Fig. 1

Fig. 2

INVENTORS
Lawrence H. Sanford
James B. Sisson

BY William J. Schangle

AGENT
PROCESS FOR FORMING ABSORBENT PAPER BY IMPRINTING A FABRIC KNUCKLE PATTERN THEREON PRIOR TO DRYING AND PAPER THEREOF

Fig. 3

Fig. 4

Fig. 5

Fig. 6

INVENTORS
Lawrence H. Sanford
James B. Sisson

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PROCESS FOR FORMING ABSORBENT PAPER BY IMPRINTING A FABRIC KNUCKLE PATTERN THEREON PRIOR TO DRYING AND PAPER THEREOF.

Lawrence H. Sanford, Cincinnati, and James B. Sisson, Hamilton, Ohio, assignors to The Procter & Gamble Company, Cincinnati, Ohio, a corporation of Ohio Filed Apr. 13, 1964, Ser. No. 269,295

Claim.

This invention relates to the production of low density paper products and has for its general object the provision of a new and useful type of bulky paper sheet for use in tissue, towelling and sanitary products together with a process for its manufacture.

More particularly, the invention disclosed herein comprises a novel process for preparing bulky paper sheets having desirable combination of softness, bulk and absorptivity characteristics engendered by particular techniques used in their formation and drying.

Specifically, the bulky paper sheets of the present invention are produced by impressing fabric patterns of selected coarseness on uncompacted paper webs at selected fiber consistencies, induced by thermal pre-drying, prior to final drying.

In addition to providing an exceptionally bulky, soft and absorbent paper sheet, the improvement disclosed herein provides means for controlling the creping frequency and regularity in a creped sheet of the present paper to further enhance its appearance and desirable combination of handling characteristics.

In the conventional manufacture of paper webs for use in tissue, towelling and sanitary products, it is customary to perform, prior to drying, one or more pressing operations on the entire surface of the paper web as laid down on the Fourdriner wire or other forming surface. Conventionally these pressing operations involve subjecting a moist paper web supported on a paper making felt to pressure developed by opposing mechanical members, for example, rolls. Pressing generally accomplishes the triple functions of mechanical water expulsion, web surface smoothing and tensile strength development, and the pressure is applied to the entire surface of the moist paper web by the relatively smooth surface of the felt. In a conventional papermaking machine comprised of a Fourdriner forming section, a felt pressing section and a Yankee dryer, one of the principal reasons for imposing the knuckle pattern of a selected imprinting fabric and finally drying without disturbing the imprinted knuckle pattern is the necessity to reduce or eliminate all pressing operations on a wet paper web in favor of impressing a selected woven fabric imprint in the partially thermally dried web prior to final drying results in desirable bulk, softness and absorptivity characteristics in a paper sheet.

In another sense, the present invention is predicated on the discovery that, while retaining all of the qualities mentioned above, practice of the invention results in a unique ability to improve the surface appearance of towelings and tissues which are creped from a drying surface. For example, in the practice of the present invention, the crepe frequency and evenness of crepe can be regulated so that the creped products have enhanced uniformity of surface and overall appearance together with an improved surface feel. Moreover, the reduction in tensile strength normally caused by creping conventional paper sheets is minimized in the process of this invention.

An object of this invention is to provide a paper sheet having improved qualities of bulk, softness and absorptivity for a given basis weight.

Another object of this invention is to provide a unique creped tissue sheet having increased caliper in relation to its weight while maintaining prerequisite sheet strength.

Still another object of this invention is to provide a unique process for the manufacture of tissue and towelweight paper products having increased caliper in relation to their weight while maintaining sheet strength.

Yet another object of this invention is to provide a process for producing a creped paper sheet wherein the creping frequency and regularity in the sheet, as described

In accordance with the aforementioned pressing procedures, conventional papers receive an overall compaction of their structure prior to drying, which destroys the desirable combination of softness, bulk and absorptivity characteristics found in the paper sheets of the instant invention.

As stated before, an attempt to approach the problem of creating bulky papers by eliminating the pressing operations creates drying problems and results in papers having somewhat less than the desired tensile strength for their intended use in tissue, towelling and sanitary products.

Contrary to the above stated limitations imposed by presently practiced papermaking processes, applicants have discovered that the drying, compaction and tensile strength problems are concurrently solved by a papermaking process wherein, in the broadest sense, a paper web is laid down on a foraminous forming carrier (which can be, but is not necessarily, a selected imprinting fabric as defined herein), thermally pre-dried to a fiber consistency substantially in excess of that normally entering the thermal drying section of a paper machine, imprinted with the knuckle pattern of a selected imprinting fabric and finally dried without disturbing the imprinted knuckle pattern.

