OF SUBJECT MATTER
INV. D21H21/18 D21H21/20 D21H27/30 D21H27/00
ADD.

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)
D21H

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 practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/173418 A1 (SUMNICHT DANIEL W [US]) 24 July 2008 (2008-07-24) page 1, paragraphs 2,6,11 page 2, paragraphs 21,23 page 5, paragraph 51 claims 18-30 ----- -/--	1-3, 13-21, 23,24, 26-35, 38, 45-52, 56, 85-97, 99-110

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

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"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	Date of mailing of the international search report
10 October 2012	19/10/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Beins, Ulrika

1

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/047802

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2007/109259 A2 (GEORGIA PACIFIC CONSUMER PROD [US]; SUMNICHT DANIEL W [US]; KOKKO BRUC) 27 September 2007 (2007-09-27) claims 1-146 page 2, lines 2-5 page 5, line 18 - page 6, line 15 page 11, line 8 - page 12, line 25 page 23, lines 1-4 page 34, lines 24-31 page 67, line 19 - page 68, line 5 page 71, line 29 - page 72, line 26 page 74, lines 28-31	1-3,6, 13-20, 26-35, 38,39, 45-51, 85-96, 99-110

X	WO 2009/038730 A1 (GEORGIA PACIFIC CONSUMER PROD [US]; SUMNICHT DANIEL W [US]; MILLER JOS) 26 March 2009 (2009-03-26) claims 1-71	1-3,6, 13-20, 26-35, 38,39, 45-51, 85-96, 99-110

X	WO 2009/038735 A1 (GEORGIA PACIFIC CONSUMER PROD [US]; SUMNICHT DANIEL W [US]; MILLER JOS) 26 March 2009 (2009-03-26) claims 1-110	1-3,6, 13-20, 26-35, 38,39, 45-51, 85-96, 99-110

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2012/047802

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008173418 A1	24-07-2008	US 2008173418 A1	24-07-2008
		US 2008173419 A1	24-07-2008
WO 2007109259 A2	27-09-2007	CA 2646559 A1	27-09-2007
		EP 2004904 A2	24-12-2008
		US 2007224419 A1	27-09-2007
		US 2010212850 A1	26-08-2010
		US 2011265965 A1	03-11-2011
		WO 2007109259 A2	27-09-2007
WO 2009038730 A1	26-03-2009	CA 2707392 A1	26-03-2009
		EP 2191066 A1	02-06-2010
		RU 2010115261 A	10-11-2011
		US 2009020248 A1	22-01-2009
		WO 2009038730 A1	26-03-2009
WO 2009038735 A1	26-03-2009	CA 2707515 A1	26-03-2009
		EP 2190657 A1	02-06-2010
		RU 2010115259 A	27-10-2011
		US 2009020139 A1	22-01-2009
		US 2012180815 A1	19-07-2012
		WO 2009038735 A1	26-03-2009