Applicants have found that this general procedure not only suffices to produce the desirable combination of softness, bulk and absorptivity characteristics heretofore mentioned, but results in a high bulk, high porosity paper sheet which in creped form possesses substantially the same tensile strength as that of conventional paper of the same basis weight in creped form, even though tensile strength has not been developed by overall pressing.

Applicants have also found that the paper sheets of this invention are especially adapted to use in paper towellings, sanitary tissues, facial tissues and like products where the softness, bulk, absorptivity, and tensile strength characteristics are of value.

Applicants therefore state, while not wishing to be bound by theory, that in one sense, their invention is predicated on the discovery that the elimination of overall pressing operations on a wet paper web in favor of impressing a selected woven fabric imprint in the partially thermally dried web prior to final drying results in desirable bulk, softness and absorptivity characteristics in a paper sheet.

In another sense, the present invention is predicated on the discovery that, while retaining all of the qualities mentioned above, practice of the invention results in a unique ability to improve the surface appearance of towellings and tissues which are creped from a drying surface. For example, in the practice of the present invention, the crepe frequency and evenness of crepe can be regulated so that the creped products have enhanced uniformity of surface and overall appearance together with an improved surface feel. Moreover, the reduction in tensile strength normally caused by creping conventional paper sheets is minimized in the process of this invention.

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from a creping surface, is controlled in the machine and cross-machine directions. The creping objects will be made apparent by the accompanying drawings describing certain preferred embodiments and in the following detailed description of the invention.

In the drawings:

FIGURE 1 is a schematic illustration of a papermaking machine in accordance with the invention.

FIGURE 2 is a schematic illustration of another papermaking machine embodying the invention.

FIGURE 3 is an enlarged partial plan view of an uncreped paper sheet produced in accordance with the practice of the invention.

FIGURE 4 is an enlarged cross sectional view of the uncreped, or machine glazed, paper sheet of FIGURE 3, taken in the cross-machine direction along the line 4—4 in FIGURE 3.

FIGURE 5 is an enlarged partial plan view of a creped paper sheet produced in accordance with the practice of the invention.

FIGURE 6 is an enlarged cross sectional view of the creped paper sheet of FIGURE 5, taken in the cross-machine direction along the line 6—6 in FIGURE 5.

Referring to FIGURE 1, there is shown an example of a papermaking machine embodying the principles of the present invention. A papermaking furnish is delivered from a closed headbox 10 to a Fourdriner wire 11 supported by a breast roll 12. An uncremped paper web 13 is formed, and the Fourdriner wire passes over forming boxes 14, which are desirable, but not necessary. Toward the dry end of the forming section, the Fourdriner wire 11 with the wet paper web 13 supported thereon passes over a plurality of suction boxes 15. Five such suction boxes are shown in the illustration, the last four of which are desirable, but not necessarily, equipped with steam nozzles 16. After passing over the vacuum boxes 15 the Fourdriner wire and the moist web pass around a Fourdriner wire return roll 17 and downwardly between a slotted steam nozzle 18 and a vacuum box 19. At this point the paper web 13 is transferred without compaction to the selected imprinting fabric 20 and continues over an imprinting fabric return roll 21 to a hot air dryer 22. The imprinting fabric and the thermally pre-dried paper web then pass over a straightening roll 23, which prevents the formation of wrinkles in the imprinting fabric, and over another imprinting fabric return roll 21 onto the surface of a Yankee dryer drum 24. The knuckles of the imprinting fabric 20 are then impressed into the pre-dried but as yet uncompacted paper sheet 13 by the pressure roll 25. The imprinting fabric 20 then returns to the Fourdriner wire 11 over several imprinting fabric return rolls 21, being washed free of clinging fibers by sprays 26 and dried by vacuum box 27 during its return. The impressed paper sheet 13 continues from the impression nip roll 25 along the periphery of the Yankee dryer drum 24 for drying and is desirably creped from the Yankee dryer surface by a doctor blade 28, but can be simply wound from the dryer surface, although these and subsequent operations are not considered essential steps in the present invention. If desired, the surface of the Yankee dryer can be sprayed with a small amount of adhesive solution from spray 29 to improve the bond between the knuckle imprints of the paper sheet and the Yankee dryer surface during drying.

In FIGURE 2 there is depicted another example of a papermaking machine embodying the present invention. In this configuration a papermaking furnish is distributed directly on an imprinting fabric 30 by a headbox 31 as the imprinting fabric passes over a breast roll 32. In this manner and uncompacted wet paper web 33 is formed and dewatered by passing over vacuum boxes 34 to a hot air dryer 35, which thermally pre-dries the uncompacted paper web. The imprinting fabric 30, carrying the pre-dried sheet 33, now passes over a return roll 36 to carry the uncompacted, thermally pre-dried sheet to the surface of a Yankee dryer drum 37. The thermally pre-dried sheet is then impressed with the knuckle pattern of the imprinting fabric by a pressure roll 38. The imprinting fabric 30 then returns to the breast roll 32 of the forming section of the papermaking machine over a plurality of return rolls 36. During its return the imprinting fabric is cleaned by a shower 39 and dried by vacuum box 40. The dry sheet is wound from the surface of the Yankee dryer over a roll 41.

FIGURE 3 illustrates the remarkable regularity of the knuckle impressions 42 in machine glazed paper made by the process of the present invention, while FIGURE 4 shows the effect of the knuckle impressions 42 in bonding together at intervals the loose fibers 43 in the present paper sheet.

FIGURE 5 illustrates the striking regularity of creping frequency appearing in a creped sheet made by the process of the present invention. The surface of the creped paper sheet depicted in FIGURE 5 not only exhibits the characteristic regularity, both as to frequency and length, of creping folds 44 induced by the present process. The knuckle impressions 42 remain between the creping folds, and the creping folds, contrary to the creping folds in conventional creping paper, are essentially uninterrupted across the sheet surface. In FIGURE 6 a cross section of FIGURE 5 is shown to use the desirable alignment of knuckle impressions 42 and loose fibers 43 in a creped sheet made by the process of the present invention.

As stated hereinbefore, the process of this invention may be generally described as a series of steps comprising (1) forming an uncremped paper web on a foraminous forming carrier, which can be a wire, a selected imprinting fabric of this invention or a perforated belt, (2) thermally pre-drying the paper web to a selected fiber consistency, (3) impressing the knuckle pattern, or warp and weft crossover points, of a selected imprinting fabric into the thermally pre-dried paper web and (4) completely drying the imprinted paper web.

The first step is carried out by forming a paper web on conventional forming equipment, except that contrary to conventional practice no means involving mechanical compaction of the paper web, such as dandy rolls, felt pickup rolls or other means involving opposition of mechanical members, are employed to dewater the wet web. The initially formed paper web is dewatered by suction boxes or other similar vacuum devices, and is then transferred to a selected imprinting fabric, if the initial formation was not accomplished therewith, and is thermally pre-dried in the second step. In the third step, the knuckle imprint of the selected imprinting fabric is impressed in the thermally pre-dried paper web by any means of applying mechanical pressure prior to completing the drying of the pre-dried sheet in the fourth step and carrying out any post-forming operation, such as creping on the dry sheet.

If desired, the knuckle imprint, mentioned above, can be carried out by pressing an impression nip roll supporting the selected imprinting fabric and the thermally pre-dried, but as yet uncompacted, web against the face of a drying drum such as a Yankee dryer, with the thermally pre-dried web next to the Yankee dryer surface. The moist web can also be molded against and into the imprinting fabric by fluid pressure, for example, vacuum pressure prior to the thermal pre-drying. The dried paper can be doctorled, or creped, from the Yankee surface. In this creping variation of the present invention a regulated creping pattern is attained according to the knuckle frequency or filament cross-over spacing of the imprinting fabric employed. This regulated creping pattern enhances the softness, bulk, absorbency and appearance impression of the finished product and avoids the substantial tensile strength loss caused by creping a conventional sheet which has been subjected to overall pressing.
The invention herein can also be practiced by fabric imprinting a paper web, thermally pre-dried to the range of fiber consistencies prescribed herein, against any relatively non-yielding surface with the selected fabric, and subsequently drying can be carried out by any of the prior art methods which do not destroy the fabric impression, including, for example, festoon, steam can, tunnel or other conventional drying methods. One preferred drying procedure, for example, is accomplished by drying the imprinted paper web on the selected imprinting fabric by means of a hot air dryer.

The thermal pre-drying step can be accomplished by any method, but it is critical that the thermal pre-drying procedure does not destroy the relationship of the moist paper web with the selected imprinting fabric after it has been established.

Applicants have, therefore, made the unexpected discovery that forming an uncompacted web against a selected woven fabric by fluid pressure followed by imprinting the thermally pre-dried web with the knuckle pattern of a selected imprinting fabric and drying the imprinted sheet enhances the softness, bulk, absorbency and felt impression in a paper sheet. In one embodiment, the inventive process also results in regulated creping frequency to further enhance the above desirable sheet characteristics.

Accordingly, the process of the present invention can be practiced by forming a paper web having a dry basis weight of about 5 to about 40, preferably about 9 to about 25 pounds per 3000 square feet, depending on the desired product weight and application, on a conventional Fourdriner or other conventional forming section. The paper web is then dewatered by multiple vacuum boxes which preferably increase their application of vacuum in the machine direction as the sheet travels between the boxes. In the preferred manner, the multiple vacuum boxes apply vacuum to the wet paper web in successive applications increasing in degree from a vacuum equivalent of about 2 inches of Hg differential in pressure to about 25 inches of Hg differential in pressure. This dewatering produces a moist web having a fiber consistency of about 10 percent to about 25 percent, and the application of successive increasing vacuums avoids compaction of the paper web.

The moist paper web is then transferred from the Fourdriner wire, or other foraminous forming wire, to a selected imprinting fabric having about 20 to about 60 meshes per inch formed from filaments having diameters of about 0.008 to about 0.02 inch. In selecting imprinting fabrics for use in the process of this invention it is generally desirable to select coarser imprinting fabrics for use with heavier basis weights, although this choice may not be absolutely necessary to result in a desirable product.

The transfer of the moist paper web from the foraminous forming wire to the selected imprinting fabric can be accomplished in certain instances by simply contacting the moist paper web on the foraminous forming wire with the imprinting fabric. These instances of easy transfer of the moist paper web occur, generally, in the not expected cases where the foraminous forming wire is coarser than the imprinting fabric. This follows the general papermaking premise that moist paper web transfer can be made from coarser to smoother surfaces.

In most cases, however, applicants have experienced considerable difficulty in transferring the moist uncompacted paper web to the imprinting fabric. To overcome this problem a variety of means of applying fluid pressure to effect sheet transfer can be used in the practice of this invention. For example, the moist web can be transferred to the imprinting fabric by juxtaposing the foraminous forming wire and the imprinting fabric with the moist web between and directing steam from a slot nozzle across the web width against the outside surface of the foraminous forming wire. A vacuum box having a slot nozzle across the width of the web can also be applied to the outer surface of the imprinting fabric. In some instances, the action of either the steam nozzle or the vacuum box is sufficient to urge the moist paper web away from the foraminous forming wire and onto the imprinting fabric. In other instances both devices are required to effect the transfer. It is noted that, although steam and air, individually and in combination, have been disclosed above as transfer means for the moist paper web, other fluid means, including gases and liquids, are also applicable to effect transfer.

The imprinting fabric, in addition to having the mesh, or filament, frequencies and diameters noted above, can be of square or diagonal weave. The imprinting fabric can also be of any specific construction, for example, single or double crimped, twilled and semi-twilled imprinting fabrics formed of monofilament or multifilament strands are suitable for use in the practice of this invention.

It is also understood that various materials can be used in the construction of the imprinting fabric, including the metal wires used in the construction of Fourdriner wires. For example, the polyamide fibers, nylon fibers, acrylic fibers and polyester fibers sold under the respective trademarks of "nylon," "Saran," "Orlon," and "Dacron" are all suitable for the construction of the imprinting fabrics.

The moist paper web, carried on the imprinting fabric can be thermally pre-dried by means of passing hot gases, for example air, through the moist paper web and the imprinting fabric. Thermal pre-drying may also be accomplished, the moist paper web remaining in undisturbed relation with the selected imprinting fabric, by infrared heaters, by conventional hot air systems, or by any other means.

The means by which the thermal pre-drying is accomplished is not critical; it is, however, critical that the relationship of the moist web to the imprinting fabric be maintained once established.

Thermal pre-drying is used to effect a fiber consistency in the moist paper web from about 30% to about 80%, preferably about 40% to about 80%. Applicants have found that above consistencies result in further drying and yielding in the next process step; namely, the imprinting step. On the other hand, applicants have found that pre-drying to fiber consistencies above about 80% precludes the development of effective tensile strengths in the imprinted paper sheet.

The fiber consistencies, set forth above, are, therefore, critical to the next step in the process which comprises imprinting the imprinting fabric knuckle pattern in the moist web by pressing the pre-dried web against a relatively non-yielding surface, for example, an unheated steel roll or a Yankee dryer surface, while the pre-dried web is yet carried on the imprinting fabric. Imprinting the fabric knuckle pattern results in a paper sheet having impressed in its surface, to a depth of at least 30% of its machine glazed caliper the knuckle pattern of an imprinting fabric. Machine glazed caliper refers to the caliper of the paper sheet taken directly from the Yankee dryer, before creping, as machine glazed paper. The imprinting step further results in the creation of a regular pattern of small translucent areas in the pre-dried web. The pressure required for the imprinting of the imprinting fabric pattern can be provided by one or more pressure rolls operating on the imprinting fabric to force the knuckles of the fabric into the surface of the pre-dried web and onto the web surface under the knuckles against the Yankee dryer surface. These pressure rolls can be fabricated of steel, composition or rubber and are operated at kiss pressure to amounts of about 1000 p.s.i. to about 12,000 p.s.i. based on the knuckle impression area of the selected imprinting fabric.
It will be understood that it is critical in the process of the present invention that the imprinting step in the process, detailed above, is the first substantial overall mechanical compaction step which the paper web has received during formation and pre-drying.

In one preferred embodiment of the present invention, as stated above, the relatively non-yielding surface is a Yankee dryer drum and the imprinted sheet is pressed and dried thereon and creped therefrom. In this preferred embodiment, there accrues an added product advantage stemming from the fact that the impressed fabric pattern has been found to beneficially control the character and frequency of creping. Specifically, applicants have found that, when the dried paper web is creped from the drying surface on which it was imprinted, the resulting creping pattern is influenced or regulated in the machine direction and cross-machine direction by the knuckle pattern or filament frequency of the imprinting fabric pattern so that a distinctive regularity is evidenced in both the frequency and the uniformity of the creping ridges. In fact, the creping ridges of the present paper sheet are substantially unbroken across the sheet width except that conventional creped papers are interrupted and broken in a random pattern. Applicants have also discovered that the tensile strength of paper sheets imprinted on a dryer surface in practicing this embodiment is less reduced by creping than is the case in normal papermaking practice. The dried machine glazed or creped paper produced can then be handled by conventional finishing techniques, including, for example, multi-lying, or subjected to further post-forming treatments.

It will be apparent to those versed in the art, that, since the imprinting fabric pattern can be employed to regulate creping, the advantages of creping are maximized in comparison to the conventional random system. It is equally apparent that the choice of imprinting fabric within the ranges and types disclosed will produce slightly different effects or influence creping in various patterns desirable according to the product type and basis weight.

In other embodiments, the imprinted pre-dried paper web is finally dried on the imprinting fabric (there being no transfer to another drying surface at the imprinting pressure roll). The pre-dried paper web can also be dried without creping after imprinting by means of a tunnel dryer, hot air dryer, or other conventional drying equipment.

From the foregoing general and specific description of the present process, it is apparent that the critical procedures to be carried out are the formation of an uncompressed web at a specified range of fiber consistency and the imprinting thereof by the knuckles of a selected imprinting fabric. The formation of the paper web and the final drying techniques together with the pre-drying, imprinting and creping procedures can be varied by one skilled in the art to produce distinctive papers for various uses while remaining within the scope of this invention.

By the foregoing procedures, paper sheets composed substantially of cellulosic fibers having basis weights of about 5 to about 40 pounds per 3000 square feet and a repeating pattern of discrete impressed areas are produced. The aforementioned discrete impressed areas have a relative density of at least about 0.7, preferably about 0.8, and a visible transparency in the impressed area of 30 to 50%. The discrete impressed areas, as illustrated in FIGURES 3, 4 and 6, comprise a total area of about 1% to about 14% of the surface area of the paper sheets before creping and define bulky absorbent areas of loose fibers in the paper sheets having dimensions of about 10% to about 90% of the average fiber length of the cellulosic fibers contained therein.

The paper sheets of this invention are further characterized by having, as defined below, bulk densities at 100 grams per square inch loading of about 1.0 gram per cubic inch to about 3.6 grams per cubic inch, proportional to their basis weight and by having compressive work values (CWV's) in inch-grams of about 0.4 to about 0.7, inversely proportional to their bulk densities. The paper sheets also exhibit absorbencies in grams of water per gram of fiber is 6 to about 17, inversely proportional to their basis weight in addition to relatively high absorbency rates.

As stated before, when the impressed fibrous sheets are creped, there is added to the above product characteristics the feature of controlling both the machine direction and cross-machine direction regularity of the creping frequency. In particular, it is noted that creped sheets manufactured in accordance with the present process are characterized by creping folds which are substantially uninterrupted across the sheet surface.

The CWV numbers reported in the tables of examples hereinbelow define the compressive deformation characteristics (sponginess as part of a total impression of softness to a person who handles the paper) of a paper sheet loaded on its opposing flat surfaces. The significance of the CWV number is better understood by the realization that the CWV number represents the total work required to compress the load of a single flat paper sheet inwardly toward each other to a unit load of 100 grams per square inch. In accomplishing the foregoing compression test, the thickness of the paper sheet is decreased, and work is done. This work, or expended energy, is similar to the work done by a person who pinches the flat surfaces of a flat sheet of paper between his thumb and forefinger to gain an impression of its softness. Applicants have found that CWV numbers correlate well with the softness impression obtained by a person who handles a paper sheet.

An Instron Tester (Model No. TM, Serial No. 261) was used to measure the CWV numbers by placing a single, 4 square inch paper sheet between compression plates. The sample was then loaded on its flat opposing surfaces at a rate of 0.02 inch of compression deformation per minute until the loading per square inch reached 100 grams.

The Instron Tester is equipped with a recording unit which integrates the compression movement of the sheet surfaces and the instantaneous loading to give the total work in inch-grams required to reach the 100 grams per square inch loading. This work expressed as inch-grams is the CWV number used hereinbelow.

The caliper of a paper sheet at 100 grams per square inch as tabulated in the table hereinbelow is the thickness of that sheet when subjected to a compressive load of 100 grams per square inch.

The bulk density of 100 grams per square inch is calculated from the weight of a given area of the paper sheet and the caliper of the paper sheet at 100 grams per square inch as set forth above. The bulk density values tabulated in the table hereinbelow are computed as the weight in grams of one cubic inch of the paper sample under a compressive loading of 100 grams per square inch.

The tensile strengths, machine direction (MD) or cross machine direction (CD), tabulated in the table hereinbelow are reported as the force in grams that a one inch wide sample with a 4-inch span between the tensile tester clamps, cut in the MD or CD direction, can withstand before breaking as measured on a standard Thwing-Albert Tensile Tester.

The absorbencies tabulated in the table below are reported as the total weight of water which an unstressed paper sample, weighing approximately 3 grams and composed of sheets of paper cut to measure 4 inches by 4 inches after conditioning for at least 12 hours at 72°F. and 50% relative humidity, will hold, expressed as grams of water per gram of conditioned fiber.
Having described the process and product of this invention, the following examples are intended to illustrate modes of advantageous operation, but it will be understood that those skilled in the art will immediately appreciate other advantages stemming from the herein disclosed inventive concept. It is understood, therefore, that the examples are intended to be illustrative and not limiting, and the scope of invention is only to be construed by the scope of the appended claims.

**EXAMPLE I**

A pulp slurry having a 0.03% fiber consistency and containing 35% bleached northern softwood kraft and 65% bleached poplar sulfite, prerefined at 3.5% consistency in a conventional conical pulp refiner at 100 kw-hr./ton, was distributed by a conventional closed hydraulic headbox on a horizontal bronze mesh Fourdrinier wire woven with 95 warp and 100 weft strands per inch moving continuously at 500 f.p.m. Flow and wire movement were regulated so that a uniform moist paper web, having a dry basis weight of 9.6 pounds per 5000 square feet, was formed on this wire. Water was removed from the web until the fiber consistency was 25% by the following successive devices located along the Fourdrinier wire: (1) a forming board contacting the under side of the wire with a deflecting face at 30° to the wire and a trailing face departing from the wire at a 1° angle; (2) a forming board contacting the under side of the wire with a deflecting face at an angle of 45° to the wire and a trailing face departing from the wire at an angle of 1°; (3) five successive vacuum boxes contacting the under side of the wire with vacuums equivalent to 3" of Hg, 8.5" of Hg, 14.5" of Hg, 15" of Hg, and 17" of Hg differential in pressure, respectively toward the dry end of the Fourdrinier wire. Four slits orifice steam nozzles with a continuous 0.025" aperture were mounted transversely to the machine direction ½" above the wire and supplied with dry steam in a manner to cause the steam jets to be directed at the apertures of the last four vacuum boxes at rates of flow adjusted to give a small amount of visible steam in excess of the amount pulled through the web into the vacuum boxes. The forming wire was then turned downwardly at an angle of 45° by a turn roll for a span of 2 feet and then returned by means of another turn roll to the unsupported wire span between these rolls, the moist web at 25% fiber consistency was transferred to a second and coarser square mesh imprinting fabric having a 34% open area woven with 35 warp strands per inch made of 0.015" diameter crimped nylon monofilament and 35 weft strands per inch similar to the warp strands, particularly in that they were crimped to the same degree, with a diameter of 0.0135". A turn roll was placed so that the nylon fabric converged upon the Fourdrinier wire at a 1° angle to the wire while moving at the same speed and was brought into contact with the moist web at a point 3" past the midpoint point of the wire span by means of a vacuum box mounted on the opposite side of the imprinting fabric from the web as shown in **Figure 1**. The transfer was accomplished by directing a steam jet from a 0.25" wide slit nozzle, mounted midway in the span transversely below and in near contact with the Fourdrinier wire against the moist web at an angle of 45° to the downwardly moving wire.

The action of the steam jet impinging on the moist web through the wire openings disengaged the moist web from the forming carrier and forced it against thedescribed imprinting fabric at a 9" of Hg differential pressure applied by the vacuum box mounted on the opposite side of the imprinting fabric immediately formed the moist uncompacted web to conform to the mesh pattern of the imprinting fabric, forming small depressions in the web corresponding to the openings in the stamp. In order to avoid retransfer of the uncompacted web to the Fourdrinier wire by continued contact, a second turn roll for the nylon fabric carrier was placed so that the fabric departed from the wire at an angle of 5°, and the vacuum box position was adjusted so that the point of departure of the imprinting fabric from the Fourdrinier wire occurred at the trailing edge of the vacuum box slit.

The moist web on the imprinting fabric was then dried to a fiber consistency of 30% by passing hot air through the imprinting fabric and the moist web. The fabric carrying the molded and pre-dried paper web was then brought into contact with an adhesive coated, 7-foot diameter, Yankee dryer drum at a point 1.5 feet ahead of a pressure nip formed by a 14-inch diameter roll covered with 1 inch of rubber having a ½ inch ball P&H hardness of 27. This nip was operated at a knuckle pressure of 2900 p.s.i. to imprint the pre-dried web with the knuckle pattern of the imprinting fabric. Prior to the point of contacting the Yankee dryer, the nylon fabric contacted a curved axis rotating rubber roll with a 30° wrap to keep it free of wrinkles. The 1.5 feet of Yankee dryer surface contact prior to the pressure nip provided time for pre-cooling the Yankee dryer surface to avoid "blistering" the sheet by sudden formation of steam bubbles on the Yankee dryer surface.

The adhesive coat on the Yankee dryer surface was spray applied at the rate of 0.03 cc. per square foot per minute and was formulated from a liquid animal glue, a liquid polyamide wet strength resin, glycerine and water such that the mixture contained 5 parts animal glue, 1 part wet strength resin, 1 part glycerine and 93.9 parts water.

The pre-dried and imprinted web was caused to part from the imprinting fabric at the pressure nip exit and adhere to the Yankee dryer surface by means of the adhesive coat described. During the return of the imprinted fabric to the pins of the Fourdrinier wire, it was washed with two showers to remove any adhering fiber, and partially dried by means of a vacuum box, operated at a vacuum equivalent to 2 inches of Hg differential pressure. The second of the two showers was supplied with water containing 2 p.p.m. non-ionic surfactant. This shower cleaning was necessary to keep the imprinting fabric return rolls from becoming coated with fiber and to keep the openings of the fabric free from fiber so that uniform web transfer and release were maintained in this continuous process.

The imprinted paper web adhering to the hot Yankee dryer drum was dried at 500 f.p.m. to a consistency of 96% and removed from the drum by means of a conventional creping doctor blade. The angle between the impact face of the 0.020 inch thick doctor blade and the tangent to the Yankee at its contact was 81°. Samples were also taken from the Yankee dryer drum without creping, as machine glazed paper. Drying on the Yankee dryer was accomplished by heating the drum with steam at 63 p.s.i.g. while impinging air against the web at 300° F. and removing it with a conventional air hood at the rate of 900 pounds per square foot of hood area per hour over approximately one half of the circumference of the dryer, while the imprinted web contacted three quarters of the dryer circumference.

The dry creped sheet was removed from the doctor blade at 430 f.p.m. by the reel so that the product had 14% stretch as crepe folds, a basis weight of 11 pounds per 3000 square feet and 8% imprint on the creped paper product formed by the process of Example I had exceptional utility for use as sanitary tissue. A paper sheet having substantially the same machine glazed and creped basis weight as that of Example I was produced by conventional papermaking techniques to provide direct comparison of sheet quality. Conventional papermaking techniques used to produce the comparison papers were those wherein the paper web was formed on a Fourdrinier wire, transferred from the Fourdrinier wire onto a felt instead of the imprinting fabric of this invention, pressed in a conventional felt press and transferred to the Yankee dryer without pre-
drying. The table below compares the sheet properties and processing conditions of the Example I sheet of this invention with those of the conventionally produced sheet. For more direct comparison of the sheet properties developed by the process of this invention, all of the sheet properties are tabulated as machine glazed sheet properties, except where creping is specifically noted, to avoid the influence of creping introduced into the paper sheets by more or less creping. The creped sample values are given at about 14% crepe. The sheet properties and processing conditions of additional sheets forming basis for Examples II to IX and produced by the process of Example I, with the exception of basis weight, fiber consistency before transfer to the Yankee dryer, knuckle pressure, wire mesh and filament diameter as noted in the table, are compared with conventionally produced sheets of substantially the same basis weight.

<table>
<thead>
<tr>
<th>TABLE—COMPARISON OF SHEET PROPERTIES AND PROCESSING CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Comparison Values</strong></td>
</tr>
<tr>
<td><strong>Example</strong></td>
</tr>
<tr>
<td>Basic Weight, sp. pounds/3,000 sq. ft.</td>
</tr>
<tr>
<td>Fiber Consistency Before First Press, percent</td>
</tr>
<tr>
<td>Fiber Consistency Before Imprinting on Yankee Dryer, percent.</td>
</tr>
<tr>
<td>Knuckle Pressure, p.s.i.</td>
</tr>
<tr>
<td>Imprinted Areas, percent</td>
</tr>
<tr>
<td>Imprinting Fabric, Meshes/inch</td>
</tr>
<tr>
<td>Fabric Crepe</td>
</tr>
<tr>
<td>Fabric Filament Diameter, Inches</td>
</tr>
<tr>
<td>Bulk Density at 100 gms. sq. in.</td>
</tr>
<tr>
<td>CWV, Inch-Grams</td>
</tr>
<tr>
<td>Absorbency, gm. H2O/gm. Fiber</td>
</tr>
<tr>
<td>Caliper at 100 gms. sq. in.</td>
</tr>
<tr>
<td>Tensile MD, gm/inch</td>
</tr>
<tr>
<td>Tensile CD, gm/inch</td>
</tr>
<tr>
<td>Creped Tensile MD, gm/inch</td>
</tr>
<tr>
<td>Creped Tensile CD, gm/inch</td>
</tr>
<tr>
<td>Product Utility</td>
</tr>
<tr>
<td>1-ply sanitary tissue</td>
</tr>
</tbody>
</table>

Substantially the same results are obtained when an imprinting fabric woven with 60 strands of crimped nylon monofilament having a diameter of 0.008 inch in both the warp and weft directions is used in Example VI.

The data presented in the table above clearly show the advantages of the present process in producing a paper sheet characterized by softness, bulkiness and high absorbency. The data also show that the tensile strength of a sheet produced by the process of this invention is less affected by creping than that of a conventionally produced sheet.

What is claimed is:

1. A process for the manufacture of a soft, bulky and absorbent paper sheet which comprises the steps of (1) forming an uncompacted paper web having a uniform basis weight of about 5 to about 40 pounds per 3000 square feet, (2) supporting said uncompacted paper web
on an imprinting fabric having about 20 to about 60 meshes per inch, said imprinting fabric being formed from filaments having a diameter of about 0.008 to about 0.02 inch, (3) thermally pre-drying said uncompacted paper web to a fiber consistency of about 30% to about 80%, (4) imprinting the knuckle pattern of said imprinting fabric in the pre-dried uncompacted paper web at a knuckle pressure of about 1000 p.s.i. to about 12,000 p.s.i. and (5) final drying the paper sheet so formed.

2. The process for the manufacture of a soft, bulky and absorbent paper sheet as described in claim 1 wherein the final drying of the paper sheet is performed on the imprinting fabric.

3. A process for the manufacture of a soft, bulky and absorbent paper sheet which comprises the steps of (1) forming an uncompacted paper web having a uniform basis weight of about 9 to about 25 pounds per 3000 square feet, (2) supporting said paper web on an imprinting fabric having about 20 to about 60 meshes per inch, said imprinting fabric being formed from filaments having a diameter of about 0.008 to about 0.02 inch, (3) thermally pre-drying said uncompacted paper web to a fiber consistency of about 40% to about 80%, (4) imprinting the knuckle pattern of said imprinting fabric in the pre-dried paper web at a knuckle pressure of about 1000 p.s.i. to about 12,000 p.s.i. and (5) final drying the paper sheet so formed on a Yankee dryer drum.

4. The process for the manufacture of a soft, bulky and absorbent paper sheet as described in claim 3 wherein the uncompacted paper web formed in step 1 is molded to conform to the pattern of the imprinting fabric prior to thermally pre-drying the uncompacted web in step 3.

5. A soft, bulky and absorbent paper sheet characterized by having a uniform basis weight of about 5 to about 40 pounds per 3000 square feet, by having impressed in its surface, to a depth of at least 30% of its machine glazed caliper the knuckle pattern of an imprinting fabric having about 20 to about 60 meshes per inch, by having about 1% to about 14% of its surface compressed in said knuckle pattern to a relative density of at least 0.7 and said soft, bulky and absorbent paper sheet being further characterized by having a bulk density at 100 grams per square inch loading of about 1.0 to about 3.6, proportional to its basis weight.

6. The soft, bulky and absorbent paper sheet described in claim 5 which has been creped and exhibits creping folds which are substantially unbroken across the paper sheet together with a distinctive regularity in its machine and cross-machine creping frequency influenced by the mesh frequency of the imprinting fabric.

7. A soft, bulky and absorbent paper sheet characterized by having a uniform basis weight of about 9 to about 25 pounds per 3000 square feet, by having impressed in its surface, to a depth of at least 30% of its machine glazed caliper the transparentized knuckle pattern of an imprinting fabric having about 20 to about 60 meshes per inch, by having about 1% to about 14% of its surface compressed in said knuckle pattern to a relative density of about 0.8 and said soft, bulky and absorbent paper sheet being further characterized by having a bulk density at 100 grams per square inch loading of about 1.0 gram per cubic inch to about 3.6 grams per cubic inch, proportional to its basis weight, by having a total work in inch-grams to reach a 100 gram per square inch loading on its flat opposing surfaces at a rate of 0.02 inch of compression deformation per minute of about 0.4 to about 0.7, inversely proportional to its bulk density and an absorbency in grams of water per gram of fiber of about 6 to about 17, inversely proportional to its basis weight.

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S. LEON BASHORE, Examiner.